North Carolina Department of Commerce

North Carolina Alternative Fuels Feasibility Study under Session Law 2012-186

North Carolina State Energy Office
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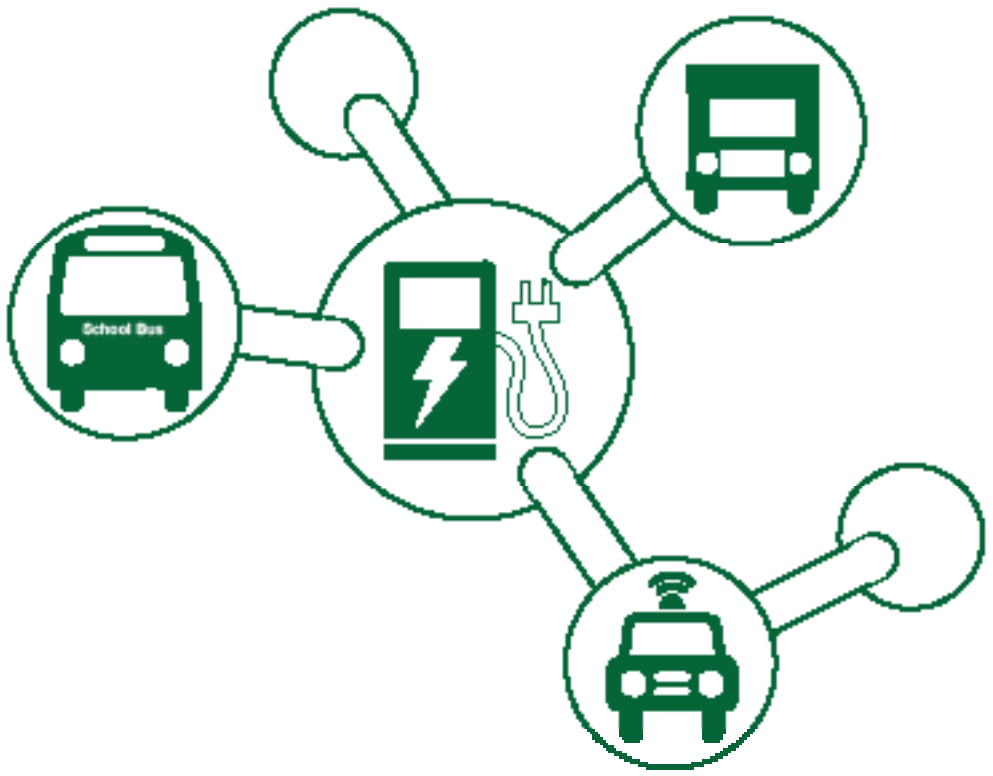

Executive Summary

The State Energy Office of North Carolina is pleased to provide this report in response to Session Law 2012-186. Energy Office staff have worked closely with and surveyed fleet managers in 27 state agencies and university campuses to assess the duty cycles of state fleet vehicles. In development of this report, staff have conducted numerous interviews with auto companies, fuel providers and others to garner the most accurate and up to date information possible. Many of these stakeholders received and commented on early drafts of this report.

Even with these interviews over the past months, the alternative fuel world is changing more rapidly now than it has in decades. New alternative fuel vehicles are being announced regularly and will soon be on the market. During the drafting of this study, energy providers have announced plans to install new alternative fuel vehicle infrastructure. State Energy Office staff and partners decided that all vehicle and fuel types need to be evaluated equally. While NC groups have announced plans to install fueling or charging stations, we cannot incorporate those plans until the particular sites have been identified. Further, as new vehicles are announced, it is difficult to assess a lifecycle cost, so vehicles that are not yet available are not included either. Once those vehicles and stations are known and available, fleet managers can use the information here to make informed decisions about what is best for their purposes.

A key effort of this report involves providing the reader with transparent data used to evaluate and score the various options for vehicles and fuels. With this information, the reader can make their own analysis if they like, including modifying the weighting for each factor. This report provides background information about the various fuels, vehicle types, fleet duty cycles, and availability of both alternative fuels and alternative fuel vehicles. No fuel is the perfect solution for all applications. In some cases, an alternative fuel and vehicle proves to be the most cost-effective option. In some cases, traditional fuels are most cost-effective and convenient.

In order to make vehicle and fuel comparisons as clear as possible, the report team opted to comment on, but leave externalities out of the equation. Externalities can include the differences tailpipe emission differences between vehicles. For example, an alternative fuel vehicle may have lower emissions of nitrogen oxides – a key component of smog – compared to traditionally fueled vehicles. In that case, use of the alternative fuel vehicle has external benefits, especially in areas with air quality problems. Externalities can also include the economic value of using energy resources produced within the state. For example, much of the biodiesel used in state fleet vehicles could be provided by in-state producers using in-state feedstocks. The state may determine that the economic benefits from using fuel produced in state outweigh any additional financial costs. The report team also worked to incorporate the cost of refueling infrastructure (if any) into the analysis. Because of the state's purchasing power, it generally can purchase fuel at a lower cost than is found at commercial sites in the state. Additional costs are incurred if the state must invest in fueling or charging sites to serve the state fleet needs.

For purposes of evaluating fuels, the state fleet was divided into vehicle categories: sedans, minivans and passenger vans, panel and utility vans, light duty trucks, medium duty trucks, heavy duty trucks, specialized trucks, and school buses. The recommendations that follow are for generic vehicles and duty cycles in these vehicle categories. There will be niche areas where a recommended fuel is not appropriate; or a niche where a secondary fuel has advantages. Fleet managers should review their vehicle usage and make informed decisions. Those fleet managers should also be given the authority to make vehicle choices based on usage patterns, fuel availability in their particular location, and externalities as appropriate. Please review the explanations throughout this document for more information about the recommendations and where other fuels and vehicles may make more economic sense or provides an external value that justifies going beyond the least cost alternative.

Vehicle Type	Recommended Fuel	Secondary Fuel Option
Sedan	Gasoline	Gasoline Hybird
Minivans/Passenger Vans	Gasoline	E-85
Panel/Utility Vans	Gasoline	E-85
Light Duty Trucks	CNG (Where appropriate*)	Gasoline
Medium Duty Trucks	Ultra Low Sulfur Diesel	B-20
Heavy Duty Trucks	Ultra Low Sulfur Diesel	B-20
Specialized Vehicles	Ultra Low Sulfur Diesel	B-20
School Buses	CNG (Where appropriate*)	Ultra Low Sulfur Diesel

*Technical and operational considerations associated with deployment of CNG-powered vehicles include, but are not limited to, commercial availability of vehicles, the duty cycle and usage pattern of a specific application, and the availability or cost of refueling infrastructure. For more information, please see the CNG subsection on page 15.

Great effort has been made by the State Energy Office report team and all of the stakeholders and participants to ensure that this report provides the most up to date and accurate data about vehicles, fuels, and fleets. The report team specifically thanks the individuals who have volunteered their time and expertise to ensure the report is accurate and free of any real or perceived bias.

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Introduction

Legislation

In Session Law 2012-186, the North Carolina General Assembly directed the North Carolina State Energy Office within the Department of Commerce, in consultation with the Department of Administration, Department of Public Instruction, Department of Transportation and other agencies, to study, via a task force, the feasibility and desirability of advancing the use of alternative fuels by State agencies.

As directed by the legislation, this report contains a cost benefit analysis of motor vehicle fleets powered by conventional fuels —gasoline and diesel —compared with five alternative fuels.

The five comparison fuels are:

- Liquefied Petroleum Gas (LPG), also known as Propane;
- E-85 Gasoline;
- B-20 Biodiesel;
- Electricity, including Hybrid Electric (HEV), Plug-in Hybrid Electric (PHEV), & Battery Electric (BEV) vehicles;
- Compressed Natural Gas (CNG)

The State Energy Office's recommendations are based on a cost benefit analysis that factors in **life cycle cost, forecasted volatility of fuel prices, infrastructure costs, and environmental costs** for each fuel type.

One factor in the life cycle cost analysis is fuel price. Current and projected conventional fuel prices (gasoline and diesel) are compared to current and projected alternative fuel prices for LPG, E-85, B-20, electricity and CNG.

In addition to fuel costs, the other factors in the life cycle cost analysis are vehicle replacement cost, operation costs (fuel), and maintenance costs for the conventional-fuel powered fleet. This information was provided by State agencies in a survey. Estimated purchase, operations, and maintenance cost assumptions for alternative-fuel powered vehicles were taken from the agency survey responses and private sector consultants.

The cost benefit analysis is broken out according to vehicle type. The study considers eight vehicle "classes" or categories. The definitions of individual vehicle categories are provided in the description and classification of the state fleet section of this report. The vehicle categories include:

- **Sedans**
- **Minivans & Passenger Vans**
- **Panel & Utility Vans**
- **Light Duty Trucks**
- **Medium Duty Trucks**
- **Heavy Duty Trucks**
- **Other Specialized Trucks (e.g. sanitation trucks)**
- **School buses**

Task Force Composition

The task force included representatives from UNC General Administration, NC Department of Transportation (NC DOT), NC Department of Agriculture (NCDA), NC Department of Administration's Motor Fleet Management (MFM), NC Public Safety Corrections (Corrections) and Juvenile Justice (Juvenile), NC Department of Environmental and Natural Resources (NC DENR) and the NC Department of Public Instruction (NC DPI). The State Energy Office created and administered a survey to 27 State agencies and university campuses. Twenty-three complete responses were received and tabulated. The State Energy Office, with advice from the task force members, led the survey analysis and development of the methodology.

Fuels

The fuels section of this report includes background information on each of the fuels considered, including:

- **Basic information**
- **Sources**
- **Market for each fuel**
- **Availability in consumer vehicles**
- **Technical considerations for vehicles**
- **Existing infrastructure**
- **Technical considerations for infrastructure & refueling**
- **Favorable applications**

In FY2011-2012, the State fleet consumed approximately 23.9 million gallons of transportation fuel. Alternative fuels and alternative/petroleum blends already make up a significant percentage of fleet consumption, including 13.8 million gallons of E-10, 7.2 million gallons of B-20, and 418,000 gallons of E-85 (North Carolina Solar Center, 2012).

State fleet vehicle operators and fleet managers currently purchase fuel in several ways. Vehicle operators may obtain fuel at state-operated depots or commercial fuel stations using a fleet card. Fleet managers with access to storage and dispensing infrastructure can purchase bulk fuel on state contracts. State contracts allow managers to purchase fuel at a discount compared to retail pricing, but usually include a minimum purchase quantity of either 500 or 6,000 gallons depending on the specific contract. LPG contracts differ in that the minimum purchase for tank wagon is 100 gallons and the transport volume is 9,000 gallons.

The research team chose to use the transport pricing with adjustments for future price projections for the life cycle cost calculations in this report. The State consistently buys in large enough quantity to obtain the preferable transport contract pricing. Transport volumes of fuel are FOB Destination and the following taxes are excluded: Inspection Tax; State Road Use Tax; State Sales & Use Tax; Federal Tax; Superfund Charge (may be listed as a separate line item) Fuel Surcharges (North Carolina Department of Administration, 2012). There are other considerations with the state fuel contracts, such as the term. These contracts allow the vendor to provide fuel under the contract for three years. Generally, the contract prices for fuel(s) change on Tuesdays except for Ultra Low Sulfur Diesel (405Q) which experience daily price adjustments.

The negotiated contract price is based on a two-day delivery designed to prevent any hardship or price disadvantage to the agency (NC Department of Administration).

The Tuesday change in pricing and the two-day delivery are significant points that must be considered by the bulk fuel purchaser. Every Wednesday, the Energy Information Administration releases its Weekly Petroleum Status Report that identifies any changes in the inventories, production rates, and the prices of crude, gasoline and distillate products. Market prices tend to increase or decrease based on the information contained in the report. For example, a significant reduction in inventory or production may cause prices to escalate, conversely, significant increases in inventory or production could have the opposite effect. The Tuesday contract change is both positive and negative aspects. On one hand the contract price is locked in prior to the EIA's report, therefore may provide some protection from price escalation, however, if the report causes prices to descend, the contract price will remain the same therefore preventing users to partake in the reduced price. Ultimately, the agency must be aware of the market trends and make educated decisions about their fuel purchasing habits.

Research into the methods agencies currently use to procure fuel indicated that few agencies have the storage and dispensing infrastructure necessary to make bulk purchases, with NC Department of Transportation (NCDOT) being a notable exception. The costs associated with construction and maintenance of fueling infrastructure, such as tanks, dispensers, land, permitting, and inspections are significant. Many other agencies rely on NCDOT for their fuel needs. Most other agencies purchase the bulk of their transportation fuels at commercial fuel stations. Another section of this report will address the price differential between bulk fuels procured on the state contract and retail fuels purchased from commercial fuel stations.

This report addresses the base case of gasoline and ultra-low sulfur diesel fuels as well as the following alternative fuels, as defined within G. S. 143-58.4:

- **Biodiesel & Biodiesel blend (B-20)**
- **Ethanol (E-85)**
- **Compressed Natural Gas (CNG)**
- **Propane (LPG)**
- **Electricity**

Gasoline (E-10)

Basic Information

Gasoline is a refined petroleum product derived from crude oil. It is a liquid under normal ambient pressure/ temperatures. Gasoline is the most common transportation fuel used nationwide. The majority of persons are familiar with its use. Almost all retail "gasoline" sold within the State contains a small percentage of ethanol (10% or less). The resulting mixture of 90 percent gasoline and 10 percent ethanol is also known as E-10.

Sources

Gasoline is derived from crude oil through several processes, the most important being fluid catalytic cracking. Crude oil is produced both domestically and internationally. North Carolina does not currently produce any crude oil, nor are any petroleum refineries located within the State. Virtually all of North Carolina's petroleum supplies (including gasoline) are brought north from refineries along the Gulf Coast via either the Colonial or Plantation pipelines. According to data from the Energy Information Administration, approximately 68 percent of crude oil processed on the Gulf Coast (PADD-3) comes from foreign sources (U. S. Energy Information Administration, 2012). Approximately 55 percent of those imports come from OPEC nations (U. S. Energy Information Administration, 2012).

After gasoline or other petroleum products arrive in North Carolina via pipeline they are temporarily deposited into one of three petroleum terminals, where they await distribution or reinjection into the pipeline for travel to markets further north. Trucks are normally used to transport products to local distributors, large consumers, or retail stations.

A small percentage (<2%) of petroleum products enter the State via ship or interstate transfer. Products arriving via ship are temporarily deposited in a harbor terminal for distribution or re-embarkation. Interstate transfers usually serve markets near interstate borders, where it may be more economical to pull product from a petroleum terminal in another state. Elizabeth City is a prime example, where it is commonly more economical and practical to pull fuel from Norfolk, VA than Selma or Greensboro.

Market for Gasoline (E-10)

Gasoline and its feedstock, crude oil, are fungible products traded on global commodity markets. Geopolitical and natural events that have actual or perceived effects on local, regional, or global supplies can drive price shifts. Fluctuations in futures and spot markets directly affect prices at the pump and ultimately local and State budgets. The consumer cost of gasoline is subject to variation over time, differences in local markets, and additional factors depending on the method of purchase. The two major methods of purchase used by fleet managers and individual vehicle operators are State contracts and the retail market.

The North Carolina Department of Administration's Division of Purchasing and Contracting maintains and administers the State contracts for gasoline. The gasoline contracts are known as 405E, 405M, and 405S. As discussed in the beginning of the fuels section, the state contract price does not include several taxes that are normally applied to retail motor fuel. The research team averaged the price of transport fuel contracts for the period of January 2011- December 2012 and identified an average price of $2.926/gallon (North Carolina Department of Administration, 2012).

When not required to use agency fuel depots, individual vehicle operators commonly purchase gasoline at local commercial fuel stations. This is often the most convenient option, allowing drivers to stop at any retail fuel station along their route. Unfortunately, purchasing fuel on the retail market is generally more expensive than the State contract rate, although the State does recover the tax portion of retail fuel prices. Retail prices vary significantly over time and across the state. The U.S. Energy Information Administration estimates that the average price of retail gasoline in the Lower Atlantic region during 2011 was $3.458 per gallon for 2011 (U.S. Energy Information Administration, 2012). The State Energy Office maintains historical records of daily average fuel prices collected by the American Automotive Association (AAA) in their Fuel Gauge report for several North Carolina metropolitan areas. The AAA fuel price reports averaged $3.478 per gallon during 2011 (American Automobile Association, 2012).

Availability of Consumer Vehicles

Gasoline is currently the dominant transportation fuel for light duty vehicles within the State fleet. The majority of State-owned sedans, passenger vans, panel/utility vans, light duty trucks and medium duty trucks are gasoline powered. Virtually all major vehicle manufacturers offer full ranges of gasoline-powered products. Gasoline powered vehicles are readily available on State contract and the open commercial market. Gasoline served as the base case fuel for the following vehicle types: sedans, passenger vans, panel/utility vans, and light duty trucks.

Existing Infrastructure

NCDOT currently operates 111 gasoline fuel sites statewide. Of the NCDOT stations, there are 73 that have 24-hour availability and 38 that are usually open during an 8-hour workday (North Carolina Department of Transportation). Gasoline is also available at the Motor Fleet Maintenance Depot in Raleigh. There are 6,471 commercial gas stations in the State. The majority of commercial stations accept the State fleet credit card. As the dominant transportation fuel, gasoline is readily available throughout the State.

Technical Considerations

There are few special technical considerations with respect to gasoline. Regulations and safety procedures for handling and storing gasoline are well developed and established. No operator training is required to re-fuel gasoline-powered vehicles (North Carolina Department of Administration).

Ultra Low Sulfur Diesel (ULSD)

Basic Information

Diesel is a refined petroleum product derived from crude oil. It is liquid under normal ambient conditions. Diesel is generally ubiquitous, and is the most commonly used fuel in commercial trucking and heavy duty vehicles. In accordance with federal regulations, all diesel fuel sold in the United States for highway use is now ultra-low sulfur diesel (ULSD). ULSD contains no more than 15 parts per million of sulfur. Limiting the amount of sulfur in diesel fuel allows for more effective after-treatment of exhaust products and reduces negative environmental effects. The terms ULSD and diesel are used interchangeably throughout this report.

Sources

Diesel is derived from crude oil through a process called fractional distillation. Crude oil is produced both domestically and internationally. North Carolina does not currently produce any crude oil, nor are any petroleum refineries located within the State. Virtually all of North Carolina's petroleum supplies (including diesel) are brought north from refineries along the Gulf Coast via either the Colonial or Plantation pipelines. According to data from the Energy Information Administration, approximately 68 percent of crude oil processed on the Gulf Coast (PADD-3) comes from foreign sources (U. S. Energy Information Administration, 2012). Approximately 55 percent of those imports come from OPEC nations (U. S. Energy Information Administration, 2012).

After diesel or other petroleum products arrive in North Carolina via pipeline they are temporarily deposited into one of three petroleum terminals, where they await distribution or reinjection into the pipeline for travel to markets further north. Trucks are normally used to transport products to local distributors, large consumers, or retail stations.

A small percentage (<2%) of petroleum products enter the State via ship or interstate transfer. Products arriving via ship are temporarily deposited in a harbor terminal for distribution or re-embarkation. Interstate transfers usually serve markets near interstate borders, where it may be more economical to pull product from a petroleum terminal in another state. Elizabeth City is a prime example, where it is commonly more economical and practical to pull fuel from Norfolk, VA than Selma or Greensboro.

Market for Diesel

Diesel and its feedstock, crude oil, are fungible products traded on global commodity markets. Geopolitical and natural events that have actual or perceived effects on local, regional, or global supplies can drive price shifts. Fluctuations in futures and spot markets directly affect prices at the pump and ultimately local and State budgets. In recent years, diesel producers have increased exports of finished product to markets such as Europe, where the majority of passenger vehicle fleets operate on diesel. The consumer cost of diesel is subject to variation over time, differences in local markets, and additional factors depending on the method of purchase. The two major methods of purchase used by fleet managers and individual vehicle operators are State contracts and the retail market.

The North Carolina Department of Administration's Division of Purchasing and Contracting maintains and administers the State contracts for diesel. The contracts are known as 405P and 405Q. As discussed in the beginning of the fuels section, the state contract price does not include several taxes that are normally applied to retail motor fuel. The research team was unable to obtain statewide historical prices for transport loads of diesel on State contract from the Department of Administration. Instead, calculations for diesel fuel costs used the FY11-12 average price for diesel purchased on State contract in Wake County. This data came from the Petroleum Displacement Plan report produced by the North Carolina Solar Center. The FY11-12 PDP report identified an average diesel price of $3.156 per gallon (North Carolina Solar Center, 2012).

When not required to use agency fuel depots, individual vehicle operators commonly purchase diesel at local commercial fuel stations. This is often the most convenient option, allowing drivers to stop at any retail fuel station along their route. Unfortunately, purchasing fuel on the retail market is generally more expensive than the State contract rate, although the State does recover the tax portion of retail fuel prices. Retail prices vary significantly over time and across the state. The U.S. Energy Information Administration estimates that the average price of retail diesel in the Lower Atlantic region during 2011 was $3.800 per gallon for 2011 (U.S. Energy Information Administration, 2012). The State Energy Office maintains historical records of daily average fuel prices collected by the American Automotive Association (AAA) in their Fuel Gauge report for several North Carolina metropolitan areas. The AAA fuel price reports averaged $3.82 per gallon during 2011 (American Automobile Association, 2012).

Availability of Consumer Vehicles

Diesel is currently the dominant fuel used in commercial trucking and the heavy duty vehicle segment. Several major light duty vehicle manufacturers and virtually all medium and heavy duty truck manufacturers offer a range of diesel-powered products. The majority of medium and heavy duty trucks on the road today are powered by diesel engines. Virtually all school buses are diesel powered. Diesel powered vehicles are readily available on State contract and the open commercial market. Diesel served as the base case fuel for the following vehicle types: medium duty trucks, heavy duty trucks, specialized vehicles, and school buses.

Existing Infrastructure

NCDOT currently operates 76 diesel fuel sites statewide, of which 51 have 24-hour availability and 38 are open eight hours during the day (North Carolina Department of Transportation). Diesel is also available at approximately 3,800 commercial fuel stations in the State. The majority of commercial stations accept the State fleet credit card. Diesel is readily available throughout the State.

Technical Considerations

There are few special technical considerations with respect to diesel. Because diesel is subject to gelling in cold weather conditions, petroleum vendors routinely winterize diesel with additives prior to sale as needed for the local climate and time of year. Fleet managers who maintain their own fueling stations should work with their vendors to ensure the product in their tanks is appropriately winterized for local conditions.
No fuel-specific operator training is required to re-fuel diesel powered vehicles.

