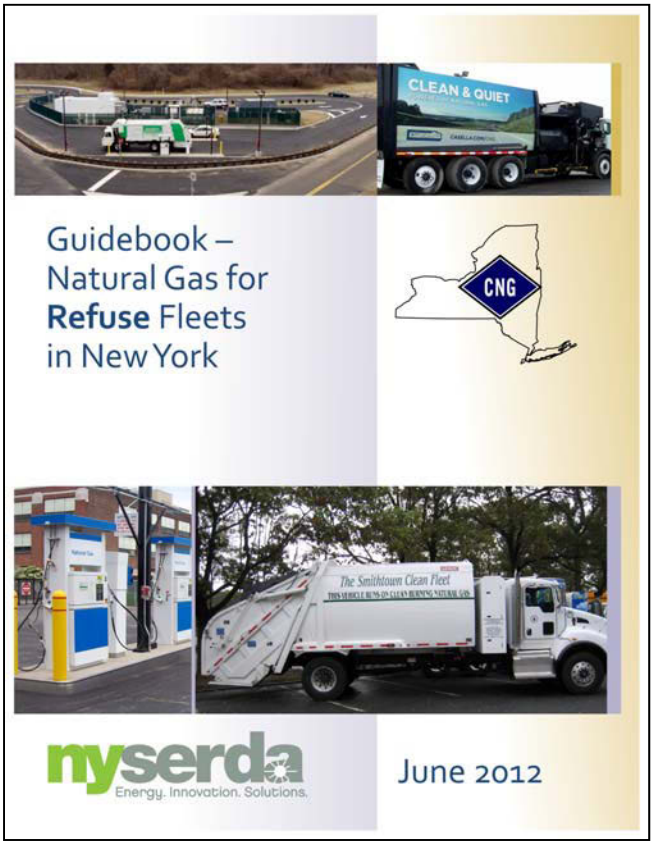
Guidebook
Natural Gas for Refuse Fleets in Pennsylvania

DELAWARE VALLEY
dvrpc
REGIONAL
PLANNING COMMISSION

April 2015
Originally published by NYSERDA
Updated and modified by DVRPC
See notice inside cover

NOTICE

This report was originally prepared by Antares Group Incorporated, Energetics Incorporated, and Modern Energy in the course of performing work contracted for and sponsored by the New York State Energy Research and Development Authority (hereafter NYSERDA). The original publication date was June 2012. The original NYSERDA document is available for download at: http://www.nyserda.ny.gov/-/media/Files/EIBD/Research/Transportation/CNG/cng-refuse-fleets.pdf.



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Acknowledgment: The DVRPC revisions and updates to this material are based upon work supported by the Department of Energy, Office of Energy Efficiency and Renewable Energy under Award Number DE-EE0006089.

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1 Purpose

The purpose of this guidebook is to help municipalities and private companies in Pennsylvania understand how compressed natural gas (CNG) vehicles can be used in their refuse services to save money. The use of CNG to displace gasoline or diesel fuel assists Pennsylvania in achieving its broad energy security and environmental air quality goals. Both municipalities and private companies that own refuse trucks and municipalities that contract out refuse services will benefit from this guidebook. This booklet describes an overall approach and process for converting a fleet to CNG. While every fleet and operation is different and has its own unique features, this material will provide overview information to assist an organization in determining if CNG vehicles are a viable option for refuse services and in locating the basic knowledge to start evaluating and implementing a CNG vehicle program. If more detailed information than provided in this guidebook is desired, the organization should contact experts in the field to learn about all available options and obtain fleet-specific advice. DVRPC, Eastern Pennsylvania Alliance for Clean Transportation (EP-ACT – formerly Greater Philadelphia Clean Cities), and Pittsburgh Regional Clean Cities are well-connected to help fleets take advantage of all available resources, learn about opportunities to share infrastructure, explore vehicle bulk buying collaborations, and learn from other local organizations that have successfully implemented a CNG vehicle program.

Interest in the use of CNG for commercial fleets, especially refuse vehicles, has been driven by the fuel cost differential. Historically, the price of CNG for transportation applications has followed the price trend for conventional petroleum fuels in the transportation market, with modestly lower prices for CNG. Natural gas is primarily produced domestically and technological advancements have increased the potential domestic supply, while petroleum imports suffer from unstable world events. This has caused the price of CNG at the pump to stabilize while conventional petroleum fuel prices have risen; during some time periods producing wide cost differentials between CNG and diesel fuel, as shown in Figure 1. This price differential will fluctuate over time, but market and supply trends for natural gas and petroleum make it likely that it will continue to be less costly to operate a CNG vehicle than a diesel vehicle.

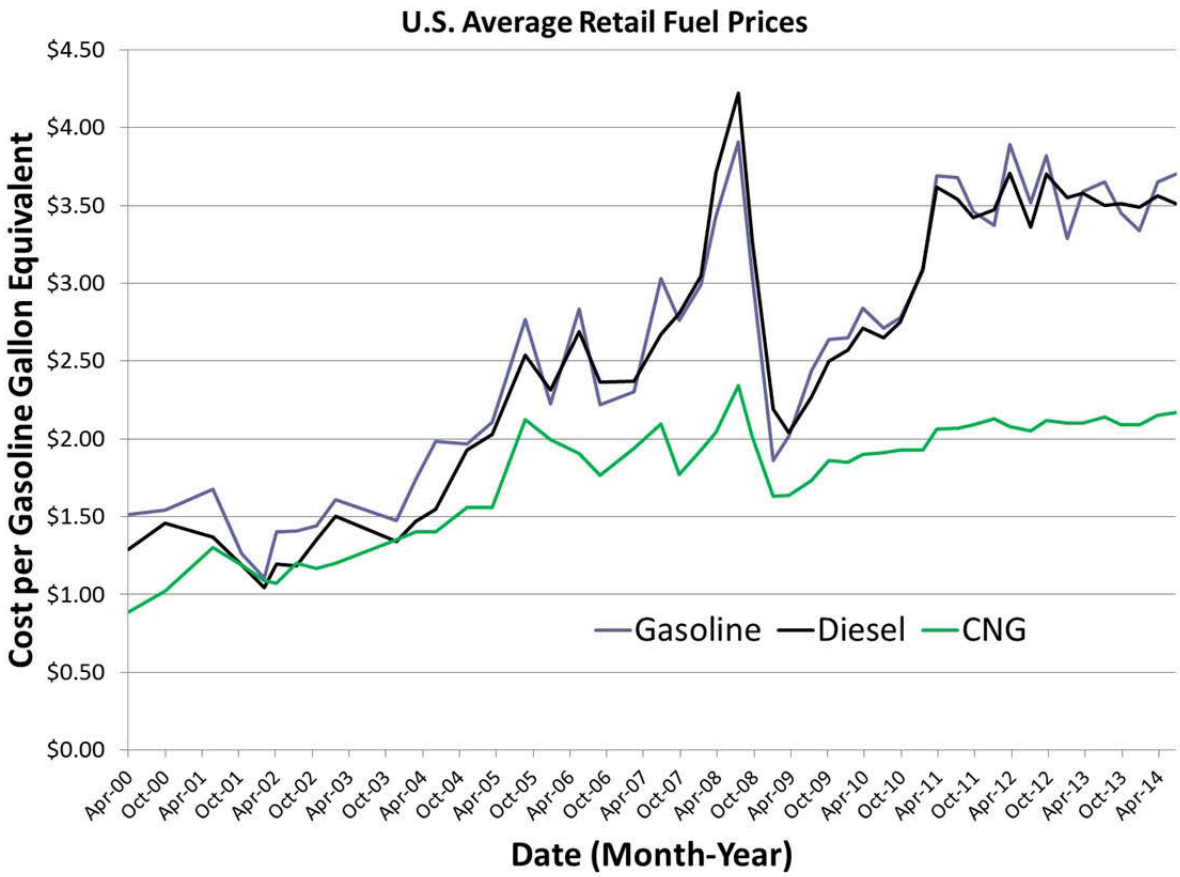

Figure 1. Average retail fuel prices in the United States (DOE 2014)

2 Introduction

Nearly every day, almost 136,000 refuse trucks collect household and commercial refuse in the United States. The refuse truck fleet in the United States is more than three times the size of the urban bus fleet. These vehicles make hundreds of starts and stops as they collect refuse in cities and towns across the country, so emissions and noise are of major concern for this vehicle segment. Diesel powered refuse truck emissions contribute to poor air quality and may pose a severe threat to public health. Because of their duty cycle, refuse trucks are one of the most fuel inefficient vehicles. At an average of 25,000 annual miles, refuse trucks can consume approximately 8,900 gallons of diesel fuel per year (Cannon 2006). Refuse vehicles historically have run on petroleum fuels, specifically diesel fuel. Petroleum fuels are Pennsylvania's largest energy source, and the transportation sector is the largest consumer of petroleum, accounting for 74 percent of the State's total petroleum consumption in 2012 (US EIA 2014). The State imports virtually all of its petroleum. As the price of oil continues to fluctuate, dependence on petroleum will continue to drain the State's economy. It also presents serious long-term energy security concerns both regionally and nationally.

Petroleum fuel combustion also contributes to poor air quality and the resulting negative health impacts. Transportation emission sources are especially significant contributors to the formation of ozone, particulate matter (PM), and toxic emissions. Metropolitan areas with high concentrations of vehicles (including refuse vehicles) such as southeastern Pennsylvania and the Pittsburgh region have air pollution levels that persistently exceed the national ambient air quality standards (EPA 2014). Petroleum fuel combustion by the transportation sector also contributed approximately 27 percent of the State's total greenhouse gas (GHG) emissions in 2007, making the transportation sector the second largest GHG emission contributor in the State for that year, after electricity generation (US EPA 2009).

The U.S. Environmental Protection Agency's (EPA's) heavy-duty engine emissions and fuel regulations have significantly reduced heavy truck emissions over the past decade. The EPA's 2007 and 2010 standards required significant reductions in particulate matter (PM) and nitrogen oxides (NO_x) emissions. Manufacturers met the 2007 PM standards using exhaust aftertreatment technologies such as diesel particulate filters (DPFs). These devices can be complex, expensive, and maintenance intensive, while also returning a slight fuel economy penalty. Because DPFs can be damaged by sulfur, EPA required refineries to reduce the level of sulfur in fuel by 97 percent as of 2006. For the NO_x reductions required by EPA's 2010 standard, most manufacturers chose to use selective catalytic reduction (SCR) technology, which improves the fuel economy while increasing complexity and adding weight. SCR technology uses a Diesel Exhaust Fluid (DEF) that creates a chemical reaction to convert the NO_x to ammonia emissions. DEF must be stored in fleet yards to replenish its supply onboard the vehicle and continually injected by the SCR into the exhaust to reduce the NO_x emissions to meet the EPA standard.

All heavy duty engines and vehicles, regardless of fuel type, must meet these emission standards. Compressed and liquified natural gas vehicles can meet them without DPF and SCR systems, but

typically still depend on some exhaust aftertreatment devices such as oxidation catalysts to meet the NO_x requirements.

EPA's heavy duty greenhouse gas rules took effect in 2014. They require manufacturers to improve fuel efficiency and reduce carbon dioxide emissions by 10-20 percent by 2018. Separate standards apply for combination tractors (semi-trucks), heavy duty pickups and vans, and vocational vehicles (e.g. delivery trucks, buses, and refuse haulers). A second phase of the greenhouse gas rules is currently under development.

The added technology deployed to lower emissions of PM, NO_x and greenhouse gases has increased the cost of heavy duty engines both in the initial purchase price and in the ongoing maintenance costs. However these increases are more than offset through the fuel savings of the greenhouse gas rule, which for a typical semi-truck owner may amount to a net savings of $73,000 over the lifetime of the vehicle.

Compressed natural gas (CNG), an alternative fuel for vehicles, can address the significant economic, environmental, and energy security concerns described above. Natural gas is extracted from underground reserves and can be found in many locations across the United States, including Pennsylvania. Domestic production of natural gas meets most of the current demand in electricity production, space and water heating, cooking, and transportation. Technical advancements have increased the amount of natural gas that can be extracted, as seen in the recent boom in supply from shale deposits. A renewable form of natural gas can be produced from decaying organic materials such as waste from landfills, wastewater, and livestock. It is estimated that North America has enough natural gas resources to last more than 100 years at current consumption levels (American Clean Skies Foundation 2012). There are approximately 120,000 natural gas vehicles on roads today in the United States, accounting for only about 0.1 percent of the total natural gas consumption (DOE 2012). Therefore, short-term increases in the number of natural gas vehicles will have minimal impact on the total consumption or available supply of this resource. The United States has a vast natural gas distribution system, with more than 300,000 miles of transmission pipelines (8,600 miles within Pennsylvania) and an additional 1.9 million miles of distribution lines within utility service areas (EIA 2009). In Pennsylvania the distribution system includes thousands of delivery, receipt, and interconnection points that make it readily available to most commercial and residential locations.

CNG, which is primarily composed of methane, can offer notable reductions in criteria pollutant and GHG emissions as compared to diesel fuel. Tests have shown significant reductions in NO_X and PM by using CNG, even relative to current production diesel engines, but these results are very dependent on the vehicle type and duty cycle. In heavy-duty vehicles, CNG engines produce 20 to 23 percent fewer GHG emissions (DOE 2012). However, unlike diesel engines that now require extensive aftertreatment (DOC+DPF+SCR), CNG engines usually use a low-cost, maintenance-free, proven three-way catalyst to meet prevailing emission standards. This has reduced the incremental cost for new heavy-duty CNG engines compared to new diesel engines, improving the economic payback. CNG engines also operate much quieter than diesel engines, resulting in a better work environment for the operator and the surrounding community.

Environmental and economic benefits of CNG vehicles as well as their "green" image have convinced a number of large companies with national fleets to implement CNG vehicle programs. This is particularly true in the refuse industry where some manufacturers are now selling as many CNG trucks as diesel trucks. AT&T has committed to using CNG where fueling is available, and the company anticipates it will purchase up to 8,000 CNG vehicles by the end of 2013. After testing a pilot fleet of 18 CNG trucks, Frito-Lay announced plans to purchase CNG vehicles as its fleet is replaced, recognizing that it is a win-win solution both in terms of sustainability strategy and reducing costs. Waste Management is implementing a nationwide plan to convert all of its 18,342 trucks to CNG because of the economics for its application. Fleet operators must consider, however, whether the available CNG vehicles fit their needs and will use enough fuel to pay back the incremental vehicle costs. In addition, companies must determine if building a CNG fueling station is feasible (either by the fleet itself or by an independent station operator) if publicly accessible fueling is not available. Because CNG may not be the right choice for every fleet, the New York State Energy Research and Development Authority (NYSERDA) sponsored the development of this document to inform organizations in New York State of the options for using CNG. With permission from NYSERDA, The Delaware Valley Regional Planning Commission (DVRPC) has modified this report for Pennsylvania, making minor changes to reflect local conditions, and updating information where feasible. The bulk of the document remains as DVRPC received it from NYSERDA. This is fundamentally NYSERDA's work.

This guidebook covers four different types of refuse operations: 1) private refuse haulers that get residential work directly from the constituent, 2) private refuse haulers responding to a bid for refuse services, 3) municipal refuse hauling by municipal owned and operated trucks, and 4) municipalities issuing contracts for refuse services by third party (private) refuse haulers. In the first three types of refuse operations the vehicles are owned and operated by the entity responsible for providing refuse services and these organizations should continue on with the following section **CNG Assessment – Organizations that Own and Operate Refuse Vehicles**. Municipalities that issue contracts to private refuse haulers to provide refuse services should skip to the section **CNG Assessment – Municipalities that Contract out Refuse Services**. Both sections describe the process to follow when considering the use of CNG vehicles for refuse services.

CNG Assessments – Step-by-Step Overview for Pursuing CNG in Refuse Services

Section 3: CNG Assessment – Organizations that Own and Operate Refuse Vehicles is for;

- Private refuse haulers that get residential work directly from the constituent
- Private refuse haulers responding to a bid for refuse services (traditional or with a CNG mandate)
- Municipal refuse hauling by municipal owned and operated trucks

Section 4: CNG Assessment – Municipalities that Contract out Refuse Services is for;

- Municipalities issuing contracts for refuse services by third party (private) refuse haulers

3 CNG Assessment – Organizations that Own and Operate Refuse Vehicles

This section outlines the basic steps for a refuse fleet to initiate a compressed natural gas (CNG) vehicle program. The section covers all the aspects necessary for adopting CNG as a fuel for the municipalities or private companies that own and operate a refuse fleet and summarizes the critical information that must be understood. Municipalities issuing contracts for refuse services by third party (private) refuse haulers should skip this section and go to the section **CNG Assessment – Municipalities that Contract out Refuse Services**. Subsequent sections and appendices provide more in-depth details and are appropriately referenced in this Fleet Assessment when further information on that topic is desired. A condensed summary of the assessment steps is in **Appendix H: Natural Gas Vehicle Project Planning Checklists**. The basic steps for initiating a program are:

- Understand the basics of natural gas and CNG vehicles
- Assess fleet vehicle characteristics (Are route characteristics, vehicle age, etc. favorable for CNG use?)
- Review CNG vehicle options (Are there available CNG options for the fleet's preferred vehicles?)
- Evaluate existing and planned CNG infrastructure (Is a fueling station available close to fleet operations or is a new CNG station being planned nearby?)
- Assess facility property (Is the fleet willing to build its own station? Is there adequate gas supply? Is the site appropriate for building a CNG station? Would public access be viable?)
- Understand the corporate business strategy (If the fleet plans onsite fueling, will it be owned or provided by a third party? Who will maintain the station? How will it be financed? What payback period is needed?)
- Examine infrastructure requirements (What will be needed to meet fleet infrastructure requirements? Have you collected enough information to issue an accurate request for proposal to have a station built?)
- Assess the business case (How quickly will investment in the CNG project pay back for the company? Does this fit with the fleet's typical business practices and preferences?)
- Develop an implementation plan and act on it

Understand the basics of natural gas and CNG vehicles – Most of the concerns and issues associated with CNG use stem from the fundamental difference in properties between natural gas and the liquid petroleum fuel that is currently being used. The section of this booklet titled **Compressed Natural Gas Basics** includes further details, but the key highlights are the following:

- Natural gas is primarily methane (CH_4), a colorless, tasteless, odorless, and nontoxic gas.
- Natural gas is lighter than air and will quickly disperse in an unconfined space, but confined space leaks can collect to form a flammable mixture that would become hazardous in the vicinity of an ignition source.

- Natural gas has a flammability range in air from 5 to 15 percent and an ignition temperature around 1,200 degrees Fahrenheit both of which are higher than for gasoline or diesel.
- As a transportation fuel, natural gas is measured in gasoline gallon equivalents (GGEs), where 5.66 pounds of natural gas has an equal amount of energy as one gallon of gasoline. In volumetric terms, 125 cubic feet of natural gas contain the same energy in one GGE and 137 cubic feet are needed for a diesel gallon equivalent (DGE).
- To increase energy density for use in vehicles, natural gas is typically compressed to 3,600 pounds per square inch (psi), but a GGE of natural gas still occupies almost four times the volume of a single gallon of liquid fuel.

CNG terminology – CNG vehicles have some unique classifications, components, and operating characteristics that are explained in more detail in the section titled **CNG Vehicle System Components**. CNG has an octane rating of 130, which provides an opportunity for CNG vehicles to have better power, acceleration, and cruise speed if the engines are tuned to take advantage of the fuel. CNG engines can be cleaner and less noisy than diesel engines. Familiarity with CNG terminology is important when discussing your options with product manufacturers.

- Dedicated CNG vehicles: Work much like gasoline-powered vehicles with spark-ignited engines. Specialized CNG components include the natural gas fuel receptacle, high-pressure fuel storage cylinders, pressure relief devices on fuel storage cylinders, a master manual shut-off valve, high-pressure fuel lines, a gas regulator, and a natural gas fuel-injection system.
- Bi-fuel CNG vehicles: Have two separate fueling systems to run on either natural gas or gasoline (the fuels are not used simultaneously). This type is not common for refuse applications.
- Dual fuel CNG vehicles: Blends 40 to 85 percent CNG with diesel after the engine is warmed up, but may operate entirely on diesel if necessary. This type is not common for residential collection applications, but could be used in roll-off or dumpster transport trucks.
- CNG receptacle: Mounts to the vehicle to enable fueling.
- CNG nozzle (i.e., at the end of the hose on the fuel dispenser): Attaches to the fuel receptacle.
    - P36: Rated for 3,600 psi, usually yellow.
    - P30: Rated for 3,000 psi, usually blue.
    - Type 1: venting.
    - Type 2/Type 3: non-venting, various configurations.
    - CT1000: 1/4-inch tubing for fast-fill fueling of light- and medium-duty vehicles or time-fill fueling of heavy-duty vehicles.
    - CT5000: 3/8-inch tubing for extremely high-flow fueling of large trucks.
- CNG vehicle tanks: pressure vessels of 5–30 GGE in size, which can be placed within the chassis frame, behind the cab, or roof mounted. Might limit cargo space if identical diesel equivalent vehicle range is desired, depending on the available space on the chassis. Primary contributor to the additional weight and cost of a CNG vehicle. The four

following types all meet safety requirements, but have trade-offs between weight and cost.

- Type 1: All-metal, steel, or aluminum (heaviest, but least expensive).
- Type 2: Steel or aluminum lined and hoop wrapped with fiber composite.
- Type 3: Aluminum lined and fully wrapped with fiber composite.
- Type 4: Thermoplastic lined and fully wrapped in fiber composite (lightest, but most expensive).

Unless weight is a concern or a limiting factor, Type 1 tanks are used to maximize the economic benefits. Types 2 and 3 provide some weight savings without paying the premium cost for Type 4 tanks. However, tank type is often specified through the system installer because these companies bulk purchase CNG tanks and will typically always use the same type on all their installations.

Assess fleet vehicle characteristics – Characteristics of an ideal CNG refuse vehicle would include the following:

- Regular, consistent routes that return to a common base location
- High annual miles, but no more than available vehicle range options based on fuel tank configurations (typically around 200 miles per tank, but larger ranges are possible if refuse collection space can be sacrificed)
- No potential need to be used for a long haul or route in an emergency

An analysis of the most up-to-date fleet inventory and operations should help determine if a CNG vehicle program is a good fit. Key characteristics that are important to record on a per-vehicle basis for CNG compatibility are the following:

- Make, model, engine, and chassis (to identify possible CNG vehicle options for replacement)
- Average fuel economy (to estimate payback)
- Average annual mileage (to estimate payback)
- Average mileage or fuel use per day
- Maximum mileage per day (to exclude vehicles that push/exceed CNG range limitation)
- Expected replacement time or vehicle lifecycle

As the use of CNG in refuse fleets is growing, so are the number of best practice examples that can be used to help determine if a CNG vehicle program is right for your fleet. Most of the fleets currently using CNG are not only great models for natural gas programs, but they are very willing to share their experiences with others. While it is typically uncommon for competing businesses to be so open about their operations, many of the key personnel that pushed their own company to adopt CNG realize that it is in their best interest to promote CNG usage. This will encourage more product manufacturers to offer CNG alternatives, more contractors to offer CNG services, and more fueling infrastructure to be developed that could be shared. The section on **Best Practices - Successful CNG Fleet Deployments in Refuse Applications** shares a number of best practices from refuse fleets that provide successful examples that may be good models to follow.