Ethanol Based Gasoline (E-85)

Basic Information

Ethanol is a biofuel derived from plant-based feedstocks such as corn, sugar or similar organic materials (U.S. Department of Energy Office of Energy Efficiency and Renewable Energy, 2003). Ethanol or ethyl alcohol is produced through fermentation and distillation. E-85 is liquid under normal ambient conditions. It is the same chemical found in alcoholic beverages. Ethanol produced for use as a motor fuel is routinely denatured to make it unsuitable for human consumption. Ethanol is commonly sold as E-85, an 85 percent ethanol/15 percent gasoline blend.

Sources

The gasoline component of E-85 arrives in North Carolina via the same sources and methods as conventional gasoline (pipelines and interstate transfer).

According to EIA data, the vast majority of domestic ethanol production occurs in the Midwestern states that make up Petroleum for Administration Defense Districts-2 (PADD-2). The primary feedstock for domestic ethanol is corn, which producers mill into flour, ferment and distill to convert its sugars and starches into ethanol, with the remainder used as animal feed. The ethanol component of E-85 enters North Carolina either by rail or ground transportation. There are no commercial ethanol producers currently operating within the state. In 2007, the U.S Department of Agriculture identified that approximately 60 percent of all ethanol was shipped by rail, 30 percent by truck and 10 percent by barge (U.S. Department of Agriculture, 2007).

Market for Ethanol (E-85)

Because 15 percent of E-85 is gasoline, E-85 is subject to many of the same market forces that act upon gasoline (E-10), although often to a lesser degree. As a biofuel derived from agricultural products, E-85 production is also affected by weather conditions such as excess rainfall, drought, or any other condition acting upon agricultural processes. Because ethanol enters the state via rail and truck transportation, it is also subject to disruption and fluctuation in transportation costs. All of these factors can affect prices at the pump and ultimately affect state and local budgets. The consumer cost of E-85 is subject to variation over time, differences in local markets, and additional factors depending on the method of purchase. The two major methods of purchase used by fleet managers and individual vehicle operators are State contracts and the retail market.

The North Carolina Department of Administration's Division of Purchasing and Contracting maintains and administers the State contracts for E-85. The E-85 contracts are known as 405R and 405X. As discussed in the beginning of the fuels section, the state contract price does not include several taxes that are normally applied to retail motor fuel. The research team averaged the price of transport fuel contracts for the period of January 2011- December 2012 and identified an average price of $2.6079/gallon (North Carolina Department of Administration, 2012).

When not required to use agency fuel depots, individual vehicle operators may purchase E-85 at local commercial fuel stations. This is often the most convenient option, allowing drivers to stop at any retail fuel station along their route. Whenever possible, it is preferred that operators refuel E-85 capable vehicles at state maintained facilities with E-85 purchased on state contract to reduce costs and turn over stock. The research team was unable to locate U.S. Energy Information Administration or the American Automotive Association retail price averages for E-85 in North Carolina. Anecdotal evidence indicates that purchasing E-85 at retail stations is more expensive than on State contract, which is consistent with other fuels.

Availability of Consumer Vehicles

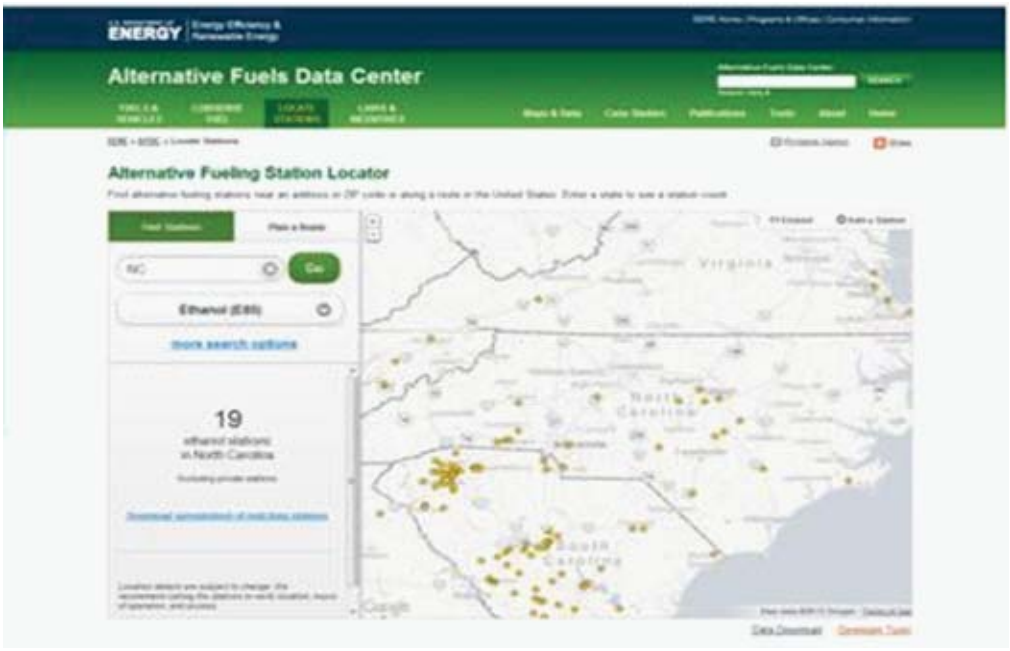
E-85 compatible vehicles are commonly referred to as “flex-fuel” vehicles, and can run on any ethanol/gasoline blend with up to 85 percent ethanol by volume. Several major vehicle manufacturers offer flex fuel capability as a no-cost option on a full range of vehicle types. Flex fuel vehicles are readily available on State contract and the open commercial market. After surveying vehicles currently available on the open market, the research team evaluated E-85 powered vehicles for the following vehicle classes: sedans, passenger vans, panel/utility vans, light duty trucks, and medium duty trucks.

Existing Infrastructure

E-85 is available at several locations within the State, but it is not as widely available as gasoline or diesel. When refueling at a state maintained fuel site is not efficient or convenient, an operator may purchase E-85 at commercial fuel stations. The majority of commercial stations accept the State fleet credit card.

There are currently 32 E-85 gas stations in North Carolina, of which 19 are commercial stations and 13 are owned or operated by a government entity. Of the 13 government stations, seven are owned/operated by state agencies; five stations by NC DOT, one by NC DOA MFM, and one at University of North Carolina Chapel Hill (UNC-CH). Of the remaining six government stations, five are located on military installations, and one in the Town of Chapel Hill (U.S. Department of Energy, Energy Efficiency & Renewable Energy, 2012). NCDOT intends to install one new E-85 station annually.

Figure 1 AFDC Map of E-85 Fuel Stations



Technical Considerations

E-85 can only be used in “flex fuel” vehicles (FFVs) which have been designed to operate on alcohol based-fuels. It cannot be used in traditional gasoline-only engines, as high concentrations of alcohol may reduce the lifespan of rubber components such as hoses and seals (Renewable Fuels Foundation, 2009). No operator training is required to re-fuel E-85 powered vehicles (North Carolina Department of Administration). Operators should recognize E-85/flex fuel vehicles by their FFV badging or the vehicle’s yellow gas cap.

Ethanol is hygroscopic, meaning it attracts and captures water from ambient air. For this reason, E-85 must be "turned over" or consumed within 60 days or risk deterioration due to water absorption. This applies to ethanol kept in on-vehicle storage and in bulk storage tanks.

During winter months, E-85 producers will vary the percentage ethanol content in order to preserve engine performance. ASTM International standard D5798 (Standard Specification for Ethanol Fuel Blends for Flexible Fuel Automotive Spark Ignition Engines) outlines the appropriate blend by region and month, as well as other properties (American Society for Testing and Materials , 2012). Bulk purchasers should ensure their vendor is providing appropriate blends for the local area and time of year.

According to NCDOT, it may cost upwards of $105,000 to construct a new E-85 fueling station (Thompson, 2012).

Favorable Applications

E-85 does not present any special requirements that limit its use beyond those associated with conventional gasoline. E-85 use could be readily increased wherever state-owned FFVs are operated near E-85 stations. If a vehicle's duty cycle takes it out of its normal area and an operator is unable to locate E-85, the vehicle will readily accept conventional gasoline from any state-owned fuel station or commercial fuel station.

Biodiesel (B-20)

Basic Information

Biodiesel is a biofuel derived from one or more of several different feedstocks such as virgin vegetable oils (soy, rapeseed, canola, sunflower, etc.), animal fats, waste cooking oil, and oil from algae. Biodiesel is liquid under normal ambient conditions. When blended with diesel, the resulting product is labeled according to the percentage of biodiesel it contains. Pure biodiesel is referred to as B100. B-20, the most common biodiesel blend in NC, contains 80 percent diesel and 20 percent biodiesel.

Sources

The diesel component of B-20 arrives in North Carolina via the same sources and methods as conventional diesel (pipelines and interstate transfer).

The primary feedstock for domestic biodiesel is virgin soy oil, which is extracted from soybeans through a crushing process. According to EIA data, approximately 75 percent of domestic biodiesel (B100) production occurs in the Midwest (U. S. Energy Information Administration, 2012). There are currently three commercial biodiesel producers in NC and their combined estimated annual production capacity is 9 million gallons. Additional biodiesel is brought into the state via rail and interstate transfer.

Market for Biodiesel (B-20)

Because 80 percent of B-20 is diesel, B-20 is subject to many of the same market forces that act upon diesel, although often to a lesser degree. In recent years, diesel producers have increased exports of finished product to markets such as Europe, where the majority of passenger vehicle fleets operate on diesel. As a biofuel derived from agricultural products, B-20 production is also affected by weather conditions such as excess rainfall, drought, or any other condition acting upon agricultural processes. Because a large percentage of biodiesel enters the state via rail and truck transportation, it is also subject to disruption and fluctuation in transportation costs. All of these factors can affect prices at the pump and ultimately affect state and local budgets. The consumer cost of biodiesel and biodiesel blends are subject to variation over time, differences in local markets, and additional factors depending on the method of purchase.

The two major methods of purchase used by fleet managers and individual vehicle operators are State contracts and the retail market. Biodiesel is essentially a substitute fuel for diesel, and its prices track diesel. As diesel prices increase, additional biodiesel feedstocks become cost competitive.

The North Carolina Department of Administration's Division of Purchasing and Contracting maintains and administers the State contracts for B-20. The B-20 contracts are known as 405V and 405L. As discussed in the beginning of the fuels section, the state contract price does not include several taxes that are normally applied to retail motor fuel. The research team averaged the price of transport fuel contracts for the period of January 2011- December 2012 and identified an average price of $3.4457/gallon (North Carolina Department of Administration, 2012).

When not required to use agency fuel depots, individual vehicle operators may purchase B-20 at local commercial fuel stations. This is often the most convenient option, allowing drivers to stop at any retail fuel station along their route. Whenever possible, it is preferred that operators refuel B-20 capable vehicles at state maintained facilities with B-20 purchased on state contract to reduce cost and turn over stock. The research team was unable to locate U.S. Energy Information Administration or the American Automotive Association retail price averages for B-20 in North Carolina. Anecdotal evidence indicates that purchasing B-20 at retail stations is more expensive than on State contract, which is consistent with other fuels.

Availability of Consumer Vehicles

Nearly all current-production diesel-powered vehicles are manufacturer approved to operate on low-concentration biodiesel blends. Manufacturers may specify an upper design limit for biodiesel blends. Several major light duty vehicle manufacturers and virtually all medium and heavy duty truck manufacturers offer a range of B-20 capable diesel-powered products. The majority of medium and heavy duty trucks and virtually all school buses are powered by B-20 capable diesel engines. B-20 capable vehicles are readily available on State contract and the open commercial market. After surveying vehicles currently available on the open market, the research team evaluated B-20 powered vehicles for the following vehicle classes: light duty trucks, medium duty trucks, heavy duty trucks, specialized vehicles, and school buses.

Existing Infrastructure

B-20 is available at several locations within the State, but it is not as widely available as gasoline or diesel. When refueling at a state maintained fuel site is not efficient or convenient, an operator may purchase B-20 at commercial fuel stations. The majority of commercial stations accept the State fleet credit card.

NCDOT currently operates 29 B-20 fuel sites statewide, of which 16 have 24-hour availability and 13 are open eight hours during the day. (North Carolina Department of Transportation). If operators of a state-owned vehicle are unable to acquire fuel at one of the DOT fuel sites, then they may acquire fuel from commercial sources. There are 28 commercial B-20 sites in the state.

Figure 2 AFDC Map of Biodiesel Stations

Technical Considerations

The NC Department of Transportation is the largest consumer of B-20 within state government. In order to ensure the quality of purchased fuel and protect state equipment, DOT only purchases B-20 from BQ-9000 accredited producers. The National Biodiesel Accreditation commission developed the BQ-9000 certification to ensure that commercially marketed fuel adheres to the ASTM standards. To become BQ-9000 certified, producers voluntarily submit to an inspection of quality control processes and laboratory testing of product.
.
ASTM 975 sets the regulations for all light, middle and heavy distillates, including any biodiesel blend less than 5 percent. This blend stock is mixed with B100 to produce B-20. Biodiesel blends in the range of 6%-20% must meet ASTM D7467. ASTM D6751-11b defines the properties of B100 blend stock.

Like diesel, B-20 is subject to gelling in cold weather conditions. Petroleum vendors routinely winterize B-20 with additives prior to sale as needed for the local climate and time of year. Additionally, consumers may require biodiesel vendors only use certain feedstocks during winter months to minimize the potential for gelling. Fleet managers who maintain their own fueling stations should ensure the product in their tanks is appropriately winterized for local conditions. No fuel-specific operator training is required to re-fuel B-20 powered vehicles.

According to the NCDOT, it may cost upwards of $105,000 to construct a new B-20 fueling station (Thompson, 2012).

Favorable Applications

B-20 does not present any special requirements that limit its use beyond those associated with conventional diesel. Use of B-20 could be increased wherever diesel powered vehicles have access to B-20 refueling stations. If a vehicle's duty cycle takes it out of its normal area and an operator is unable to locate B-20, the vehicle will readily accept conventional diesel from any state-owned fuel station or commercial fuel station.

Liquefied Petroleum Gas (Auto-gas/LPG/Propane)

Basic Information

Liquefied Petroleum Gas (LPG), commonly known as propane, is a byproduct of natural gas processing and crude oil refining. LPG is a gas under normal ambient conditions, and generally stored as a liquid under pressure. LPG is naturally odorless and colorless. An odorant is added for safety reasons. Historically, both gasoline and diesel engines have been converted to run on LPG. Two North Carolina law enforcement agencies, Iredell County Sheriff's Office and the Raleigh Police Department, have transitioned a portion of their patrol vehicles to LPG. The research team was unable to identify any propane-powered vehicles currently being used in the State fleet.

Sources

North Carolina does not currently produce LPG. Virtually all of North Carolina's LPG supplies enter the state via the Dixie pipeline, which brings LPG north from refineries in Texas, Louisiana, and Mississippi. The pipeline terminates at a terminal in Apex, NC where LPG is stored prior to redistribution. Redistribution usually occurs via ground transportation such as rail or trucks delivering fuel to local distributors or end-users.

Market for Liquefied Petroleum Gas (LPG)

North Carolina does not produce or refine LPG, and is dependent upon refineries on the Gulf Coast. This dependence can increase price volatility associated with LPG. LPG demand is seasonal, with prices traditionally rising during the winter heating months. Bulk consumers may be able to reduce vulnerability to seasonal price swings through strategic purchasing. The consumer cost of LPG is subject to variation over time, differences in local markets, and additional factors depending on the method of purchase. It is available on State contracts and the retail market.

The North Carolina Department of Administration's Division of Purchasing and Contracting maintains and administers the State contracts for LPG. The LPG contracts are known as 405A and 405K. The contracts for LPG differ from gasoline or diesel products in that LPG tank wagon contracts require a minimum delivery of 100 gallons whereas transport contracts require a minimum of 9,000 gallons. As discussed in the beginning of the fuels section, the state contract price does not include several taxes that are normally applied to retail motor fuel. The research team averaged the price of transport fuel contracts for the period of January 2011- December 2012 and identified an average price of $1.6785/gallon (North Carolina Department of Administration, 2012). This price level equates to a gasoline-gallon equivalent price of approximately $2.32/GGe. The economic analysis contained in this report uses the estimated cost of LPG purchased on the state contract, not on the retail market.

When not required to use agency fuel depots, individual vehicle operators may purchase LPG at local LPG dealers or commercial fuel stations. This is often the most convenient option, allowing drivers to stop at any retail fuel station along their route. Whenever possible, it is preferred that operators refuel LPG capable vehicles at state maintained facilities with LPG purchased on state contract to reduce cost and turn over stock. The research team had some difficulties identifying a reliable source for retail price averages for LPG. The American Automobile Association does not include LPG prices in its Fuel Gauge Report and the Energy Information Administration (EIA) only records LPG prices during the heating season (October-March) and by Petroleum Administration for Defense Districts (PADD's). During the six month period tracked by EIA the average wholesale price of LPG was $1.48 per gallon (U.S. Department of Energy, Energy Information Administration, 2012).

The research team consulted industry representatives in an attempt to identify a fair method for estimating the retail price for LPG used as a motor fuel. They provided the following method for estimating per-gallon price for retail LPG sold as a motor fuel.

Wholesale LPG price + $0.389 for road tax + $0.50 dealer margin = retail price

The research team would expect to see an estimated $0.89 cent increase over the posted wholesale price. Assuming a wholesale LPG price of $1.30 per gallon, $0.389 per gallon in road tax and an approximate $0.50 cent per gallon margin would produce a retail price of approximately $2.189 per gallon, or $3.02 per gasoline gallon equivalent.

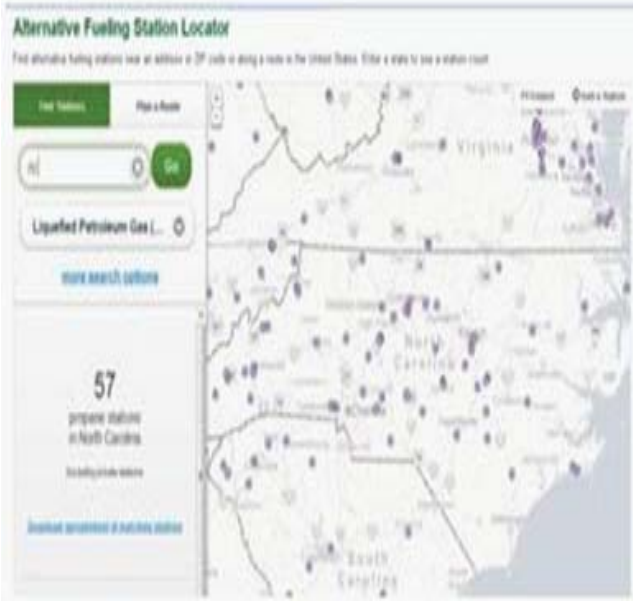
Availability of Consumer Vehicles

Several major manufacturers currently offer a limited range of LPG powered vehicles direct from the factory. Additionally, there are several OEM-approved third party firms that install LPG conversion systems on gasoline and diesel powered vehicles. When possible, the research team collected pricing data for vehicles designed and manufactured to run on LPG. This data was supplemented with pricing data from third party firms installing EPA-certified LPG conversion systems. Some common examples of LPG vehicles are the Ford Crown Victoria, F250 and F350 trucks, Chevy Silverado or GMC Sierra trucks and E-Series passenger vans. After surveying vehicles currently available on the open market, the research team evaluated LPG powered vehicles for the following vehicle classes: sedans, passenger vans, panel/utility vans, light duty trucks, medium duty trucks, specialized vehicles, and school buses.

Existing Infrastructure

LPG is sold throughout North Carolina for use as a heating, cooking and agricultural fuel, but it is not commonly sold as a motor fuel in North Carolina. According to the Alternative Fuels Data Center, there are at least six private access and 58 public access LPG filling stations in the state. Of the private access stations, NCDOT operates LPG filling stations in Raleigh; Fayetteville; McLeansville; and Winston Salem, another station is military only, and the remaining station is for authorized users only (North Carolina Department of Transportation).

Figure 3 AFDC Map of LPG Stations



Technical Considerations

LPG-powered vehicles are available in dedicated LPG and bi-fuel (LPG & gasoline) configurations.

- Dedicated engines only run on a single fuel type, such as propane. They have only one fuel storage and delivery system. Dedicated LPG configurations typically have greater on-board LPG storage capacity and LPG-only range.
- Bi-Fuel vehicles have a separate fuel storage system that allows the vehicle to operate on either an alternative fuel such as propane or a conventional fuel such as gasoline or diesel. Bi-Fuel vehicles have two fuel storage and delivery systems, and operate on only one fuel source at a time. Bi-fuel configurations typically have less LPG storage capacity, but are also able to operate on conventional gasoline from any government or commercial fuel station. Bi-Fuel vehicles have more flexibility in that the operator has control over which fuel is used, and has the option of selecting the most cost-effective fuel.

LPG is stored in an on-board cylinder pressurized to approximately 250 pounds per square inch (PSI). Automotive LPG cylinders are equipped with a pressure relief valve to vent gas if pressure exceeds a safety threshold. Cylinders can be mounted in several locations depending on vehicle type. In sedans, the tank is usually located in the trunk and in light duty pick-up trucks the tank is usually in or under the bed of the truck. Agencies considering adopting LPG vehicles should consider the impact on available space.

According to information provided by industry consultants, a basic LPG filling station could be installed for approximately $28,000. This price would include a 1,000 gallon tank, motor, electric connection and skid (base) capable of filling 50 vehicles (assuming 20 gallon tanks and 50 vehicles). This system would not have the ability to track fuel usage by vehicle and/or mileage and would need daily refills if vehicles expended their tanks on a daily basis. Another potential option is the installation of an 18,000 gallon tank that could cost approximately $120,000. The research team elected to use the 18,000 gallon system for life cycle cost calculations as it appeared to provide the best value and could support the instantaneous demand of the 50-vehicle notional fleet used for infrastructure cost comparisons.

While the initial price tag for LPG infrastructure is substantial, there are opportunities for the State to avoid some costs. There are providers who are willing to provide and install the infrastructure at a significant discount in return for a contract to supply the fuel for some period, usually three years. Several municipal entities within the state have engaged this purchase method; the City of Raleigh, Iredell County Sheriff's Office and the Town of Knightdale Police Department.

According to the North Carolina Propane Gas Association, drivers must attend safety training in order to understand how to fuel the vehicle. National Fire Protection Association standard 58 (NFPA-58) outlines considerations for safe storage, handling, transportation and risk mitigation measures for propane gas.

Favorable Applications

Successful LPG deployments are typically depot-refueled fleets with moderate to high fuel consumption. Moderate to high fuel consumption applications are better able to recoup up-front costs and realize net savings through lower ongoing fuel costs.

Compressed Natural Gas (CNG)

Basic Information

Compressed Natural Gas (CNG) is a mixture of methane and other hydrocarbon gases that has been compressed into a pressurized storage vessel. CNG is a gas under normal ambient conditions. CNG is naturally odorless and colorless. An odorant is added for safety reasons. Historically, both gasoline and diesel engines have been converted to run on CNG.

Sources

Natural Gas is traditionally found in areas that are abundant with crude oil. The vast majority of natural gas consumed in the United States is produced domestically. North Carolina does not currently produce natural gas. The State's natural gas supply arrives via either one of two interstate transmission pipelines: the Columbia Gas Transmission Company pipeline or the Williams Transcontinental Gas Pipe Line Corporation (Transco). Both of these pipelines bring pressurized gas north from processing facilities located along the Gulf Coast. Spur lines branch off these lines at several points to bring gas to local distribution companies (LDCs). The major LDC's in North Carolina are Piedmont Natural Gas Company, Public Service Company of North Carolina (PSNC) Frontier Natural Gas Company and Toccoa Natural Gas.

Market for Compressed Natural Gas (CNG)

The primary benchmark price for natural gas is set at a major interconnection point for several interstate transmission pipelines known as the Henry Hub, located in Erath, LA. The price of natural gas can vary based on several factors such as volume of gas produced, volumes currently stored, export rates, seasonal factors such as weather, and the price of crude oil. Natural gas is primarily used as a heating and power generation fuel. Stocks usually build during summer months, putting downward pressure on prices. Prices tend to see upward pressure when temperatures drop and the demand for heating fuel increases. Production, storage, and transportation of natural gas can be affected by severe weather events that occur in the Gulf of Mexico, such as Hurricane Isaac, which briefly shut in production of natural gas (U.S. Department of Energy, Energy Information Administration).

Larger LDCs such as Piedmont, PSNC, Frontier, and Toccoa are regulated by the North Carolina Utility Commission (NCUC). If the natural gas is provided by a municipal system, more than likely is not regulated by the NCUC. The NCUC does not set natural gas prices, but it does provide oversight on rates charged by LDCs. Retail gas prices are a combination of the cost of the actual gas, transportation fees from the point of injection to the LDC, and transportation costs from the LDC to the customer's meter (North Carolina Utility Commission). The Henry Hub spot market price is the most commonly cited benchmark price. For the purposes of life cycle cost analysis, the research team calculated the 12-month average of Piedmont Natural Gas Company's Schedule 142 rate for natural gas vehicle fuel in 2011. Schedule 142 provides pricing in both therms and gasoline-gallon equivalents or GGes. The 2011 average was $0.94/GGe. This is functionally equivalent to the natural gas vehicle fuel pricing of PSNC Energy, another large LDC serving the North Carolina market.

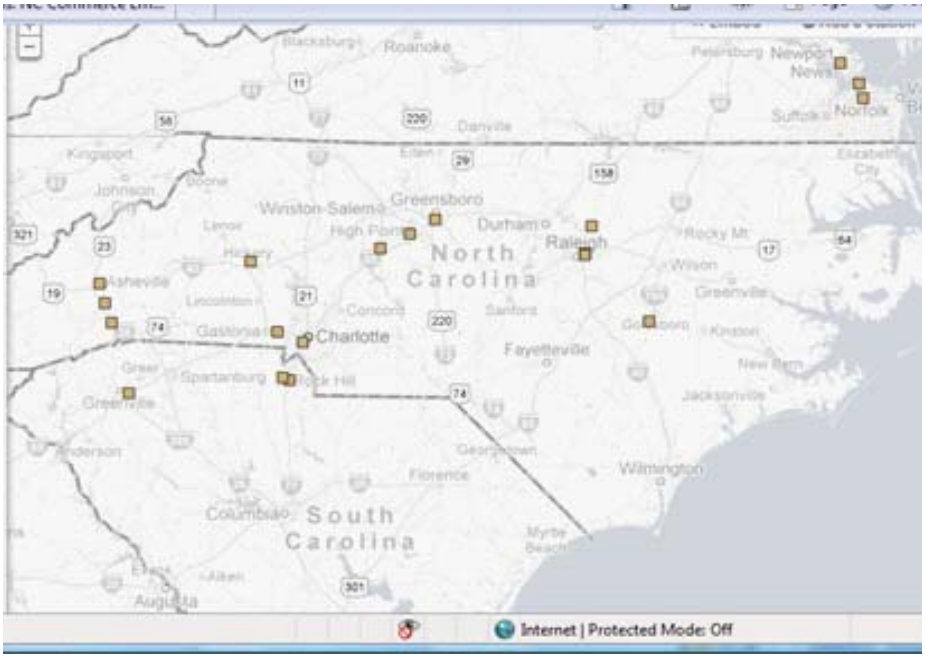
Availability of Consumer Vehicles

Several major manufacturers currently offer a limited range of CNG powered vehicles direct from the factory. Additionally, there are several OEM-approved third party firms that install CNG conversion systems on gasoline and diesel powered vehicles. When possible, the research team collected pricing data for vehicles designed and manufactured to run on CNG. This data was supplemented with pricing data from third party firms installing EPA-certified CNG conversion systems. After surveying vehicles currently available on the open market, the research team evaluated CNG powered vehicles for the following vehicle classes: passenger vans, panel/utility vans, light duty trucks, medium duty trucks, heavy duty trucks, specialized vehicles, and school buses.

Existing Infrastructure

At this time, there is one State maintained CNG refueling site located in Winston Salem (North Carolina Department of Transportation). According to the Alternative Fuels Data Center, there are at least 16 private access and 13 public access CNG filling stations in the state. Of the 16 private access CNG filling stations, five are owned and operated by municipal governments, two are owned by the federal government, one by a state agency (NC DOT), one by Duke University, and seven are owned by commercial entities. Of the 13 public access stations, six are owned and operated by municipal entities that are available to the public to use. The seven remaining public stations are owned by commercial entities and are open to the public.

Figure 4 AFDC Map of CNG Stations



Technical Considerations

Compressed Natural Gas (CNG) vehicles are commonly classified as one of three types: Dedicated, Bi-Fuel, Dual-Fuel. The majority of CNG applications in light and medium vehicles are either dedicated or bi-fuel engines. Dual-fuel configurations are more common in heavy duty vehicles such as refuse trucks and tractor trailers.

- Dedicated engines only run on a single fuel type, being compressed natural gas. They have only one fuel storage and delivery system.
- Bi-Fuel vehicles have a separate fuel storage system that allows the vehicle to operate on either an alternative fuel such as natural gas or a conventional fuel such as gasoline or diesel. Bi-Fuel vehicles have two fuel storage and delivery systems, and operate on only one fuel source at a time. Bi-Fuel vehicles have more flexibility in that the operator has control over which fuel is used, and has the option of selecting the most cost-effective fuel.
- Dual-Fuel vehicles operate on the alternative fuel, such as natural gas, but use the traditional fuel such as diesel for ignition. If the vehicle should run out of alternative fuel, the engine will automatically revert to the conventional fuel and operate as a conventionally fueled vehicle.

CNG is stored on vehicles in one or more cylinders that are pressurized between 3,000-3,600 pounds per square inch (PSI) when full. Lines with pressure regulators carry the gas forward to the vehicle's intake manifold for injection into the combustion chamber. Most CNG-powered engines are spark ignited, although some manufacturers are now offering compression ignited CNG-engines that use a small amount of diesel fuel to ignite a larger CNG charge.

Safety training will be required for vehicle operators needing to refuel CNG-powered vehicles. National Fire Protection Association standard 57 (NFPA-57) outlines considerations for safe storage, handling, transportation and risk mitigation measures for natural gas.

The research team held conversations with several entities to estimate the cost of a CNG refueling station. Asheville, North Carolina installed a CNG filling station in 2005 for a cost of approximately $500,000 and later upgraded the station under an ARRA grant with $320,000 in matching funds. With the upgrades, this station was upgraded to support 50-60 vehicles per day. Consultation with Piedmont Natural Gas Company and PSNC Energy produced estimates ranging from $680,000-800,000 for a fast-fill station that would support a 50-vehicle fleet with 1000 GGe of daily demand (McElrath, 2012) (Nestor, 2012).

There are opportunities for the State to reduce or recover the costs associated with the installation of the natural gas filling station. Infrastructure can be designed and installed to serve both a fleet operator and public at large. By building a refueling station that the private sector can use, an infrastructure owner can offset their costs through retail sales of CNG. Several municipal entities within the state have been able to utilize forms of this cost-mitigation mechanism, including: the City of Asheville, Henderson County, the City of Hickory, City of Raleigh, City of Wake Forest, Davidson County Garage.

Favorable Applications

The most cost-effective CNG vehicle applications are typically depot-based heavy duty vehicles with high fuel consumption and operating on predictable routes, such as a hub and spoke system or A-to-B route. High fuel consumption applications are better able to recoup up-front costs and realize net savings through lower ongoing fuel costs. The term hub and spoke refers to the concept that the vehicles start from the hub, travel outward (on the spoke), and return to the hub at the end of the day. This is also known as "Return to Base" or RTB operation.

Battery Electric, Plug-in Electric, Hybrid Electric Vehicles

Basic Information

This category encompasses three variations of automotive engine technology: gas hybrids, plug-in hybrid electric vehicles (PHEVs), and battery electric vehicles (BEVs).

Note: The following descriptions are generalities. Specific makes/models may differ in application.

Gas hybrids are conventionally powered vehicles that use a secondary electric drive train to supplement an internal combustion engine and improve fuel economy. All energy for locomotion is ultimately generated by an internal combustion engine. Example vehicles are the Honda Insight, Toyota Prius, or Ford Fusion Hybrid. Most major automobile manufacturers now offer one or more models of gas hybrids.

Plug-in Electric Hybrids (PHEVs) differ in that they can operate solely on their electric drive train, at least for short distances at low speeds. Some PHEVs (such as the Chevrolet Volt) can drive up to 40 miles at highway speeds on battery power alone (Electric Power Research Institute, 2011). The batteries in a PHEV are normally recharged by plugging the vehicle into an electrical outlet, where it will draw power from the grid.

If a PHEV's onboard batteries are depleted during normal operation, or the driver requests more power than the electric drive train can produce, it will engage an internal combustion engine to run a generator or provide power to the wheels. Example vehicles are the Toyota Plug-in Hybrid Prius or the Chevrolet Volt. Several manufacturers have announced additional PHEV models currently in development for future release.

Battery Electric Vehicles (BEVs) are pure electric vehicles and do not have an on-board internal combustion engine to supplement or recharge their batteries. They typically have large battery packs, capable of delivering a range of approximately 100 miles under ideal conditions (Electric Power Research Institute, 2011). BEVs must be plugged into an electrical outlet or dedicated charging station in order to "refuel" by charging their batteries. Example vehicles are the Nissan Leaf and Mitsubishi i-MiEV.

Sources

Gas hybrids generate all of their locomotive power from the combustion of gasoline. Information about the source of gasoline is available in the Gasoline (E-10) section of this report. Gas hybrids require access to gasoline refueling infrastructure.

Because PHEVs derive their locomotive power from a combination of gasoline and electricity, their energy profile is essentially a hybrid of that of BEVs and conventional gasoline vehicles.

BEVs generate all of their locomotive power from an electrical charge stored in their batteries. They are completely dependent upon the electric grid for energy. The modern electric grid is an integrated system spanning multiple states and operated by multiple utility providers. In North Carolina, there are two Investor Owned Utilities (IOU's) (Duke/Progress and Dominion), two municipal power agencies (NCEMPA & NCMPA1) which serve approximately 70 communities, and 26 electric membership cooperatives that are interconnected within the existing electric infrastructure. Each entity provides electricity to various parts of the state and each has their own rate schedule. The existing electric infrastructure is an integrated system that is not bound by the state's borders. In fact, electricity flows into and away from NC. However, during 2010, North Carolina's electric generation was produced by the following fuel mix: 56 percent coal-fired power plants, 32 percent at nuclear power plants, 6 percent natural gas-fired generation, 4 percent hydro-electric and 2 percent other renewables (U.S. Department of Energy, Energy Information Administration, 2012).

Market for Electricity

Electricity rates are subject to much lower fluctuation over time than many other fuel sources. Electricity is generally provided by regulated entities, under rate schedules approved by the North Carolina Utility Commission (NCUC). The cost to recharge a specific vehicle will vary based on local electric rates, distance travelled, battery capacity, and vehicle efficiency. For example, a Nissan Leaf driver who drives less than 40 miles a day should spend less than $1.40 a day on electricity if recharging at $0.10/kWh, an average rate for Duke Energy's service area. The price of electricity varies depending on the appropriate rate schedule for the application.

If the vehicle operator is charging the vehicle at the workplace, a variety of rates could be used and will likely need to be negotiated prior to installation of the charging station. Public charging infrastructure may require a different pricing schema, such as space rental versus paying for the electricity. If a charging location is subject to time of use surcharges, it may be beneficial to charge during off-peak periods. The research team used the Duke-Progress Energy Small General Service (SGS) schedule rate of $0.1086/kWh for its life cycle cost calculations.

Availability of Consumer Vehicles

Several major manufacturers currently offer a limited range of gas hybrid vehicles direct from the factory. After surveying vehicles currently available on the open market, the research team evaluated gas hybrid vehicles for the following vehicle classes: sedans, specialized vehicles, and school buses. There are very few manufacturers currently offering PHEVs.

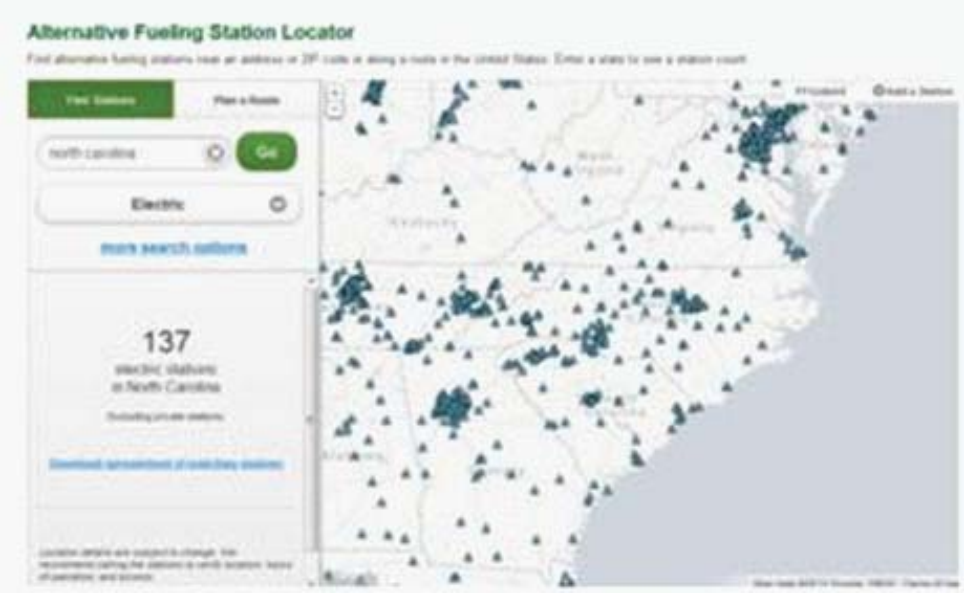
The research team did not identify a competitive market for PHEVs that would be suitable for state fleet purchases. Several manufacturers are currently developing PHEV products, which will be worth consideration once deployed and information becomes available.

There are multiple manufacturers offering a limited range of BEVs. The research team evaluated BEVs for the sedan vehicle class. The research team did not identify any OEM approved third-party conversion options as additional sources.

Existing Infrastructure

BEVs must have access to charging stations to re-charge its onboard battery. According to the Alternative Fuels Data Center, there are at least 60 private access stations and 137 public access stations in North Carolina, see appendix. Of the 60 private access stations, meaning that they are meant for use by the employees or guests of the entity, 35 are associated with Nissan dealerships, four are municipal entities; the remaining 21 are private business access only.

Figure 5 AFDC Map of EV Charging Stations



Gas hybrids and PHEVs are able to refuel using gasoline infrastructure. For a discussion of gasoline infrastructure, see the Gasoline (E-10) section of this report.

Technical Considerations

The primary technical limitation for electric vehicles is range. EV designers must balance the weight and cost of additional batteries against the benefit of increased range. “Range anxiety” is a concern that a BEV could run out of battery charge during its duty cycle. This can be prevented by deploying BEVs in use cases where operators are able to maximize their cost-saving potential without requiring travel beyond the vehicle’s range.

BEV/PHEV operators will require training to utilize charging stations, and to maximize battery range in order to realize potential cost savings from BEV/PHEV operation. PHEVs benefit from being able to use lower cost electrical power stored in their batteries for short-range operations and gasoline for extended range operations.

PHEVs can also refuel at the same infrastructure as conventional gasoline-powered vehicles or recharge at EV charging stations. BEV operators will need to remain aware of the available battery charge, proximity to nearby charging stations and the length of time required to recharge the battery.

PHEV/BEVs can be charged by using the provided level one charger and any 120v electrical outlet. Level one charging is the slowest method available, and will recharge a vehicle's batteries at a rate of approximately three to four miles of potential travel per hour (Waters, 2012). Level one chargers are included with the purchase of all BEVs.

For faster charging, PHEV/BEV operators may choose to use a level two charger, which requires 240v electrical outlet or permanently installed connection. Level two charging will replenish a vehicle's batteries at a charging at a rate of approximately 10-20 miles of potential travel per hour (Waters, 2012). Level two chargers require professional installation by a licensed electrician. The fastest charging option is known as level three, or Direct Current (DC) Fast Charge. These stations can provide up to an 80% battery charge in approximately 30-minutes (Waters, 2012). DC Fast Charge technology is not standardized within the United States and the equipment and installation can be extremely expensive. They are not commonly available.

The research team conducted several meetings with various industry stakeholders to estimate the costs associated with purchasing and installing an electric vehicle charging station. This station would support the same fifty-vehicle fleet used for the other alternative fuel types, recharging their batteries while they were parked overnight. The cost estimate assumes that the charging station would be in an existing parking lot, with access to an electrical source within 200-feet. Consultation with representatives from General Electric, State Electric Supply Co, and Hi-Lite Electric Incorporated produced a budgetary estimate of approximately $700,000 for a 50-vehicle charging station (Schepers, 2012).

Favorable Applications

Because they are able to recapture energy normally lost during braking, hybrids and EVs are well suited for urban environments or other settings with significant stop-and-go traffic. Fleet managers considering EV deployment should look for use cases with low mileage requirements and the ability to charge overnight.

Description & Classification of the State fleet

The Federal Highway Administration (FHWA), U.S. Department of Energy, Environmental Protection Agency, Census Bureau and the North Carolina Department of Transportation utilize different vehicle classification systems.[1]

This report considers those classification systems and has organized motor vehicles into eight categories to simplify the cost benefit calculations. The eight categories used in this report resemble the FHWA classifications, but some categories are compressed, as shown in the table 1 below.

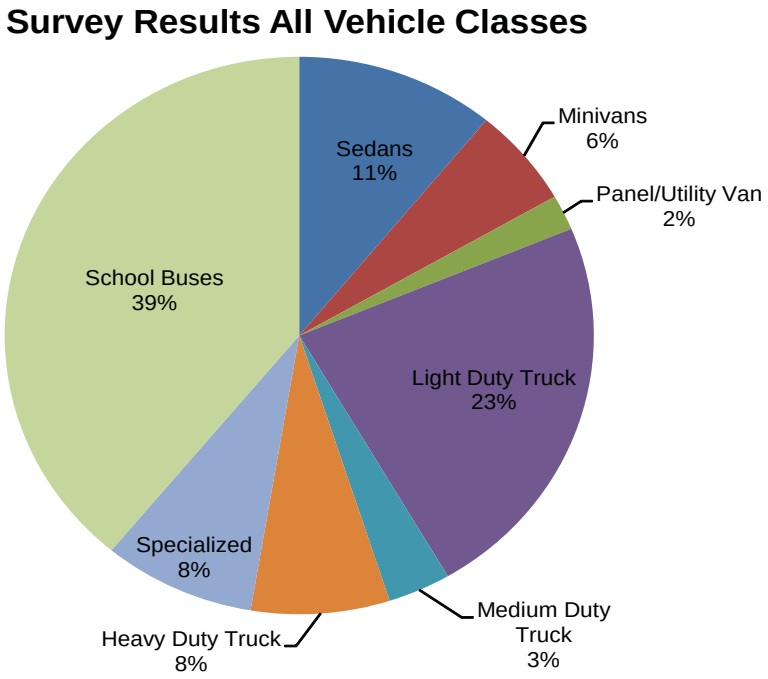
Table 1 Motor Vehicle Classification System

Vehicle Type	Vehicle Class	GVWR	Example
Sedans	Class 1&2	<10,000 lbs	Chevrolet Impala, Ford Fusion, Dodge Avenger
Minivans/Passenger Vans	Class 1&2	<10,000 lbs	Dodge Caravan, Chrysler Town & Country, Honda Odyssey
Panel/Utility Vans	Class 1-3	10,001-26,000 lbs	Ford E-series, Dodge Grand Caravan,
Light Duty Trucks	Class 1-3	<14,000 lbs	Ford F-150, Chevrolet Silverado, Dodge Ram
Medium Duty Trucks	Class 4-6	14,001-26,000	Ford F-450, Ford F-550 Dodge Ram 5500
Heavy Duty Trucks	Class 7-8	>26,0001	Peterbilt or Kenworth trucks tractor trailers or dump trucks
Specialized Vehicles	Class 4-8	>14,001	Ambulances, Vocational trucks, buses
School Buses		> 26,001	Thomas Saf-T Liner C2

For the purposes of this report, the term “state fleet” refers to the fleet described in survey responses received by the State Energy Office, which may differ from the actual fleet of vehicles owned and operated by North Carolina state government.

1 The Federal Highway Administration (FWHA) identifies vehicles by Gross Vehicle Weight Rating (GVWR) and Vehicle Class. All categories are separated by weight. The U.S. Census Bureau also separates vehicles into classes. The EPA classifies vehicles by weight, purpose and engine type. The U.S. EPA publishes vehicle fuel economy data and defines vehicle classes for cars, trucks and special purpose vehicles based on interior passenger and cargo volumes. The size class for trucks is defined by the gross vehicle weight rating (weight of the vehicle, plus carrying capacity). Fuel economy regulations do not apply to heavy-duty vehicles. The North Carolina Department of Transportation closely follows the FWHA classification convention but separates vehicles by weight, purpose and but fuel type (gasoline or diesel).