Review CNG vehicle options – There are many CNG vehicle options currently available for refuse truck applications (both residential collection and dumpster transport), but the selection does not include every size and type that a fleet may want to use. Natural gas engines are a limiting factor in which vehicles may be offered with CNG options. At present, there are two engine options as listed in the **CNG Engines for Refuse Application** section, although one additional option should be available soon. The Cummins Westport Inc. (CWI) engines are options available from various chassis manufacturers that integrate the CNG fueling system into their product offerings. Current CNG engine and chassis options are detailed in **Appendix A: CNG Vehicles for Refuse Fleet Applications** and include the following:

- Cummins Westport Inc. 8.9-liter V6 ISL-G
  - 250-320 horsepower (hp) with 660-1,000 pound-foot (lb-ft) of torque
  - Residential collection: American LaFrance Condor 830S/880S, Autocar Xpeditor ACX, Crane Carrier Company COE2, Crane Carrier LET2/LETCC/LDT2, International LoadStar, Mack TerraPro, and Peterbilt 320.
  - Dumpster transport: Freightliner 114SD, Freightliner M2 112, Kenworth T440/T470, and Peterbilt 365
- Cummins Westport Inc. ISX12 G
  - 330-400 hp with 1,150-1,450 lb-ft of torque
  - Residential collection: Autocar Xpeditor ACX, Crane Carrier LET2/LETCC/LDT2, and Peterbilt 320.
  - Dumpster transport: Freightliner 114SD, Mack Granite, and Peterbilt 365

Refuse body manufacturers are also supporting CNG refuse trucks by incorporating CNG tanks into their refuse body designs. Some, including Heil Environmental, McNeilus, and New Way, integrate the above listed CNG chassis options when ordering refuse trucks directly through the refuse body manufacturers. Based on this listing, there should be CNG refuse vehicles that meet the fleet needs unless a very specialized refuse vehicle or manufacturer is required. The fleet must also review normal replacement schedules to identify how many new CNG vehicles could be acquired and on what timeframe. The fleet should investigate how many new CNG vehicles could be acquired on an accelerated replacement schedule, or if it is possible to retrofit CNG engines in recent vehicle purchases. Note that CNG vehicle availability can sometimes be limited. Some manufacturers do not begin production of CNG vehicles until a sufficient number of orders have been received, or they might schedule a single production run at an established time of the year, so having flexibility on the delivery times of these vehicles is necessary.

Another aspect to consider is the operation and maintenance of CNG vehicles. If the fleet outsources its maintenance, it is critical to verify that a CNG vehicle maintenance provider is available if the fleet purchases CNG vehicles. If CNG vehicle maintenance is performed on-site, the fleet should investigate the facility upgrades necessary to meet fire codes with the local fire marshal. Further information on this topic is included in the section **CNG Vehicle Operation and Maintenance**.

Fleets with existing CNG vehicle programs can offer best practices for performing these upgrades cost-effectively. While this is usually not a major investment, the cost burden for the upgrades

will be distributed among the CNG vehicles, so there may need to be a sufficient number of vehicles to make the business case to justify this expense.

Decision – Is the fleet a good candidate for a CNG vehicle program?

Evaluate existing and planned CNG Fueling Infrastructure - There are close to 50 CNG stations in service in Pennsylvania, described in the section **Public Fueling Options.** 25 stations are publically accessible and all except 3 of these are open 24-hours a day. Further station details in **Appendix F: CNG Stations in** may provide additional guidance for initiating an investigation into whether one of these is suitable for the fleet. If one of these stations is close to the existing fleet operations, then the fleet could likely implement a CNG vehicle program incrementally by starting with a few vehicles to become comfortable with the technology. As additional CNG vehicles are added to the fleet, other fueling options may be explored. However, before committing to a CNG program that relies on a public fueling station, investigate the following features to ensure that it will suit the needs of the fleet:

- Accessibility – In terms of both hours of operation and ease of use for the fleet vehicles, consider the traffic flow and turn lanes from the main road as well as the ingress and egress within the station itself.
- Location – A location closer to the fleet base or near the landfill, transfer station, or waste energy plant would be better to reduce additional time and effort associated with fueling. Route planning can also be used to coordinate fueling at public stations.
- Dispensing capability – To ensure complete fill-ups, 3,600 pounds per square inch (psi) of pressure is necessary (3,000 psi would only fill tanks to about 80 percent capacity). Larger compressors provide adequate flow rates to reduce fueling times and can sometimes be used with large CT5000 diameter nozzles. Ample on-site CNG storage can also better support faster filling times, but their ability to contribute fuel will depend on the station usage.
- Pricing – The advertised price will provide a starting price point, but significant regular fueling at one station may allow the company to negotiate a strategic pricing contract.
- Reliability – Find out if there is any redundancy in equipment in the event a failure or maintenance. Talk to other users of the station and find out how often the station has been down or out of service and how long it typically takes to get back up.

Always involve the station owner in the evaluation of the CNG fueling capabilities to find out about the current usage of the station, which may affect the accessibility and dispensing capability. With the opportunity to support your additional fleet fuel requirements, the owner may be able to upgrade the station to suit your needs at a much lower investment than building an entirely new station.

Some private fast-fill CNG stations may consider allowing another company to use its facility through a negotiated agreement and could implement a Fleet Fuel Card system to handle the accounting. Other CNG stations may be willing to add the equipment necessary to enable public fueling at their site if they are aware of a large fleet that would fuel there. New CNG stations are

being planned and built throughout Pennsylvania as more fleets turn to CNG and these may offer additional opportunities for collaboration. Expressing interest in CNG to the local Clean Cities coordinator (www.ep-act.org or www.pgh-cleancities.org) or DVRPC (www.dvrpc.org) could facilitate a public/private partnership opportunity for municipal and private fleets to combine their projected CNG usage and encourage a fuel provider to invest in a new CNG station.

Recommendation – If public CNG fueling is acceptable, incrementally pursue a CNG vehicle program until it is large enough to justify on-site fueling.

Decision – If public fueling is not possible, will the company consider on-site fueling (i.e., is the business/personnel capable of operating a fueling station and/or will the CNG fleet be large enough to justify the investment)?

Assess facility property – Onsite CNG fueling infrastructure can be a profitable business venture. As an example, Indiana Geothermal, a private company that provides geothermal products, custom system designs, and system installations, built a CNG station to support its light- and medium-duty truck fleet and is now profiting from CNG sales to other fleets that are fueling at its location. However, a few critical factors must be investigated to determine if the location makes sense as a fueling station. Most importantly, CNG supply from the utility should be readily available and have a sufficient capacity to support vehicle fueling. The local utilities, listed in **Appendix C: Local Utilities in Pennsylvania**, should be contacted for this assessment, which is commonly referred to as a Gas Capacity Request. The gas utility will need to know the size of the compression equipment for the proposed fueling station. The utility will then evaluate the additional gas demand and evaluate the gas supply and determine the gas system requirements necessary to meet your new gas demand. The utility may also help identify a larger supply line separate from where the current natural gas is being requested that could be more suitable for CNG vehicle fueling. Increased distance from the adequate natural gas supply to the fueling infrastructure adds costs, so this might dictate where the station should be located. It is also important to assure the required electrical power is available in close proximity to where the compression equipment is to be located.

The business must have adequate space available on-site to build the CNG fueling infrastructure. The section on **CNG Station Basics** outlines the types of fueling systems, components, and applicable code requirements for CNG infrastructure. Time-fill fueling nozzles are strategically placed between dedicated CNG parking spaces for the system to deliver fuel to vehicles that are parked for an extended period of time. This avoids the need for the operator to drive to a dispenser and fuel the vehicle. Fast-fill stations require one or more fueling islands with ample space for the vehicles to flow through. These stations will also typically utilize large tanks (usually vessels or spheres) for the onsite storage of CNG that must be properly secured and protected. Another important siting consideration is the potential to open up the station for public access or pre-arranged contract access. This public/private partnership is often a requirement if grant funding is being provided or an independent operator is building the station based on a long term fuel agreement with the fleet as its base demand. However, security concerns must be

addressed (compression and station equipment is typically located "inside the fence" while dispensers are located "outside the fence" for user access) and station costs could increase (payment system, certified dispensers, more fueling locations, increased safety precautions, etc.) with public accessible stations. Consider and investigate if the company's management and insurance company will allow for public access (or pre-arranged contract access), since the fuel provider role may not be something the company is interested in pursuing. Also consider whether the location is suitable for public access and will draw enough business to make it worth the investment. A good public accessible station will be near other fleets (municipalities, refuse, other private delivery companies, phone carriers, etc.) and also near major highways for personal CNG vehicles or out-of-town CNG fleet vehicles to utilize.

Decision – Is the facility a good candidate for installing a CNG station? Would publicly accessible fueling work and would the company consider it?

Understand the corporate business strategy – The approach to building and operating a CNG station is often dictated by the capabilities and strategic business plan of the company. Different portions of the CNG vehicle program can be outsourced to experts, with various levels of risk and reward. It is important to have a good understanding of the level of risk the company is willing to take for a natural gas program and the existing capabilities of the staff to oversee various operation and maintenance responsibilities. Ownership can have significant financial benefits, but it carries with it additional risk.

- Ownership of the CNG station – Requires a significant initial investment by the company and depending on other available CNG fueling in the region, could require system redundancy (backup provisions) to assure for fuel availability. May be a good choice for fleets that only require time-fill fueling, which would not require as much equipment, such as storage tanks and metered dispensers. Might be the only choice for small and medium fleets that do not have the required fuel usage for an independent operator to commit to building a station.
- Outsourcing of the CNG station – If the fleet has enough CNG demand to serve as the base load, an independent operator may be willing to build the station at its costs and expect to recoup that investment through a long-term fuel agreement. The fleet may likely receive a favorable CNG price that is lower than public fueling costs, but it may need to provide land for the station and maintain negotiated fuel throughput. It may also be an opportunity to receive a monthly lease or a "royalty fee" for the fuel sold by the operator to other third party users. The longer the initial contract, the more favorable the fuel prices because the initial station costs is spread out over more years.
- Ownership of CNG station service and maintenance – An option for companies that own the station, but this option requires significant expertise and knowledge from company personnel to regularly service the equipment, diagnose problems, maintain an inventory of parts, and have the capability to replace broken parts quickly to minimize downtime. This is not typically done, but it is an option if this competency exists internally.

- Outsourcing of CNG station service and maintenance – Included when outsourcing the station itself, but also an option for CNG station owners that wish to delegate this responsibility to a third party. This can be written into the contract awarded to the firm that builds the station, but it can also be issued as an independent bid. Companies that outsource service and maintenance often still train one or more of their staff to be familiar with the CNG infrastructure to diagnose simple issues and respond to minor service needs to keep the system operating until the service provider arrives. While many companies hate to "leave money on the table" by outsourcing this, there are numerous advantages to placing the responsibility of maintaining parts inventories, training technicians, and ensuring regular service to the equipment on others.

Common advice from existing CNG fleets is to only take on the aspects that the company and employees can handle. Large fleets typically have more capabilities and options in developing CNG infrastructure, but the cost differential between CNG and conventional liquid fuels permits companies to pay a little extra for decreased risk and responsibility while still maintaining an economic advantage with CNG vehicles.

Decision – Is owning or outsourcing the CNG station build and maintenance the best option for the company? If outsourcing is preferred, would ownership be considered if the fleet is not able to reach an agreement with an independent operator?

Examine infrastructure requirements – Both ownership and outsourcing approaches can use a bid process to acquire the services of a CNG infrastructure specialist. Most of the existing CNG programs are willing to share the framework and even the language used in their bid documents to assist in drafting these for a new CNG station. Accurately quantifying the fleet's current and future expected CNG utilization is critical for bidders to appropriately size the CNG infrastructure. The contract's scope of services and duration will also significantly affect the proposed solution and costs. Identify and reach out to potential qualified bidders to gauge interest and gather insight into the special requirements that might be needed at this site. However, avoid over-specification in the bid to allow for flexibility to meet the needs of the fleet, which may reduce costs. With the ownership approach, it is possible to separately bid out the station design and construction, but many CNG infrastructure suppliers combine these services. An independent consultant could be used to help develop, review, and oversee the procurement process if there is not enough in-house expertise to intelligently review the responses from the bidders. Based on the quantity and quality of the bids received, it may be necessary to re-assess or adjust the approach.

Decision – Was an acceptable CNG station proposal received that meets the fleet's requirements for a CNG vehicle program?

Assess the business case – While CNG vehicles are typically less expensive to operate because of lower fuel costs, a CNG vehicle may not always be the most cost-effective solution. CNG vehicles cost more than diesel or gasoline vehicles, referred to as the vehicle's incremental

cost. Vehicle utilization is the primary factor in determining how long it takes for operational savings to payback the incremental system cost. An example of simple calculation of payback using refuse vehicle example factors of yearly fuel use of 9,500 DGE/yr, an incremental CNG new vehicle cost of $32,000, and fuel savings of $1.44 per DGE works out as follows:

9,500 DGE/yr * $1.44 = $13,680/yr | $32,000/$13,680 = 2.3 years

After the incremental cost of the CNG system is paid back, the company accrues the operational savings as a return for its investment. Greater annual mileage reduces the payback time and increases the lifetime cost savings for the vehicle, but it can also require additional range. CNG vehicles can be range-limited by the amount of fuel they hold and the availability of fueling. Additional CNG storage tanks can be added to increase range, but they add cost and can decrease load capacity and vehicle weight.

The business case for a CNG vehicle program depends on a number of factors, many of which have already been mentioned above (e.g., number of CNG capable vehicles to be acquired; incremental cost per vehicle; average fuel use, which is dependent on annual mileage; cost of natural gas; cost for maintenance facility upgrades; cost for the fueling infrastructure). A simplified approach to calculating overall CNG program pay back would incorporate the initial expenses for the maintenance facility and fueling infrastructure into the overall CNG fuel cost by amortizing these costs over the expected gallons of fuel used for the duration of these investments. Ongoing costs such as the electricity for the station operation and service and maintenance of the CNG station can also be integrated into a fully-loaded CNG fuel cost. Public CNG fueling prices already reflect these cost components plus an operator's profit margin. Comparing this to the anticipated cost of conventional fuels will result in the potential cost savings per gallon of fuel used which will estimate the economic benefits of CNG for the fleet. In addition, some companies consider intangible benefits (e.g., corporate image, environmental benefits, energy security, driver satisfaction), and may monetize them as part of their business case analysis; others may consider only the tangible costs and benefits. These factors, described in more detail in section **Business Case Analysis for a Natural Gas Program**, will all feed the calculation of an expected payback period for the CNG vehicle program, which will need to conform to the fleet's expectations for a successful project. In some cases, financial assistance in the form of grants, low-interest loans, public/private partnerships, or other novel financing arrangements may be available to improve the business case by lowering the costs of the program. CNG applicable financial assistance options are listed and summarized in section **Funding Options for Vehicles and Infrastructure**.

Decision – Does a CNG vehicle program make economic sense for the fleet?

Develop an implementation plan and act on it – As with any other large initiative, the fleet should develop a plan for the proposed CNG program. Items to be identified in the plan include the following:

- CNG vehicles – Proposed number to be purchased and the time period in which they will be acquired.
- Financing to cover the incremental vehicle costs – Through corporate financing or other financial assistance options.
- Procurement of fuel – Using public stations at market cost, using long-term fuel purchase agreement, or developing on-site fueling.

Careful planning at the start of the project will allow the fleet to realize the maximum benefits of a successful project.

The CNG industry has grown significantly over the past decade, and many companies can support the development of a CNG vehicle program. Even with significant in-house expertise and capabilities, if CNG is something new for the fleet, then further consulting or training may be needed to increase knowledge about the regulations and safety requirements. This guidebook is a starting point to implement a CNG vehicle program. See **Appendix D: Vendors for Natural Gas Equipment and Services**

Appendix **E: Resources for Additional Information** for a listing of resources and organizations that provide CNG-specific information and knowledge. Clean Cities can be available to assist with funding or other technical questions through its network of coordinators across the country. While many CNG equipment and product manufacturers offer an abundance of advice and support, there are also independent consultants whose services can be used to guide decisions and help address the requirements necessary for using CNG in your fleet.

Once the plan has been developed, the fleet should start taking action. Fleets should track success wherever possible: verifying fuel savings as compared to current practices will ensure management buy-in to maintain the program and possibly expand it. Fleets should also share successes with other fleets in Pennsylvania to help build momentum for wider markets.

Decision flowchart – Figure 2 is a summary of the key factors an organization that owns refuse vehicles should consider when investigating CNG for their fleet. It may be necessary to use the remaining sections of this guidebook to understand the reasoning behind these questions and to reach an appropriate answer for the company and its fleet. However, this high-level flow chart should help decision makers determine if CNG is an option for their fleet.

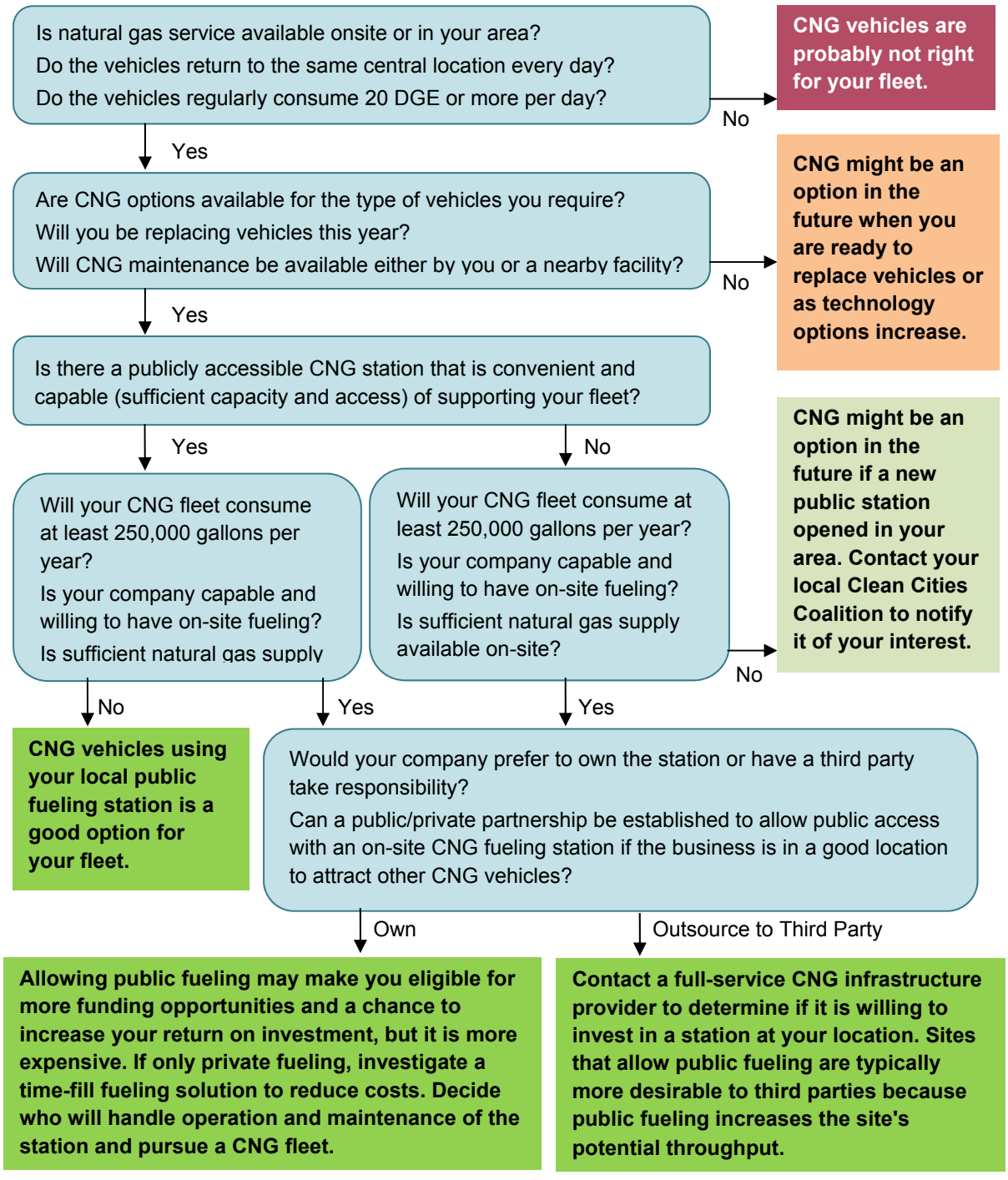

Figure 2. Decision flowcharts to determine if CNG vehicles are right for your organization

4 CNG Assessment – Municipalities that Contract out Refuse Services

This section outlines the basic steps for initiating a compressed natural gas (CNG) mandate for a municipality that contracts out refuse services. The section covers all the aspects necessary for releasing a refuse service bid with a CNG mandate and summarizes the critical information that must be understood. This section is only relevant for municipalities issuing contracts for refuse services by third party (private) refuse haulers. A municipality or private company that owns and operates its refuse vehicles should refer only to the section **CNG Assessment – Organizations that Own and Operate Refuse Vehicles**. Subsequent sections and appendices provide more in-depth details and are appropriately referenced in this Assessment when further information on a specific topic is desired. A condensed summary of the assessment steps is in **Appendix H: Natural Gas Vehicle Project Planning Checklists**. The basic steps for initiating a CNG mandate are:

- Understand the basics of natural gas and CNG vehicles
- Assess refuse service characteristics (Are route characteristics, volume of refuse, prospective bidder pool, etc. favorable for CNG use?)
- Evaluate existing and planned CNG infrastructure (Is a fueling station available close to refuse operations or is a new fueling station being planned nearby?)
- Assess new station options (Is there enough CNG demand to interest a third-party fuel provider? Is there a site appropriate for having a CNG station built?)
- Examine bid specification details (Have you collected enough information to issue an appropriate bid for both fuel procurement and CNG refuse services?)
- Develop an implementation plan and act on it

Understand the basics of natural gas and CNG vehicles – Most of the concerns and issues associated with CNG use stem from the fundamental difference in properties between natural gas and the liquid petroleum fuel that is currently being used. The section of this booklet titled **Compressed Natural Gas Basics** includes further details, but the key highlights are the following:

- Natural gas is primarily methane (CH_4), a colorless, tasteless, odorless, and nontoxic gas.
- Natural gas is lighter than air and will quickly disperse in an unconfined space, but confined space leaks can collect to form a flammable mixture that would become hazardous in the vicinity of an ignition source.
- Natural gas has a flammability range in air from 5 to 15 percent and an ignition temperature around 1,200 degrees Fahrenheit, both of which are higher than for gasoline or diesel.
- As a transportation fuel, natural gas is measured in gasoline gallon equivalents (GGEs), where 5.66 pounds of natural gas has an equal amount of energy as one gallon of gasoline. In volumetric terms, 125 cubic feet of natural gas contain the same energy in one GGE and 137 cubic feet are needed for a diesel gallon equivalent (DGE).