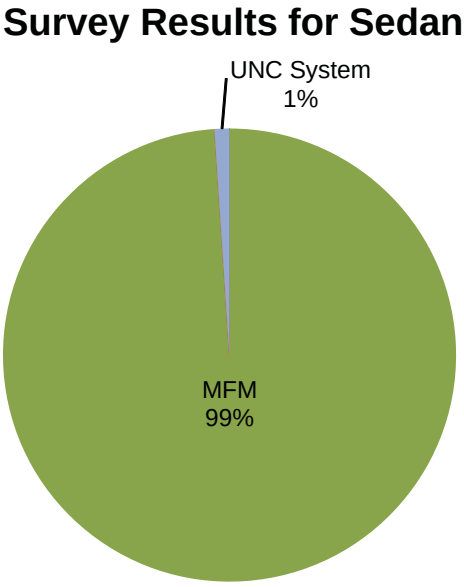
Figure 6 Survey Results for all Vehicle Classes



Sedans

Although sedans only make up approximately 11 percent of the State vehicle fleet, it may be prudent to examine these vehicles for the possibility that the category could grow in size and take up a larger share of the total vehicle fleet. Currently, a vast majority of the sedans in the state fleet are operated by the Motor Fleet Management (MFM) followed by the University of North Carolina College System (UNC-System) accounting for approximately 5,000 sedans and 50 sedans, respectively.

Figure 7 Survey Results for Sedans



Sedans are classified in the light duty vehicle category. Within the State fleet, the majority of sedans log highway miles transporting passengers to distant locations and returning to base(s) in various locations around the state. Some sedans are used for a specialty purpose such as law enforcement and others are take-home cars. The majority of the sedans in the state fleet can operate using gasoline or E-85 blend, although some are gasoline hybrids. On average, sedans can be expected to travel approximately 13,000 miles and consume about 500 gallons of fuel annually.

Vans

Vans are classified as either light or medium duty vehicles depending on gross vehicle weight rating. In total, vans account for 8 percent of the State fleet or approximately 3,600 vehicles. For the purpose of this study, the research team divided vans into two sub categories based upon purpose, passenger and utility vans. Both categories include vehicles that fall under the class 1-3 vehicle categories. Passenger vans are primarily used to transport anywhere from one to eight passengers. Panel or utility vans are primarily used to transport cargo and usually carry no more than two passengers. There are distinct differences in the fuel economy, comfort, engine size, and fuel type. The majority of these vehicles can operate on gasoline (E-10), diesel or biodiesel (B-20), or E-85.

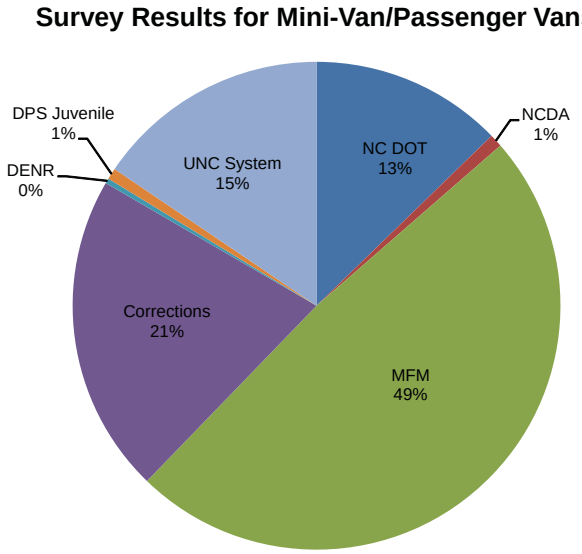
Passenger Vans

Passenger vans make up approximately 6 percent of the state fleet or about 2,700 vehicles. Currently, MFM leads the state with approximately 49 percent or 1,300 mini-vans/passenger vans. The North Carolina Department of Corrections (Corrections) accounts for approximately 21 percent or 570 vehicles, UNC System accounts for 15 percent or 420 vehicles and NC DOT accounts for 13 percent or 340 vehicles.

Passenger vans include both full-size and mini-vans. Passenger vans are designed to move people, therefore performing very little cargo hauling. The majority of the survey respondents indicated that their use of passenger vans was to transport employees, students and prisoners.

The majority of the miles were logged as highway use, however, some, namely the University of North Carolina College system and the Department of Environmental and Natural Resources indicated that a significant amount of miles were logged using surface streets or in a campus environment. On average, a vehicle in this class travels approximately 10,000 miles and consumes about 530 gallons of fuel annually.

Figure 8 Survey Results for Minivans\Passenger Vans



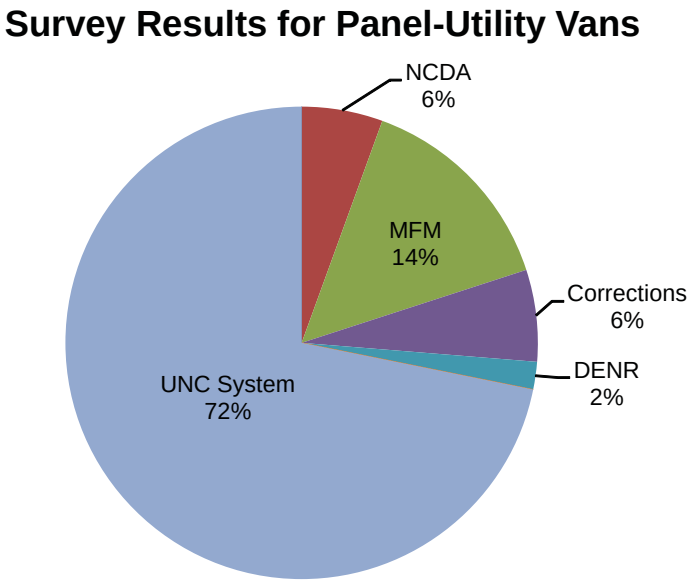
Panel/Utility Vans

Panel/utility vans make up approximately 2 percent of the state fleet or about 955 vehicles. Currently, the
University of North Carolina College system leads the state with approximately 72 percent of the share of van in this category with an estimated 686 units. MFM accounts for approximately 15 percent or 138 units, Corrections and NCDA each represent 6 percent of the share with 60 and 53 units respectively.

This category includes conventional van bodies and "cutaways", where the rear of the van body is removed and replaced with an oversized box. Since the utility vans are primarily used to haul cargo, they are expected to carry no more than two persons. The cargo can range from library books, mail, maintenance or service parts, or inspection equipment. Survey respondents indicated that panel/utility vans generally travel less than 40 miles per day and are usually constrained to a campus or surface street transportation pattern.

On average, a vehicle in this class travels approximately 7,500 miles and consumes about 600 gallons of fuel annually.

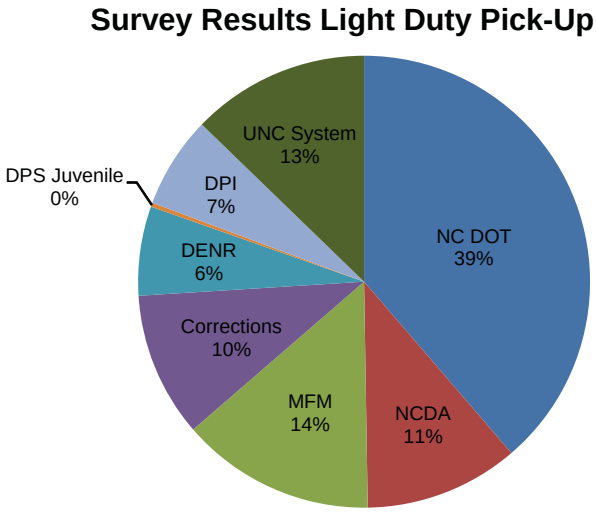
Figure 9 Survey Results for Panel\Utility Vans



Light Duty Trucks

Light Duty Trucks (Classes 1-3) make up approximately 23 percent of the State fleet, or 10,657 vehicles. NCDOT leads the state in possession of vehicles in this category with 39% or approximately 4,124 units. MFM and the UNC System follow with 14 percent (1,482) and 13 percent (1,389) of light duty pick-up trucks, respectively. Survey respondents indicated that light duty trucks were commonly used to move persons and some light to medium cargo. The light duty trucks were used to perform roadside maintenance, emergency response, fire and law enforcement duties, roving patrols, and towing of boats in both a surface street and off road setting. On average, a vehicle in this class travels approximately 8,000 miles and consumes about 660 gallons of fuel annually.

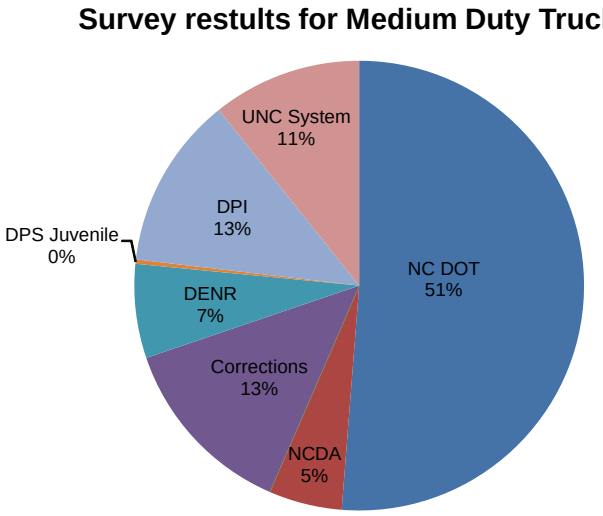
Figure 10 Survey Results for Light Duty Trucks



Medium Duty Trucks

Medium duty trucks (Classes 4-6) account for 3 percent of the state's fleet or about 1,610 vehicles. NC DOT represents approximately 51 percent of this category with approximately 825 medium duty trucks. Corrections and DPI each represent 11 percent with 215 and 200 medium duty trucks respectively. As with light duty trucks, the medium duty trucks are designed to move cargo and a limited amount of personnel. Survey respondents indicated a wide variety of duties for medium duty trucks, such as transportation or shuttle services, delivery of heavy materials, emergency and fire response, and mobile refueling of other vehicles. On average, a vehicle in this class travels approximately 6,600 miles and consumes about 880 gallons of fuel annually.

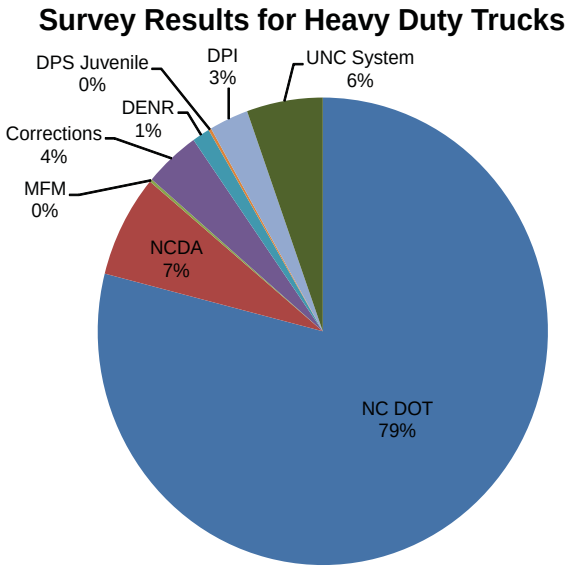
Figure 10 Survey Results for Medium Duty Trucks



Heavy Duty Trucks

The Heavy Duty Truck classification (Classes 7 & 8) accounts for eight percent of the State fleet, or 3,570 vehicles. NC DOT represents approximately 79 percent of the heavy duty truck category with approximately 2,805 vehicles. NCDA represents seven percent of the category with around 250 heavy duty trucks while the UNC System represents six percent of the category with around 210 heavy duty trucks. Survey respondents indicated a wide variety of duties for heavy duty vehicles, such as debris or refuse removal or heavy material transport, wrecker services, firefighting/emergency services and a specialty use as a mobile health clinic. On average, these vehicles travel approximately 9,100 miles and consume about 1,300 gallons of fuel annually.

Figure 12 Survey Results for Heavy Duty Trucks

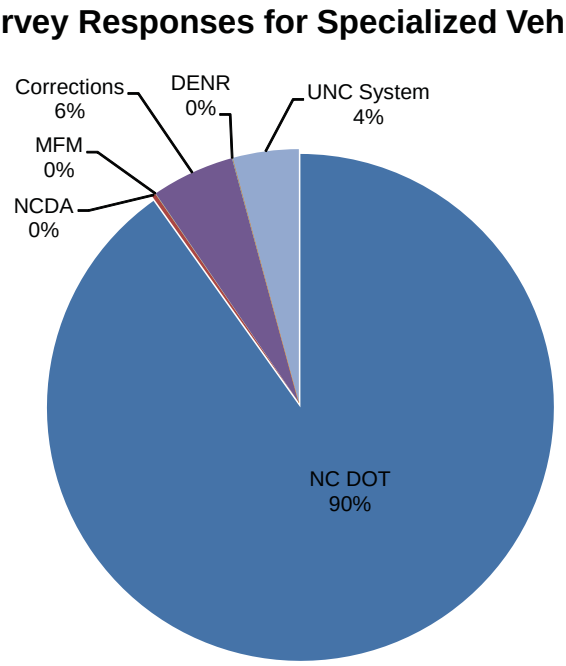


Specialized Vehicles

Specialized vehicles account for approximately eight percent of the State fleet or about 3,900 vehicles. This is a broad category that encompasses several types of vehicles, most of which are designed to perform a specific function. The largest operator of specialized vehicles is the NC Department of Transportation with approximately 3,520 vehicles. The Department of Public Safety follows with approximately 200 vehicles and the UNC System with 160. Survey respondents identified a multitude of duties for specialized vehicles, including construction, emergency response, passenger transportation, mobile laboratories, mobile hospitals, and bucket trucks.

It is difficult to make representative generalizations about specialized vehicles due to their diverse applications and duties. Survey respondents indicated that the average specialized vehicle travels anywhere from 1,000 to 15,000 miles annually and consumes between 300-7,000 gallons. Nearly all of these vehicles are powered by diesel or B-20. Some vehicles within this category operate from centralized depots; others are delivered to a job site where they will operate for days or weeks. Some vehicles idle their engines for extended periods to drive power take-off equipment.

Figure 13 Survey Results for Specialized Vehicles



School Buses

The North Carolina Department of Public Instruction (NC DPI) works with local education agencies (LEAs) to provide school buses for transportation of students. NC DPI does not directly own or operate any school buses. The 115 LEAs across North Carolina currently operate around 18,200 school buses. This category includes buses used for route transportation of students to and from school, activity buses, and backup buses. The majority of LEAs operate Type C school buses, which is a conventional front-engine, rear-drive configuration. The duty cycle for school buses varies by location. The vast majority of school buses are parked overnight at schools. Some larger LEAs park buses overnight at centralized depots. Some LEAs in rural, less densely populated areas park buses at satellite locations or driver residences. School buses are normally refueled in the field by mobile fuel trucks. The average school bus travels approximately 12,850 miles and consumes 1,900 gallons of diesel fuel annually. The primary fuel for school buses is currently diesel.

Environmental Considerations

Environmental Benefits & Impacts of Alternative Vehicles & Fuels

This section discusses the environmental benefits and impacts of each type of vehicle and fuel. While there are many types of benefits and impacts to discuss, this report focuses on the air quality benefits and impacts of each fuel. Air pollution from vehicles represents a significant portion of the total air emissions in the State of North Carolina. Vehicle emissions represent approximately 65 percent of our ground level ozone forming emissions and approximately 30 percent of our greenhouse gas emissions. Vehicle emissions are the primary cause of air pollution in many urban areas.

This sector is referred to as “on-road mobile sources” in the regulatory community. It can be broken down into two basic groups; light duty passenger automobiles and trucks and heavy duty trucks. Each of these groups is discussed in more detail in the following sections.

Air Pollution Emissions

Several air pollutants are considered in this report. The air pollutants and a basic definition of each are given below in Table 2. These pollutants are given in two categories: criteria pollutants and greenhouse gas pollutants. Criteria pollutants emitted from vehicles are currently regulated using emissions standards set by EPA. Emissions of greenhouse gases are not regulated for Model Year 2012 vehicles and engines. EPA has developed greenhouse gas emissions and fuel economy standards for both light and heavy duty vehicles (2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards, 2010) (Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles; Final Rule, 2011). However, these standards will be phased in starting in 2017 for light duty vehicles and 2014 for heavy duty vehicles.

In this report, CO2, CH4 and N2O are expressed as CO2 equivalent emissions. This approach normalizes the data to reflect the global warming potential of each compound with CO2 as a baseline. This is the standard practice for reporting GHG emissions.

Emissions of these pollutants come from a variety of sources including the burning of fuel in vehicle engines, refueling of vehicles, fuel storage and transportation, and fuel production. The scope of this study is limited to vehicle tailpipe emissions. A more detailed analysis of all vehicle-related emissions specific to North Carolina is beyond the scope of this report.

Table 2 Criteria & Greenhouse Gas Air Pollutants

Criteria Pollutants	
Nitrous Oxides, NO and NO2 (NOX)	NOX is a lung irritant. When combined with hydrocarbons and sunlight, NOX compounds form smog.
Carbon Monoxide (CO)	CO is a colorless, odorless, poisonous gas.
Non-methane Organic Compounds (NMOC)	Compounds containing carbon which, when combined with NOX in the presence of sunlight, form smog. Some of these pollutants include air toxics, such as benzene, that are known or suspected to cause serious health effects.
Particulate Matter (PM)	Tiny particles of solid matter that lodge in the lungs and form deposits on buildings. PM is likely a cancer-causing carcinogen.
Greenhouse Gas Compounds (GHGs)	
Carbon Dioxide (CO2)	Greenhouse gases trap heat in the earth's atmosphere and are linked to global climate change. There are more GHGs than listed here. The listed compounds are the primary compounds of concern.
Methane (CH4)	
Nitrous Oxide (N2O)	

Air Pollution Score

Emissions and percent reductions were estimated using standard tools and readily available data from US EPA and DOE. A model year 2005 base case vehicle/engine was evaluated along with model year 2012 engines and fuels as described in the following tables. In order to calculate emissions reductions a base year had to be established. The 2005 base year was chosen since this is when the Tier II emissions standards were in effect and because this was the latest model year available for some alternative fuel vehicle types. Retrofitting of heavy duty diesel engines with simple air pollution control equipment was also evaluated and given an air pollution score. These controls can provide significant environmental benefits at much lower cost than purchasing a newer vehicle.

Assigning an air pollution score required estimating the reductions in emissions of each pollutant between the base case and the vehicle/fuel of interest. The percent reduction in emissions for each air pollutant was then turned into a fraction and subtracted from 1, resulting in a pollutant specific “score”. A lower score represents lower emissions of a given pollutant. The individual scores for each pollutant were then summed together to give a total air pollution reduction score. Each pollutant was weighted the same. The equations used to develop the air pollution score are given below.

$$\text{Pollutant Specific Score} = 1 - \frac{(\%\ \text{Reduction})}{100}$$

$$\text{Total Air Pollution Reduction Score} = \sum \text{Pollutant Specific Score}$$

Note particulate matter emissions from CNG engines are negligible; therefore, these emissions were assigned a reduction efficiency of 99 percent.

Two transportation fuels are actually blends of fossil and biofuels. E-85 is made up of 85 percent ethanol and 15 percent gasoline and B-20 is a blend of 20 percent biodiesel and 80 percent diesel fuel. Biofuels are often referred to as “carbon neutral”. In theory, the CO2 released during combustion of the fuel is offset by the CO2 adsorbed by the plant material when it is grown. EPA is currently studying the life cycle implications of producing and using biofuels on CO2 emissions.

The CO2 emissions from the combustion of the ethanol and biodiesel are generally reported as biomass CO2 emissions (or biogenic emissions) and are generally tracked separately from fossil fuel CO2 emissions. In this report the CO2 emissions from the combustion of B-20 and E-85 were set to zero; therefore, the air pollution score reflects that emissions of biomass CO2 are carbon neutral and do not contribute to the net GHG emissions.

Light Duty Vehicles

In the light-duty market, the primary mission of the vehicles is to transport passengers and light cargo. These vehicles are generally used on paved roads traveling at known speeds and engine loads (Standards and Gasoline Sulfur Control Requirements, Engine Programs and Compliance Division, Office of Mobile Sources, 1999). The manufacturers of light duty vehicles build complete vehicles. Therefore, the manufacturer has control over every part of the vehicle as it is being produced.

There are federal and state-specific fuel economy and emissions standards for these vehicles dating back to the early 1970’s. Federal "Tier 1" regulations went into effect starting in 1994, and "Tier 2" standards were phased in from 2004 to 2009 (Control of Air Pollution From New Motor Vehicles: Tier 2 Motor Vehicle Emissions Standards and Gasoline Sulfur Control Requirements, 2000). Note Tier 2 emissions standards are the same for both cars and trucks. In 2009, EPA announced a new fuel economy and emissions policy for greenhouse gases.

These standards are currently being phased in starting in 2012. By 2016, the combined fleet fuel economy for an auto manufacturer of cars and trucks with a GVWR of 10,000 lbs or less will have to average 35.5 mpg and tailpipe emissions of CO2 will be limited to 250 grams per mile (2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards, 2010). These new standards make gasoline engines more competitive with alternative fuel vehicles such as CNG, hybrid, and electric.

NC Division of Air Quality (NC DAQ) researched readily available fuel efficiency and air pollution emissions factors for the light duty vehicle sector. The following four tables present the fuel efficiency and emissions factors for various light duty vehicles that are of interest for this study. This includes sedans, passenger vans, cargo vans, and light duty trucks. This data was obtained predominately from US EPA’s Green Vehicles Guide online tool (U. S. Environmental Protection Agency, 2012). Model year 2005 was used as a base case and compared to 2012 vehicle emissions.

A. Sedans

Emissions from a standard Tier 2 gasoline engine (2005 model year) were compared to the following vehicle types:

1) **2012 gasoline vehicle,**
2) **2012 flex fuel vehicle using E-85,**
3) **2005 CNG vehicle,**
4) **2012 hybrid vehicle,**
5) **2012 plug in electric hybrid vehicle (PHEV)**
6) **2012 electric vehicle (EV).**

LPG vehicles have a similar emissions profile to a CNG vehicle, therefore this sector is not presented separately. All the vehicles were assumed to be 4-cylinder engines, with automatic transmission and 2-wheel drive. Annual vehicle miles traveled was assumed to be 15,000 miles. Note that the CNG, hybrid and electric vehicles were all smaller 1.4 and 1.8 liter displacement engines rather than standard 2.4 liter engine. The smaller engines have higher fuel efficiency and this contributes to the emissions reductions.

While operating in all-electric mode plug in hybrid electric and electric vehicles produce zero tailpipe emissions. The source of air pollutant emissions are shifted to the electricity generation plant used to charge the batteries. The amount of total emissions depends on how much the vehicle is driven in gas and electric mode, the source of the electricity, and charging times. NC DAQ used two sources of data to estimate greenhouse gas and NOX emissions from charging of electric vehicles. Argonne National Laboratory's Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation Model (GREET) was used to obtain the electricity use per mile estimate (kW/mile) (Argonne National Laboratories, 2012). In addition, GREET data provided the percentage of PHEV annual miles driven on electricity and gas, 70 percent of miles using electric and 30 percent of miles using gas. US EPA's Emissions & Generation Resource Integrated Database (eGRID) (U. S. Environmental Protection Agency, 2012)was used to obtain GHG and NOX emissions factors published for Year 2009 for the SERC Virginia/Caroline electric grid. No emissions factors are available for the other criteria pollutants. Therefore, the air pollution score was adjusted to reflect the use of just two pollutants by equally weighting GHG and NOX.

The annual air emissions and expected reductions for all 2012 models are also given in Table 3. The air pollution score that was calculated for each vehicle group is also presented.

Table 3 Air Pollution Scores for Sedans

Emissions (TPY)	2005 Base	2012 Gasoline	2012 E-85	2012 CNG\LPG	2012 Hybird	2012 PHEV	2012 EV
GHG	6.6	6.2	6.2	4.3	3.2	3.4	2.8
NOX	3.31E-03	8.27E-04	6.61E-04	3.31E-04	4.96E-04	1.43E-03	1.74E-03
CO	6.94E-02	4.63E-02	3.47E-02	3.47E-02	3.47E-02	N/A	N/A
NMOC	2.07E-03	1.27E-03	1.16E-03	1.65E-04	9.09E-04	N/A	N/A
PM	3.31E-04	1.65E-04	1.65E-04	N/A	1.65E-04	N/A	N/A
Percent Reductions		**Gasoline**	**E-85**	**CNG/LPG**	**Hybrid**	**PEV**	**EV**
GHG		7.0%	6.5%	36%	52%	49%	58%
NOX		75.0%	80.0%	90%	85%	57%	48%
CO		33.3%	50.0%	50%	50%	N/A	N/A
NMOC		38.7%	44.0%	92%	56%	N/A	N/A
PM		50.0%	50.0%	99%	50%	N/A	N/A
Air Pollution Score		**2.04**	**2.31**	**1.33**	**2.07**	**2.63**	**2.64**

Alternative fuel vehicles have similar performance in reducing NOX as a standard 2012 gasoline engine. NOX is formed primarily by the heat of combustion. The lower the temperature of the engine, the less NOX is formed. Note that NOX emissions from the electricity grid are higher than those from a 2012 gasoline engine. Therefore, fuel switching does not achieve a substantial reduction in NOX when compared to a new 2012 gasoline engine, although it may shift the production of NOX outside of population centers.

CNG/LPG vehicles can provide some additional reductions in NMOC and PM from the other fuel types since it is a cleaner fuel. However, the fuel efficiency of hybrid vehicles makes it comparable to a CNG vehicle when including greenhouse gas emissions in the assessment.

B. Passenger Vans & Cargo Vans
Emissions from a standard Tier 2 gasoline engine (2005 model year) were compared to the following:

1) 2012 gasoline vehicle,
2) 2012 flex fuel vehicle using E-85
3) 2005 CNG vehicle.

There was no data available for a 2012 CNG vehicle, therefore a 2006 or 2005 model year vehicle, the latest available, was used for this assessment. LPG vehicles have a similar emissions profile to a CNG vehicle, therefore this sector is not presented separately. The engines were 6-cylinder or 8-cylinder engines, with automatic transmission and 2-wheel drive. Annual vehicle miles traveled was assumed to be 6,000 miles for passenger vans and 10,000 miles for cargo vans. The annual air emissions, expected reductions, and air pollution score for all 2012 models are given in Table 4 for passenger vans and Table 5 for cargo vans.

Alternative fuel vehicles have similar performance in reducing NOX as a standard 2012 gasoline engine as discussed above for sedans. Therefore, fuel switching does not achieve a substantial reduction in NOX. CNG vehicles can provide some additional reductions in NMOC and PM from the other fuel types since it is a cleaner fuel. However, the GHG emissions are higher for a CNG vehicle when compared to a 2012 gasoline engine. This is due to the higher methane content of this fuel. Methane has a global warming potential that is 21 times greater than carbon dioxide.

Table 4 Air Pollution Scores for Passenger Vans

Emissions (TPY)	2005 Base	2012 Gasoline	2012 E-85	2005 CNG\LPG
GHG	3.9	3.5	3.0	4.2
NOX	6.61E-03	7.72E-04	1.03E-03	2.09E-04
CO	4.63E-02	4.63E-02	3.09E-02	1.55E-02
NMOC	3.09E-03	9.92E-04	9.74E-04	1.37E-04
PM	8.82E-04	1.10E-04	1.47E-04	0.00E+00
Percent Reductions		**Gasoline**	**E-85**	**CNG\LPG**
GHG		12%	25%	-7%
NOX		88%	84%	97%
CO		0%	33%	67%
NMOC		68%	68%	96%
PM		88%	83%	99%
Air Pollution Score		**2.45**	**2.06**	**1.49**

Table 5 Air Pollution Scores for Cargo Vans

Emissions (TPY)	2005 Base	2012 Gasoline	2012 E-85	2012 CNG\LPG
Base	2012	5.79	4.92	6.98
Gasoline	2012	1.32E-03	1.32E-03	2.65E-04
E-85	2012	2.78E-02	2.78E-02	1.74E-02
CNG/LPG	1.03E-03	4.63E-04	8.27E-04	2.78E-04
PM	5.29E-04	1.32E-04	1.32E-04	0.00E+00
Percent Reductions		**Gasoline**	**E-85**	**CNG/LPG**
GHG		12%	25%	-7%
NOX		67%	67%	93%
CO		0%	0%	37%
NMOC		55%	20%	73%
PM		75%	75%	99%
Air Pollution Score		**2.92**	**3.14**	**2.04**

C. Light Duty Trucks

Emissions from a standard Tier 2 gasoline engine (2005 model year) were compared to the following:

1) 2012 diesel vehicle,
2) 2012 diesel vehicle using B-20,
2) 2012 flex fuel vehicle using E-85, and
3) 2012 CNG vehicle.

LPG vehicles have a similar emissions profile to a CNG vehicle, therefore this sector is not presented separately. For this vehicle sector, fuel switching to B-20 was also evaluated using a percentage reduction published by EPA.

Note that on-road fuel efficiency for this sector is generally not reported. Estimates of fuel efficiency for the current fleet were obtained from the SEO survey data. According to US EPA, fuel efficiency for light duty trucks improved by one mpg in recent years (Office of Transportation and Air Quality, 2012). Therefore, a one mpg increase in fuel efficiency was added to the assumptions for the 2012 diesel emissions estimates.

The vehicles were either 6-cylinder or 8-cylinder engines, with automatic transmission and 4-wheel drive. Annual vehicle miles traveled was assumed to be 20,000 miles. The annual air emissions and expected reductions for all 2012 models are given in Table 6 for light duty trucks.

As noted previously, alternative fuel vehicles have similar performance in reducing NOX as a standard 2012 diesel or gasoline engine. Gasoline and diesel engines have the same criteria pollutant emissions standards. Therefore, fuel switching does not achieve a substantial reduction in NOX. Fuel switching to B-20 does not affect NOX emissions but does lower CO, NMOC, and PM slightly and lowers GHG emissions by 14 percent. However, fuel efficiency is decreased by approximately 2 percent. CNG vehicles can provide some additional reductions in NMOC and PM from the other fuel types since it is a cleaner fuel. GHG emissions are lower for this type of vehicle but that may be due to the smaller engine typically installed on these vehicles.

Table 6 Air Pollution Scores for Light Duty Trucks

Emissions (TPY)	2005 Base Gasoline	2012 Gas\Diesel	2012 B-20	2012 E-85	2012 CNG\LPG
GHG	18.19	17.45	15.44	13.28	14.34
NOX	1.98E-02	4.41E-03	4.41E-03	4.41E-03	1.01E-02
CO	1.61E-01	1.61E-01	1.43E-01	9.26E-02	2.63E-02
NMOC	6.17E-03	4.30E-03	3.44E-03	2.76E-03	3.40E-04
PM	1.76E-03	4.41E-04	3.97E-04	4.41E-04	0.00E+00
Percent Reductions		**Gas\Diesel**	**B-20**	**E-85**	**CNG**
GHG		4%	15%	27%	21%
NOX		78%	78%	78%	49%
CO		0%	11%	42%	84%
NMOC		30%	44%	55%	95%
PM		75%	78%	75%	99%
Air Pollution Score		**3.13**	**2.74**	**2.22**	**1.52**

Heavy Duty Vehicles

The heavy-duty vehicle industries include the manufacturers of Class 2b through Class 8 trucks, engines, and some equipment. Vehicles in these classes range from over 8,500 pounds (lbs) gross vehicle weight rating (GVWR) to upwards of 80,000 lbs. This market is very diverse in terms of both vehicle types and usage patterns.

The nature of the commercial truck market is more complicated due to the production process, diversity of products, and the many different missions of this sector. Many of the trucks are custom-built to user specifications using parts from various manufacturers. The configuration of the truck itself varies significantly with its function. For example, the trucks may have different body or box types, engines, the axle/gear ratios, cab sizes, any special equipment installed depending on its use as a cargo carrier or a specialized function like a bucket truck or emergency vehicle. The trucks may be used for personal or cargo transportation, they may idle for long periods, or be used primarily at a specific site. (Office of Transportation and Air Quality, 2011) Each division of state/local government will have a variety of missions and configurations for their medium and heavy duty trucks, making it difficult to characterize this fleet succinctly.

EPA Heavy Duty Diesel Rule

EPA published the Heavy-Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements Rule on January 18, 2001 (Control of Air Pollution from New Motor Vehicles: Heavy-Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements, 2001). This rule establishes a single control program that regulates both the heavy-duty vehicles and diesel fuel as a single system. The regulations are located in 40 CFR Part 80 subpart I.

Under this rule, sulfur content was reduced from 500 parts per million to 15 parts per million. This fuel is referred to as Ultra Low Sulfur Diesel (ULSD). It was phased in for highway diesel fuel from 2006-2010. Exhaust emissions decreased by more than 90 percent from the use of ULSD fuel. ULSD also allows engine manufacturers to use more advanced emissions control systems.

Under this same rule, EPA also established new emissions standards for heavy duty diesel engines. These standards were completely phased in by 2010. The engines are tested to ensure they meet EPA 2010 standards but this value is not the same as actual tailpipe emissions. As a result of the diesel fuel engine rule, diesel tailpipe emissions from new medium and heavy duty vehicles are much cleaner, especially in terms of NOX and PM.

Post-Combustion Treatment with ULSD

There are two primary technologies available to put on diesel engines using ULSD to reduce air pollution, diesel oxidation catalysts and diesel particulate matter filters. Retrofitting a pre-2010 engine with one of these two control devices significantly reduces emissions from a diesel engine. Diesel oxidation catalysts are devices that use a chemical process to break down pollutants in the exhaust stream into less harmful components. Diesel oxidation catalysts can reduce emissions of PM by 20 percent and hydrocarbons by 50 percent and carbon monoxide by approximately 40 percent. Diesel particulate matter filters are ceramic devices that collect the particulate matter in the exhaust stream. The high temperature of the exhaust heats the ceramic structure and allows the particles inside to break down (or oxidize) into less harmful components. They can be installed on new and used vehicles, but must be used in conjunction with ULSD. PM filters work best on engines built after 1995. The combination of PM filters and ULSD can reduce emissions of PM, HC, and CO by 60 to 90 percent (U.S. Environmental Protection Agency, 2012).

The Department of Environment and Natural Resources has managed grants that fund diesel retrofit projects. A report on retrofit grants for school buses titled *Implementation of "School Bus Retrofits in Nonattainment Areas*" was prepared for the Environmental Review Commission, Department of Public Instruction, and Department of Transportation, which provides detailed information on the retrofit projects including emissions reductions and costs (Department of Public Instruction and Department of Transportation, 2012).

Fuel Economy

The fuel economy of medium and heavy duty trucks depends heavily on its engine, equipment configuration, use patterns, and engine duty cycles. These vehicles are not required to meet any fuel efficiency standards and fuel efficiency data for a given vehicle is generally not published by the manufacturer. Table 7 presents recent fuel economy data published in the GREET model. Fuel economy data collected by the State Energy Office was used to estimate emissions for the base case while data for the various vehicle/fuel types was estimate using Table 7 presented below.

Lastly, reducing the use of fuel by reducing vehicle miles traveled and idling of trucks and buses can provide significant reductions in operating costs and air pollution emissions. Idling a truck-tractor's engine can use a gallon of fuel per hour. The various strategies for reducing fuel use in heavy duty trucks, including the use of auxiliary power units and reducing idle times, should be included when evaluating new fleet purchases.

Table 7 Average Fuel Economy for Heavy Duty Vehicle Type in GREET Model

Vehicle Type	Gasoline	Diesel	Diesel HEV	B-20	E-85	CNG	LPG
School Bus	6	7	8.5	7	6	6	6
Transit Bus	2.5	3	3.8	3	2.5	2.5	2.5
Shuttle/Paratransit Bus	7	8	10	8	7	7	7
Waste Hauler	2	2.5	3	2.5	2	2	2
Street Sweeper	3	4	5	4	3	3	3
Delivery Step Van	12	15	18.5	15	12	12	12
Medium/Heavy Duty Pickup Truck	9	11	13.5	11	9	9	9
Maintenance Utility Vehicle	20	25	31	25	20	20	20
Transport/Freight Truck	5	6	7.5	6	5	5	5

Source: GREET Fleet Footprint Calculator, US DOE (U. S. Environmental Protection Agency, 2012)

Emissions Estimates

As stated above, engine emissions for this sector are expressed as a function of the engine brake horsepower per hour rather than simply miles traveled or gallons used. Tailpipe emissions are generally determined in computer-based models that account for the various engine emissions factors, loads and duty cycles for each vehicle type. North Carolina runs EPA's MOVES model to determine emissions from this vehicle sector. However, this would require more resources and time then available for this study.

Average vehicle miles traveled and fuel use provided by the State Energy Office for each vehicle type was used to estimate air pollution emissions and emissions reductions. Average tailpipe emissions were determined for several classes of vehicles using an EPA tool called Diesel Emissions Quantifier (U.S. Environmental Protection Agency, 2012). It estimates emissions using vehicle miles traveled, gallons used and idle time. A tool published by DOE, GREET Fleet Footprint Calculator (U.S. Environmental Protection Agency, 2012), was also used to estimate GHG emissions from hybrid diesels and fuel switching to E-85. The average of the two GHG emissions reduction values was to calculate the air pollution score for these vehicles.

Table 8 provides the vehicle type, the assumptions for fuel use and vehicle miles traveled as well as the air pollution emissions reductions and calculated air pollution score for all the heavy duty vehicle sectors. In all cases, the lowest air pollution score was calculated for a new 2012 engine burning either diesel or B-20. As stated previously, this is due to the use of ULSD and the new heavy duty diesel engine emissions standards that are now in place. Emissions of NOX and PM are significantly reduced because of this rule. E-85 and B-20 provide some additional benefits in reduction of CO2 emitted from heavy duty vehicle engines when assuming the biofuel portion of these fuels is carbon neutral.

Table 8 Air Pollution Scores for Heavy Duty Buses & Trucks

Vehicle Type	Assumptions		Engine & Fuel Type	NOx	PM2.5	HC	CO	CO2	Air Pollution Score
School Bus	Fuel (gal/yr)	1,455	**Base Case 2005 with ULSD (TPY)**	**0.0511**	**0.0041**	**0.00720**	**0.0520**	**16.15**	
	VMT (mi)	9,472	2005 PM Filter Retrofit	0%	85%	90%	90%	0%	**2.35**
	Idle (hours)	15	2005 with B-20 and oxidation catalyst	-5%	25%	55%	35%	1%	**3.89**
	Calculated MPG	6.5	2012 CNG with oxidation catalyst	50%	95%	50%	0%	0%	**3.05**
			2012 Hybrid with PM filter	50%	95%	90%	0%	9%	**2.56**
			2012 ULSD with PM filter	84%	95%	90%	45%	0%	**1.85**
			2012 B-20 with PM filter	84%	95%	90%	45%	0%	**1.85**
Medium Duty Truck	Fuel (gal/yr)	779	**Base Case 2005 with ULSD**	**0.0638**	**0.0019**	**0.0046**	**0.0298**	**8.65**	
Class 5 (16,001-19,500 lbs)	VMT	6,696	2005 PM Filter Retrofit	0%	85%	90%	90%	0%	**2.35**
	Idle Hours	100	2005 with B-20 and oxidation catalyst	-5%	25%	55%	35%	1%	**3.89**
	Calculated MPG	8.6	CNG with oxidation catalyst	50%	95%	50%	0%	0%	**3.05**
			2012 E-85	67%	74%	89%	81%	13%	**1.77**
			2012 ULSD	67%	74%	89%	81%	0%	**1.90**
			2012 B-20	67%	74%	89%	81%	0%	**1.90**
Heavy Duty Truck	Fuel (gal/yr)	1,994	**Base Case 2005 with ULSD**	**0.0944**	**0.0061**	**0.0107**	**0.0446**	**22.13**	
Class 7 (26,001-33,000 lbs)	VMT	10,827	2005 PM Filter Retrofit	0%	85%	90%	90%	0%	**2.35**
	Idle Hours	100	2005 with B-20 and oxidation catalyst	-5%	25%	55%	35%	1%	**3.89**
	Calculated MPG	5.4	2012 CNG with oxidation catalyst	50%	95%	50%	0%	0%	**3.05**
			2012 ULSD with PM filter	74%	90%	91%	85%	0%	**1.60**
			2012 B-20 with PM filter	74%	90%	91%	85%	0%	**1.60**
Bucket Truck	Fuel (gal/yr)	1,273	**Base Case 2005 with ULSD (TPY)**	**0.0884**	**0.0057**	**0.0098**	**0.0412**	**14.13**	
Class 7 (26,001-33,000 lbs)	VMT	10,006	2005 PM Filter Retrofit	0%	85%	90%	90%	0%	**2.35**
	Idle Hours	100	2005 with B-20 and oxidation catalyst	50%	95%	50%	0%	0%	**3.05**
	Calculated MPG	7.9	2012 CNG/LPG with oxidation catalyst	50%	95%	50%	0%	0%	**3.05**
			2012 Hybrid with PM filter	50%	95%	90%	0%	10%	**2.55**
			2012 ULSD with PM filter	73%	89%	90%	85%	0%	**1.63**
			2012 B-20 with PM filter	73%	89%	90%	85%	0%	**1.63**

Cost Calculations

Life Cycle Cost

A baseline life cycle cost (LCC) per vehicle type was developed using the survey responses to develop cost estimates associated with the baseline fleet. The baseline fleet is defined as all vehicles in the survey population. Some survey respondents were removed from the baseline fleet population due to data quality issues. Agencies were asked to characterize the typical costs and uses of the vehicles in their fleets. Detailed survey responses for individual agencies can be found in the appendix along with estimated inputs to LCC calculations.

Survey questions included:

- **The total number of vehicles in the fleet;**
- **A breakdown of vehicles by type;**
- **The proportion of vehicles in the total fleet by age of vehicle;**
- **Characterization of the typical vehicle in the fleet by vehicle "class," including expected lifespan, average replacement cost, lifetime maintenance cost, current fuel type, associated infrastructure costs, annual miles driven, fuel consumed annually in gallons, duty functions, and duty cycle;**
- **The geographic distribution of the fleet;**
- **The typical annual vehicle purchase on a "normal" refresh cycle;**
- **How fuel is procured;**
- **The types of fuel procured;**
- **Experience with alternative fueled vehicles and alternative fuels.**

Life Cycle Cost estimates for the baseline and alternative fuel vehicles include the estimated replacement price and the estimated lifetime costs.

LCC= Replacement price + Lifetime costs

Replacement price estimates are taken from the survey results. Lifetime costs include estimated fuel costs and estimated maintenance costs for each vehicle and fuel type over the expected lifetime of a vehicle. Replacement costs and maintenance expense are expressed in constant 2012 dollars while fuel costs are expressed in constant 2011 dollars.

Lifetime costs= (annual maintenance costs + annual fuel costs) * average lifespan

The annual maintenance costs were assumed to be constant over the lifetime of each vehicle. Fuel costs estimates are derived from the estimated average annual fuel consumed in gallons and the estimated price per gallon of fuel.[2] Forecasted fuel costs for future years are based on U.S. Energy Information Agency forecasts.[3] EIA forecasts were used for all fuel types including conventional fuel.

2 This report assumes an equal and average MPG across all agencies due to limited data availability. However, most agencies do not calculate and record miles per gallon (MPG) on a per-vehicle basis. To compute a fuel cost per gallon, this analysis required a miles per gallon estimate. Vehicles in the same class, as defined by the U.S. EPA, which measures fuel economy, can have different MPG performance. The way a vehicle is driven can have a significant impact on fuel efficiency as well.

3 EIA price forecasts are estimated for wholesale market prices. The incremental change in the projected price in the wholesale market year over year was added to the estimate retail market prices from the State Contract, Duke Energy and PNC (see "source" in Equivalency table) to arrive at the annual fuel cost estimates. This one-to-one relationship in the real prices is a strong assumption. However, this approach captures the direction of the forecasted price change and provides the general relative increase or decrease to be expected.

Annual fuel costs= average annual fuel consumed* estimated price per gallon of fuel

The Life Cycle Cost calculations allow for comparison of relative cost differences between vehicle and fuel types. All estimates have been rounded to the nearest thousandth. The estimates are not intended to represent the complete costs of owning a vehicle. The following table compares the baseline lifetime costs of the surveyed state fleet. The estimates were later used by the State Energy Office in their evaluation matrix of costs and benefits.

Table 9 Baseline Fleet Estimated Life Cycle Costs by Vehicle

Baseline Fleet Estimated Life Cycle Costs by Vehicle							
Sedans	Minivans & Passenger Vans	Panel & Utility Vans	Light Duty Truck (1-3)	Medium Duty Trucks (4-6)	Heavy Duty Trucks (7)	Specialized\ Other Trucks (Non-DPI Buses)	Specialized\ Other Trucks (Buses from DPI)
$37,000	$46,000	$38,000	$47,000	$85,000	$219,000	$152,000	$270,000

Life Cycle Cost Analysis

The table below highlights estimated life cycle costs by fuel type, relative to the baseline Life Cycle Costs of the current base fleet. Some options could actually cost less over the lifetime of the vehicle for DPI buses and Light Duty Trucks using CNG. On the other hand, several alternative fuels were examined and would likely be extremely expensive to use in fleets such as BEV Sedans and Hybrid Specialized Trucks. A simple LCC analysis does show that on the margin, the relative higher replacement costs for Hybrid Sedans and E-85 Minivans and Light Duty Trucks could be feasible for state fleets. These LCC comparisons are utilized in the evaluation matrix to measure costs and benefits of different fuel/vehicle combinations.