- To increase energy density for use in vehicles, natural gas is typically compressed to 3,600 pounds per square inch (psi), but a GGE of natural gas still occupies almost four times the volume of a single gallon of liquid fuel.

CNG terminology – CNG vehicles have some unique classifications, components, and operating characteristics that are explained in more detail in the section titled **CNG Vehicle System Components**. CNG has an octane rating of 130, which provides an opportunity for CNG vehicles to have better power, acceleration, and cruise speed if the engines are tuned to take advantage of the fuel. CNG engines can be cleaner and less noisy than diesel engines. Familiarity with CNG terminology is important when discussing your options with product manufacturers.

- Dedicated CNG vehicles: Work much like gasoline-powered vehicles with spark-ignited engines. Specialized CNG components include the natural gas fuel receptacle, high-pressure fuel storage cylinders, pressure relief devices on fuel storage cylinders, a master manual shut-off valve, high-pressure fuel lines, a gas regulator, and a natural gas fuel-injection system.
- Bi-fuel CNG vehicles: Have two separate fueling systems to run on either natural gas or gasoline (the fuels are not used simultaneously). This type is not common for refuse vehicles.
- Dual fuel CNG vehicles: Blends 40 to 85 percent CNG with diesel after the engine is warmed up, but may operate entirely on diesel if necessary. This type is not common for residential collection applications, but could be used in roll-off or dumpster transport trucks.
- CNG receptacle: Mounts to the vehicle to enable fueling.
- CNG nozzle (i.e., at the end of the hose on the fuel dispenser): Attaches to the fuel receptacle.
    - P36: Rated for 3,600 psi, usually yellow.
    - P30: Rated for 3,000 psi, usually blue.
    - Type 1: venting.
    - Type 2/Type 3: non-venting, various configurations.
    - CT1000: 1/4-inch tubing for fast-fill fueling of light- and medium-duty vehicles or time-fill fueling of heavy-duty vehicles.
    - CT5000: 3/8-inch tubing for extremely high-flow fueling of large trucks.
- CNG vehicle tanks: pressure vessels of 5–30 GGE in size, which can be placed within the chassis frame, behind the cab, or roof mounted. Might limit cargo space if identical diesel equivalent vehicle range is desired, depending on the available space on the chassis. Primary contributor to the additional weight and cost of a CNG vehicle. The four following types all meet safety requirements, but have trade-offs between weight and cost.
    - Type 1: All-metal, steel, or aluminum (heaviest, but least expensive).
    - Type 2: Steel or aluminum lined and hoop wrapped with fiber composite.
    - Type 3: Aluminum lined and fully wrapped with fiber composite.
    - Type 4: Thermoplastic lined and fully wrapped in fiber composite (lightest, but most expensive).

Unless weight is a concern or a limiting factor, Type 1 tanks are used to maximize the economic benefits. Types 2 and 3 provide some weight savings without paying the premium cost for Type 4 tanks. However, tank type is often specified through the system installer because these companies bulk purchase CNG tanks and will typically always use the same type on all their installations.

Assess refuse operations – Ultimately, the companies responding to the refuse services bid specification will need to decide whether or not they are able to accommodate a CNG requirement and determine their costs to do so. However, considering some key aspects of the refuse operation will assist in determining if CNG could be a good fit, and would provide some indication of how contractors may respond to the bid. An analysis of the refuse service requirements should help determine if a CNG vehicle program is a good fit for the municipality. Key characteristics that are important to consider for CNG compatibility include the following:

- Type of refuse truck used (needed to verify that CNG alternatives to these trucks are available).
- Amount of refuse to be collected under this contract, which would determine if the contractor's vehicles would be dedicated to this work or might have different requirements when not working on the municipality refuse collection.
- Typical distance of their route, including travel to landfill or transfer station.
- Age of the current fleet for the organization performing the contract, to gauge whether that company would have the opportunity to and would consider buying new CNG vehicles to replace older existing vehicles.
- Contracting logistics.

While CNG vehicles are typically less expensive to operate because of lower fuel costs, they cost more than diesel or gasoline vehicles. If the vehicle is not utilized enough, the operational savings will take a long time to return the initial investment in the incremental system cost. The typical payback period for a CNG refuse truck is two years. A refuse contract will likely need to be longer to justify the investment that the contractor must make for CNG. The volume of refuse collection likely dictates whether the contractor will be dedicating trucks specifically for specific contract or if there are other responsibilities the trucks undertake when not fulfilling the contract. If used for other jobs, the switch to CNG would also need to be compatible with those efforts.

CNG vehicles can be range-limited by the amount of fuel they hold if the same weight and volume capacity are needed. Additional CNG storage tanks can be added to increase range, but they add cost and weight, and can decrease load capacity. CNG fueling options are limited at present, so the vehicles will need to operate on routes accessible to the CNG station. Long travel distances to the landfill or a CNG station that is not conveniently located on regular routes may increase the initial vehicle system cost or add to the mileage and driver time for the contractor.

There are many CNG vehicle options currently available for refuse truck applications and engine sizes that should accommodate all needs unless the service is very specialized. While not the prime responsibility of the municipality, it is good to consider if the current refuse provider or many of the other potential bidders have recently replaced their vehicles. Fleets with very new

vehicles or those with old vehicles might not desire to convert to CNG, which might limit the number of responses and competition for a CNG refuse service bid. Another consideration is to allow the contractor to phase into CNG vehicles with established minimum percentage of the fleet goals through the period for the contract. This would allow the contractor to switch to CNG on a more normal replacement schedule and not have to purchase an entire fleet of CNG trucks the first year. Also, CNG engine or vehicle availability can sometimes be limited which could prevent a contractor from meeting an accelerated schedule of CNG vehicle use. Some manufacturers do not begin production of CNG vehicles until a sufficient number of orders have been received, or they might schedule a single production run at an established time of the year, so having flexibility on the delivery times of these vehicles may be necessary.

Another aspect that the municipality may want to discuss with its potential bidders prior to issuing a bid specification is the operation and maintenance of CNG vehicles. If the contractor outsources its maintenance, it will need to have a CNG vehicle maintenance provider in the area. If CNG vehicle maintenance is performed on-site, the contractor will need to investigate the facility upgrades necessary to meet fire codes with the local fire marshal. Further information on this topic is included in the section **CNG Vehicle Operation and Maintenance**. While this is usually not a major investment, the cost burden for the upgrades will be distributed among the CNG vehicles, so there may need to be a sufficient number of vehicles to make the business case to justify this expense. It is also another potential delay that the contractor might encounter while trying to comply with the CNG mandate.

As mentioned, it is the bidder's responsibility to investigate all of these aspects and incorporate the results of its investigation into its bid price. However, it is wise to consider these factors on behalf of the potential bidders to determine if CNG is really not a good fit for this particular service. While most service providers may initially complain and try to have the CNG mandate removed because they are concerned about change, the municipality should not let this discourage it from releasing a CNG refuse service specification and valuating responses. Because it is likely something new for many of the fleets, providing advanced notification of the specification's release and an extended period to respond to the specification may be necessary to ensure every potential bidder has time to investigate these aspects of implementing a CNG program. Flexibility in accommodating the CNG mandate through the duration of the awarded contract might also relieve some apprehension the bidders might have with moving immediately to a 100 percent CNG-fueled fleet. Some guidance and suggested language for a CNG mandate in a refuse service bid can be found in the section **Municipal Refuse Hauling Contracts.**

One other critical consideration is the timing of the next refuse bid specification for the municipality. If it is too soon, there may not be enough time to perform the investigation and prepare the prospective bidders for a CNG mandate. Extending the existing contract for a short period may allow the municipality to include a CNG mandate in the upcoming bid specification so it does not have to wait until the next round. If the refuse service contract is in place and will not be issued again for some time, it is still not too early to perform an initial investigation and prepare for the next contract. As mentioned, additional time in the bid process is good, especially if the bid process needs to be coordinated with the fuel provider. Also, if prospective bidders know the municipality is planning to move to CNG, they may choose to start converting their

fleet early in preparation for that new contract. Inserting a CNG mandate is fairly simple, especially because most of the language can be copied from another municipality that has already done this, but each entity may have its own special rules to follow when changing a specification that may not have been modified in many years. Ensure that the municipality is willing to approve a CNG mandate before committing too many resources to investigate its feasibility.

The pool of prospective bidders for a refuse service bid specification in each municipality may also affect the ability to follow through with a CNG mandate. Without adequate competition, if some companies choose not to respond to the bid specification with a CNG mandate, the municipality may not receive the required number of bids to make an award. Others may choose to unreasonably respond with costs higher than for diesel truck service, even though the costs should be lower if they are not interested in using CNG. The presence of increased competition and knowledgeable prospective bidders would hopefully eliminate this possibility, but as with any major change, the municipality should be prepared with a back-up plan.

As the use of CNG in refuse fleets is growing, so are the number of best practice examples that can be used to help determine if a CNG vehicle program will work for your organization. Most of the organizations currently mandating CNG for refuse services are great models and are very willing to share their experiences with others. The section on **Best Practices - Successful CNG Fleet Deployments in Refuse Applications** includes a case study example from Smithtown in Long Island, which was the first municipality on the East Coast to utilize a 100 percent CNG mandate on its refuse services. Smithtown has been used as a model for many other municipality CNG mandates throughout North America. After initially being forced to adopt CNG for the mandate in Smithtown, many of the refuse haulers there are now choosing to switch to CNG on their own because they recognize the price stability and the impact that it has on how they bid services.

Decision – Does the municipality have refuse services that are a good candidate for implementing a CNG mandate?

Evaluate existing and planned CNG fueling infrastructure – There are close to 50 CNG stations in service in Pennsylvania; those stations are described in the section **Public Fueling Options**. Twenty-five stations are publicly accessible and all except three of these are open 24-hours a day. Further station details in **Appendix F: CNG Stations in Pennsylvania** may provide additional guidance for initiating an investigation into whether one of these is suitable for the fleet. If one of these stations is within the refuse service area or on the route to the landfill or transfer station, then the municipality could likely implement a CNG mandate. However, before committing to a CNG mandate that would rely on a public fueling station, investigate the following features to ensure that it will suit the needs of refuse vehicles:

- Accessibility – In terms of both hours of operation and ease of use for the refuse vehicles, consider the traffic flow and turn lanes from the main road as well as the ingress and egress within the station itself.

- Location – A location closer to the landfill, transfer station, or waste energy plant would be better to reduce additional time and effort associated with fueling. This would also reduce bias toward a particular contractor because all contractors would pass by it.
- Dispensing capability – To ensure complete fill-ups, 3,600 pounds per square inch (psi) of pressure is necessary (3,000 psi would only fill tanks to about 80 percent capacity). Larger compressors provide adequate flow rates to reduce fueling times and can sometimes be used with large CT5000 diameter nozzles. Ample onsite CNG storage can also better support faster filling times, but their ability to contribute fuel will depend on the station usage.
- Pricing – If the station owner is willing to consider negotiating a strategic pricing contract, then this could be arranged prior to the CNG refuse service bid specification based on expected fuel use. This would help entice prospective contractors to respond because they would know the fixed cost fuel, and thus be able to more accurately prepare their bids.
- Reliability – Find out if there is any redundancy in equipment in the event a failure or maintenance. Talk to other users of the station and find out how often the station has been down or out of service and how long it typically takes to get back up.

Always involve the station owner in the evaluation of the CNG fueling capabilities to find out about the current usage of the station which may affect the accessibility and dispensing capability. With the opportunity to support your additional fleet fuel requirements, the owner may be able to upgrade the station to suit the municipality knowing that there will be significant fuel sales.

Some private fast-fill CNG stations may consider allowing another company to use its facility through a negotiated agreement and could implement a Fleet Fuel Card system to handle the accounting. Other CNG stations may be willing to add the equipment necessary to enable public fueling at their site if they are aware of a large fleet that would fuel there. New CNG stations are being planned and built throughout Pennsylvania as more fleets turn to CNG and these may offer additional opportunities for collaboration. Expressing interest in CNG to the local Clean Cities coordinator (www.ep-act.org or www.pgh-cleancities.org) or DVRPC (www.dvrpc.org) could facilitate a public/private partnership opportunity for municipal and private fleets to combine their projected CNG usage and encourage a fuel provider to invest in a new CNG station.

Recommendation – If public CNG fueling is acceptable, pursue a strategic pricing contract and issue a CNG mandate in the next refuse service bid.

Decision – If adequate public fueling is not available, does the municipality have enough proposed refuse vehicles and other vehicles to warrant building a CNG station? Are there enough other fleets in the area interested in CNG to create sufficient demand for a third-party fuel provider to build a station?

Investigate options for a new CNG station – It is assumed that municipalities that contract out refuse services are unlikely to build and own a CNG station. If this is not the case, follow the steps listed in the following **CNG Assessment –** when examining the factors surrounding station ownership. Full responsibility of the station construction, as well as operation and maintenance can be outsourced to an independent operator if the municipality has identified enough CNG demand to serve as the base load. That owner would expect to recoup that investment through a long term fuel agreement. The fleet may receive a favorable CNG price that is lower than public fueling costs, but it may need to provide land for the station and maintain negotiated fuel throughput. The longer the initial contract, the more favorable the fuel prices because the initial station costs is spread out over more years.

A few critical factors must be investigated to determine if the municipality has a location that makes sense as a fueling station. Most importantly, CNG supply from the utility should be readily available and have a sufficient capacity to support vehicle fueling. The local utilities, listed in Appendix C: Local Utilities in Pennsylvania, should be contacted for this assessment, which is commonly referred to as a Gas Capacity Request. The gas utility will need to know the size of the compression equipment for the proposed fueling station. The utility will then evaluate the additional gas demand and evaluate the gas supply and determine the gas system requirements necessary to meet your new gas demand. The utility may also help identify a larger supply line separate from where the current natural gas is being requested that could be more suitable for CNG vehicle fueling. Increased distance from the adequate natural gas supply to the fueling infrastructure adds costs, so this might dictate where the station should be located. It is also important to assure the required electrical power is available in close proximity to where the compression equipment is to be located.

The site must have adequate space available on-site to build the CNG fueling infrastructure. The section on **CNG Station Basics** outlines the types of fueling systems, components, and applicable code requirements that are required with CNG infrastructure. This application would require fast-fill stations with one or more fueling islands and ample space for the vehicles to flow through. These stations will also typically utilize large tanks (usually vessels or spheres) for the onsite storage of CNG that must be properly secured and protected. Another important siting consideration is the potential to open up the station for public access or pre-arranged contract access. Security concerns regarding increased access and use of the property must be addressed, which is typically accomplished by locating the compression and station equipment "inside the fence" while dispensers are located "outside the fence" for user access. Also consider whether the location is suitable for public access and will be able to draw additional business to make it more worthwhile for the independent operator. A good public accessible station will be near other fleets (refuse haulers, private delivery companies, phone carriers, etc.) and also near major highways for personal CNG vehicles or out-of-town CNG fleet vehicles might to utilize.

Decision – Does the municipality have a good location for installing a publicly accessible CNG station?

Examine bid specification details – A bid process can be used to select an independent CNG fuel provider. Municipalities with existing CNG programs are willing to share the framework and even the language used in their bid documents to assist in drafting these for a long-term fuel agreement. Accurately quantifying the expected CNG utilization is critical for bidders to appropriately price the fuel cost for the municipality and size the CNG infrastructure. The contract's duration will also significantly affect the proposed solution and costs. Identify and reach out to potential qualified bidders to gauge interest and gather insight into the special requirements that might be needed at this site. However, avoid over-specification in the bid specification to allow for flexibility, which may reduce costs. An independent consultant could be used to help develop, review, and oversee the procurement process if there is not enough in-house expertise to intelligently review the responses from the bidders. Based on the quantity and quality of the bids received, it may be necessary to re-assess or adjust the approach.

Decision – Was an acceptable CNG fuel agreement received that will enable the municipality to insert a CNG mandate in the refuse service RFP?

Develop an implementation plan and act on it – As with any other large initiative, the municipality should develop a plan and schedule for enacting the CNG mandate. Careful planning at the start of the project will assist the municipality in achieving a successful project later on. Items to be identified in the plan include the following:

- Preliminary discussions with potential bidders – Verify details of the requirements needed to use CNG (vehicles, fueling station), provide advanced notification for bidders to prepare to respond to a bid specification, and gauge bidder interest in responding to the bid.
- Procurement of fueling agreement – Use of public stations or long-term fuel purchase agreement in association with a new station.
- Procurement of refuse services with a CNG mandate – Develop the details of the bid, allow adequate time for bidders to respond, and evaluate quality and value of bids.
- Contracting – First date of fuel availability, proposed number or percentage of CNG trucks to be used in conjunction with a compliance schedule.

The CNG industry has grown significantly over the past decade, and many companies can support the development of a CNG vehicle program. Even with significant in-house expertise and capabilities, if CNG is something new for the municipality, then further education or outside consulting may be needed to increase knowledge about using this fuel. This guidebook is a starting point to implement a CNG mandate for refuse services. See **Appendix D: Vendors for Natural Gas Equipment and Services** and **Appendix E: Resources for Additional Information** for a listing of resources and organizations that provide CNG-specific information and knowledge. Clean Cities can be available to assist with information or other technical questions through its network of coordinators across the country. While many CNG equipment and product manufacturers offer an abundance of advice and support, there are also independent consultants whose services can be used to guide decisions and help address the requirements necessary for using CNG for refuse services.

Once the plan has been developed, the municipality should start taking action. Municipalities should track success wherever possible: documenting the lessons learned will make the process smoother next time the refuse services are put out for bid. Municipalities should also share successes with other municipalities in Pennsylvania to help pass on the insight they were able to gain through this process.

Decision Flowchart – Figure 3 is a summary of the key factors a municipality should consider when investigating a CNG mandate to be included in their refuse service bid. It may be necessary to use the remaining sections of this guidebook to understand the reasoning behind these questions and to reach an appropriate answer for the municipality. However, this high-level flow chart should help decision makers determine if a CNG mandate is viable.

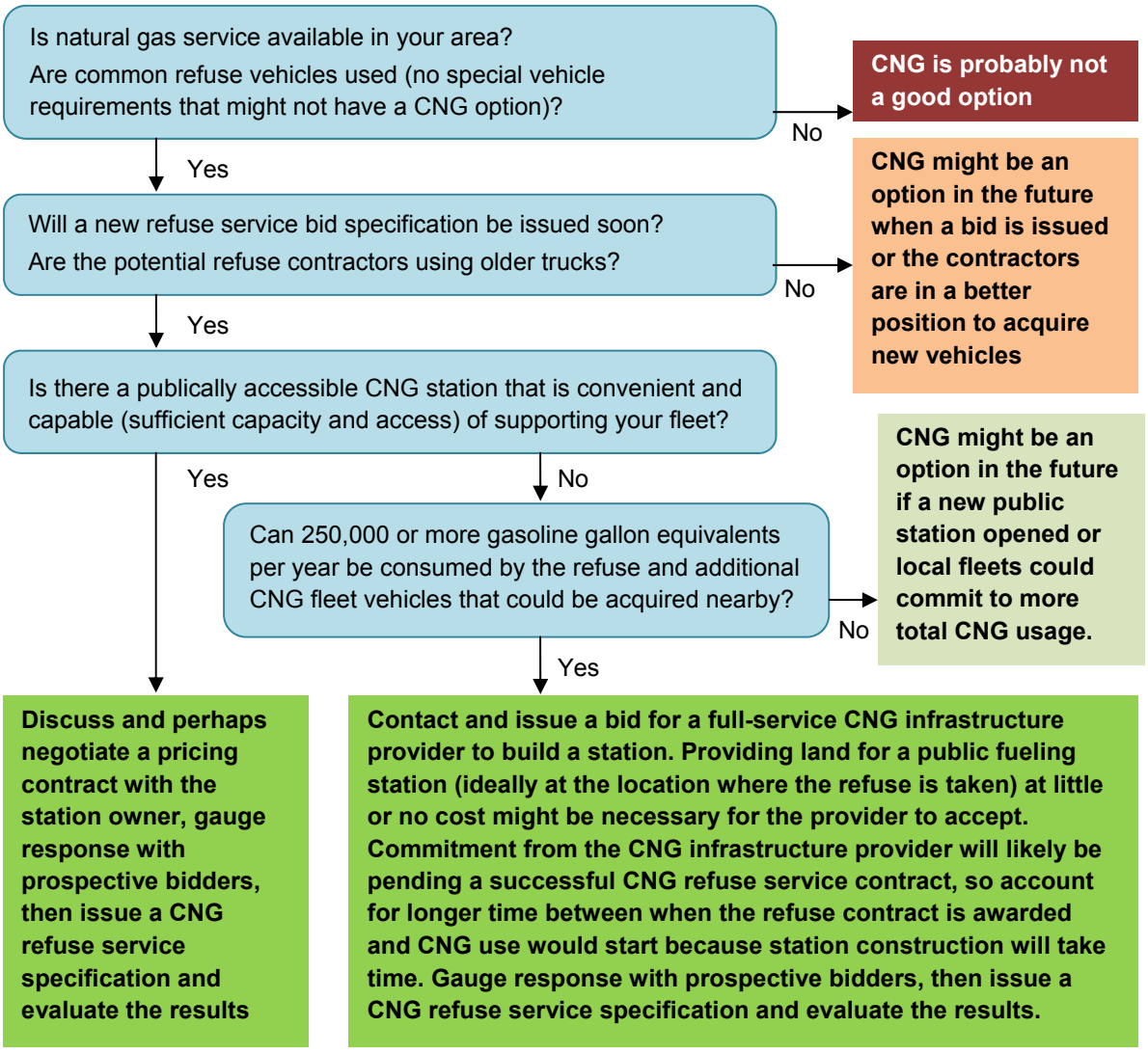

Figure 3. Decision flowchart to determine if a compressed natural gas mandate is right for your municipality

5 Compressed Natural Gas Basics

Natural gas, in its pure form, is colorless, tasteless, odorless, and nontoxic. The distinctive “rotten egg” smell often associated with natural gas is actually an odorant called mercaptan that is added to the gas before it is delivered to the end-user. This aids in detecting any leaks. As produced from gas wells, natural gas is a mixture of gaseous hydrocarbons consisting primarily of methane, but may also include ethane, propane, butane and pentane. Additional impurities that are removed in the refining process include carbon dioxide, hydrogen sulfide, nitrogen, and water vapor (NaturalGas.org 2011). Natural gas is considered 'dry' when it is almost pure methane, having had most of the other commonly associated hydrocarbons removed. Dry natural gas is what is typically delivered through the network of pipelines. When other hydrocarbons are present, the natural gas is referred to as 'wet'. Regardless of the source, it is commonly recommended to filter natural gas with a dryer to remove any water vapor prior to compressing for use in vehicles.