Table 10 Life Cycle Cost Comparison by Fuel Type Relative to Baseline

Life Cycle Cost Comparison by Fuel Type Relative to Baseline							
	Base	**E-85**	**Hybrid**	**BEV**	**LPG**	**CNG**	**B20**
Sedans	$37,000	2%	1%	26%	11%	-	-
Minivans & Passenger Vans	$46,000	1%	-	-	12%	3%	-
Panel & Utility Vans	$38,000	1%	-	-	16%	10%	-
Light Duty Truck (1-3)	$47,000	2%	-	-	10%	-7%	17%
Medium Duty Truck (4-6)	$85,000	3%	-	-	13%	7%	3%
Heavy Duty Truck (7)	$219,000	-	-	-	-	6%	3%
Specialized\Other Trucks (Non DPI Buses)	$152,000	-	33%	-	5%	13%	3%
Specialized\Other Trucks (Buses from DPI)	$270,000	-	15%	-	-1%	-11%	4%

Recommendations

Methodology & Assumptions

The Department of Commerce's Labor and Economic Analysis Division (LEAD) designed the life cycle cost methodology using information from the task force survey, the State Energy Office and outside data sources such as the EIA. Specific methodologies are described in the Life Cycle Cost Calculations section of this report. The results of the economic analysis are provided below, in Table 8. The State Energy Office's recommendations are based primarily on the results of this economic analysis, consultation with partner State agencies, and research into currently available alternative fueled vehicles.

Table 11 Life Cycle Cost Estimates Relative to Baseline

Life Cycle Cost by Fuel Type Relative to Baseline							
	Base	E-85	Hybrid	BEV	LPG	CNG	B20
Sedans	$37,000	2%	1%	26%	11%	-	-
Minivans & Passenger Vans	$46,000	1%	-	-	12%	3%	-
Panel & Utility Vans	$38,000	1%	-	-	16%	10%	-
Light Duty Truck (1-3)	$47,000	2%	-	-	10%	-7%	17%
Medium Duty Truck (4-6)	$85,000	3%	-	-	13%	7%	3%
Heavy Duty Truck (7)	$219,000	-	-	-	-	6%	3%
Specialized\Other Trucks (Non DPI Buses)	$152,000	-	33%	-	5%	13%	3%
Specialized\Other Trucks (Buses from DPI)	$270,000	-	15%	-	-1%	-11%	4%

The research team considered a variety of alternative fuel-vehicle type combinations based on the results of market research and consultation with government and private sector representatives. For additional information regarding the vehicle types evaluated for each alternative fuel, see the availability of consumer vehicles subsection of the particular alternative fuel.

Per-vehicle infrastructure costs were estimated for a typical example of each vehicle type using survey data and cost estimates from State agencies and consultants with private sector experience installing and/or operating refueling alternative fuel infrastructure. The base cases of gasoline and diesel were assumed to have no new infrastructure costs, as there is already a well-established network of both State-owned and privately-owned commercial refueling stations throughout North Carolina. All figures assume the State bears the full cost of installing the required infrastructure, and does not take into account any potential tax incentives, subsidies, or cost-sharing arrangements with fuel providers.

Agency survey data identified the average fuel consumption of each vehicle type in gallons of gasoline or diesel. The team assumed each vehicle was operated an average of 250 business days per calendar year to identify how many gasoline gallon equivalents (GGes) of fuel each vehicle required on a daily basis.

Gasoline base case: (Annual fuel consumption/250 business days) = GGe per day

The difference in energy content between gasoline gallon equivalents and diesel gallon equivalents was accounted for using a GGe to DGe conversion factor.

GGe to DGe conversion factor: (115400 Btus per gallon of gasoline/ 128700 Btus per gallon of diesel) = .8966

Diesel base case: (Annual diesel consumption/250 business days)/.8966 = GGe per day

Cost estimates were developed for refueling infrastructure that would support a fifty (50)-vehicle fleet with a daily throughput of approximately 1000 GGes. Each vehicle type's daily fuel demand as a percentage of daily station capacity was then used to estimate per-vehicle infrastructure costs.

(GGe per day/1000 [station daily capacity in GGe])*Estimated Station Cost = Estimated per-vehicle infrastructure cost (in dollars)

Table 9 lists per-vehicle infrastructure cost estimates for each considered fuel/vehicle combination, rounded to the nearest $20.

Table 12 Estimated Per-Vehicle Infrastructure Costs (Rounded)

Rounded Infrastructure Estimates							
	Base	E-85	Hybrid	BEV	LPG	CNG	B20
Sedans	$0	$240	$0	$1,660	$280	-	-
Minivans & Passenger Vans	$0	$240	-	-	$260	$1,600	-
Panel & Utility Vans	$0	$200	-	-	$240	$1,400	-
Light Duty Truck (1-3)	$0	$300	-	-	$360	$2,140	$0
Medium Duty Truck (4-6)	$0	$360	-	-	$420	$2,520	$0
Heavy Duty Truck (7)	$0	-	-	-	-	$6,480	$0
Specialized\Other Trucks (Non DPI Buses)	$0	-	$0	-	$680	$4,140	$0
Specialized\Other Trucks (Buses from DPI)	$0	-	$0	-	$1,020	$6,160	$0

Table 10 displays combined lifecycle cost estimates and estimated per-vehicle infrastructure costs relative to the baseline.

Table 13 Lifescycle Cost Estimates + Estimated Per-Vehicle Infrastructure Costs Relative to Baseline

Lifecycle Cost Estimates by Fuel Type + Estimated Infrastructure Costs Relative to Baseline							
	Base	E-85	Hybrid	BEV	LPG	CNG	B20
Sedans	$37,000	3%	1%	30%	12%	-	-
Minivans & Passenger Vans	$46,000	2%	-	-	13%	6%	-
Panel & Utility Vans	$38,000	2%	-	-	17%	14%	-
Light Duty Truck (1-3)	$47,000	3%	-	-	11%	-2%	17%
Medium Duty Truck (4-6)	$85,000	3%	-	-	13%	10%	3%
Heavy Duty Truck (7)	$219,000	-	-	-	-	9%	3%
Specialized\Other Trucks (Non DPI Buses)	$152,000	-	33%	-	5%	15%	3%
Specialized\Other Trucks (Buses from DPI)	$270,000	-	15%	-	-1%	-9%	4%

While the LCC and infrastructure costs are very important factors and readily quantified in terms of dollars, there are environmental factors that are worth considering that may not equate to an immediate financial cost. All factors, including environmental impacts as described in the legislation directing this report, should be considered as part of any vehicle purchasing decisions. The environmental factors produced by the Department of Environment and Natural Resources' Division of Air Quality and contained in the environmental considerations section of this report are one method of comparing the tailpipe emissions of one alternative fuel relative to another or to the baseline.

The following recommendations are derived from an agency-level analysis, given the usage patterns described by survey respondents. Niche applications may avail themselves to cost-effective use of alternative fuels within each agency.

Sedans

For a description of Sedans, see page 22.

Summary

The base case fuel for sedans was gasoline. The economic analysis suggests that continuing to use gasoline is the most economical option for sedans. Gasoline powered vehicles were found to have the lowest life cycle cost given the usage patterns described by survey respondents.

Gas hybrids were found to have nearly the same life cycle cost as the base case fuel. Anecdotal evidence suggests that gas hybrids may produce net savings in higher-mileage applications. Motor Fleet Management provided the research team with historical data for 110 gas hybrids currently in the State fleet which indicating a reduction in fuel costs per mile driven and maintenance costs for hybrid vehicles. If the purchase premium for hybrid vehicles continues to decline or the price of gasoline increases, hybrids could potentially become the most desirable fuel option for sedans.

Applications

The primary user of sedans within the State fleet is Motor Fleet Management. The analysis recommends continued use of gasoline for sedans. If Motor Fleet Management wishes to increase their use of alternative fuels, the SEO recommends expanded deployment of gas hybrids as the next most appropriate option within the context of MFM's unique mission and duty requirements.

Passenger Vans

For a description of Passenger Vans, see page 22.

Summary

The base case fuel for passenger vans was gasoline. The economic analysis suggests that continuing to use gasoline is the most economical option for passenger vans. Gasoline powered vehicles were found to have the lowest life cycle cost given the usage patterns described by survey respondents. E-85 had the next lowest life cycle cost, with slightly higher annual fuel costs and improved emissions.

CNG had the third lowest life cycle cost. Although the analysis does not suggest CNG is the most desirable fuel for passenger vans, the research team did identify anecdotal evidence of very successful CNG deployments in some specialized applications. Fleet managers with vans that regularly operate for prolonged periods and do not need large geographic range (such as shuttle buses) may realize significant cost savings using CNG as a motor fuel. The key factors for these applications are access to a central refueling facility and high fuel consumption.

Applications
The primary users of passenger vans within the State fleet are Motor Fleet Management, Corrections, and the UNC system. The analysis recommends continued use of gasoline for passenger vans. If these agencies wish to increase their use of alternative fuels, the SEO recommends they consider E-85 and CNG as the next most appropriate options within the context of each agency's unique mission and duty requirements.

Panel/Utility Vans
For a description of Panel/Utility Vans, see page 23.

Summary
The base case fuel for panel/utility vans was gasoline. The economic analysis suggests that continuing to use gasoline is the most economical option for panel/utility vans. Gasoline powered vehicles were found to have the lowest life cycle cost given the usage patterns described by survey respondents. E-85 had the next lowest life cycle cost, with slightly higher annual fuel costs and improved emissions.

CNG had the third lowest life cycle cost. Although the analysis does not suggest CNG is the most desirable fuel for passenger vans, the research team did identify anecdotal evidence of very successful CNG deployments in some specialized applications. Fleet managers with vans that regularly operate for prolonged periods and do not need large geographic range (such as couriers) may realize significant cost savings using CNG as a motor fuel. The key factors for these applications are access to a central refueling facility and high fuel consumption.

Applications
The primary users of panel/utility vans within the State fleet are the UNC system, Motor Fleet Management, NCDA&CS, and Corrections. The analysis recommends continued use of gasoline for panel/utility vans. If these agencies wish to increase their use of alternative fuels, the SEO recommends they consider E-85 and CNG as the next most appropriate options within the context of each agency's unique mission and duty requirements.

Light Duty Trucks
For a description of Light Duty Trucks, see page 24.

Summary
The base case fuel for light duty trucks was gasoline. The economic analysis suggests that where appropriate, expanding the use of CNG is the most desirable option for light duty trucks. Dramatic savings in annual fuel costs resulted in the lowest life cycle cost. CNG also had favorable scores for tailpipe emissions. There are significant infrastructure costs and technical considerations involved with the operation of CNG powered vehicles which an agency will need to evaluate prior to any deployments. The base case (gasoline) had the next lowest life cycle cost.

Applications
The primary users of light duty trucks within the State fleet are NCDOT, NCDA&CS, and Motor Fleet Management. The analysis recommends these agencies consider the use of CNG powered light duty trucks within the context of each agency's unique mission and duty requirements. If CNG is not a suitable fuel for their application, SEO recommends continued use of gasoline for light duty trucks.

Medium Duty Trucks

For a description of Medium Duty Trucks, see page 24.

Summary

The base case fuel for medium duty trucks was ultra-low sulfur diesel (ULSD). The economic analysis suggests that continuing to use diesel is the most desirable option for medium duty trucks. Diesel powered vehicles were found to have the lowest life cycle cost given the usage patterns described by survey respondents.

B-20 had the next lowest life cycle cost, with slightly higher annual fuel costs. There are three biodiesel producers in North Carolina, making it possible to purchase B-20 where the biodiesel component is State-produced. NCDOT has successfully used B-20 throughout its fleet, substantially contributing to the State's target of displacing 20 percent of petroleum consumption (North Carolina Solar Center, 2012).

Applications

The primary users of medium duty trucks within the State fleet are NCDOT, NCDPI, Corrections, and the UNC System. The SEO recommends continued use of diesel and B-20 for medium duty trucks, within the context of each agency's unique mission and duty requirements.

Heavy Duty Trucks

For a description of Heavy Duty Trucks, see page 25.

Summary

The base case fuel for heavy duty trucks was ultra-low sulfur diesel (ULSD). The economic analysis suggests that continuing to use diesel is the most desirable option for heavy duty trucks. Diesel powered vehicles were found to have the lowest life cycle cost given the usage patterns described by survey respondents.

B-20 had the next lowest life cycle cost, with slightly higher annual fuel costs. There are three biodiesel producers in North Carolina, making it possible to purchase B-20 where the biodiesel component is State-produced. NCDOT has successfully used B-20 throughout its fleet, substantially contributing to the State's target of displacing 20 percent of petroleum consumption (North Carolina Solar Center, 2012).

Applications

The primary users of heavy duty trucks within the State fleet are NCDOT, NCDA&CS, and the UNC System. The SEO recommends continued use of diesel and B-20 for heavy duty trucks, within the context of each agency's unique mission and duty requirements.

Specialized Vehicles

For a description of Specialized Vehicles, see page 25.

Summary

The base case fuel for specialized vehicles was ultra-low sulfur diesel (ULSD). The analysis suggests that continuing to use diesel is the most desirable option for specialized vehicles. Diesel powered vehicles were found to have the lowest life cycle cost given the usage patterns described by survey respondents.

B-20 had the next lowest life cycle cost, with slightly higher annual fuel costs. There are three biodiesel producers in North Carolina, making it possible to purchase B-20 where the biodiesel component is State-produced. NCDOT has successfully used B-20 throughout its fleet, substantially contributing to the State's target of displacing 20 percent of petroleum consumption (North Carolina Solar Center, 2012).

Applications

The primary user of specialized vehicles within the State fleet is NCDOT. The SEO recommends continued use of diesel and B-20 for specialized vehicles, within the context of NCDOT's unique mission and duty requirements.

School Buses

For a description of School Buses, see page 26.

Summary

The base case fuel for school buses was ultra-low sulfur diesel (ULSD). The economic analysis suggests that where appropriate, expanding the use of CNG is the most desirable option for school buses. Considerable savings in annual fuel costs resulted in the lowest life cycle cost and CNG also scores well for tailpipe emissions. The research team was unable to identify any school bus manufacturers currently offering CNG-powered school buses in the configuration or passenger capacity that NC DPI routinely purchases. Furthermore, there are significant infrastructure costs and technical considerations involved with the operation of CNG powered vehicles. Considering that school buses have a wide variety of duty cycles and usage patterns further analysis is required prior to any deployment.

The base case fuel (diesel) had the next lowest life cycle cost.

Applications

NCDPI is the sole purchaser of school buses within the State fleet. The SEO recommends NCDPI consider the purchase of CNG powered school buses within the context of its unique mission and duty requirements. Where CNG is not an appropriate option, the SEO recommends continued use of diesel.

Conclusion

The economic analysis indicates that at an agency-wide level it is not economically advantageous to increase the use of alternative fuels. With the exception of two vehicle types, the most economical option was to maintain the status quo and continue to use gasoline and diesel for transportation fuel. Compressed Natural Gas had the lowest life cycle costs for the light duty truck and school bus segments. Additional research is required to conduct more a more detailed cost-benefit analysis and identify specific best-fit applications for CNG within the agencies that operate these vehicle types.

The U.S. Energy Information Administration price projections used for the economic analysis are an estimate of weighted average costs for each fuel type until 2035. These figures do not provide a factor for price volatility, which varies significantly between the considered fuel types. One of the major risks associated with high price volatility is premature budget depletion due to rapid price increases. Acknowledging that every fuel is subject to some degree of price fluctuation, the research team suggests that diversification of the State fleet to include multiple fuel types could reduce the State's exposure to rapid, unsustainable price increases.

Retrofitting older diesel-powered vehicles with modern emissions controls may be a cost-effective method of reducing tailpipe emissions from the existing State fleet. Retrofit kits are available that allow older diesel vehicles to realize many of the potential environmental benefits of new nationwide ultra-low sulfur requirements for diesel fuel. NC DENR has experience managing retrofit grant projects to retrofit emissions controls on school buses, and recently released a report discussing the costs and benefits of such a strategy.

Alternative energy is a rapidly changing and developing sector of our economy. This analysis was limited to vehicles and refueling infrastructure currently available on the commercial market, and therefore did not consider the potential costs or benefits of vehicles or infrastructure products that are currently in development or scheduled for release. The research team expects to see the price premium for alternative fueled vehicles and the cost of infrastructure continue to trend downwards as these technologies gain market acceptance and additional firms enter the market.

Although this analysis did not find unqualified economic benefits for increased adoption of alternative fuels at an agency-wide level, it is very likely that opportunities exist within many or all agencies for cost savings through limited adoption of one or more alternative fuels. Each alternative fuel and associated vehicle technology has its own technical and market considerations. The most cost-effective deployments will occur through individual agency assessments of mission requirements and use cases and then matching those criteria with the most appropriate alternative fuel or fuels. The State Energy Office could provide additional training and materials to vehicle fleet managers interested in reducing costs through adoption of alternative fuels.

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Appendix A E-85 Stations

Fuel Type Code	Station Name	Street Address	Intersection Directions	City	State	Groups With Access Code
E-85	Star Mart - Exxon	10515 Cleveland Rd W	Garner	Garner	NC	PLANNED - not yet accessible
E-85	North Carolina DOT	244 DOT Dr	Asheboro	Asheboro	NC	Private - government only
E-85	Camp Lejeune Marine Corps Base	1070 Michael Rd	Camp Lejeune	Camp Lejeune	NC	Private - government only
E-85	Camp Geiger		G-656	Camp Lejeune	NC	Private - government only
E-85	Camp Lejeune Marine Corps Base	River Rd & O St	Bldg 162	Camp Lejeune	NC	Private - government only
E-85	Town of Chapel Hill	6836 Millhouse Rd	Chapel Hill	Chapel Hill	NC	Private - government only
E-85	University of North Carolina - Chapel Hill	109 Airport Dr	Chapel Hill	Chapel Hill	NC	Private - government only
E-85	North Carolina DOT	7901 District Dr	Charlotte	Charlotte	NC	Private - government only
E-85	Cherry Point Marine Corps Air Station	Curtis & 2nd Ave	Building 160	Cherry Point	NC	Private - government only
E-85	Fort Bragg - Army & Air Force Exchange Service	Longstreet Rd & Gruber Rd	Fort Bragg	Fort Bragg	NC	Private - government only
E-85	North Carolina DOT	441 W Belvoir Hwy	Greenville	Greenville	NC	Private - government only
E-85	North Carolina DOT	2122 Clarence Walters	Hillsborough	Hillsborough	NC	Private - government only
E-85	North Carolina DOT	3931 NC 226 S	Marion	Marion	NC	Private - government only
E-85	NC Motor Fleet Management	1915 Blue Ridge Rd	At Reedy Creek Rd	Raleigh	NC	Private - government only
E-85	Newport Mini Mart	101 Main St	Newport	Newport	NC	Public - credit card after hours
E-85	C-Mini Mart - Shell	902 US 64 W	Apex	Apex	NC	Public - see hours
E-85	Carlie C's IGA	604 S Wall St	Benson	Benson	NC	Public - see hours
E-85	Gasland #10 - Thomas Petroleum	230 E College Ave	Boiling Springs	Boiling Springs	NC	Public - see hours
E-85	R&K Express - BP	8712 Pence Rd	Charlotte	Charlotte	NC	Public - see hours

Appendix B Bio Diesel (B-20)

Fuel Type Code	Station Name	Street Address	City	State	Groups With Access Code
BD	Hertford County - North Carolina DOT	Modlin Hatchery Rd	Ahoskie	NC	Private - government only
BD	Stanly County - North Carolina DOT	Coble Ave	Albemarle	NC	Private - government only
BD	Randolph County - North Carolina DOT	NC-1150	Asheboro	NC	Private - government only
BD	Buncombe County - North Carolina DOT	11 Old Charlotte Hwy	Asheville	NC	Private - government only
BD	McDowell County - North Carolina DOT	NC-226 S	Bakersville	NC	Private - government only
BD	Watauga County - North Carolina DOT	NC-194	Boone	NC	Private - government only
BD	Swain County - North Carolina DOT	Toot Hollow Rd	Bryson City	NC	Private - government only
BD	Franklin County - North Carolina DOT	NC 39 Highway S	Bunn	NC	Private - government only
BD	Pender County - North Carolina DOT	Smith Rd	Burgaw	NC	Private - government only
BD	Yancey County - North Carolina DOT	1115 Bakers Creek Rd	Burnsville	NC	Private - government only
BD	Moore County - North Carolina DOT	NC-1652	Carthage	NC	Private - government only
BD	New Hanover County - North Carolina DOT	Barbados Blvd	Castle Hayne	NC	Private - government only
BD	Town of Chapel Hill	6836 Millhouse Rd	Chapel Hill	NC	Private - government only
BD	University of North Carolina - Chapel Hill	109 Airport Dr	Chapel Hill	NC	Private - government only
BD	Mecklenburg County - North Carolina DOT	7703 District Dr	Charlotte	NC	Private - government only
BD	Cherry Point Marine Corps Air Station	Curtis & 2nd Ave	Cherry Point	NC	Private - government only
BD	Sampson County - North Carolina DOT	NC-1311	Clinton	NC	Private - government only
BD	Columbus County - North Carolina DOT	Prison Camp Rd	Columbus	NC	Private - government only
BD	Polk County - North Carolina DOT	Locus St	Columbus	NC	Private - government only
BD	Washington/Tyrell County - North Carolina DOT	US-64	Creswell	NC	Private - government only
BD	Gaston County - North Carolina DOT	1301 Dallas Cherryville Hwy	Dallas	NC	Private - government only
BD	Surry County - North Carolina DOT	703 Prison Camp Rd	Dobson	NC	Private - government only

Fuel Type Code	Station Name	Street Address	City	State	Groups With Access Code
BD	Durham County - North Carolina DOT	3910 Guess Rd	Durham	NC	Private - government only
BD	Chowan County - North Carolina DOT	State Route 1303	Edenton	NC	Private - government only
BD	Pasquotank/Camden County - North Carolina DOT	US-17	Elizabeth City	NC	Private - government only
BD	Bladen County - North Carolina DOT	US-701 N	Elizabethtown	NC	Private - government only
BD	Cumberland County - North Carolina DOT	549 Transportation Dr	Fayetteville	NC	Private - government only
BD	Fort Bragg - Army & Air Force Ex-change Service	Longstreet Rd & Gruber Rd	Fort Bragg	NC	Private - government only
BD	Macon County - North Carolina DOT	Windy Gap Rd	Franklin	NC	Private - government only
BD	Gates County - North Carolina DOT	US-158	Gatesville	NC	Private - government only
BD	Wayne County - North Carolina DOT	2671 US-70 W	Goldsboro	NC	Private - government only
BD	Alamance County - North Carolina DOT	Prison Camp Rd	Graham	NC	Private - government only
BD	Pamlico County - North Carolina DOT	NC-306	Grantsboro	NC	Private - government only
BD	Pitt County - North Carolina DOT	1811 N Greene St	Greenville	NC	Private - government only
BD	Halifax County - North Carolina DOT	NC-903	Halifax	NC	Private - government only
BD	Currituck County - North Carolina DOT	Lucinda Lane	Harbinger	NC	Private - government only
BD	Clay County - North Carolina DOT	225 Tusquittee Rd	Hayesville	NC	Private - government only
BD	Vance County - North Carolina DOT	465 Gillburg Rd	Henderson	NC	Private - government only
BD	Henderson County - North Carolina DOT	693 Mountain Rd	Hendersonville	NC	Private - government only
BD	Perquimans County - North Carolina DOT	US-17	Hertford	NC	Private - government only
BD	Guilford County - North Carolina DOT	Sandy Camp Rd	High Point	NC	Private - government only
BD	Orange County - North Carolina DOT	NC-1009	Hillsborough	NC	Private - government only
BD	Northampton County - North Carolina DOT	NC-305	Jackson	NC	Private - government only
BD	Onslow County - North Carolina DOT	US-17	Jacksonville	NC	Private - government only
BD	Duplin County - North Carolina DOT	NC-11	Kenansville	NC	Private - government only
BD	Lenoir County - North Carolina DOT	US-258	Kinston	NC	Private - government only

Fuel Type Code	Station Name	Street Address	City	State	Groups With Access Code
BD	Caldwell County - North Carolina DOT	Pleasant Hill Rd	Lenoir	NC	Private - government only
BD	Davidson County - North Carolina DOT	Raleigh Rd	Lexington	NC	Private - government only
BD	Harnet County - North Carolina DOT	1108 E McNeill St	Lillington	NC	Private - government only
BD	Lincoln County - North Carolina DOT	499 Prison Camp Rd	Lincolnton	NC	Private - government only
BD	Robeson County - North Carolina DOT	NC-711	Lumberton	NC	Private - government only
BD	Dare County - North Carolina DOT	Simon St	Manteo	NC	Private - government only
BD	Currituck County - North Carolina DOT	NC-1246	Maple	NC	Private - government only
BD	Cherokee County - North Carolina DOT	NC-141	Marble	NC	Private - government only
BD	Madison County - North Carolina DOT	US-70 & US-25 Business	Marshall	NC	Private - government only
BD	Mecklenburg County - North Carolina DOT	12033-A E Independence Blvd	Matthews	NC	Private - government only
BD	Greene County - North Carolina DOT	Highway 903	Maury	NC	Private - government only
BD	Guilford County - North Carolina DOT	4253 Camp Burton Rd	McLeansville	NC	Private - government only
BD	Davie County - North Carolina DOT	Prison Camp Rd	Mocksville	NC	Private - government only
BD	Union County - North Carolina DOT	US-74	Monroe	NC	Private - government only
BD	Burke County - North Carolina DOT	2161 Mount Home Church Rd	Morganton	NC	Private - government only
BD	Cabarrus County - North Carolina DOT	State Route 2604	Mount Pleas-ant	NC	Private - government only
BD	Nash County - North Carolina DOT	US-64	Nashville	NC	Private - government only
BD	Craven County - North Carolina DOT	S Glenburnie Rd	New Bern	NC	Private - government only
BD	Avery County - North Carolina DOT	NC-1346 & NC-181	Newland	NC	Private - government only
BD	Carteret County - North Carolina DOT	Mason Town Rd	Newport	NC	Private - government only
BD	Catawba County - North Carolina DOT	1302 Prison Camp Rd	Newton	NC	Private - government only
BD	Wilkes County - North Carolina DOT	303 Statesville Rd	North Wilkes-boro	NC	Private - government only
BD	Granville County - North Carolina DOT	5677 Cornwall Rd	Oxford	NC	Private - government only
BD	Mecklenburg County - North Carolina DOT	6820 Rozzelles Ferry Rd	Paw Creek	NC	Private - government only

Fuel Type Code	Station Name	Street Address	City	State	Groups With Access Code
BD	Hoke County - North Carolina DOT	390 Mockingbird Hill Rd	Raeford	NC	Private - government only
BD	Wake County Equipment Depot - North Carolina DOT	5105 Beryl Rd	Raleigh	NC	Private - government only
BD	Wake County Method Shop - North Carolina DOT	1301 Blue Ridge Rd	Raleigh	NC	Private - government only
BD	Graham County - North Carolina DOT	40 State Shed Rd	Robbinsville	NC	Private - government only
BD	Richmond County - North Carolina DOT	SR-1005	Rockingham	NC	Private - government only
BD	Transylvania County - North Carolina DOT	Old Rosman Hwy	Rosman	NC	Private - government only
BD	Person County - North Carolina DOT	517 Leasburg Rd	Roxboro	NC	Private - government only
BD	Rowan County - North Carolina DOT	Camp Rd	Salisbury	NC	Private - government only
BD	Lee County - North Carolina DOT	1502 S 7th St	Sanford	NC	Private - government only
BD	Seymour Johnson Air Force Base	1825 Jabarrah Ave	Seymour Johnson AFB	NC	Private - government only
BD	Brunswick County - North Carolina DOT	NC-1348	Shallotte	NC	Private - government only
BD	Cleveland County - North Carolina DOT	254 Kemper Rd	Shelby	NC	Private - government only
BD	Chatham County - North Carolina DOT	E Raleigh St	Siler City	NC	Private - government only
BD	Johnston County - North Carolina DOT	US-70	Smithfield	NC	Private - government only
BD	Alleghany County - North Carolina DOT	NC-1172	Sparta	NC	Private - government only
BD	Rutherford County - North Carolina DOT	909 Ledbetter Rd	Spindale	NC	Private - government only
BD	Mitchell County - North Carolina DOT	942 Greenwood Rd	Spruce Pine	NC	Private - government only
BD	Iredell County - North Carolina DOT	124 Prison Camp Rd	Statesville	NC	Private - government only
BD	Hyde County - North Carolina DOT	SR-1129	Swan Quarter	NC	Private - government only
BD	Jackson County - North Carolina DOT	NC-116	Sylvia	NC	Private - government only
BD	Edgecombe County - North Carolina DOT	Wilson St	Tarboro	NC	Private - government only
BD	Alexander County - North Carolina DOT	2370 Highway 90 E	Taylorsville	NC	Private - government only
BD	Jones County - North Carolina DOT	336 Highway 41 E	Trenton	NC	Private - government only
BD	Montgomery County - North Carolina DOT	Glen Rd	Troy	NC	Private - government only

Fuel Type Code	Station Name	Street Address	City	State	Groups With Access Code
BD	Montgomery County - North Carolina DOT	Prison Camp Rd	Wadesboro	NC	Private - government only
BD	Scotland County - North Carolina DOT	US-401 & SR-1407	Wagram	NC	Private - government only
BD	Stokes County - North Carolina DOT	NC-8 & NC-89	Walnut Cove	NC	Private - government only
BD	Warren County - North Carolina DOT	State Route 1001	Warrenton	NC	Private - government only
BD	Beaufort County - North Carolina DOT	803 Grimes Rd	Washington	NC	Private - government only
BD	Haywood County - North Carolina DOT	Paragon Pkwy	Wayesville	NC	Private - government only
BD	Rockingham County - North Carolina DOT	NC-87 & NC-65	Wentworth	NC	Private - government only
BD	Ashe County - North Carolina DOT	SR-1131	West Jefferson	NC	Private - government only
BD	Martin County - North Carolina DOT	Prison Camp Rd	Williamston	NC	Private - government only
BD	Martin County - North Carolina DOT	US-64	Williamston	NC	Private - government only
BD	Wilson County - North Carolina DOT	Ward Blvd	Wilson	NC	Private - government only
BD	Bertie County - North Carolina DOT	120 Powell Rd & Stokes Rd	Windsor	NC	Private - government only
BD	Forsyth County - North Carolina DOT	399 Craft Dr	Winston-Salem	NC	Private - government only
BD	Yadkin County - North Carolina DOT	US-601	Yadkinville	NC	Private - government only
BD	Caswell County - North Carolina DOT	NC-1572	Yanceyville	NC	Private - government only
BD	Camp Lejeune Marine Corps Base	1070 Michael Rd	Camp Lejeune	NC	Private access only
BD	Carolina Biodiesel	1410 Cross St	Durham	NC	Public - call ahead
BD	Godar's Garage	1000 Willbea Rd	Durham	NC	Public - call ahead
BD	Reba & Rose's	112 Baldwin Rd	Hillsborough	NC	Public - call ahead
BD	Piedmont Biofuels Industrial	220 Lorax Ln	Pittsboro	NC	Public - call ahead
BD	Piedmont Biofuels - Carrboro Public Works	100 Public Works Dr	Carrboro	NC	Public - card key after hours
BD	Piedmont Biofuels - T.S. Designs	2053 Willow Spring Ln	Burlington	NC	Public - card key at all times
BD	Piedmont Biofuels - Edible Earthscapes	37 Thomas Ln	Moncure	NC	Public - card key at all times
BD	Piedmont Biofuels - Larry's Beans	1507 Gavin St	Raleigh	NC	Public - card key at all times

Fuel Type Code	Station Name	Street Address	City	State	Groups With Access Code
BD	Saxapahaw General Store	1735 Saxapahaw-Bethlehem Church Rd	Saxapahaw	NC	Public - card key at all times
BD	Piedmont Biofuels - Tidal Creek Co-op	5331 Oleander	Wilmington	NC	Public - card key at all times
BD	America's Fuel - Bill Smith Ford	1010 Old US Highway 1 S	Southern Pines	NC	Public - credit card after hours
BD	Gas-Up	405 Haywood Rd	Asheville	NC	Public - see hours
BD	Eblen Short Stop #8	1438 Tunnel Rd	Asheville	NC	Public - see hours
BD	Stanley's Station Citgo	479 Weaverville Rd	Asheville	NC	Public - see hours
BD	Eblen Short Stop #2	217 Amboy Rd	Asheville	NC	Public - see hours
BD	Eblen Short Stop #6	425 Broadway St	Asheville	NC	Public - see hours
BD	Black Mountain Natural Foods Store	108 Black Mountain Ave	Black Mountain	NC	Public - see hours
BD	Cruizers #20	1914 Sedwick Rd	Durham	NC	Public - see hours
BD	Eblen Short Stop #15	1185 Charlotte Hwy	Fairview	NC	Public - see hours
BD	Patriot Biodiesel	110 North Chimney Rock Rd	Greensboro	NC	Public - see hours
BD	Sparky's Marketplace	106 Regents Center Ct	Lexington	NC	Public - see hours
BD	Oakboro Oil Co	104 N Main St	Oakboro	NC	Public - see hours
BD	Stop & Quick	1321 S Blount St	Raleigh	NC	Public - see hours
BD	Taylor's Grocery	10005 Six Forks Rd	Raleigh	NC	Public - see hours
BD	Crown Express Mart - New Bern Station	1210 New Bern Ave	Raleigh	NC	Public - see hours
BD	Gasland USA #7	1801 E Dixon Blvd	Shelby	NC	Public - see hours
BD	Aztex BP	21 Steeple Rd	Sylva	NC	Public - see hours
BD	Triangle Biofuels Industries	1724 Baldree Rd S	Wilson	NC	Public - see hours

Appendix C Liquefied Petroleum Gas (LPG)

Fuel Type Code	Station Name	Street Address	City	State	Groups With Access Code
LPG	Camp Lejeune Marine Corps Base	1070 Michael Rd	Camp Lejeune	NC	Private - government only
LPG	Cumberland County - North Carolina DOT	549 Transportation Dr	Fayetteville	NC	Private - government only
LPG	Guilford County - North Carolina DOT	4253 Camp Burton Rd	McLeansville	NC	Private - government only
LPG	Wake County Equipment Depot - North Carolina DOT	5105 Beryl Rd	Raleigh	NC	Private - government only
LPG	Forsyth County - North Carolina DOT	399 Craft Dr	Winston-Salem	NC	Private - government only
LPG	North Carolina Propane Gas Association - Headquarters	5109 Hollyridge Dr	Raleigh	NC	Private access only
LPG	Efird-Quality Gas	32139 Canton Rd	Albemarle	NC	Public - call ahead
LPG	McLamb's LP Gas & Supply	3469 Highway 242 S	Benson	NC	Public - call ahead
LPG	Lynch Oil Co Inc	1609 W Webb Ave	Burlington	NC	Public - call ahead
LPG	Blossman Gas Inc	8 Comet Dr	Burnsville	NC	Public - call ahead
LPG	Heritage Propane	347 E US Highway 19 E Bypass	Burnsville	NC	Public - call ahead
LPG	Thomas Gas Co	2772 Armentrout Dr	Concord	NC	Public - call ahead
LPG	Western LP Gas	708 Virginia Rd	Edenton	NC	Public - call ahead
LPG	Blossman Gas Inc	6080 Brevard Rd	Etowah	NC	Public - call ahead
LPG	Parker Gas Co	2669 Owen Dr	Fayetteville	NC	Public - call ahead
LPG	Western LP Gas	6553 Caratoke Hwy	Grandy	NC	Public - call ahead
LPG	Blossman Gas Inc	3500 Associate Dr	Greensboro	NC	Public - call ahead
LPG	Heritage Propane	25 McDonald Rd	Hayesville	NC	Public - call ahead
LPG	Carolane Propane Gas Inc	339 S Main St	Lexington	NC	Public - call ahead
LPG	Blossman Gas Inc	502 National Blvd	Lexington	NC	Public - call ahead
LPG	Energy United Propane	1900 S Main St	Lexington	NC	Public - call ahead
LPG	Foust's Fuel Gas Co	411 E Center St	Mebane	NC	Public - call ahead
LPG	Southern Gas Co - Heritage Propane	1568 Roosevelt Blvd	Monroe	NC	Public - call ahead
LPG	Heritage Propane	359 Pleasant Valley Rd	Murphy	NC	Public - call ahead
LPG	Parker Gas Co	2414 McLamb Rd	Newton Grove	NC	Public - call ahead
LPG	Jenkins Propane	43 Hadley Mill Rd	Pittsboro	NC	Public - call ahead
LPG	Carolane Propane Gas Inc	1010 W Innes St	Salisbury	NC	Public - call ahead
LPG	Blossman Gas Inc	2221 S Horner Blvd	Sanford	NC	Public - call ahead

Fuel Type Code	Station Name	Street Address	City	State	Groups With Access Code
LPG	Parker Gas Co	1308 S Brightleaf Blvd	Smithfield	NC	Public - call ahead
LPG	Blossman Gas Inc	150 Parcel Dr	Statesville	NC	Public - call ahead
LPG	Blossman Gas Inc	536 E Main St	Sylva	NC	Public - call ahead
LPG	Williams Fuel	1406 W St James St	Tarboro	NC	Public - call ahead
LPG	Blossman Gas Inc	4991 US Highway 421 N	Vilas	NC	Public - call ahead
LPG	Piedmont Propane	710 US Highway 52 S	Wadesboro	NC	Public - call ahead
LPG	Energy United Propane	735 W Ridgeway St	Warrenton	NC	Public - call ahead
LPG	Waynesville Gas Service	19 Buffalo Ln	Waynesville	NC	Public - call ahead
LPG	Blossman Gas Inc	2161 Dellwood Rd	Waynesville	NC	Public - call ahead
LPG	Williams Fuel	2400 Wilco Bvd S	Wilson	NC	Public - call ahead
LPG	Carolane Propane Gas Inc	1421 S Main St	Winston-Salem	NC	Public - call ahead
LPG	U-Haul	387 Swannanoa River Rd	Asheville	NC	Public - see hours
LPG	German Motor Werks	1274 Sweeten Creek Rd	Asheville	NC	Public - see hours
LPG	Blossman Gas Inc	6109 W Wilkinson Blvd	Belmont	NC	Public - see hours
LPG	Van Derveer Gas Co Inc	2265 Highway 24-27 E	Biscoe	NC	Public - see hours
LPG	Heritage Propane	4481 Highway 105 S	Boone	NC	Public - see hours
LPG	Blossman Gas Inc	1401 Smokey Park Hwy	Candler	NC	Public - see hours
LPG	Parker Gas Co	1504 Sunset Ave	Clinton	NC	Public - see hours
LPG	KB Johnson Oil & Gas Co	1709 N Main St	Fuquay-Varina	NC	Public - see hours
LPG	U-Haul	1702 Mechanical Blvd	Garner	NC	Public - see hours
LPG	U-Haul	3919 E Franklin Blvd	Gastonia	NC	Public - see hours
LPG	Franklin Auto Care	1510 E Franklin Blvd	Gastonia	NC	Public - see hours
LPG	Blossman Gas Inc	4560 Hickory Blvd	Granite Falls	NC	Public - see hours
LPG	Guilford Gas Service	710 Patton Ave	Greensboro	NC	Public - see hours
LPG	U-Haul	911 W Lee St	Greensboro	NC	Public - see hours
LPG	U-Haul	2908 N Main St	High Point	NC	Public - see hours
LPG	Cherry Energy	2947 Hull Rd	Kinston	NC	Public - see hours
LPG	Moore's Auto Clinic	4142 Arendell St	Morehead City	NC	Public - see hours
LPG	Carolane Propane	1766 Andy Griffith Pkwy S	Mount Airy	NC	Public - see hours

Fuel Type Code	Station Name	Street Address	City	State	Groups With Access Code
LPG	C-Co Mini-Mart	5674 Highway 70	Newport	NC	Public - see hours
LPG	Efird - Quality Gas	1505 N Main St	Oakboro	NC	Public - see hours
LPG	U-Haul	716 Capital Blvd	Raleigh	NC	Public - see hours
LPG	U-Haul	3001 N Capital Blvd	Raleigh	NC	Public - see hours
LPG	Cooper LP Gas Co	3097 Hal Siler Dr	Sanford	NC	Public - see hours
LPG	Thompson Gas	3175-B S Brightleaf Blvd	Smithfield	NC	Public - see hours
LPG	VanDerveer Gas Service	2105 Juniper Lake Rd	West End	NC	Public - see hours

Appendix D Compressed Natural Gas (CNG) Stations

Fuel Type Code	Station Name	Street Address	City	State	Groups With Access Code
CNG	Charlotte-Mecklenburg School Bus	3901 Craig Ave	Charlotte	NC	PLANNED - not yet accessible
CNG	PSNC Energy	15 Overland Industrial Blvd	Asheville	NC	PLANNED - not yet accessible
CNG	PSNC Energy	2541 Whilden Dr	Durham	NC	PLANNED - not yet accessible
CNG	PSNC Energy	2712 Discovery Dr	Raleigh	NC	PLANNED - not yet accessible
CNG	City of Rocky Mount	106 E Grand Ave	Rocky Mount	NC	PLANNED - not yet accessible
CNG	PSNC Energy	121 Houston Rd	Troutman	NC	PLANNED - not yet accessible
CNG	Town of Chapel Hill	6836 Millhouse Rd	Chapel Hill	NC	Private - government only
CNG	Fort Bragg		Fort Bragg	NC	Private - government only
CNG	Town of Garner	610 Rand Mill Rd	Garner	NC	Private - government only
CNG	City of Winston Salem	650 Stadium Dr	Winston-Salem	NC	Private - government only
CNG	Forsyth County DOT	399 Craft Dr	Winston-Salem	NC	Private - government only
CNG	Butner Federal Correctional Complex	Old NC Highway 75	Butner	NC	Private access only
CNG	Piedmont Natural Gas - Charlotte - Private Access	112 Verbena St	Charlotte	NC	Private access only
CNG	All Bright Sanitation	180 Ada Moore St	Columbus	NC	Private access only
CNG	Piedmont Natural Gas - Goldsboro - Private Access	250 Five Points Rd	Dudley	NC	Private access only
CNG	Duke University	117 S Buchanan St	Durham	NC	Private access only
CNG	BuildSense	502 Rigsbee Ave	Durham	NC	Private access only
CNG	City of Gastonia	800 N Broad St	Gastonia	NC	Private access only
CNG	City of Greensboro	401 Patton Ave	Greensboro	NC	Private access only
CNG	Piedmont Natural Gas - Greensboro - Private Access	2611 Greengate Dr	Greensboro	NC	Private access only
CNG	Thomasbuilt Bus	1116 Tryon St	High Point	NC	Private access only
CNG	Piedmont Natural Gas - High Point - Private Access	2623 Uwharrie Rd	High Point	NC	Private access only
CNG	NC-CNG	2618 Hendersonville Rd	Arden	NC	Public - credit card at all times
CNG	City of Asheville	45 McCormick Pl	Asheville	NC	Public - credit card at all times
CNG	Piedmont Natural Gas - Charlotte - Public Access	112 Verbena St	Charlotte	NC	Public - credit card at all times
CNG	Piedmont Natural Gas - Goldsboro - Public Access	250 Five Points Rd	Dudley	NC	Public - credit card at all times
CNG	PSNC Energy	800 Gaston Rd	Gastonia	NC	Public - credit card at all times

Fuel Type Code	Station Name	Street Address	City	State	Groups With Access Code
CNG	Piedmont Natural Gas - Greensboro - Public Access	2611 Greengate Dr	Greensboro	NC	Public - credit card at all times
CNG	Henderson County	320 Williams St	Hendersonville	NC	Public - credit card at all times
CNG	City of Hickory	1441 9th Ave NE	Hickory	NC	Public - credit card at all times
CNG	Piedmont Natural Gas - High Point - Public Access	2623 Uwharrie Rd	High Point	NC	Public - credit card at all times
CNG	City of Raleigh	4120 New Bern Ave	Raleigh	NC	Public - credit card at all times
CNG	PSNC Energy	4211 Global St	Raleigh	NC	Public - credit card at all times
CNG	Town of Wake Forest	401 Elm Ave	Wake Forest	NC	Public - credit card at all times
CNG	Davidson County	925 N Main St	Lexington	NC	Public - see hours