The methane molecule, shown in Figure 4, is comprised of one carbon atom and four hydrogen atoms (CH_4), making it the simplest hydrocarbon gas. This ratio of carbon to hydrogen is significantly lower than diesel ($C_{14}H_{30}$) or gasoline (C_8H_{18}), making it a low carbon fuel that emits fewer greenhouse gas emissions when combusted. Methane itself is a greenhouse gas, and care should be taken to avoid leaks wherever possible. Natural gas is lighter than air, so it will not pool on or near the ground as gasoline, diesel, or propane vapors do. It is nontoxic and poses no threat to land or water if accidentally released into the atmosphere where it will quickly disperse in an unconfined space. However, indoor or confined space leaks can collect near the top of confined spaces and form a flammable mixture, which could be an issue if the gas is in the vicinity of an ignition source. Methane is also slightly soluble in water and under certain anaerobic conditions does not biodegrade.

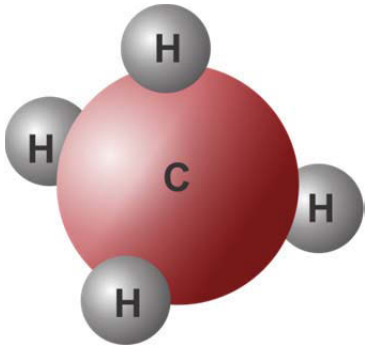

Figure 4. Methane molecule consisting of one carbon atom and four hydrogen atoms

Natural gas is deregulated in Pennsylvania, allowing customers to choose their supplier. While the utilities deliver the gas and respond to service interruptions and outages, gas can be purchased from alternate suppliers know as Natural Gas Suppliers. If no alternative gas supplier is chosen, the utility is the “default service” and serves as a benchmark for pricing in the market, with rates typically changing every month. Some Natural Gas Suppliers offer a locked-in gas supply rate, which can provide additional price stability.

As with conventional fuels, natural gas is safe to use in vehicle applications when proper safety procedures are followed. In fossil fuels, energy is stored as chemical potential energy, which is converted to gaseous expansion energy in the course of combustion. Natural gas has a low expansion-energy potential and therefore, like other fuels, does not pose a significant risk of tank explosion. However, the risk of explosion is high when natural gas (or any other fuel) comes into contact with air after leakage or tank rupture, especially in confined spaces. Natural gas has a

flammability range (the concentration of gas in an air-fuel mixture that will ignite or explode) from 5 to15 percent, whereas diesel is 0.6 t 5.5 percent, gasoline is 1.4 to 7.6 percent, and propane is 3.4 to 13.8 percent. It also has a very high ignition temperature (approximately 1200 degrees Fahrenheit), about double that of diesel or gasoline, making accidental ignition or combustion less likely (Gordon, Burdelski and Cannon 2003). In order for natural gas vehicles to effectively provide satisfactory and safe operations for users, standards were established to address specific issues relative to the use of natural gas as a vehicle fuel. The Society of Automotive Engineers (SAE) Recommended Practice for Compressed Natural Gas Vehicle Fuel, J1616, presents the more important physical and chemical characteristics of natural gas vehicle fuel and describes pertinent test methods for defining or evaluating these properties. Approved by the American National Standards Institute (ANSI), the intent of SAE J1616 is to protect the interior surface of fuel containers (storage cylinders) and fuel system components (injectors, exhaust catalyst elements, engine, etc.) from the onset of corrosion, poisoning, the deposition of liquids or large dust particles, and the formation of water, ice particles, frost or hydrates (SAE 1994).

By weight, natural gas has an energy content of approximately 21,000 British thermal units per pound (Btu/lb), which is greater than gasoline at around 18,400 Btu/lb. A standard of 5.66 lbs of natural gas was set by the National Institute of Standards and Technology (NIST) as equal to one gallon of gasoline (6 lbs) and defined as the gasoline gallon equivalent (GGE) for which natural gas is measured and priced for use as a transportation fuel. Since diesel fuel has 13 percent more energy content per gallon than diesel, a greater mass of natural gas is needed to provide expected energy equivalents for heavy-duty vehicles. By volume however, it takes 125 cubic feet of natural gas to contain the same energy in one gallon of gasoline and 137 cubic feet for the equivalent of one gallon of diesel fuel (DOE 2012). It is not practical to store this volume of uncompressed gas on a vehicle, so the fuel is compressed for use in the transportation sector. Modern compressed natural gas (CNG) storage systems in the United States pressurize to 3,600 pounds per square in (psi). In the past, natural gas systems were limited to 3,000 psi, which still is the case in other countries (public CNG fueling in Canada is limited to 3,000 psi). Pressures were raised in the United States to allow greater fuel capacities onboard a vehicle. At 3,600 psi, a GGE of natural gas still takes up 0.51 cubic feet, which is almost four times larger than a single gallon of liquid fuel. Therefore, CNG vehicles must either have larger tanks to provide equivalent ranges or reduce the distance for which it can travel between fueling.

Strict safety standards set forth by the National Fire Protection Association (NFPA) through Standard 52 make CNG vehicles as safe as gasoline-powered vehicles. CNG cylinders undergo extreme testing for both heat tolerance (if involved in a fire) or impact tolerance (if involved in an accident), before they receive standards approval. Despite this, proper safety precautions must still be observed. Any system under pressure has the potential to be harmful if the gas is uncontrollably released in a short period. Caution must be taken when fueling and repairs or maintenance should only be performed by qualified personnel. Various training programs and safety workshops are offered through nationally recognized programs that should be attended by anyone working with CNG.

6 CNG Vehicle System Components

There are three types of compressed natural gas (CNG) vehicles: dedicated, bi-fuel, and dual fuel. Dedicated CNG vehicles are designed to run only on compressed natural gas, while bi-fuel CNG vehicles can operate either on CNG or on a conventional fuel (but not both simultaneously). Both use spark-ignited internal combustion engines. In general, dedicated CNG vehicles can demonstrate better performance and have lower emissions than bi-fuel CNG vehicles because their engines are usually specifically tuned to run on a gaseous fuel to take advantage of the favorable properties of natural gas. They are also not as heavy as bi-fuel vehicles that must have two separate fueling systems to run on either natural gas or conventional fuels. Bi-fuel CNG systems are only found in light- and medium-duty vehicles. CNG has an octane rating of 130, which can be used to great advantage in dedicated vehicles with spark-ignited internal combustion engines. If the engine is optimized for natural gas, a CNG vehicle's power, acceleration, and cruise speed can be greater than that of a gasoline-powered vehicle, which makes it an acceptable alternative to diesel in larger vehicles. Due to the characteristics of the fuel, natural gas engines are quieter than diesel engines (EPA 2002). The use of CNG eliminates the cold weather start issues associated with diesel.

Dedicated CNG vehicles work much like gasoline-powered vehicles with spark-ignited engines. During fueling, CNG enters the vehicle through a natural gas fill valve and flows into high-pressure cylinders. When the engine requires natural gas, the gas leaves the cylinders and passes through a master manual shut-off valve. The gas travels through a high-pressure fuel line and enters the engine compartment where it enters a regulator, which reduces the gas pressure used for storage (up to 3,600 pounds per square inch [psi]) to the required vehicle fuel injection system pressure. A natural gas solenoid valve allows natural gas to pass through a fuel filter and into the gas mixer or fuel injectors. Natural gas mixed with air flows down through the fuel-injection system and enters the engine combustion chambers where it is burned to produce power. Some CNG vehicles have a safety interlock on the fill port cover that prevent the ignition from turning on if it is open. The American National Standards Institute (ANSI) natural gas vehicle (NGV) 3.1 establishes requirements for newly produced compressed natural gas fuel system components, intended for use on natural gas powered vehicles (ANSI 2012). This includes the check valve, manual valve, manual container valve, automatic valve, gas injector, pressure indicator, pressure regulator, gas flow adjuster, gas/air mixer, pressure relief valve, pressure relief device, excess flow valve, gas tight housing and ventilation, hoses, rigid fuel line, flexible fuel line, filter, fittings, and relief line closures.

Dual fuel CNG systems burn natural gas in a compression ignition (diesel) cycle. Under the pressures found in the combustion chamber of a normal diesel engine, natural gas requires a higher ignition temperature than diesel. During initial startup, the engine operates on 100 percent diesel fuel. After certain permissive criteria are satisfied the automatic control system commences dual fuel operation. In dual fuel operation, low pressure natural gas mixes with the intake air much like a spark ignition engine, such that an air and natural gas fuel mixture enters the cylinder. As it is compressed, the diesel fuel system injects a small quantity of diesel fuel, which

auto-ignites and burns the air and natural gas fuel mixture. In dual fuel mode, natural gas can displace 40to 65 percent of the diesel fuel. Because there are no changes in the engine compression ratio, cylinder heads, or basic operation, the engine can operate entirely on diesel if CNG is not available. When idling, the engine operates on 100 percent diesel. Dual fuel engine designs can be retrofitted on existing engines to allow the combustion of natural gas. Dual fuel systems are offered by American Power Group. The systems are currently approved by the EPA on engines that are classified as "outside of useful life" (OUL) because they are old or have been used enough that the EPA is not concerned about emission testing the system as long as the manufacturer meets certain requirements. Dual fuel CNG conversions may provide a cost-effective upgrade for some applications.

Dual fuel systems are different from high-pressure direct injection (HPDI) or high-pressure fuel injection (HPFI) systems that enable an engine to retain the efficiency advantage of compression-ignition while consuming natural gas, in the form of liquefied natural gas (LNG), as its primary fuel. To assist with ignition in this system, diesel fuel is injected into the engine cylinder followed by the main LNG fuel injection. The diesel acts as a pilot, rapidly igniting in the hot compressed air in the cylinder (as with conventional diesels) and serving as the catalyst to begin natural gas combustion. Fuel injection timing has a large influence on the engine performance, combustion, and emissions. Technologically advanced injection systems are key to providing precise control over the amount of fuel injected to provide an optimally mixed air to fuel ratio that produces combustion performance and emissions characteristics equivalent to well-designed, state-of-the-art internal combustion engines. HPDI engines are factory-built and designed to maximize natural gas use by burning only 5 to 10 percent diesel to ignite it. These engines cannot operate without natural gas, which is used in liquid form for storage and in the fuel delivery system. These engines are often used in Class 8 delivery trucks with longer routes. The engines are often larger and more powerful than currently-available, spark-ignited natural gas engines although the latest CNG engine offering from Cummins will offer more power capability than has historically been available with CNG.

The NGV1 standard is the most common system used in North America for CNG fueling connection devices (ANSI 2006). The part that attaches to the fueling device at the end of the hose is called the nozzle, shown in Figure 5. The part that mounts to the vehicle is called the receptacle, shown in Figure 6. There are two different pressure ratings for both these components; the P30 is for 3,000 psi service and is usually blue, while the P36 is for 3,600 psi service and is usually yellow (as shown in Figure 5). In order to prevent a P36 nozzle from connecting to a P30 receptacle, the P30 receptacle is 1 millimeter (mm) larger in diameter at the rear. A P30 nozzle

Figure 5. P36 CT1000 compressed natural gas push-pull actuating nozzle

can connect to a P36 receptacle, but will only be able to fill up the tank to 80 percent capacity. Note that P30 systems are exceedingly rare, having been replaced with P36 systems. There are venting (Type-1) and non-venting (Type-2 and Type-3) nozzles. Type-1 nozzles release pressure built up in the fuel hose at the nozzle end and capture this gas at disconnect by operating a manual "fill/vent" valve on the device after fueling is complete. The relieved gas pressure is then diverted to a separate hose leading back to the fueling apparatus to be vented into the atmosphere or fed back into the compressor. A Type-1 nozzle can also vent directly into the atmosphere at the nozzle end, thus precluding the requirement for a separate relief hose. A Type-3 nozzle relies on the fueling apparatus to vent the pressure at the supply end. A Type-2 nozzle is basically a Type-3 nozzle with a separate relief valve fitted to it at the nozzle end, so it operates much like a Type-1 nozzle. The Type-1 nozzles are usually found in fast-fill applications, while the Type-2 and Type-3 nozzles are usually found in slow-fill fueling applications.

Figure 6. P36 CT1000 compressed natural gas receptacle

Figure 7. P36 CT5000 Type-1 compressed natural gas ball valve nozzle

CNG nozzles and receptacles also come in various sizes to allow more rapid fueling rates for larger vehicles. The CT1000 has a ¼-inch stainless-steel vent tube that is used for quick-fill, self-service fueling of light and medium duty vehicles or time-fill fueling of heavy duty vehicles. The CT5000 has 3/8-inch stainless steel tubing for extremely high-flow fueling of large trucks, shown in Figure 7. There are also CNG defueling receptacles and nozzles that do not have a check valve. These are designed to safely depressurize vehicles if maintenance is required on the high-pressure system. CNG defueling receptacles can be used to transfer fuel from one vehicle to another, which is an important backup option if a vehicle runs out of fuel away from the base.

CNG tanks sizes range from 5 to 30 gasoline gallon equivalents (GGE) which are typically custom configured in the chassis or body of the vehicle to minimize impedance on normal vehicle operations. However, if a driving range equivalent to a similar diesel fueled vehicle is desired, then the extra tanks will likely require a reduction in cargo space or payload. CNG cylinders must be installed on a vehicle in compliance with the National Fire Protection Association (NFPA)

Standard 52 which provides guidance on proper and secure mounting, along with protection from damage caused by road hazards, loading and unloading, sunlight, heat, accidental cargo leakage, and collision damage. The most vulnerable element of the CNG cylinder is the cylinder valve. Shown in Figure 9, tanks are commonly placed within the chassis, behind the cab, or on the roof. Most include an enclosure that provides multiple mounting points and protection from the above mentioned hazards. The CNG tanks, enclosures, and fuel delivery system add weight to the vehicle when compared to a similar diesel or gasoline vehicle. These components and their installation usually represent the majority of the additional costs of a CNG vehicle (commonly referred to as incremental cost), since the increased cost of the CNG engine is offset by the cost savings from the simpler emissions control system. For medium and heavy duty delivery vehicles, the additional incremental cost for a CNG platform can range between $25,000 and $35,000, primarily depending on the amount of CNG storage that is desired. The increased fuel storage system weight may have some fuel economy penalty and could cause a slight increase in braking distance or slower acceleration. However, because the fuel system is a small fraction of the vehicle's total weight, this is a relatively small concern.

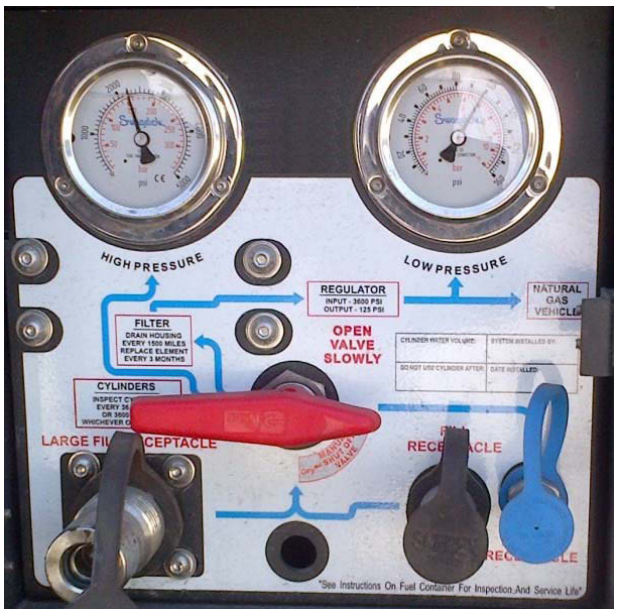

Figure 8. Multiple compressed natural gas receptacles (CT5000, CT1000, and defueling) for a large truck application

Figure 9. Compressed natural gas vehicle storage tank configurations: behind the cab, on the roof, or within the chassis

Many refuse body manufacturers are supporting CNG refuse trucks by incorporating CNG tanks into refuse body designs. Some offer integrated CNG chassis options when ordering refuse trucks directly through them. A few examples of refuse body manufacturers that support the use of CNG include Heil Environmental, McNeilus, and New Way. Table 1 shows refuse body configurations offered by manufacturers that are specifically designed to incorporate CNG storage tanks.

Table 1: Examples of CNG tank configurations offered by refuse body manufacturers*

Refuse Body Manufacturer	CNG Tank Mounting Location
Amrep	Roof or frame
F.F. Gomez	Roof or frame
Heil	Roof, frame, or behind cab
Labrie	Behind the cab
Leach	Roof, frame, or behind cab
McNeilus	Roof, frame, or behind cab
New Way	Roof
Wittke	Roof

*Note: this is not intended to be an complete list of refuse body manufacturers that offer CNG tank integrations into their designs

The American National Standard for Natural Gas Vehicle Containers, NGV2, establishes a standard for safe operation, substantial and durable construction, and performance testing of containers for the onboard storage of compressed natural gas for vehicle operation (ANSI 2007). Each must be designed, manufactured, and tested to pass a bonfire test, pressure test for 18,000 cycles of pressurization and depressurization, gunfire test, and drop test. There are four different CNG tank types used by the industry. Each type must meet the stringent safety requirements and are generally equivalent in storage performance. Type 1 tanks are all-metal using steel or aluminum: these are the least expensive, but heaviest. Type 1 cylinders typically pass inspections easily because they are allowed to show some wear, whereas the other three cylinder types are held to a higher standard of visual damage. Type 2 tanks use a mix of metal and composite materials, often steel or aluminum lined and hoop wrapped (covering the sides, not the ends) with fiber composite. Type 3 tanks also employ a mix of metal and composite materials, but these tanks are aluminum lined and fully wrapped with fiber composite. The lightest and most expensive tanks are type 4, which are entirely composite materials using a thermoplastic lining and fully wrapped in fiber composite. A 10 GGE Type 1 cylinder could weigh more than 350 lbs, but only cost around $1,000. On the other hand, a 10 GGE Type 4 cylinder may weigh less than 100 lbs, but cost more than $7,000 (SkyCNG 2012). The life of any CNG cylinder can be 15, 20, or—most typically—25 years, which should be matched to the vehicle life cycle or replacement period. The burst pressure of the tanks is 2.25 times its operating pressure rating, with pressure release devices (PRDs) set to release the fuel in a controlled manner well below this threshold in the event of a fire. The basic requirements for PRDs are set by the standard PRD1 and subsequent addenda 1a and 1b (ANSI 2007). In colder climates like Pennsylvania, moisture trapped in PRDs and their vent lines can freeze and damage these safety components. Routine inspection of the PRD vent system to verify the integrity of the vent lines and assure that all vent caps are in place is recommended. Tanks must be inspected every three years.

7 CNG Engines for Refuse Application

There are many vehicle options available in compressed natural gas (CNG) for the refuse fleet market in Pennsylvania. Additionally, many major engine manufacturers are currently engineering and designing additional heavy duty CNG engines that will be commercially available in the near future. Currently there are 2 dedicated CNG engines suited for the demands of residential collection and dumpster transport vehicles, with additional offerings projected to enter the market in the near future. The U.S. Environmental Protection Agency (EPA) has adopted emission standards for almost every kind of engine, including OEM engines that run on CNG. To show compliance with these emission standards, the following engine manufacturers have followed test procedures specified in the Code of Federal Regulations.

Heavy-Duty Engines

CNG engines for heavy-duty applications are produced by OEM engine manufacturers and installed by chassis manufacturers. The available chassis that can use these engines are listed below, but further details on the vehicles for delivery applications are in **Disclaimer: The lists contained in this guidebook are** for informational purposes only, and are not intended to be comprehensive. The reader is encouraged to review all available source material before making any purchase decisions about natural gas vehicles or equipment.

Appendix A: CNG Vehicles for Refuse Fleet Applications. More information on certified SVM that can be used and dealers where they can be obtained in Pennsylvania are in **Appendix B: CNG System Manufacturers and Pennsylvania Dealers**.

Cummins Westport Inc. (CWI) designs, engineers, and markets spark-ignited dedicated CNG engines for commercial transportation applications. CWI was formed in 2001 as a fifty-fifty joint venture between Cummins Inc. and Westport Innovations. The CWI ISL G is designed to operate on natural gas for medium- and heavy-duty truck applications. The CWI ISX12 G, to be available in 2013, is designed for regional haul tractors and other larger truck applications.

The CWI 8.9-liter 6-cylinder ISL-G dedicated natural gas engine, shown in Figure 10, features the ability to operate on liquefied natural gas (LNG), CNG, or biomethane. The engine is available with outputs of 250–320 horsepower (hp), and

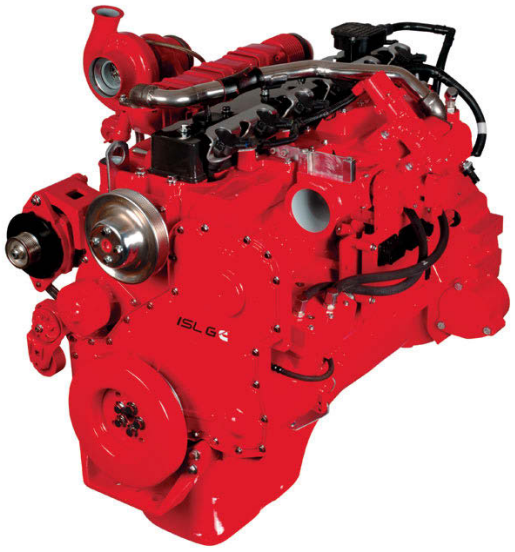

Figure 10. Cummins Westport Inc. 8.9 liter ISL-G dedicated natural gas engine

660–1,000 pound-foot (lb-ft) of torque (CWI 2012). Compared with previous Cummins Westport lean-burn natural gas engines, ISL G torque at idle is improved over 30 percent, and fuel economy is improved by up to 5 percent. The reduction in emissions allows for a maintenance-free emissions aftertreatment system, consisting of a three-way catalytic converter. Residential collection trucks that offer the ISL G engine as an option include the American LaFrance Condor 830S/880S, Autocar Xpeditor ACX, Crane Carrier Company COE2, Crane Carrier LET2/LETCC, International LoadStar (anticipated by 1st quarter 2013), Mack TerraPro, and Peterbilt 320. ISL G engine availability on dumpster transport vehicles includes the Freightliner 114SD, Freightliner M2 112, International WorkStar (anticipated by 4th quarter 2012), Kenworth T440/T470, and Peterbilt 365.

Figure 11. Cummins Westport Inc. ISX12 G dedicated natural gas engine

The CWI ISX12 G natural gas engine, shown in Figure 11, is based on the Cummins ISX12 diesel engine platform, the newest member of Cummins heavy duty-engine family. The ISX12 G engine features three-way catalyst aftertreatment, which is packaged as a muffler and is maintenance free. As with the ISL G, no diesel particulate filter or selective catalytic reduction aftertreatment is required. Fuel can be carried on the vehicle as either CNG or LNG, utilizing Cummins Westport's proprietary spark-ignited, stoichiometric combustion with cooled exhaust gas recirculation technology, first introduced with the 8.9L ISL G engine. Maximum power ratings range from 330–400 hp, and maximum torque ranges from 1,150–1,450 lb-ft (CWI 2012). Field testing is underway, and production is expected to begin in early 2013. Pending ISX12 G engine availability from the launch partner OEMs that CWI is currently working with include the Autocar Xpeditor ACX, Crane Carrier LET2/LETCC/LDT2, and Peterbilt 320 for residential collection and the Freightliner 114SD, Mack Granite, and Peterbilt 365 for dumpster transport. Cummins expects to expand OEM availability following the initial product launch.

8 CNG Vehicle Operation and Maintenance

Safety procedures and a safe working environment are essential when working on any vehicle, including those that operate on compressed natural gas (CNG). General measures for personal and shop safety still apply, and all personnel should be properly trained and have the correct tools for the type of vehicle they are servicing. Because of specific characteristics of natural gas vehicles, there are special safety considerations that must be taken into account. Society of Automotive Engineers (SAE) J2406: *Recommended Practices for CNG Powered Medium- and Heavy-Duty Trucks* provides guidance for the construction, operation, and maintenance of CNG-powered medium- and heavy-duty trucks (SAE 2002). Some manufacturers require that mechanics working on its engines are certified by the National Institute for Automotive Service Excellence (ASE) in order to maintain warrantee provisions.

Similar to a gasoline- or diesel-fueled vehicle, a CNG vehicle's fuel system should be inspected periodically. In fact, the United States Department of Transportation (DOT) Federal Motor Vehicle Safety Standard 304 for CNG fuel container integrity requires a label on all CNG cylinders used on motor vehicles that states: "This container should be visually inspected after a motor vehicle accident or fire and at least every 36 months or 36,000 miles, whichever comes first, for damage and deterioration" (DOT 2003). The Compressed Gas Association (CGA) pamphlet entitled "Methods for External Visual Inspection of Natural Gas Vehicle (NGV) and Hydrogen Vehicle (HV) Fuel Containers and Their Installations" is taken as the acceptable practice in the industry for complying with the US DOT Safety Standard 304 and the American National Standards Institute NGV2 (CGA 2007). Qualified inspectors, following a standard developed by NGV industry engineers, will check for cuts, cracks, gouges, abrasions, discoloration, broken fibers, loose brackets, damaged gaskets or isolators, heat damage, or other problems, and recommend proper action to ensure fuel system safety (AFV International 2009). Some CNG vehicle manufacturers, local gas utilities, and cylinder manufacturers offer cylinder inspection services by qualified inspectors. CSA is the only nationally recognized organization certifying CNG cylinder inspectors in the United States and Canada. The certification test that is required to become a CSA America Certified inspector is offered as computer-based exams through the National Alternative Fuels Training Consortium; AFV International; Natural Gas Vehicle Institute; Advanced Transportation Technology; Energy Transfer Technology; Phoenix Energy; College of the Desert; and CNG-NGV Solutions, Inc. Many of these facilities provide on-demand exam sessions allowing flexibility in taking the exam.

A CNG vehicle utilizes a gaseous fuel that is stored at high pressure and is ready to be delivered when requested by valves and regulators. As a safety precaution, a manual shutoff valve is installed to enable the fuel line between the fuel tank and the engine to be closed. When servicing the engine or fuel system, the technician should close the manual shutoff valve and release all fuel from the system downstream of that point in accordance with the Service Manual procedure.

Most natural gas engines require special oil with a lower sulfated ash limit (CWI 2012). The use of diesel engine oil may cause valve torching, piston scuffing, and reduction in spark plug life. The primary difference between natural gas and other internal combustion engine oils is the

necessity to withstand the various levels of oil degradation caused by the gas fuel combustion process, which results in the accumulation of oxides of nitrogen. However, natural gas engine oil may not need to be changed as frequently because CNG burns more cleanly than gasoline or diesel, producing fewer deposits in the oil (Leugner 2003). Cummins Westport recommends oil changes every 15,000 miles, 500 hours, or 6 months on the ISL G natural gas engine. Spark plug changes should be scheduled after 60,000 miles, 1,500 hours, or 24 months, but there should be an initial overhead adjustment after the first year (CWI 2012).

Natural gas is typically filtered and dried as it enters the compressor station from the pipeline. A vehicle CNG filter located prior to the engine ensures a flow of clean natural gas. Coalescing filter elements are specially designed to remove liquid contaminants from gaseous flows. Coalesced liquid (water and oil) collects in the bowl awaiting drainage, while clean air or gas exits the housing through the outlet port. Particulate contaminants are captured and held in the media. Grade 6 filter elements have a coalescing efficiency of 99.97 percent and are used when "total removal of liquid aerosols and suspended fines" is required. This is the filter that is recommended by most manufacturers for natural gas vehicle applications. Grade 10 filter elements only have a coalescing efficiency of 95 percent, which allows more carryover oil and contaminates to pass through. Filter housings have a drain port to remove excess water that was filtered from the gas. CNG vehicle drivability problems can result from failing to maintain the coalescent filter, so it is important to adopt a coalescent filter inspection and maintenance schedule. The recommended filter change interval is every 15,000 miles under normal operating conditions and every 5,000–10,000 miles under severe operating conditions. The quality and cleanliness of the CNG at the local fueling station determines whether the vehicle is operating under "normal" or "severe" conditions (i.e., whether there is a dryer and if the station filter is regularly changed).

Maintenance facilities for CNG vehicle service might need to be modified or constructed to conform to safety requirements related to the unique properties of natural gas. However, some modern maintenance facilitates with sufficient ventilation have been approved to repair and maintain CNG vehicle with no required modifications so it is important to discuss with your local fire marshal and electrical inspector. Existing vehicle maintenance facilities are constructed to ensure safety when dealing with liquid fuels which, when leaked, pool on the ground. Natural gas, on the other hand, rises in the event of a leak because it is lighter than air. This primary difference is the principle behind the requirements for CNG vehicle maintenance facility modifications. The National Fire Protection Association (NFPA) is the overarching organization responsible for the standards that govern CNG vehicle maintenance facilities and typically become adopted as code. NFPA 30A: Code for Motor Fuel Dispensing Facilities and Repair Garages applies to motor fuel dispensing facilities located inside buildings and at fleet vehicle motor fuel facilities, as well as motor vehicle repair garages. This code is recommended for use as the basis for legal regulations and its provisions are intended to reduce the hazards of motor fuels to a degree consistent with reasonable public safety, without undue interference with public convenience and necessity (NFPA 2012). Within Pennsylvania, enforcement of safety regulations for a CNG vehicle maintenance facility falls to the local fire marshal and electrical inspector who will use their interpretation of the Uniform Construction Code of Pennsylvania, Pennsylvania Fire Code of , and the Fuel Gas Code of Pennsylvania (which reference NFPA 30A for CNG

applications) to determine if a facility is approved for use (ICC 2010). As mentioned, the codes can be interpreted differently, but they are applied based on the unique characteristics of each facility.

Regardless of whether an existing facility is being modified for CNG vehicle maintenance, or a new facility is being constructed, there are three primary considerations: ventilation, heating, and potential ignition sources. Because natural gas is lighter than air, NFPA defines the Class 1 Division 2 Group D[1] area in CNG vehicle maintenance facilities as the area extending from the ceiling downward 18 inches. In these facilities, air must be introduced at a lower level and exhausted at the ceiling (the reverse of facilities designed for liquid-fueled vehicles). However, if there is a minimum of four air changes per hour there may be no need for ventilation system modifications. Measures or equipment to ensure appropriate ventilation for CNG vehicle maintenance include methane detectors; modified heating, ventilation, and air conditioning systems; supplemental exhaust systems; and appropriate exhaust fan(s) over the vehicle maintenance bays where CNG vehicles will be maintained. In a facility where CNG vehicles will be maintained, NFPA codes indicate that open flame heaters are not allowed within the top 18 inch cavity. NFPA further indicates that if an open flame heater is mounted below 18 inches from the ceiling, it is considered to be located in a general purpose area and is allowed. However, best practices recommend that CNG vehicles never be parked below any open flame heater area under any circumstances. To meet the code requirements for heating systems in CNG vehicle maintenance facilities, sealed combustion, catalytic, or infrared heaters with a skin temperature below 750°F may be used. The ignition temperature of natural gas is approximately 1,200°F, which allows these heaters to operate safely. No potential source of ignition that could create an arc or spark that would ignite natural gas should be located 18 inches from the ceiling or higher in a CNG vehicle maintenance facility. This includes lighting systems. Special lighting systems can be used, or traditional lighting can be pendant mounted below the 18 inch cavity from the ceiling. Also, general electrical equipment should not be located within the 18 inch space below the ceiling. For example, motors that operate roll-up electrical doors that are located in that 18 inch space must either be relocated or must be Class 1 Division 2 Group D rated. (Thomason 2011)

Figure 12. Emergency shut-off buttons for compressed natural gas maintenance facilities and fueling infrastructure

It is good practice not to bring a vehicle into the maintenance facility with a full CNG tank if it is expected to be in the garage overnight or an extended period of time. For this reason, a safe and properly grounded defueling venting stack or defueling nozzle to transfer fuel from a vehicle to be maintained to another vehicle is something to consider installing. The vehicles must also have a defueling receptacle to utilize this feature.

[1] Class I Division 2 locations are those in which flammable vapors and gases in ignitable concentrations are handled, processed or used, but which are normally in closed containers or closed systems from which they can only escape through accidental rupture or breakdown of such containers or systems. Group D is the explosive behavior classification for natural gas.

Emergency buttons, an example of which is shown in Figure 12, that can be used by personnel if they detect a gas leak or suspect potential hazardous conditions may be required in CNG vehicle maintenance facilities and fueling infrastructure. Depending on the control system, various automatic responses can be integrated into the emergency button. For maintenance facilities, this could involve opening all doors to vent out the gas, activating high-mounted exhaust fans, cutting off power to certain equipment, or stopping any potential gas flows. At fueling facilities, this action will shut down the station, turn off the gas, and cease fueling operations. Pressing the emergency button may also activate an alarm, flash lights, or notify a call center that could automatically dispatch emergency vehicles if the call center operator is not able to confirm that the situation is under control. Once pressed, the emergency button locks into position and does not reset until manually reset by the operator.

9 Public Fueling Options

Pennsylvania currently has 25 public compressed natural gas (CNG) fueling stations and all except 3 are open 24 hours a day, 7 days a week. These are shown in Figure 13. Public compressed natural gas fueling stations in Pennsylvania

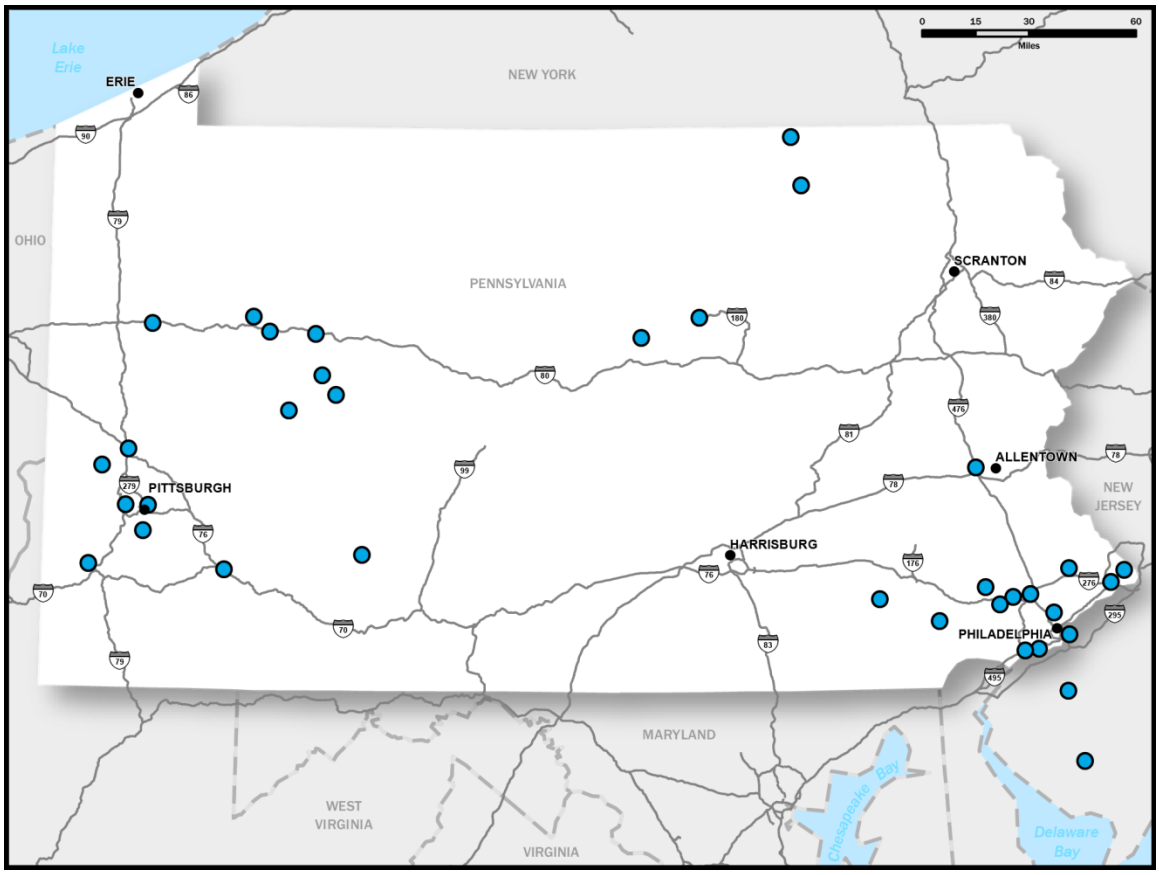

Figure 13. Public compressed natural gas fueling stations in Pennsylvania (DOE 2014)

Almost all of these stations are able and willing to accommodate local refuse fleet vehicles that can conveniently pass by the stations on their route. **Appendix F: CNG Stations in Pennsylvania** has detailed information and regional maps of these public stations throughout Pennsylvania, as well in the neighboring parts of southern New Jersey. It is recommended that fleets contact the station and talk to the operator if they are considering using it for regular fueling. While most can handle the overall increased CNG demand, stations with more limited storage capacity may provide quicker fueling at certain times of the day. Also, some of the operators use individual key cards and account payments that would need to be coordinated prior to using the station. Table 2 lists a few websites and smartphone apps maintain an interactive database of CNG stations with up-to-date information on the sites, including operational status and prices in some cases.

Table 2. Listing of online interactive databases of compressed natural gas stations

US DOE Alternative Fuels and Advanced Vehicles Data Center Alternative Fueling Station Locator	Location, Station details, directions, contact	www.afdc.energy.gov/afdc/locator/stations/
Alternative Fuel Prices and Fill Stations Map	Location, prices, customer comments	www.altfuelprices.com
CNG Now Station Map	Location, prices, directions, customer ratings	www.cngnow.com/stations/Pages/information.aspx
MapMuse CNG Fuel Stations Location Map	Location, details, customer reviews	http://find.mapmuse.com/map/cng
CNG Prices Map	Location, price, details, reviews	www.cngprices.com/station_map.php
CNG Now Fuel Finder App	Location, prices, pressure, directions, customer ratings	www.cngnow.com/app/Pages/information.aspx
MapMuse Alternative Fuel Finder App	Location, directions, photos, reviews	http://find.mapmuse.com/apps/alt-fuel

In addition to the publicly accessible CNG stations, there are 21 private CNG fueling sites in Pennsylvania, and fueling stations that are planned but not yet opened. **Appendix F: CNG Stations in Pennsylvania** provides additional information on these CNG stations. Private stations were designed and built to service only vehicles within the fleet of the organization that installed the station and may only have time-fill capability for fueling of vehicles during extended periods. These station owners may have chosen not to allow public fueling because of site or corporate restrictions, or to minimize station costs. However, with expressed interest from other fleets, these locations may be willing to consider installing a publicly accessible CNG dispenser or sharing the station with a limited number of other fleets if sufficient interest is generated. Because these stations currently possess the staff and expertise to operate a station, if there is enough known demand, they may be willing to invest or look for funding to add public fueling.

Due to the increased interest in CNG and its significantly lower operating costs, additional CNG stations are being considered or in the process of being planned. Waste Management recently announced that it is pushing forward on a nationwide plan to convert all of its 18,342 trucks to CNG (Shauk 2012). That means that all Waste Management locations in Pennsylvania may have CNG fueling in the near term. Waste Management's facility in Bristol (Bucks County) currently has time-fill CNG for its trucks and a public station outside its fence. A high-volume nozzle was included on that station to service its trucks if necessary, as well as other heavy-duty trucks in the area.

Fueling at a public CNG station significantly minimizes the risk for a refuse vehicle fleet that is interested in pursuing this alternative fuel. By eliminating the initial capital cost of a CNG station and the associated need to generate significant cost savings to offset that cost, a fleet has more flexibility to gradually transition to a CNG fleet as vehicles are replaced. Beyond negotiating with a private station to provide public access, multiple fleets, both private and municipal, could

"pool" their CNG demand to encourage a third party to build and operate a CNG station that would service all of the fleets. However, in many places, reasonably priced land in a central location that is easily accessible by fleets may not be easy to find, so a fleet in the "pool" may wish to offer space at its facility on which to build the station. In addition, combined time-fill (for the fleet at the station location) and fast-fill (for other fleets) fueling is often a cost-effective approach to balance the CNG demand and minimize needed on-site storage. The local Clean Cities Coordinators (www.ep-act.org or www.pgh-cleancities.org) can facilitate collaboration in coordinating CNG demand from delivery fleets and working with third-party CNG station operators that might be interested in building a station.

10 CNG Station Basics

In situations where a compressed natural gas (CNG) program would make financial sense for a fleet, but no public CNG fueling is currently available or planned, it may be necessary for a fleet to build its own infrastructure. Large fleets, especially those that already manage on-site liquid fueling facilities, may choose to build a CNG station for convenience, greater economic benefit potential, and to leverage existing capabilities within the company. This section contains a brief overview of the factors to consider when installing CNG infrastructure. A fleet should consult experts in the field, listed in **Appendix D: Vendors for Natural Gas Equipment and Services**, before committing to this undertaking because an improperly designed, sized, or operated fueling station can impact the use of the CNG vehicles and potentially negate the economic savings that could be realized through a CNG vehicle program.

CNG stations are usually time-fill capable, fast-fill capable, or a combination of both. A time-fill station, as illustrated in Figure 14, dispenses fuel over an extended period of time, and is often used to fuel multiple vehicles in a fleet overnight. This is an excellent fueling method for vehicles that park in the same exact spot at the end of every work shift for an extended period of time (typically at least 10-16 hours). Time-fill system compressors raise the pressure of the entire fueling apparatus as a unit, including any vehicles that are connected. The vehicle connected with the lowest pressure (emptiest) will receive all the CNG from the compressor until the system pressure is raised to that of the truck with the next lowest pressure, at which time that truck will begin fueling. As the system pressure rises, eventually all connected vehicles will receive fuel until all of them reach the CNG pressure limit of 3,600 pounds per square inch (psi) at 70^{o} F (or 3,000 psi at 70^{o} F on older stations). Provided the vehicles are parked long enough, a time-fill station will always fill the vehicle tanks completely because the slower rate allows the gas to fully equalize its temperature inside each tank. Time-fill systems typically include only minimal on-site CNG buffer storage, which lowers the installation cost, and the compressors operate for an extended period of time from when the first vehicle is connected until the entire fleet is filled (then the compressors may remain off for a long period of time until the vehicles return from route). Having the compressors operate only once per day reduces maintenance and extends the life of the equipment. Time-fill systems may be able to reduce electric costs to operate compressors by filling trucks during off-peak hours, thus eliminating any demand charges and enabling an off-peak electric rate if provided by the utility. Fuel management (except for the main utility gas meter) and payment systems are not necessary if the station is not fueling vehicles outside of the fleet, which further reduces station costs.

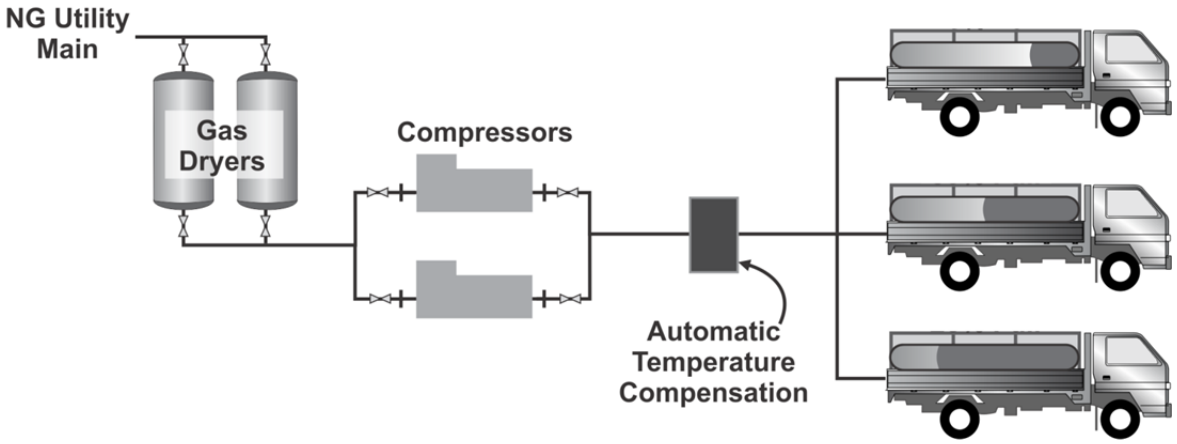

Figure 14. Schematic of a time-fill compressed natural gas fueling system

Fast-fill stations are designed to provide fill rates comparable to liquid fueling stations for conventional fuels. This is necessary for any station with public accessibility. CNG is metered and dispensed similar to ordinary liquid fuel dispensers. A typical dispenser has two hoses and stations can have multiple dispensers so more than one customer can fuel their vehicles simultaneously. The dispensers can also incorporate different nozzles from the same system that provide 3,000 psi gas, 3,600 psi gas, or higher volume fueling with a CT5000 nozzle (transit and large truck applications). Many fast-fill systems can incorporate a card reader, which accepts universal fuel cards or credit cards, for authorizing, dispensing, and storing the transaction for billing, although some only permit specialized cards or keys that route fueling information to the station operator who would bill the fleet directly for fuel costs. When set up with this system, public-access CNG stations can be unmanned and open to the public 24 hours a day and 7 days a week. Fast-fill stations require less space for construction and dispensing, but they need to have onsite storage tanks. In Pennsylvania, municipalities are permitted to require that CNG fuel dispensers have a person with a Certificate of Fitness "line of sight" on the property at all times fueling is being performed, although DVRPC cannot find any municipalities that impose this requirement.