Appendix E Electric Vehicle Charging Stations

Fuel Type Code	Station Name	Street Address	City	State	Groups With Access Code
ELEC	Orange County - West Campus Office Building	131 W Margaret Ln	Hillsborough	NC	PLANNED - not yet accessible
ELEC	Raleigh Municipal Fleet Station	222 W Hargett St	Raleigh	NC	Private - fleet customers only
ELEC	City of Raleigh - Police Fleet Station	6716 Six Forks Rd	Raleigh	NC	Private - fleet customers only
ELEC	City of Raleigh - Transit Center - Fleet	808 Bus Way	Raleigh	NC	Private - fleet customers only
ELEC	City of Durham - Justice Center Deck	247 S Mangum St	Durham	NC	Private - government only
ELEC	Eaton Corporation	221 Heywood Rd	Arden	NC	Private access only
ELEC	Asheboro Nissan - Service Center	1635 E Dixie Dr	Asheboro	NC	Private access only
ELEC	Anderson Nissan - Service Center	629 Brevard Rd	Asheville	NC	Private access only
ELEC	Progress Energy - Asheville	555 Brevard Rd	Asheville	NC	Private access only
ELEC	University Nissan - Service Center	2462 Highway 421 S	Boone	NC	Private access only
ELEC	Carolina Nissan - Service Center	1329 Huffman Mill Rd	Burlington	NC	Private access only
ELEC	Dick Shirley Automotive	2616 Alamance Rd	Burlington	NC	Private access only
ELEC	Leith Nissan - Service Center	2000 Auto Park Blvd	Cary	NC	Private access only
ELEC	Duke Energy	526 S Church St	Charlotte	NC	Private access only
ELEC	Duke Energy	6325 Wilkinson Blvd	Charlotte	NC	Private access only
ELEC	Celgard	13800 S Lakes Dr	Charlotte	NC	Private access only
ELEC	Duke Energy	201-399 W 1st St	Charlotte	NC	Private access only
ELEC	East Charlotte Nissan - Service Center	6901 E Independence Blvd	Charlotte	NC	Private access only
ELEC	South Charlotte Nissan - Service Center	9215 S Blvd	Charlotte	NC	Private access only
ELEC	Modern Nissan of Concord - Service Center	967 Concord Pkwy S	Concord	NC	Private access only
ELEC	Modern Nissan of Lake Norman - Service Center	18615 Statesville Rd	Cornelius	NC	Private access only
ELEC	Duke University Facilities Management - Smith Warehouse Building	114 S Buchanan Blvd	Durham	NC	Private access only
ELEC	Duke University Facilities Management - Smith Warehouse Building - Blink	114 S Buchanan Blvd	Durham	NC	Private access only
ELEC	Alliance Nissan - Service Center	1712 N Rd St	Elizabeth City	NC	Private access only
ELEC	Stewart Nissan - Service Center	929 Bragg Blvd	Fayetteville	NC	Private access only
ELEC	McCurry Deck Nissan - Service Center	156 Oak St Extension	Forest City	NC	Private access only
ELEC	Gastonia Nissan - Service Center	2755 E Franklin Blvd	Gastonia	NC	Private access only
ELEC	Deacon Jones Nissan - Service Center	1220 W Grantham St	Goldsboro	NC	Private access only
ELEC	Crown Nissan - Service Center	3900 W Wendover Ave	Greensboro	NC	Private access only
ELEC	Volvo Technology of America	7825 National Service Rd	Greensboro	NC	Private access only
ELEC	Greenville Nissan - Service Center	991 Greenville Blvd SW	Greenville	NC	Private access only
ELEC	Hunter Nissan - Service Center	1340 Spartanburg Hwy	Hendersonville	NC	Private access only
ELEC	Crossroads Nissan of Hickory - Service Center	1555 Highway 321 N	Hickory	NC	Private access only
ELEC	Vann Yorks High Point Nissan - Service Center	1810 S Main St	High Point	NC	Private access only
ELEC	Novartis	475 Green Oaks Pkwy	Holly Springs	NC	Private access only
ELEC	Don Williamson Nissan - Service Center	310 Western Blvd	Jacksonville	NC	Private access only
ELEC	Lumberton Nissan - Service Center	1949 Roberts Ave	Lumberton	NC	Private access only
ELEC	General Electric - Energy Industrial Systems	6801 Industrial Dr	Mebane	NC	Private access only

Fuel Type Code	Station Name	Street Address	City	State	Groups With Access Code
ELEC	Qualcomm Incorporated	8041 Arco Corporate Dr	Morrisville	NC	Private access only
ELEC	Simmons Nissan - Service Center	1994 Rockford St	Mount Airy	NC	Private access only
ELEC	Eastern Carolina Nissan - Service Center	3315 Highway 70 E	New Bern	NC	Private access only
ELEC	Green Square Public Parking Garage - Level B1	120 W Edenton St	Raleigh	NC	Private access only
ELEC	Green Square Public Parking Garage - Level P1	120 W Edenton St	Raleigh	NC	Private access only
ELEC	Solar EV Pilot	614 S Salisbury St	Raleigh	NC	Private access only
ELEC	Advanced Energy - ChargePoint	909 Capability Dr	Raleigh	NC	Private access only
ELEC	Advanced Energy	909 Capability Dr	Raleigh	NC	Private access only
ELEC	North Carolina State University - Keystone Science Center - Private	1791 Varsity Dr	Raleigh	NC	Private access only
ELEC	Southern States Nissan - Service Center	2511 Wake Forest Rd	Raleigh	NC	Private access only
ELEC	Reidsville Nissan - Service Center	1123 Freeway Dr	Reidsville	NC	Private access only
ELEC	CBRE	7025-7 Kit Creek Rd	Research Triangle Park	NC	Private access only
ELEC	Nissan of Roanoke Rapids - Service Center	320 Becker Dr	Roanoke Rapids	NC	Private access only
ELEC	Griffin Nissan - Service Center	1780 E Broad Ave	Rockingham	NC	Private access only
ELEC	Ben Mynatt Nissan - Service Center	629 Jake Alexander Blvd S	Salisbury	NC	Private access only
ELEC	Crossroads Nissan - Service Center	3305 NC Highway 87 S	Sanford	NC	Private access only
ELEC	Pinehurst Nissan - Service Center	10910 S US Highway 15-501	Southern Pines	NC	Private access only
ELEC	Classic Nissan Statesville - Service Center	1244 E Garner Bagnal Blvd	Statesville	NC	Private access only
ELEC	Crossroads Nissan of Wake Forest - Service Center	11120 Capital Blvd	Wake Forest	NC	Private access only
ELEC	Wilkes Nissan - Service Center	1933 US Highway 421B	Wilkesboro	NC	Private access only
ELEC	Capital Nissan of Wilmington - Service Center	5406 Market St	Wilmington	NC	Private access only
ELEC	Lee Nissan - Service Center	4801 Ward Blvd	Wilson	NC	Private access only
ELEC	Modern Nissan - Service Center	5795 University Pkwy	Winston Salem	NC	Private access only
ELEC	Ritz Carlton - Charlotte	201 E Trade St	Charlotte	NC	Public - call ahead
ELEC	Leith Nissan	1405 Vision Dr	Apex	NC	Public - see hours
ELEC	Asheboro Nissan	1635 E Dixie Dr	Asheboro	NC	Public - see hours
ELEC	BioWheels RTS Headquarters	81 Coxe Ave	Asheville	NC	Public - see hours
ELEC	BioWheels RTS - Asheville Public Works	163 S Charlotte St	Asheville	NC	Public - see hours
ELEC	BioWheels RTS	339 New Leicester Hwy	Asheville	NC	Public - see hours
ELEC	Asheville Chamber of Commerce & Visitors Center	36 Montford Ave	Asheville	NC	Public - see hours
ELEC	College Street Parking Deck	164 College St	Asheville	NC	Public - see hours
ELEC	Ingles Markets - Skyland Plaza	1865 Hendersonville Rd	Asheville	NC	Public - see hours
ELEC	Hilton Asheville - Biltmore Park	42 Town Square Blvd	Asheville	NC	Public - see hours
ELEC	Anderson Nissan	629 Brevard Rd	Asheville	NC	Public - see hours
ELEC	Consolidated Electrical Distributors	343 Hilliard Ave	Asheville	NC	Public - see hours
ELEC	Skyland Automotive	255 Smokey Park Hwy	Asheville	NC	Public - see hours
ELEC	Asheville Chevrolet	205 Smokey Park Hwy	Asheville	NC	Public - see hours
ELEC	University of North Carolina - Asheville Brightfield	300 Campus View Rd	Asheville	NC	Public - see hours
ELEC	North Carolina Department of Transportation - Benson Eastbound Rest Area	I-40 E	Benson	NC	Public - see hours
ELEC	North Carolina Department of Transportation - Benson Westbound Rest Area	I-40 W	Benson	NC	Public - see hours

Fuel Type Code	Station Name	Street Address	City	State	Groups With Access Code
ELEC	Black Mountain Public Safety Building	102 Montreat Rd	Black Mountain	NC	Public - see hours
ELEC	Makoto's Japanese Steak House & Sushi Bar	2124 Blowing Rock Rd	Boone	NC	Public - see hours
ELEC	University Nissan	2462 Highway 421 S	Boone	NC	Public - see hours
ELEC	North Carolina Department of Transportation - Alamance County Northbound Rest Area	I-85 N	Burlington	NC	Public - see hours
ELEC	North Carolina Department of Transportation - Alamance County Southbound Rest Area	I-85 S	Burlington	NC	Public - see hours
ELEC	Carolina Nissan	1329 Huffman Mill Rd	Burlington	NC	Public - see hours
ELEC	Alamance Regional Medical Center	1240 Huffman Mill Rd	Burlington	NC	Public - see hours
ELEC	McDonald's	1299 Kildaire Farm Rd	Cary	NC	Public - see hours
ELEC	City of Cary - Public Works	270 James Jackson Ave	Cary	NC	Public - see hours
ELEC	Leith Nissan	2000 Auto Park Blvd	Cary	NC	Public - see hours
ELEC	Umstead Hotel & Spa	100 Woodland Pond Dr	Cary	NC	Public - see hours
ELEC	Orange County - Robert and Pearl Seymour Center	2551 Homestead Rd	Chapel Hill	NC	Public - see hours
ELEC	Orange County - Skills Development Center	503 W Franklin St	Chapel Hill	NC	Public - see hours
ELEC	Bank of America	111 E 7th St	Charlotte	NC	Public - see hours
ELEC	Bank of America	950 E Trade St	Charlotte	NC	Public - see hours
ELEC	Duke Energy - Mint Street Parking Deck R1-R5	404 S Mint St	Charlotte	NC	Public - see hours
ELEC	Duke Energy - Mint Street Parking Deck L1-L6	410 S Mint St	Charlotte	NC	Public - see hours
ELEC	Charlotte Douglas International Airport - Business Valet Parking Deck	5601 Wilkinson Blvd	Charlotte	NC	Public - see hours
ELEC	The Green Parking Garage	435 S Tryon St	Charlotte	NC	Public - see hours
ELEC	Charlotte-Mecklenburg Utilities Department - Environmental Services Facility	4222 Westmont Dr	Charlotte	NC	Public - see hours
ELEC	Duke Energy	2310 Corrine Ct	Charlotte	NC	Public - see hours
ELEC	Charlotte-Mecklenburg Government Center	232 S Davidson St	Charlotte	NC	Public - see hours
ELEC	City of Charlotte	1428 South Blvd	Charlotte	NC	Public - see hours
ELEC	City of Charlotte	103 N Tryon St	Charlotte	NC	Public - see hours
ELEC	I-485 Station Park & Ride	9510 South Blvd	Charlotte	NC	Public - see hours
ELEC	Mallard Creek Park & Ride	1712 JN Pease Pl	Charlotte	NC	Public - see hours
ELEC	City of Charlotte	505 S Tryon St	Charlotte	NC	Public - see hours
ELEC	BECO South	8505 IBM Dr	Charlotte	NC	Public - see hours
ELEC	East Charlotte Nissan	6901 E Independence Blvd	Charlotte	NC	Public - see hours
ELEC	South Charlotte Nissan	9215 S Blvd	Charlotte	NC	Public - see hours
ELEC	Charlotte-Mecklenburg Police Department - Parking Deck	698 E 5th St	Charlotte	NC	Public - see hours
ELEC	Cherokee Welcome Center	498 Tsali Blvd	Cherokee	NC	Public - see hours
ELEC	Haywood Community College	185 Freedlander Dr	Clyde	NC	Public - see hours
ELEC	Modern Nissan of Concord	967 Concord Pkwy S	Concord	NC	Public - see hours
ELEC	Modern Nissan of Lake Norman	18615 Statesville Rd	Cornelius	NC	Public - see hours
ELEC	South Main Square	422 S Main St	Davidson	NC	Public - see hours
ELEC	Neal's Garage	1907 W Markham Ave	Durham	NC	Public - see hours
ELEC	BSMG - American Tobacco Campus	601 Carr St	Durham	NC	Public - see hours
ELEC	Housing & Community Develop	807 E Main St	Durham	NC	Public - see hours

Fuel Type Code	Station Name	Street Address	City	State	Groups With Access Code
ELEC	Michael Jordan Nissan	3930 Chapel Hill Blvd	Durham	NC	Public - see hours
ELEC	City of Durham - Human Services Building Lot	414 E Main St	Durham	NC	Public - see hours
ELEC	City of Durham - Main Library	300 N Roxboro St	Durham	NC	Public - see hours
ELEC	City of Durham - North Regional Library	221 Milton Rd	Durham	NC	Public - see hours
ELEC	City of Durham - South Regional Library	4505 S Alston Ave	Durham	NC	Public - see hours
ELEC	Alliance Nissan	1712 N Rd St	Elizabeth City	NC	Public - see hours
ELEC	Stewart Nissan	929 Bragg Blvd	Fayetteville	NC	Public - see hours
ELEC	Transportation Museum Annex	302 W Russell St	Fayetteville	NC	Public - see hours
ELEC	City of Fayetteville	208 Franklin St	Fayetteville	NC	Public - see hours
ELEC	Blue Ridge Community College - Alternative Fuels Lab	2 E Campus Dr	Flat Rock	NC	Public - see hours
ELEC	Blue Ridge Community College - Spearman Building	2 E Campus Dr	Flat Rock	NC	Public - see hours
ELEC	McCurry Deck Nissan	156 Oak St Extension	Forest City	NC	Public - see hours
ELEC	Schiele Museum	1500 E Garrison Blvd	Gastonia	NC	Public - see hours
ELEC	Gaston County - Highland Health Center	609 N Highland St	Gastonia	NC	Public - see hours
ELEC	Gastonia Nissan	2755 E Franklin Blvd	Gastonia	NC	Public - see hours
ELEC	Deacon Jones Nissan	1220 W Grantham St	Goldsboro	NC	Public - see hours
ELEC	PART Park & Ride	820 S Main St	Graham	NC	Public - see hours
ELEC	Crown Nissan	3900 W Wendover Ave	Greensboro	NC	Public - see hours
ELEC	Greenville Nissan	991 Greenville Blvd SW	Greenville	NC	Public - see hours
ELEC	Dogwood Parking Lot	411 N Church St	Hendersonville	NC	Public - see hours
ELEC	Hunter Nissan	1340 Spartanburg Hwy	Hendersonville	NC	Public - see hours
ELEC	Boyd Automotive	901 Asheville Hwy	Hendersonville	NC	Public - see hours
ELEC	Crossroads Nissan of Hickory	1555 Highway 321 N	Hickory	NC	Public - see hours
ELEC	Vann Yorks High Point Nissan	1810 S Main St	High Point	NC	Public - see hours
ELEC	Orange County - Durham Technical Community College Park & Ride Lot	525 College Park Dr	Hillsborough	NC	Public - see hours
ELEC	Town of Hookerton - Town Office	227 E Main St	Hookerton	NC	Public - see hours
ELEC	Huntersville Gateway Park & Ride	10300 Compass St	Huntersville	NC	Public - see hours
ELEC	Don Williamson Nissan	310 Western Blvd	Jacksonville	NC	Public - see hours
ELEC	Duke Energy	1000-1098 Beason Creek Rd	Kings Mountain	NC	Public - see hours
ELEC	Schneider Electric - Visitor Lot	8001 Knightdale Blvd	Knightdale	NC	Public - see hours
ELEC	Shoppes at Childress Vineyards	517 Vineyards Crossing	Lexington	NC	Public - see hours
ELEC	Lumberton Nissan	1949 Roberts Ave	Lumberton	NC	Public - see hours
ELEC	Montreat College	310 Appalachian Way	Montreat	NC	Public - see hours
ELEC	Simmons Nissan	1994 Rockford St	Mount Airy	NC	Public - see hours
ELEC	Eastern Carolina Nissan	3315 Highway 70 E	New Bern	NC	Public - see hours
ELEC	Central Carolina Community College & Community Library	764 West St	Pittsboro	NC	Public - see hours
ELEC	North Carolina State University	1017 Main Campus Dr	Raleigh	NC	Public - see hours
ELEC	Advanced Energy - Shorepower	909 Capability Dr	Raleigh	NC	Public - see hours
ELEC	Dominion Realty	8325 Six Forks Rd	Raleigh	NC	Public - see hours
ELEC	City of Raleigh Municipal Building	285 W Hargett St	Raleigh	NC	Public - see hours
ELEC	City of Raleigh Downtown	215 W Cabarrus St	Raleigh	NC	Public - see hours
ELEC	Green Square Public Parking Garage - Level P2	120 W Edenton St	Raleigh	NC	Public - see hours

Fuel Type Code	Station Name	Street Address	City	State	Groups With Access Code
ELEC	City of Raleigh - City Center Deck	429 S Wilmington St	Raleigh	NC	Public - see hours
ELEC	Marriott Hotel Underground Deck	1 E Lenoir St	Raleigh	NC	Public - see hours
ELEC	City of Raleigh - Performing Arts Center Deck	128 W South St	Raleigh	NC	Public - see hours
ELEC	City of Raleigh - Wilmington Station Deck	115 S Wilmington St	Raleigh	NC	Public - see hours
ELEC	Museum of Natural Sciences	121 W Jones St	Raleigh	NC	Public - see hours
ELEC	North Carolina State University - Keystone Science Center - Public - Eaton	1791 Varsity Dr	Raleigh	NC	Public - see hours
ELEC	Wilkerson Nature Preserve Park	11408 Raven Ridge Rd	Raleigh	NC	Public - see hours
ELEC	City Municipal Deck	112 S McDowell St	Raleigh	NC	Public - see hours
ELEC	City of Raleigh	231 Fayetteville St	Raleigh	NC	Public - see hours
ELEC	City of Raleigh -Walnut Creek Wetland Center	950 Peterson St	Raleigh	NC	Public - see hours
ELEC	City of Raleigh - Optimist Park & Community Center	5910 Whittier Dr	Raleigh	NC	Public - see hours
ELEC	City of Raleigh - Jaycee Park & Community Center	2401 Wade Ave	Raleigh	NC	Public - see hours
ELEC	City of Raleigh - Wilders Grove	630 Beacon Lake Dr	Raleigh	NC	Public - see hours
ELEC	City of Raleigh - Transit Center	808 Bus Way	Raleigh	NC	Public - see hours
ELEC	BSMG - WRAL Raleigh	2619 Western Blvd	Raleigh	NC	Public - see hours
ELEC	North Hills	4291 The Circle At North Hills St	Raleigh	NC	Public - see hours
ELEC	North Carolina State University - McKimmon Center & Solar House	1201 Gorman Ave	Raleigh	NC	Public - see hours
ELEC	North Carolina State University - Joyner Visitor Center	1210 Varsity Dr	Raleigh	NC	Public - see hours
ELEC	Northern Wake Tech Community College	6600 Louisburg Rd	Raleigh	NC	Public - see hours
ELEC	Whole Foods Market	8710 Six Forks Rd	Raleigh	NC	Public - see hours
ELEC	American Institute of Architects	14 E Peace St	Raleigh	NC	Public - see hours
ELEC	North Carolina State University - Keystone Science Center - Public - ClipperCreek	1791 Varsity Dr	Raleigh	NC	Public - see hours
ELEC	Southern StatesNissan	2511 Wake Forest Rd	Raleigh	NC	Public - see hours
ELEC	Reidsville Nissan	1123 Freeway Dr	Reidsville	NC	Public - see hours
ELEC	Nissan of Roanoke Rapids	320 Becker Dr	Roanoke Rapids	NC	Public - see hours
ELEC	Griffin Nissan	1780 E Broad Ave	Rockingham	NC	Public - see hours
ELEC	Ben Mynatt Nissan	629 Jake Alexander Blvd S	Salisbury	NC	Public - see hours
ELEC	Taylor Automotive	1007 Hawkins Ave	Sanford	NC	Public - see hours
ELEC	Crossroads Nissan	3305 NC Highway 87 S	Sanford	NC	Public - see hours
ELEC	Pinehurst Nissan	10910 S US Highway 15-501	Southern Pines	NC	Public - see hours
ELEC	Duke Energy	6769 Old Plank Rd	Stanley	NC	Public - see hours
ELEC	Energy United Headquarters	567 Mocksville Hwy	Statesville	NC	Public - see hours
ELEC	Classic Nissan Statesville	1244 E Garner Bagnal Blvd	Statesville	NC	Public - see hours
ELEC	Crossroads Nissan of Wake Forest	11120 Capital Blvd	Wake Forest	NC	Public - see hours
ELEC	Siemens Energy	7000 Siemens Rd	Wendell	NC	Public - see hours
ELEC	Wilkes Nissan	1933 US Highway 421B	Wilkesboro	NC	Public - see hours
ELEC	Capital Nissan of Wilmington	5406 Market St	Wilmington	NC	Public - see hours
ELEC	Mayfair Shopping Center	900 Town Center Dr	Wilmington	NC	Public - see hours
ELEC	Lee Nissan	4801 Ward Blvd	Wilson	NC	Public - see hours
ELEC	Modern Nissan	5795 University Pkwy	Winston Salem	NC	Public - see hours

Appendix F Figures

Figure 14 Examples of Classification Schemes

Gross Vehicle Weight Rating (lbs)	Federal Highway Administration		US Census Bureau
	Vehicle Class	GVWR Catagory	VIUS Classes
<6,000	Class 1: <6,000 lbs	Light Duty <10,000 lbs	Light Duty <10,000 lbs
10,000	Class 2: 6,001 – 10,000lbs		
14,000	Class 3: 10,001 – 14,000 lbs	Medium Duty 10,001 – 26,000 lbs	Medium Duty 10,001 – 19,500 lbs
16,000	Class 4: 14,001 – 16,000 lbs		
19,500	Class 5: 16,001 – 19,500 lbs		
26,000	Class 6: 19,501 – 26,000 lbs		Light Heavy Duty: 19,001 – 26,000 lbs
33,000	Class 7: 26,001 – 33,000 lbs	Heavy Duty >26,001 lbs	Heavy Duty >26,001 lbs
>33,000	Class 8: >33,001 lbs		

Image source: http://www.afdc.energy.gov/data/tab/vehicles/data_set/103810

Figure 15 Example Vehicles Within Each Class

Image source: http://www.afdc.energy.gov/data/tab/vehicles/data_set/10381

NORTH CAROLINA

DEPARTMENT OF COMMERCE