There are two storage configuration designs for fast-fill stations: cascade or buffered storage. Cascade systems are generally used in situations where a number of smaller vehicles (10-30) are filled in a peak fueling period (30-90 minutes), or where a few large vehicles are fueled sporadically throughout the day. A cascade fast-filling station typically has banks of storage with different pressures—low, medium or mid, and high—and a priority panel that directs the flow of gas to the banks. When a vehicle is fueling, it will draw first CNG from the low bank, provided the cylinder pressure of the vehicle's tank is lower than that of the low pressure storage bank. Once the vehicle's tank pressure equalizes that of the low pressure bank, the system will switch to the medium pressure bank to fuel the vehicle's tank up to its level. Finally, the high pressure bank will be used to ensure that the vehicle is fueled up ("topped off") to its maximum allowable pressure. This configuration ensures that the desired filling pressure will be available as long as the mid or high pressure bank has a higher pressure than the cylinders on board the vehicle. When the compressor comes on, it prioritizes the flow of gas to fill the banks in the reverse order, from

high to mid to low bank so that the high bank always has enough pressure to fill or "top off" the vehicle. The priority panel can also direct the high pressure CNG directly to the vehicle from the compressor (bypassing the storage banks), but the flow rate is limited by the output size of the compressor. In addition to always maintaining a reservoir of high pressure CNG, the cascade system uses the low bank to fuel vehicle tanks first, which is more cost effective and helps address some thermodynamic concerns that will be discussed later.

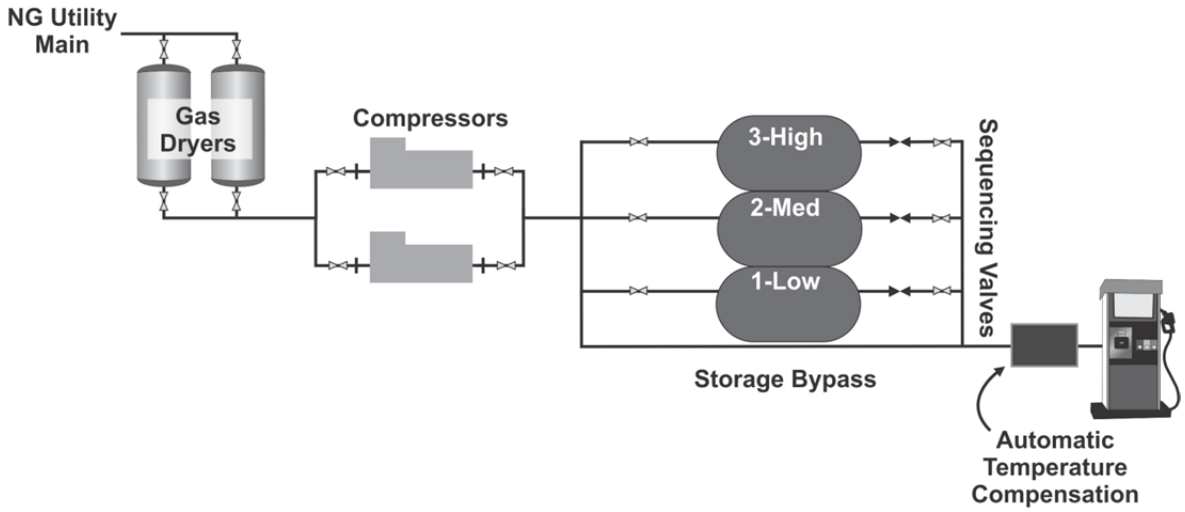

Figure 15. Schematic of a fast-fill cascade compressed natural gas fueling system

Buffered fast-fill is generally used in situations where large vehicles are fueling on a continuous basis. Unlike cascade systems that primarily fill vehicles from stored gas, the buffer system provides most of the vehicle fill directly from the compressor, which is sized accordingly to deliver a high flow rate. The buffer storage is utilized to allow the compressor to continue to run between vehicle fueling (commonly referred to as "dwell" time) to fill the buffer tanks with CNG that can be used to increase the rate of fill for the next vehicle. The buffer system tanks are all maintained at the same pressure and are used only when their pressure is higher than that of the vehicle storage tanks. In a buffer fill methodology, the highest pressure to "top off" the vehicle's tanks must always come directly from the compressor.

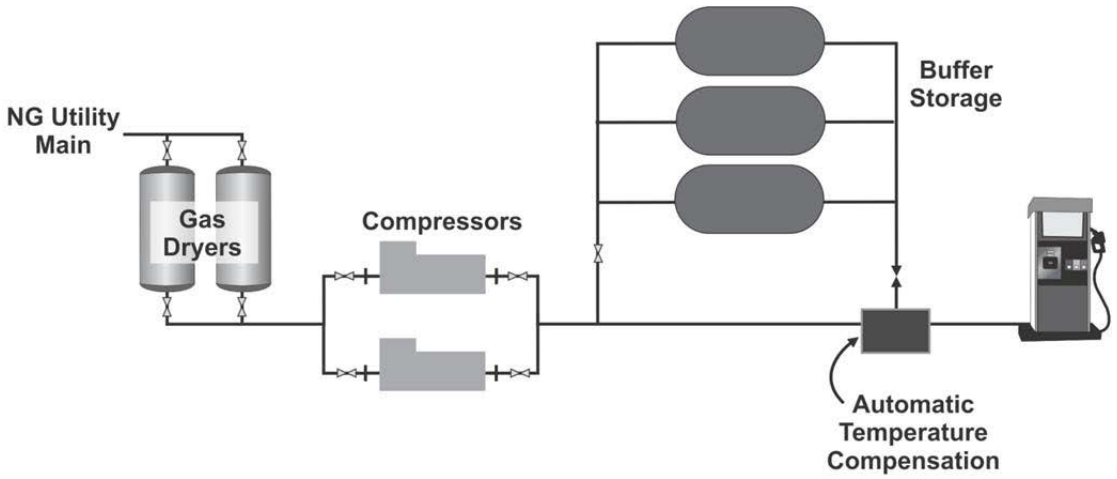

Figure 16. Schematic of a fast-fill buffered compressed natural gas fueling system

Combination stations combine the features of a fast-fill system and a time-fill system. When there is an opportunity to do so, it is very efficient to perform fast-fill dispensing operations during the daytime along with time-fill operations during the nighttime. This combination allows high utilization of the station compression capacity during the daytime and nighttime.

Under-filling of CNG vehicle storage cylinders during fast-fill fueling operations can occur at fueling stations. This is partially the result of the fueling station dispenser control system either failing to compensate for, or inaccurately estimating, the elevated CNG storage cylinder gas temperatures, which occur during fueling, due to compression, mixing, and other complex and transient thermodynamic processes. Most modern CNG dispensers have controls with temperature compensation to account for this, but fast-fill fueling may not result in a completely full tank after the CNG has time to "settle" in the tank. The customer is still provided an accurate measurement and cost for the fuel that was provided, but the tank pressure may not be at its maximum limit, which can slightly reduce the vehicle's range. The industry has worked on this thermodynamic factor and the Gas Technology Institute has a temperature compensated, full fill algorithm that is available to any dispenser manufacturer or fuel station developer.

Pipeline gas from the utility may contain moisture and other impurities that cause problems when the gas is compressed. Excessive moisture can affect the operation of the CNG compressors and even the vehicles, so it is important to use a gas dryer to "clean" the gas to provide high-quality fuel. Within the gas dryer, the natural gas first flows through a series of filters to remove any particulate matter from the gas stream. Then the gas runs through a desiccant drying bed to remove moisture. When the desiccant bed in a gas dryer becomes saturated, the dryer must be "regenerated." The regeneration process heats up the desiccant in order to remove the liquids from the dryer bed. CNG station owners should be aware that the effluent from the dryer is classified as hazardous waste and must be handled and disposed of properly. A gas dryer may be a single- (one desiccant bed) or twin- (two desiccant beds) tower design. A single-tower design keeps costs low and is appropriate for small to medium CNG projects, such as a time-fill refuse station. The main drawback to a single-tower design is that the dryer must be taken off-line during the regeneration process and fuel may not be available during this time (depending on

storage). In the twin-tower design, when one side of the dryer is saturated, the gas flow will automatically be directed to the second side. This type of dryer is typically used in stations that require operational redundancy, such as fast-fill transit CNG stations. Dryers with manual regeneration require a technician to monitor the dryer operation and perform the process. Systems that regenerate automatically have computers on board that determine when the system needs to be regenerated and carry out the process without the intervention of a technician. (Trillium 2010)

Natural gas compressors transform ordinary, low-pressure gas into a high-pressure fuel stream for vehicles. Most natural gas compressors are classified as positive displacement compressors. Two main types of compressors in this category are reciprocating (includes single-acting and double-acting designs, as well as diaphragm compressors) and rotary (includes lesser-used types such as scroll, screw, and liquid ring compressors). In the more common reciprocating designs, gas is compressed in cylinders by pistons, which are driven by a crankshaft. The cylinders are arranged in "stages," typically numbering between two to five, to compress the gas for vehicular use. The number of compression stages required will depend on the suction pressure provided by the gas utility and the size of the primary mover (motor) in terms of horsepower. Natural gas compressors come in a wide array of sizes and are rated by the amount of CNG they discharge in standard cubic feet per minute (SCFM). As a rough estimate, dividing the compressor's SCFM at its rated inlet psi by two will equal the gasoline gallon equivalents (GGEs) per hour that it can produce. Inaccurately estimating the station's desired GGE per hour of output could result in under-sizing (leading to poor fills or over use) or over-sizing (leading to station reliability issues and increased power costs) of the compressors. Most equipment manufacturers have CNG calculators that can be used to accurately size the station.

Though it is certainly possible to successfully operate a CNG fueling station with a single compressor, in most cases fleets require fueling redundancy to prevent potential fueling downtime and missed fleet rollouts. A CNG station with "full redundancy" must have at least two compressors and the station's compression capacity must equal or exceed twice the amount of the fleet's daily fuel use. In the event of a malfunction with one compressor, the fleet would still be able to fuel its entire fleet within the fueling window. A two-compressor system can also balance wear on individual compressors and extend the life of the fueling system. At larger CNG stations, it is often more efficient and cost-effective to design with partial redundancy. For instance, a large transit CNG station might require two active compressors to meet SCFM requirements, but the addition of a third compressor could provide sufficient redundancy if the station receives dedicated maintenance. Though such a design does not provide complete redundancy, the control system would promote balanced wear and increased equipment longevity. (Trillium 2010) If there is another CNG fueling facility accessible to your fleet along the route your vehicle travels, then that station could be considered as the "redundant" station, thus eliminating the need for a redundant compressor on your property, which will lower the cost.

NFPA 52: *Vehicular Gaseous Fuel Systems Code*, applies to the design, installation, operation, and maintenance of CNG engine fuel systems on vehicles of all types and for fueling vehicle (dispensing) systems and associated storage (NFPA 2013). While many of these requirements are integrated into the equipment that is purchased, there are some site-specific codes that must be adhered to for the local fire marshal and electrical inspector to approve the permit. There are also

a number of standards listed in the following table that apply to CNG stations. Station owners and operators should be aware of these standards so that all equipment purchased is compliant with these requirements.

Table 3. Standards for compressed natural gas fueling infrastructure and components (ANSI 2009)

American National Standards Institute (ANSI)/IAS NGV4.1-99/CSA 12.5-M99(R09) **Natural Gas Vehicle Dispensing Systems**	Applies to the mechanical and electrical features of newly manufactured systems that dispense natural gas for vehicles, where such a system is intended primarily to dispense the fuel directly into the fuel storage container of the vehicle.
ANSI/IAS NGV4.2-99/CSA 12.52-M99(R09) **Hoses for Natural Gas Vehicles and Dispensing Systems**	Applies to compressed natural gas hose assemblies that are used for natural gas vehicle dispensing stations to connect the dispenser to the fueling nozzle, or used as part of a vehicle onboard fuel system and for gas lines that carry vented gas back to a safe location.
ANSI/IAS NGV4.4-99/CSA 12.54-M99(R09) **Breakaway Devices for Natural Gas Dispensing Hoses and Systems**	Applies to newly produced compressed natural gas vehicle dispenser shear valves and fueling hose emergency breakaway shutoff devices.
ANSI/IAS NGV4.6-99/CSA 12.56-M99(R09) **Manually Operated Valves for Natural Gas Dispensing Systems**	Applies to manually operated valves for high-pressure natural gas.
NGV 4.8-2002/CSA 12.8-2002 (R07) **Natural Gas Fueling Station Reciprocating Compressor Guidelines**	Details construction and performance requirements for natural gas compressors for use in compressed natural gas fueling stations service. The compressor package should include, but not be limited to, all necessary equipment from the inlet connection immediately upstream from the isolation valve to the packager-specified discharge connection.

11 Funding Options for Vehicles and Infrastructure

Grants, tax incentives, and low-interest loans can ease the cost burden of converting a diesel fleet to compressed natural gas (CNG) vehicles. Grant awards and tax incentives are available for the purchase of CNG vehicles and infrastructure through federal and state agencies. State tax exemptions can lower the fuel cost of operating a fleet of CNG vehicles compared to a diesel-based fleet.

Grants and Low-Interest Loans

Federal and state grant funds are available to entities that are willing to put in the extra effort needed to prepare successful applications. Federal agencies such as the U.S. Department of Energy (DOE), the U.S. Environmental Protection Agency (EPA), and the U.S. Department of Transportation (DOT) all provide grants aimed at providing economic aid for the adoption and use of alternative fuel vehicles and infrastructure. In New York State, the New York State Energy Research and Development Authority (NYSERDA) also issues several opportunities that encourage the adoption of alternative clean vehicle technologies.

Successful grant applications often include several elements; inclusion of these elements in your proposal will ensure that you have the most competitive proposal possible. Grants are often administratively cumbersome; the prospective awardee must meet deadlines for filing, submit appropriate forms and schedules and back-up documentation, and format the application as required. Failure to meet application requirements reflects poorly on the applicant's ability to manage the process. Additionally, ongoing reporting of project completion and vehicle usage/fuel displacement is a typical administrative requirement of all grants.

It is important to speak to the area of interest and the evaluation criteria of the agency funding the grant. DOE and state energy offices often focus on petroleum reduction and energy efficiency. The EPA and state environmental offices focus primarily on pollution reduction and air quality benefits affecting the greatest number of population. Economic development agencies' proposals should focus on jobs created and tax revenues generated for the state.

Clearly spell out the proposed benefits, the criteria by which you plan to measure those benefits, and the action plan and the proposed processes in place to manage resources and take corrective action mid-stream to achieve the goal(s). Show that measurement of performance and the ability to adjust are critical to your process.

Successful partnering is also important. Letters of support from any regional organizations or groups that could benefit are looked upon favorably, including but not limited to your local gas utility and any potential project partner or supporter. Collaboration with Clean Cities is also highly favorable. Clean Cities may even be able to help coordinate collaboration with another organization that could make the project larger and more favorable to the funders. Consultants or

university partners that regularly write grants can help strengthen your proposal, and for a portion of the funding they may manage the measurement and administrative aspects of the project.

DOE's Clean Cities Program

DOE's Clean Cities Program is designed to accelerate the use of alternative fueled, in a fuel neutral manner, and petroleum reduction strategies in the transportation sector throughout the country. The overall mission of the program is to improve our national energy security while providing environmental benefits through emission reductions of greenhouse gases, particulate matter, and other criteria pollutants. Clean Cities grants have expanded the use of natural gas vehicles in a variety of applications, such as school buses, transit buses, airport vehicles, taxis, refuse, delivery, and municipality fleets. Grants have also been used to build fueling infrastructure, with a focus on locations that provide public access, as this provides the opportunity to further increase the number of vehicles using natural gas. The program works through a network of 90 volunteer coalitions headed by Clean Cities Coordinators that develop public-private partnerships. Support for the various Clean Cities coalitions is provided through DOE's State Energy Program Special Projects. Stakeholders of the Clean Cities Coalition can apply for DOE's Special Projects grants. Becoming a stakeholder is free and is as simple as filling out an application. These grants, awarded competitively, can be used to cost-share up to 75 percent of the proposed project. They can cover the incremental cost of purchasing natural gas vehicles and the cost of installing fueling equipment. For more information, contact your local Clean Cities Coalition, which are listed in **Appendix E: Resources for Additional Information**.

DOT's Congestion Mitigation and Air Quality Improvement Program

DOT's Congestion Mitigation and Air Quality (CMAQ) Improvement Program funds projects and programs that reduce transportation-related emissions in areas, such as southeastern Pennsylvania, that do not meet the EPA's National Ambient Air Quality Standards for healthy air. DVRPC works very closely with the Pennsylvania Department of Transportation to administer and assist in making these funds available for the alternative fuel vehicle programs. CMAQ provides grants that can pay for the incremental cost of purchasing natural gas vehicles and can be used to fund alternative fuel fueling projects, although they must have 20 percent local or regional co-funding. Funding is allowed for private-public partnerships. More information on this DOT program administered by the Federal Highway Administration and the Federal Transit Administration can be found here: www.fhwa.dot.gov/environment/air_quality/cmaq/.

EPA's Clean Diesel Program

The EPA's National Clean Diesel Funding Assistance Program awards competitive grants to fund projects that reduce emissions from existing diesel engines through a variety of strategies. These strategies include cleaner fuels, engine upgrades or replacements, and vehicle or equipment replacements. Under this grant program, funding is restricted to the use of technologies, fuels, and engines that have been verified or certified by the EPA or the California Air Resources Board (CARB).

Diesel Emissions Reduction Grants

On January 4, 2011, President Obama signed legislation (H.R. 5809) reauthorizing Diesel Emission Reduction Act (DERA) grants to eligible entities for projects that reduce emissions from existing diesel engines. The bill authorizes up to $100 million annually for fiscal year (FY) 2012 through FY2016 and allows for new types of funding mechanisms. Congress appropriated $29.9 million for FY2012. Seventy percent of the funds each year are direct federal grants and 30 percent is set aside as funding for state programs. CNG projects that qualify for DERA funding include repowering of diesel vehicles with a natural gas engine (75 percent of cost), or complete diesel vehicle replacement with a new natural gas powered vehicle (25 percent of cost). The grants do not cover normal fleet turnover or expansion, but they do cover early replacement of vehicles (old engines must be scrapped, rebuilt, or disabled). More information on the DERA grants program can be found here: www.epa.gov/cleandiesel/grantfund.htm.

EPA's SmartWay Clean Diesel Program

The EPA's SmartWay Clean Diesel Program issues competitive grants to establish national low-cost revolving loans or other financing programs that help fleets reduce diesel emissions. The program offers innovative financing programs to buyers of eligible diesel or alternatively fueled vehicles and equipment, with a focus on long-haul trucks. These innovative financing projects include those where the loan recipient receives a specific financial incentive (e.g., better than current market rates or conditions) for the purchase of eligible vehicles or equipment. Particular emphasis is on establishing low-cost loan programs for the retrofit of used highway vehicles with pre-2007 diesel engine and non-road equipment with EPA- or CARB-verified emission control technologies. There will be no SmartWay Finance competition in 2012, but visit this site for future opportunities: www.epa.gov/cleandiesel/prgfinance.htm

National Fuel Gas Distribution Corporation

The National Fuel Gas Distribution Corporation established a program in 2011 to advance funds to help its customers buy-down the cost of installing CNG fueling stations and/or purchasing new CNG vehicles, thereby lowering their payback. Proposed typical buy-downs per customer are expected to be in range of $10,000–$200,000. Actual buy-down is calculated based on the incremental margin received from each project. The pilot program has an initial term of three years, with an annual cap of $1 million per year, for a total of $3 million. See www.natfuel.com for more information. Other New York State utilities may consider using similar incentive programs for their customers.

Navistar-Clean Energy Incentive Program

Truck maker Navistar International Corp. and natural gas fuel supplier Clean Energy Fuels Corp. are offering an incentive program (Fuel and Truck) that will mitigate or equalize the cost of a natural gas vehicle with its diesel equivalent. Under the program, a user would purchase a CNG vehicle manufactured by Navistar and then commit for five years to buying 1,000 gallons of natural gas per month. In return, Clean Energy would offer the user a $500 monthly rebate, which, over the five-year span, would offset the estimated $28,000 per-unit differential between

buying a CNG truck and a new diesel-powered vehicle. In addition, the user would pay for natural gas fueling at a price 60 cents a gallon below the prevailing price of diesel fuel as calculated each week by the DOE's Energy Information Administration (EIA). Customers would be able to opt out of the agreement at any time without penalties. For more information, visit: www.internationaltrucks.com/trucks/naturalgas.

This would provide a guaranteed savings over diesel fuel for five years, but may not provide the best return on investment. On April 9, the national average price for a gallon of diesel fuel stood at $4.148, according to EIA data. Thus, a customer would have paid $3.55 a gallon for the first 1,000 gallons consumed during the month (after the first 1,000 gallons are purchased the customer would purchase fuel at Clean Energy's the "retail" rate). Total monthly savings are $600 for the fuel and $500 with the rebate for $1,100. Without the program users would be purchasing CNG at Clean Energy's "retail" rate, which was about $2.90 a gallon at that time. Total monthly savings for 1,000 gallons of CNG would have been $1,250 and it could have been bought at any CNG location. Fleets may be able to get an even lower CNG price with a long-term fueling agreement, which would result in even greater savings without the incentive program. However, this savings varies with the cost differential between diesel and CNG while through the Navistar-Clean Energy program it is fixed as long as the user purchases 1,000 gallons of fuel from a Clean Energy station each month.

Commonwealth of Pennsylvania Programs

Alternative Clean Energy Program (ACE)

The Alternative and Clean Energy Program (ACE) provides financial assistance in the form of grant and loan funds that will be used by eligible applicants for the utilization, development and construction of alternative and clean energy projects in the state. The program is administered jointly by the Department of Community and Economic Development (DCED) and the Department of Environmental Protection (DEP), under the direction of the Commonwealth Financing Authority (CFA).

The ACE supports activities to promote the utilization, development and construction of alternative and clean energy projects, infrastructure associated with compressed natural gas and liquified natural gas fueling stations, plus energy efficiency and energy conservation projects in the state. Businesses, economic development organizations, and political subdivisions—including municipalities, counties and school districts—are eligible

Grants for any alternative energy production or clean energy project shall not exceed $2 million or 30 percent of the total project cost, whichever is less. Guarantees: Grants shall not exceed $5 million and have a term of not more than five years. For more information, visit: www.newpa.com/find-and-apply-for-funding/funding-and-program-finder/alternative-and-clean-energy-program-ace

Alternative Fuel Incentive Grant Program (AFIG)

The Alternative Fuels Incentive Grant (AFIG), established in 1992 under Act 166, helps to create new markets for alternative fuels in Pennsylvania which enhances energy security. An investment is being made not only in alternative fuels, but the deployment of alternative fuel vehicles, fleets and technologies.

Alternative Fuel Incentive Grant projects promote and build markets for advanced, renewable and alternative energy transportation technologies. The intent is to provide a stimulus for opportunities that better manage Pennsylvania's fuel resources in a way that also improves the environment, supports economic development and enhances the quality of life. For more information, visit:
www.portal.state.pa.us/portal/server.pt/community/alternative_fuels_incentive_grant/10492

Alternative Fuel Rebate Program

The program is part of the Alternative Fuel Incentive Program (AFIG), and provides rebates to consumers for the purchase of new plug-in hybrid, plug-in electric, natural gas, propane and hydrogen fuel cell vehicles. To be eligible for a rebate, an alternative fuel vehicle (AFV) must be a new vehicle with an odometer reading of less than 500 miles at the time of purchase. For more information, visit:
www.portal.state.pa.us/portal/server.pt/community/alternative_fuels_incentive_grant/10492/alternative_fuel_vehicles/553206

Natural Gas Vehicle Program

Act 13 of 2012 established the Natural Gas Energy Development Program with $20M for use under the program The purpose of this program is to provide funding to support the purchase or retrofit of natural gas vehicles (NGVs) that utilize new or existing natural gas fueling stations within Pennsylvania. The objective is to increase the use of domestically-produced natural gas and realize both economic and environmental benefits through the increase in the number of natural gas vehicles operating in Pennsylvania. For more information, visit:
www.portal.state.pa.us/portal/server.pt/community/act_13/20789/natural_gas_vehicle_program/1157504

Clean Diesel Grant Program

The Pennsylvania Department of Environmental Protection (DEP) offers reimbursement grant funding for mobile source diesel emission reduction projects in the Commonwealth of Pennsylvania. The primary goal of the Pennsylvania State Clean Diesel Grant Program is to improve Pennsylvania’s air quality by decreasing emissions from diesel-powered mobile sources.

Eligible applicants include businesses, non-profit organizations, school districts, municipalities, counties, and municipal authorities. Many types of diesel emission reduction projects are eligible, including the purchase of compressed natural gas (CNG) highway and nonroad vehicles that lower emissions; and purchase and installation of CNG refueling stations

Tax Incentives

Federal

The federal incentives to encourage the use of natural gas vehicles have expired, including the vehicle credit (December 31, 2010), along with the fueling infrastructure credit and 50-cent fuel credit (December 31, 2011).

A bipartisan team of Senators is attempting to retool the *New Alternative Transportation to Give Americans Solutions Act* (S.1863/H.R.1380), known as the NAT GAS Act, to gain greater congressional support.

If passed, the NAT GAS Act would provide tax credits of up to $7,500 toward the purchase of consumer CNG and LNG vehicles, and as much as $64,000 for heavier-grade commercial trucks. It would also provide a 50-cent per gallon discount on the federal fuel tax, a 50 percent tax credit (maxing out at $100,000) toward the installation of CNG/LNG pumps at public and private filling stations, and a $2,000 credit toward the installation of home fueling appliances. The NAT GAS Act would also allow the natural gas vehicle and natural gas fueling infrastructure credits to count against the Alternative Minimum Tax provision in both cases of business use or personal use. Additionally, it allows for these credits to be transferred to the manufacturer, seller or lessee.

12 Business Case Analysis for a Natural Gas Program

Unlike personal vehicles whose purchase is driven by many factors (including some that can be intangible), refuse vehicles are purchased for business purposes by fleet owners, both municipal and private, who are seeking a vehicle to complete a job effectively and efficiently. For this reason, new technologies are of interest to a fleet owner if that technology can prove to be economically beneficial. Most fleets have their own internal processes and procedures (with varying levels of detail) for determining the business case or payback period for any capital cost investment, so this booklet will not endeavor to replace those processes. However, the following is some broad information about the contributors to a positive business case for compressed natural gas (CNG) vehicles in fleet applications to consider when investigating a CNG vehicle program.

Economic Aspects of Natural Gas Vehicles – Simple Payback

As has been noted elsewhere in this booklet, CNG vehicles are usually sold at an increased cost relative to conventional gasoline or diesel vehicles as a result of their lower production volumes and unique natural gas components (mainly storage cylinders), among other factors. This incremental cost represents a capital investment on the part of the fleet buyer. Additional capital costs may also be incurred, including any garage facility upgrades or investments in fueling facilities, if those prove necessary.

These capital investments can be recouped through several means, including grant funding or tax credits to offset a portion of the incremental vehicle cost or fueling station costs, and through operational cost savings resulting from reduced fuel costs. Some types of vehicles may yield maintenance cost savings through increased oil drain intervals or the removal of the need to clean diesel particulate filters, but these savings are not seen in all cases and will not be considered here. In the simplest case, an economic payback can be calculated by knowing the following factors:

- Incremental cost of the natural gas vehicle relative to the conventional vehicle it would replace
- Amount of grant or tax credit funding applied to reduce the incremental cost of the vehicle (if any)
- Annual mileage traveled and fuel economy (miles per gallon [mpg]) for the conventional vehicle (or total gallons used per year for that vehicle)
- Annual mileage and fuel economy (miles per diesel gallon equivalent [mpdge]) expected for the natural gas vehicle (or total projected diesel gallon equivalent [DGE] use for the natural gas vehicle)
- Cost per gallon for conventional fuel
- Cost per DGE for CNG

If these factors are known, then the simple payback for the natural gas option on a given vehicle is simply the total incremental cost to be paid back, divided by the yearly cost savings from fuel use. To demonstrate a simple payback calculation, here is an example for a refuse vehicle in Pennsylvania:

- Incremental cost for a new CNG truck = $32,000
- Amount of grant or tax credit = $0 (for this illustrative example)
- Annual fuel use = 9,500 DGE/yr
- Cost per gallon of diesel in Central Atlantic region = $3.91 (DOE 2014)
- Cost per DGE of natural gas in Central Atlantic region = $2.49 (DOE 2014)

Based on this information, this vehicle would incur fuel costs of about $37,145 per year with diesel fuel (9,500 DGE/year times $3.91 per diesel gallon) and $23,655 per year with CNG (9,500 DGE/year times $2.49 per DGE), or a fuel cost savings of $13,490 per year. This would result in a simple payback of about 2.4 years in this conservative estimate ($32,000 divided by $13, 490 per year). Tax credits or grant funding, examples of which are outlined in the prior section **Funding Options for Vehicles and Infrastructure**, would improve this payback time considerably by reducing the incremental cost of the CNG truck.

Retrofitting or repowering an existing vehicle with a new CNG engine can have a greater incremental cost because it does not offset the cost of the new diesel engine that would have been purchased in a new vehicle. A conversion on an existing vehicle may cost between $60,000 and $70,000, minus any value from the old engine which is likely very minimal. However, this may still be economically viable if the vehicle will be in service for many more years.

An additional resource accompanying this guidebook is a tool that will allow a fleet to estimate its economic return on investment from using CNG by entering some basic information about the vehicles and operations. More details are provided in **Appendix G: Cost Evaluation Tool for Fleet Analysis**, including a link to where this Excel tool can be downloaded from the internet.

Other factors may need to be considered when examining the payback of a CNG vehicle program, such as more or less staff time necessary to fuel the vehicles (depending on how this changed from previous operations) or differences in training between diesel and natural gas technologies. These factors may not be included in all cases.

Because the major influence on payback is the cost savings per gallon of fuel used, the best business case will result from fleet vehicles using a large amount of fuel per year. In the example above, increasing the amount of fuel used to 12,000 DGE/yr will cut the payback period down to approximately 1.9 years, all else being equal.

The example above shows a very simple payback calculation that can help fleets identify at a high level whether their vehicles are good candidates for conversion to natural gas. These basic factors concerning vehicle cost and fuel usage would also be used in more complex calculations (internal rate of return, cash flow, net present value, etc.) that a fleet may consider in making final business decisions about moving forward with a CNG vehicle program.

It should be noted that this example uses prices from the DOE Alternative Fuel Price Report, which reports on retail at-the-pump prices including all taxes and fees. The CNG price includes the pipeline delivery fees and the retailer's cost to purchase the gas and compress it to the required pressure for delivery, as well as the retailer's costs for purchasing and depreciating the capital equipment (compressors, dispensers, etc.) and for maintaining the station equipment. If a fleet chooses to build and operate its own station and incur these costs, the calculations for simple payback will need to include those in the analysis.

Economic Aspects of Natural Gas Fueling Stations

In 2010, the National Renewable Energy Laboratory (NREL) published a report on their Vehicle and Infrastructure Cash-flow Evaluation tool describing how the tool would be used in fleet decision-making for natural gas use. Part of the tool includes an algorithm for the relationship between natural gas fueling station monthly throughput and the resulting cost of that station, assuming buffered fast-fill technology for the station for quickly fueling a large number of high-capacity vehicles. Separate relationships were developed for transit buses, school buses, and refuse trucks, based on their differing fueling characteristics (available window for fueling, equipment type needed, etc.). The algorithm, based on cost calculators created by Marathon Technical Services, estimates costs for stations up to 300,000 DGE monthly throughput (accounting for very large fueling station designs). NREL used the Marathon calculator to develop a linear approximation for the fueling station cost as a function of monthly throughput for the three cases studied. CNG stations for refuse applications, which should be similar to delivery applications, were reported to cost between $1.25 and $2 million result for a small station (less than 50,000 DGE per month) and just under $5 million for the largest stations (300,000 DGE per month). Although these costs are for a large throughput station, NREL states that "the calculator takes into account the reduction in equipment needed by reducing the overall cost of the station close to that of a comparable time-fill station. Therefore, the cost estimate is realistic over a wide range of station sizes." (Johnson 2010)[2]

Other Externalities – Energy and Environment

CNG vehicles can offer value to a fleet beyond the simple dollars-and-cents world of fuel cost savings and incremental purchase costs. In many cases, CNG vehicles can demonstrate emissions benefits relative to their existing fleet vehicles, which may make a natural gas vehicle program eligible for grant funding for emission reductions. If these emission benefits could be monetized, they could be included as a cost savings in the payback calculations as an income stream. This is not usually done in fleet analyses as it is difficult to place a cost on these emission benefits.

Similarly, energy benefits may also offer value to a fleet: the Pennsylvania Clean Cities coalitions are frequently seeking ideas for new projects that would reduce energy consumption within the

[2] After the original NYSERDA version of this document was published, NREL completed a second study of station costs providing similar conclusions: Mitchell, George. *Business Case for Compressed Natural Gas in Fleet Applications*, NREL/TP-5400-63707. Golden, CO: National Renewable Energy Laboratory, March 2015. www.nrel.gov/docs/fy15osti/63707.pdf

state, and may have the ability to connect fleets with grant funding sources that would offset all or part of the incremental cost of CNG vehicles. Similarly to environmental benefits, if the energy security benefits could be monetized, they could also be included as a cost savings in the payback calculations as an income stream.

Finally, public relations benefits may accrue from the use of CNG vehicles. Communities may view a delivery fleet's use of CNG as a positive "green" step toward being a better corporate citizen within the community. These benefits are very difficult to convert to a monetary basis, but fleets should be aware that CNG vehicles can provide these benefits to the company, should this be necessary for senior management buy-in. These benefits could provide a sales and marketing advantage over a competitor company still using petroleum based fuels.

Other Resources

A number of resources are available online that could provide additional information for the fleet user. These references offer much more complex and detailed analysis efforts than have been outlined in this booklet, so the reader is encouraged to review these reports at the links below for additional details.

Deal, Anna Lee. *What Set of Conditions Would Make the Business Case to Convert Heavy Trucks to Natural Gas? – a Case Study*. National Energy Policy Institute, April 2012. www.nepinstitute.org/wp-content/uploads/2012/05/Natural-Gas-for-Heavy-Trucks-201205011.pdf.

International Energy Agency. *World Energy Outlook: Are We Entering a Golden Age of Gas?* Paris: International Energy Agency, 2011. www.iea.org/weo/docs/weo2011/WEO2011_GoldenAgeofGasReport.pdf.

Johnson, Caley. "Natural Gas Vehicles, Fueling Infrastructure and Economics." Presentation at the EESI Natural Gas Briefing, National Renewable Energy Laboratory, Golden, CO, March 16, 2011. http://files.eesi.org/johnson_031611.pdf.

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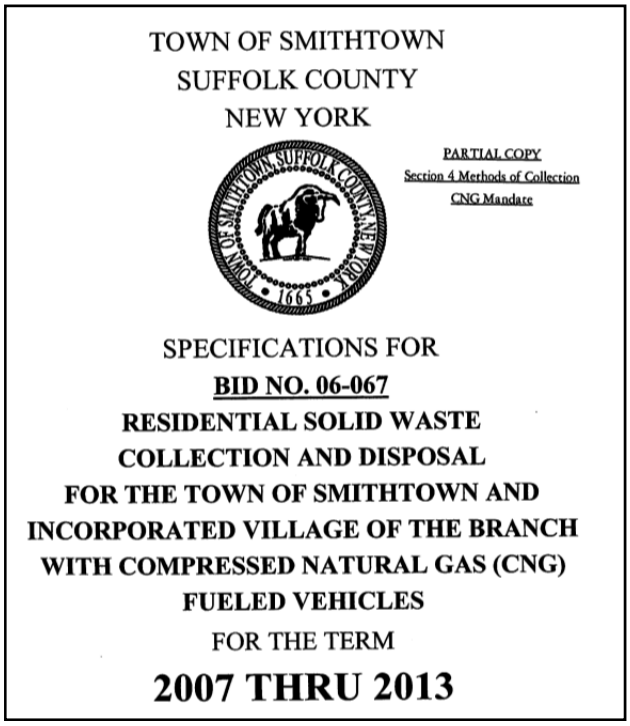
TAIX. *U.S. and Canadian Natural Gas Vehicle Market Analysis: Compressed Natural Gas Infrastructure*. America's Natural Gas Alliance, 2012. www.anga.us/media/247965/11_1803_anga_module5_cng_dd10.pdf.

Werpy, M, D. Santini, A. Burnham, and M. Mintz. *Natural Gas Vehicles: Status, Barriers, and Opportunities*, ANL/ESD/10-4. Oak Ridge, TN: Argonne National Laboratory, August 2010. www.afdc.energy.gov/afdc/pdfs/anl_esd_10-4.pdf.

Whyatt, GA. *Issues Affecting Adoption of Natural Gas Fuel in Light- and Heavy-Duty Vehicles*, PNNL-19745. Richland WA: Pacific Northwest National Laboratory, September 2010. www.pnl.gov/main/publications/external/technical_reports/PNNL-19745.pdf.

13 Municipal Refuse Hauling Contracts

Municipalities have the ability to include provisions in their bid specifications to mandate the use of compressed natural gas (CNG) vehicles. However, numerous factors covered in the section **CNG Assessment – Municipalities that Contract out Refuse Services** should be considered to avoid a bias towards one particular bidder that is in a significantly better position to switch to CNG than others (i.e. the fueling station is much more convenient for it than other bidders, it has already converted to CNG while others have not, or only one fleet is in a position to buy new CNG vehicles because the other bidders recently bought new refuse vehicles). If this is the case, then the bid specification can be set up to support CNG use (establishing a CNG fueling option and preliminarily setting up a long-term fueling agreement), but not mandate it. Because of the favorable economics in using CNG, the lowest bid will likely be submitted by the refuse service provider with these alternatively fueled vehicles.


TOWN OF SMITHTOWN
SUFFOLK COUNTY
NEW YORK

PARTIAL COPY
Section 4 Methods of Collection
CNG Mandate

SPECIFICATIONS FOR
BID NO. 06-067
RESIDENTIAL SOLID WASTE COLLECTION AND DISPOSAL FOR THE TOWN OF SMITHTOWN AND INCORPORATED VILLAGE OF THE BRANCH WITH COMPRESSED NATURAL GAS (CNG) FUELED VEHICLES
FOR THE TERM
2007 THRU 2013

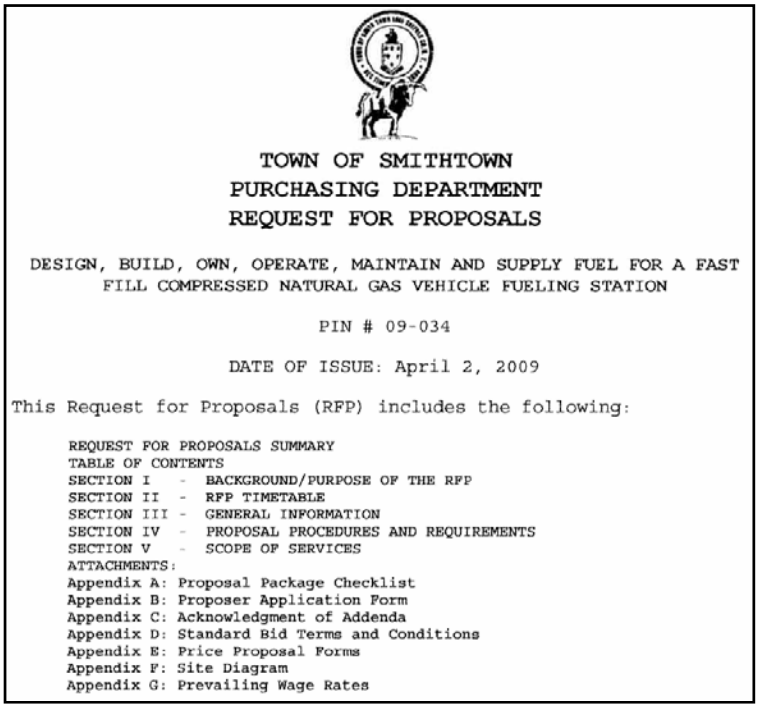
Figure 17. Smithtown bid specification cover for refuse collection mandating compressed natural gas vehicles (Smithtown 2006).

If the municipality chooses to issue a bid specification with a CNG mandate, it is recommended that the title itself clearly indicates that CNG vehicles are required. Because this will likely be a significant change for the refuse service providers to comply with from when the bid specification was previously issued, clearly specifying the use of CNG refuse vehicles from the start will hopefully reduce the number of proposals received that are noncompliant with the requirement. Smithtown's most recent bid specification title shown in Figure 17 reflects this. Within the bid specification, the CNG mandate is written as the first requirement in the collection vehicle specification section as follows:

> "All collection vehicles shall be model year 2006 or newer and shall be EPA-certified to emission standards of 1.4 grams NOX and 0.01 grams Particulates. All collection vehicles used in providing services pursuant to this contract, including spares, shall use compressed natural gas (CNG) fuel." (Smithtown 2006)

Smithtown secured a CNG fueling agreement with an independent fuel provider that was under contract to operate a station in the area that would support CNG refuse trucks under contract with the town. The address of the station and contact for the fuel provider was listed for prospective bidders to evaluate the impact of fueling at this location for their bid response and if they wanted

further information on the station or its capabilities. By negotiating a long term fueling agreement with the fuel provider prior to releasing the bid specification for the refuse services, Smithtown was able to list the guaranteed not to exceed fuel prices that it secured. This removed a significant unknown factor that prospective bidders would have typically had to account for in their response, and may have even included a contingency clause to account for unreasonably high increases in fuel costs during the contract period. The request for proposal for the new CNG station, shown in Figure 18, is available upon request.



TOWN OF SMITHTOWN
PURCHASING DEPARTMENT
REQUEST FOR PROPOSALS

DESIGN, BUILD, OWN, OPERATE, MAINTAIN AND SUPPLY FUEL FOR A FAST FILL COMPRESSED NATURAL GAS VEHICLE FUELING STATION

PIN # 09-034

DATE OF ISSUE: April 2, 2009

This Request for Proposals (RFP) includes the following:

REQUEST FOR PROPOSALS SUMMARY
TABLE OF CONTENTS
SECTION I - BACKGROUND/PURPOSE OF THE RFP
SECTION II - RFP TIMETABLE
SECTION III - GENERAL INFORMATION
SECTION IV - PROPOSAL PROCEDURES AND REQUIREMENTS
SECTION V - SCOPE OF SERVICES
ATTACHMENTS:
Appendix A: Proposal Package Checklist
Appendix B: Proposer Application Form
Appendix C: Acknowledgment of Addenda
Appendix D: Standard Bid Terms and Conditions
Appendix E: Price Proposal Forms
Appendix F: Site Diagram
Appendix G: Prevailing Wage Rates

Figure 18. Smithtown compressed natural gas station request for proposals

Also included in the Smithtown specification was a clause that the contractors were under no obligation to purchase CNG fuel from the fuel provider that had a long-term fuel agreement with the town. It was possible to include this because the fuel provider was upgrading an existing CNG station to support the CNG refuse vehicles, which meant less investment costs. This specification was published at a time when fuel providers were more willing to take a risk on station investments to promote and encourage this alternative fuel. Depending on the situation (i.e., using an existing station) and the terms of the long-term fuel agreement, it may be possible to include this clause in other bid specifications, which is very favorable for prospective bidders. However, most fuel providers today are not willing to make a large investment into a station unless they have a minimum guaranteed CNG throughput for a set number of years to recoup their costs. If the fuel agreement has this stipulation, then a modified clause that does not require the prospective bidder to use the negotiated fuel agreement may be necessary. But, if they do choose to use it, then they are obligated to use it for all their vehicles for the duration of the contract. This would allow flexibility in the prospective bidder's decision to use the negotiated fuel agreement initially, but once a decision is made one way or another, then the bidder must stick with it. That would prevent the refuse fleet from building its own CNG fueling station midway through the contract before the town fulfills its obligation to the fuel provider for its investment in a station to support the refuse vehicles. This is also the case if the refuse vehicles are part of a critical mass of CNG usage that is needed to bring in an independent fuel provider.

Further information on Smithtown's experience implementing the CNG mandate for all vehicles contracted to fulfill its refuse services can be found in the **Best Practices - Successful CNG Fleet Deployments in Refuse Applications** section.

14 Best Practices - Successful CNG Fleet Deployments in Refuse Applications

Compressed natural gas (CNG) vehicle program success stories illustrate good fleet deployment approaches and examples of good fleet practices in adopting these vehicles. A few local best practice examples are summarized below and the contact identified is willing to share further advice and information if desired.

Casella Waste Systems (CNG Refuse Fleet)

Casella Waste Systems, Inc, headquartered in Rutland, Vermont, provides solid waste, recycling and resource management services in seven Northeastern states. Casella's operations include seven recycling facilities, 12 disposals facilities, 31 collection operations, and 29 transfer stations and a fleet of more than 800 vehicles including 25 CNG refuse trucks. Locations in Upstate New York include Dunkirk, Olean, Elmira, Newfield, Geneva, Oneonta, Lowville, Potsdam, Malone, Plattsburg, and Fort Edward.

Figure 19. Autocar dedicated CNG refuse trucks with Cummins-Westport ISL G CNG engines in front and side-loader configurations.

As part of their Sustainable Environmental and Economic Development program, Casella implemented Vermont's first CNG refuse vehicle fleet. In addition to its belief that using a domestically produced fuel is the right thing to do for our country, CNG trucks fit well within Casella's strategy to tie economic and environmental models together to create value for its customers. A transition to a CNG fleet meets Casella's business goals by providing positive investment returns and reduced fuel cost volatility. CNG also provides a proven technology that meets the operating standard of a refuse fleet on the road, is quieter than diesel, simplifies repairs and reduces oil change intervals.

To adhere to the U.S. Environmental Protection Agency's (EPA's) new heavy-duty truck standards for 2010, Casella plans to convert approximately 10 percent of its 800 truck fleet to CNG within 3 years. Casella's current fleet includes 3 dual fuel CNG vehicles and 22 dedicated CNG vehicles. The company ordered 16 more dedicated CNG trucks and it has plans to purchase 25 new CNG vehicles in 2013. Casella saves $1,200–$1,500

per month on each truck. Each CNG vehicle will achieve a payback on the incremental cost within two years of service. The new trucks will emit about one-quarter less greenhouse gas and cut emissions by about 95 percent.

Casella received grant funding to support CNG vehicle purchases through the EPA under the Diesel Emissions Reduction Act and the New York State Energy Research and Development Authority.

Casella Waste Systems opened its first CNG fueling station in Chittenden County, Vermont, at its Williston facility. Time-fill CNG stations are now being used at the company's facilities in Geneva and Fort Edward in New York. Casella has contracted for a new station at its Elmira facility. It hopes to install the fueling infrastructure before the winter of 2012, as the company found that installation during cold weather creates issues with moisture and condensation.

Figure 20. Casella Waste Systems time-fill compressed natural gas station for refuse vehicles

The biggest challenge for Casella in switching to CNG was addressing the compliance regulations for its maintenance garage. None of the upgrades completed were too complicated or costly, but it was not clear exactly what was required through the standards. Casella worked closely and early on with the local fire marshal; however, when the company started on a different site, the process was still challenging because it was with a different fire marshal who had a different interpretation of the requirements. Casella found that inspectors who were not familiar with natural gas tended to request that the company incorporate more safety measures than would be required by inspectors who had prior knowledge of natural gas vehicles. For every location where CNG vehicles were introduced and facility upgrades were necessary, Casella found it necessary to get outside assistance, such as independent consultants or professional engineers, to assist with regulation compliance requirements.

Peter Vanderhoof, Fleet Manager
802-772-2234 | Peter.Vanderhoof@Casella.com

Waste Management (CNG Refuse Fleet)

Waste Management, Inc., based in Houston, Texas, is a provider of comprehensive waste management services in North America. Through its subsidiaries, the company provides collection, transfer, recycling and resource recovery, and disposal services. It is one of the largest residential recyclers and also a leading developer, operator, and owner of waste-to-energy and landfill gas-to-energy facilities in the United States. The company's customers include residential, commercial, industrial, and municipal customers throughout North America.

With 30,000 collection and support vehicles on the road throughout North America, Waste Management is committed to reducing the environmental impacts of these vehicles. Waste Management is a national leader in the use of alternative fuels for heavy-duty trucks, and it is committed to transitioning diesel fleets to CNG. The fleet currently includes more than 1,400 natural gas trucks, the largest of its kind in the waste industry. In 2012, natural gas vehicles will represent 80 percent of the company's annual new truck purchases. Waste Management will continue to replace the fleet with natural gas vehicles and may accelerate replacement through a number of initiatives.

For every truck replaced with natural gas, Waste Management reduces its use of diesel fuel by an average of 8,000 gallons per year, and also achieves a reduction of 22 metric tons of greenhouse gas emissions per year. The vehicles powered by CNG reduce air particulates by up to 90 percent, cut greenhouse gas emissions by nearly 25 percent, and are far quieter than their predecessors. Unlike diesel, most natural gas is produced domestically and provides a great opportunity to stimulate the economy throughout the supply chain. Natural gas vehicles are also easier to maintain and weigh less than their new diesel truck equivalents. They can also use biomethane from landfill gas, sewage treatment facilities, and dairies, which can reduce greenhouse gas emissions by more than 85 percent.

Figure 21. Waste Management's compressed natural gas refuse truck

Figure 22. Waste Management time-fill compressed natural gas station in Chicago

Waste Management is constructing its own fueling stations. It owns the stations, purchases the fuel, and finances the construction of the stations. The company also enters into maintenance contracts for some stations with third-party companies. Waste Management believes this strategy allows it to secure better prices in the long run. To optimize costs, its preferred platform for these stations is to time-fill the trucks according to a set schedule. For public access fueling stations, which serve both commercial and consumer vehicles, Waste Management installs fast-fill capability. Waste Management operates 28 fueling stations in North America and intends to have nearly 50 in operation by the end of 2012.

In 2007, as part of its corporate sustainability goals, Waste Management committed to increasing its fleet's fuel efficiency by 15 percent and reducing fleet emissions by 15 percent by 2020. Achieving this goal by 2020 will yield significant benefits including an estimated savings of the following:

- 350 million gallons of fuel
- 3.5 million metric tons of carbon dioxide emissions
- $1 billion in operational costs

Complementing its own internal efforts to improve its fleet, Waste Management is working collaboratively with others to promote progress across all sectors. This includes supporting increased fuel efficiency for heavy-duty trucks. Through its participation in Securing America's Future Energy, a non-partisan organization that seeks to reduce America's dependency on oil, Waste Management supported provisions that became a law in the Energy Independence and Security Act of 2007. This legislation will require a study of ways to increase the efficiency of work trucks and promulgate regulations that will increase their fuel efficiency. Waste Management also supported provisions in the Senate's climate change bill of 2008 that would have provided rebates to purchasers of heavy-duty hybrid trucks that use less fuel than conventional trucks.

Smithtown (Contracts out refuse services mandating CNG)

Smithtown, New York, was the first town outside of California to require its private refuse fleet to be 100 percent CNG-fueled. The rising cost of contracted refuse services, primarily due to the increased diesel fuel costs, caused the town to evaluate its fleet fueling options. While the economics from more stable CNG prices was the primary driver to use CNG, Smithtown officials welcomed the environmental benefits that would be associated with new CNG trucks replacing the aging diesel refuse fleet. In 2006, the town developed a mechanism for municipality purchasing process to support CNG use in refuse vehicles through private refuse carriers.

Smithtown first secured a contract with a fuel supplier to agree to put in a station if a CNG refuse service bid was awarded. The town negotiated a fixed price for fuel to eliminate the uncertainty for contractors. After researching CNG extensively, visiting organizations that were already using CNG in refuse applications, and testing its own bi-fuel pickup truck, Smithtown decided to make a full commitment to CNG. The town issued bid specifications requiring 100 percent CNG power for refuse contracts in 2006 and CNG vehicle service started in January 2007. Prior to the bid specifications being issued, prospective bidders expressed concerns and tried to get Smithtown to remove the CNG mandate. However, after reviewing the specifications that were issued and understanding the advantages the town gained through the fuel agreement they secured, a greater number of responses were received for the CNG mandated bid than for the previous refuse service bids, which did not have a CNG mandate. Refuse fleets in the area quickly realized the benefit that CNG provides through the reduced risk due to fuel price stability, and many started using CNG vehicles even when not mandated to do so.

Today, Smithtown's refuse service is carried out by 22 CNG trucks operated by private haulers and supplemented by two municipality owned CNG vehicles for special pick-ups. The dedicated CNG refuse vehicles operating in the town include the following:

- Autocar Xpeditor : Cummins Westport Inc. (CWI) L Gas Plus engine, FAB Industries roof mounted fuel system
- Crane Carrier LET2: CWI L Gas Plus engine, Dynetek Industries pedestal mounted fuel system
- Kenworth T440: CWI ISL G engine, pedestal mounted fuel system

Figure 23. Smithtown 2010 Kenworth T440 CNG refuse truck with pedestal mount fuel system

From 2007–2010, the fleet used a Clean Energy operated public access CNG fueling station at the New York State Office of General Services facility in Hauppauge, New York. In 2010, an additional fueling station in Smithtown was installed at the Smithtown Municipal Services Facility in Kings Park, New York through a bid award to support refuse vehicles in Smithtown and the Town of Huntington. The Town of Huntington wanted to replicate Smithtown's CNG mandate but did not have a public fueling option or the appropriate property to put in a station. This unique collaboration between two municipalities created the demand for another CNG station that both could benefit from. This site, which is also owned operated and maintained by

Clean Energy, supported the expansion of CNG in Smithtown's own fleet and the fuel throughput was sufficient to attract bids from three fuel providers. An extended 15-year fuel agreement was used to spread out the cost of the initial investment for the station construction and lower costs for the townships and the private carters contracting with the towns.

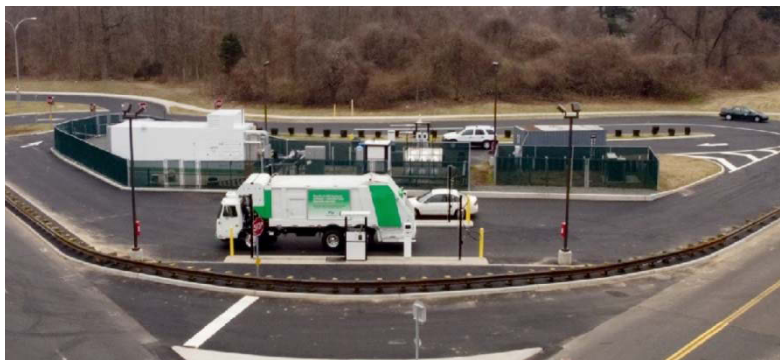


Figure 24. Hauppauge fast-fill compressed natural gas station

Smithtown's Town Supervisor, Patrick R. Vecchio, estimated that over the seven-year life of the town's refuse hauling contract, a CNG fleet would reduce costs, give the residents cleaner air, and eliminate the need for more than 1.5 million gallons of diesel fuel. The fleet reduced the town's dependence on foreign petroleum products by the equivalent of nearly 200,000 gallons of gasoline and diesel fuel in 2010. The Town Supervisor estimates that CNG is providing Smithtown with savings of approximately $3 per home per year as compared to using diesel fuel. Employees who work on the CNG vehicles have been very pleased with their performance and the mechanics were very glad to have an opportunity to gain knowledge and experience with an alternative fuel. The contractor's drivers are satisfied with the performance, the noise reduction is an added benefit for the operators, and the personnel who ride on the back of the trucks are glad not to be breathing diesel fumes all day.

Since the introduction of the Smithtown CNG refuse fleet, other CNG vehicles have been purchased by the Smithtown Municipality, including the following:

- Freightliner M2 dump/plow trucks, some of the first acquired were powered by a John Deere CNG engine, more recent acquisitions have the CWI ISL G engine
- International dump/plow trucks repowered with an Emissions Solutions Phoenix engine
- Seven Honda Civic GX Sedans
- Schwarze M6000 Street Sweeper

Smithtown's "CNG Champion," Russell Barnett, has supported the use of CNG for refuse services in numerous other municipalities throughout North America. With the adjacent townships of Brookhaven and Huntington awarding CNG refuse service contracts, just under 1 million people in this part of Long Island receive refuse collection exclusively by CNG vehicles. Based on his experience, Russell recommends that municipalities and fleets considering CNG should not extend beyond their core capabilities when implementing a CNG vehicle program. There is a competitive environment in the CNG industry and there are plenty of third-party organizations ready to compete for the opportunity to provide equipment and services.

Russell K. Barnett, Director of Smithtown Environment & Waterways
631-360-7514 | rkbarnett@optonline.net

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List of Appendices

Disclaimer: The lists contained in this guidebook are for informational purposes only, and are not intended to be comprehensive. The reader is encouraged to review all available source material before making any purchase decisions about natural gas vehicles or equipment.

Appendix A. *CNG Vehicles for Fleet Applications*

Disclaimer: The lists contained in this guidebook are for informational purposes only, and are not intended to be comprehensive. The reader is encouraged to review all available source material before making any purchase decisions about natural gas vehicles or equipment.

Residential Collection

Autocar Xpeditor ACX

Engine
Cummins Westport ISL G, ISX12 G
Transmission
Allison 4500 Rugged Duty Series automatic
Chassis GVWR
60,000 lbs
Website
www.autocartruck.com/Voc/Files/Media/ACbrochpumper.pdf

Photo courtesy of Autocar

Crane Carrier Company COE2

Engine
Cummins Westport ISL G
Transmission
Allison 3000, 3500, 4000, or 4500 Rugged Duty Series automatic
Chassis GVWR
Class 6, 7, or 8 weight rating
Website
www.cranecarrier.com

Photo courtesy of Crane Carrier Company

Crane Carrier Company LET2 & LETCC

Engine
Cummins Westport ISL G
Cummins Westport ISX12 G
Transmission
Allison 3000, 3500, 4000, or 4500 Rugged Duty Series automatic
Chassis GVWR
Class 6, 7, or 8 weight rating
Website
www.cranecarrier.com

Photo courtesy of Crane Carrier Company

International LoadStar

Engine
Cummins Westport ISL G
Transmission
Allison 3000, 4000, or 4500 Rugged Duty Series automatic
Chassis GVWR
Up to 66,000 lbs.
Website
www.internationaltrucks.com/trucks/trucks/series/loadstar


Photo courtesy of Navistar

Mack TerraPro Cabover

Engine
Cummins Westport ISL G
Cummins Westport ISX12 G
Transmission
Allison 3000 or 4000 Rugged Duty Series
Chassis GVWR
66,000 lbs.
Website
www.macktrucks.com/default.aspx?pageid=49


Photo courtesy of Mack Trucks

Mack TerraPro Low Entry

Engine
Cummins Westport ISL G
Cummins Westport ISX12 G
Transmission
Allison 3000 or 4000 Rugged Duty Series
Chassis GVWR
66,000 lbs.
Website
www.macktrucks.com/default.aspx?pageid=49


Photo courtesy of Mack Trucks

Peterbilt 320

Engine
Cummins Westport ISL G, ISX12 G
Transmission
Fuller Manual / Allison Automatic
Chassis GVWR
Class 7 or 8 weight rating
Website
www.peterbilt.com/voc320.1.aspx


Photo courtesy of PACCAR

Roll-off/Dumpster Transport

Freightliner M2 112

Engine
Cummins Westport ISL G
Transmission
Eaton Manual / Fuller Automatic / Allison Automatic
Chassis GVWR
Up to 62,000 lbs.
Website
www.freightlinertrucks.com/Trucks/Alternative-Power-Trucks/Natural-Gas/M2-112-NG


Photo courtesy of Daimler

Freightliner 114 SD

Engine
Cummins Westport ISL G
Transmission
Allison 3000 Automatic
Chassis GVWR
Up to 62,000 lbs.
Website
www.freightlinertrucks.com/Trucks/Alternative-Power-Trucks/Natural-Gas/114SD-NG


Photo courtesy of Daimler

International DuraStar

Engine
NGV Moteri 7.7 DT466
Transmission
Allison 3000 Automatic
Chassis GVWR
Up to 32,000 lbs.
Website
www.internationaltrucks.com/StaticFiles/internationalTrucks/pdf/cng/durastar_cng.pdf


Photo courtesy of Navistar

Kenworth T440

Engine
Cummins Westport ISL G
Transmission
Allison Highway Series or Rugged Duty Series automatic
Chassis GVWR
33,000 to 68,000 lbs.
Website
www.kenworth.com/trucks/t440.aspx


Photo courtesy of PACCAR

Kenworth T470

Engine
Cummins Westport ISL G, ISX12 G
Transmission
Allison Highway Series or Rugged Duty Series automatic
Chassis GVWR
33,000 to 68,000 lbs.
Website
www.kenworth.com/trucks/t470.aspx

Photo courtesy of PACCAR

Peterbilt 365

Engine
Cummins Westport ISL, G ISX12 G
Transmission
Fuller Manual / Fuller Automatic / Allison Automatic
Chassis GVWR
Class 7-8 weight rating
Website
www.peterbilt.com/voc365.1.aspx

Photo courtesy of PACCAR

Appendix B. *CNG System Manufacturers and Pennsylvania Dealers*

Engine OEMs

Cummins Westport Inc.

Cummins Westport Inc. designs, engineers, and markets 6 to 12 liter spark-ignited automotive natural gas engines for commercial transportation applications such as truck and buses. The dedicated 100 percent natural gas engines are manufactured by Cummins and available as a factory-direct option from leading truck and bus manufacturers.

Website www.powersystems.cummins.com

Contact Geoffrey S. Ruch, Vice President, Engine Business
Cummins Power Systems, LLC
(215) 785-6005 x21001 | geoffrey.s.ruch@cummins.com

Chassis OEMs

Autocar

Autocar is focused on building and supporting Class 8 LCF trucks with innovations like improved ergonomic cabs, integrated controls, and an advanced body-chassis interface. Autocar also has exclusive agreements to use Cummins engines and Allison transmissions, and a nationwide service network that now includes Cummins distributorships.

Website www.autocartruck.com

PA Dealer	*Dealer Website*	*Contact Information*
River's Truck Center, Inc. 2975 Cape Horn Road Red Lion, PA 17356	riverstruck.com	800-930-4903

Crane Carrier

Since 1953, Crane Carrier has been a major producer of custom-engineered heavy-duty Class 8, diesel and alternate fueled truck chassis. Crane Carrier is a leading manufacturer of custom vehicles for heavy truck, refuse collection, mobile drill rig, terminal tractors, OEM and various other demanding on & off highway vocational applications.

Website www.cranecarrier.com

Contact Freddie Payne - 918-519-4569 | fpayne@cranecarrier.com

PA Dealer	*Dealer Website*	*Contact Information*
Trans Edge Truck Center 1501 Beaver Ave	www.transedgetruck.com	888-284-0083

Pittsburgh, PA 15233

Freightliner

Freightliner Trucks is the largest division of Daimler Trucks North America. Freightliner manufactures Class 5-8 trucks that serve a wide range of commercial vehicle applications.

Website www.freightlinertrucks.com/Trucks/Alternative-Power-Trucks/Natural-Gas

Contact Robert Carrick, Vocational Sales Manager — Natural Gas
503-745-2888 | Robert.Carrick@Daimler.com

PA Dealer	*Address*	*Phone Number*
Eck's Garage, Inc.	3074 Lycoming Mall Drive Muncy, PA 17756	800-441-1353
Freightliner of Altoona	424 Kuhn Ln. Duncansville, PA 16635	888-922-2309
Freightliner of Harrisburg	4303 Lewis Road Harrisburg, PA 17111	800-871-1935
Murrays Freightliner Sterling Western Star	1844 Rich Highway Du Bois, PA 15801	888-371-9707
Freightliner of Lancaster	1675 Rohrerstown Road Lancaster, PA 17601	800-769-9887
Sherwood Freightliner, Sterling & Western Star, Inc.	5578 Sr 6 Tunkhannock, PA 18657	800-490-8323
Berman Freightliner	83 Ashley Way Leesport, PA 19533	800-554-6937
Freightliner of Latrobe	3690 Route 30 Latrobe, PA 15650	800-922-2309
Sherwood Freightliner, Sterling & Western Star, Inc.	107 Monahan Avenue Dunmore, PA 18512	800-810-7447
Horwith Freightliner	1449 Nor Bath Blvd. Northampton, PA 18067	800-220-8807
FYDA Freightliner Barkeyville	5758 State Route 8 Harrisville, PA 16038	800-218-7827
FYDA Freightliner Pittsburgh, Inc.	20 Fyda Drive Canonsburg, PA 15317	800-393-2556
Freightliner of Philadelphia	11 Runway Road Levittown, PA 19057	866-788-8587

Kenworth

Kenworth, a PACCAR company, offers heavy-duty trucks for the vocational and over-the-road markets in Classes 5 through 8.

Website www.kenworth.com

PA Dealer	*Address*	*Phone Number*
Coopersburg Kenworth	1930 Route 309 Coopersburg, PA 18036	610-282-4500
Kenworth of Pennsylvania - Carlisle	198 Kost Road Carlisle, PA 17013	717-766-8000

Kenworth of Pennsylvania - Clintonville	4054 State Road 308 Clintonville, PA 16372	814-385-1040
Kenworth of Pennsylvania - Dunmore	109 Keystone Industrial Park Dunmore, PA 18512	570-347-5671
Kenworth of Pennsylvania - Lancaster	4030 Old Harrisburg Pike Mount Joy, PA 17552	717-898-2650
Kenworth of Pennsylvania - New Stanton	530 North Center Avenue New Stanton, PA 15672	724-925-5000
Kenworth of Pennsylvania - Pittsburgh	67 Neville Avenue McKees Rocks, PA 15136	412-778-0160
Kenworth of Pennsylvania - Shartlesville	16 Motel Drive Shartlesville, PA 19554	610-488-1660
Kenworth of Pennsylvania-York	755 Vogelsong Road York, PA 17404	717-848-8797

Mack Trucks

Founded in 1900, Mack is one of the largest producers of heavy-duty trucks in North America. Mack, a division of Volvo, offers trucks for the vocational and over-the-road markets.

Website www.macktrucks.com

Contact Curtis Dorwart, Vocational Marketing Product Manager
336-291-9147 | curtis.dorwart@macktrucks.com

PA Dealer	*Address*	*Phone Number*
W. W. Engine and Supply, Inc. Kylertown Division	I-80 Exit 21 Old Kylertown, PA 16847	814-345-5693
W W Engine & Supply Inc. Milesburg Div.	250 Tracey Dale Rd Howard, PA 16841-1470	814-355-0691
W W Engine & Supply Inc. New Stanton Division	2141 Mount Pleasant Rd West Newton, PA 15089-9183	724-872-1200
W W Engine & Supply Inc. Altoona Div.	649 Brush Mountain Rd Altoona, PA 16601-1897	814-742-8055
Transedge Truck Center	1407 Bulldog Dr Allentown, PA 18104-4197	610-395-6801
Pennsylvania Truck Centers Reading	4226 Pottsville Pike Reading, PA 19605-5120	610-929-9433
W. W. Engine and Supply, Inc. Dubois Division	4563 Rockton Rd Du Bois, PA 15801-1567	814-371-2515
W. W. Engine and Supply, Inc. Somerset Div.	178 Lewis Dr Somerset, PA 15501-1107	814-445-9617
P V C Sales and Service	206 Dairy Rd Tamaqua, PA 18252-2551	570-386-5157
Pennsylvania Truck Centers York	310 Mifflin Dr Wrightsville, PA 17368-8919	717-792-2636
W W Engine & Supply Inc. Shippenville Division	20273 Paint Blvd Shippenville, PA 16254-4462	814-226-8920
W. W. Engine and Supply, Inc. Harrisburg Division	4230 Industrial Rd Harrisburg, PA 17110-0295	717-238-6225
Watt's Truck Center, Inc.	8059 State Route 22 New Alexandria, PA 15670-0310	724-668-2201

Tri-County Truck Center	1098 State Route 28 & 66 Kittanning, PA 16201	724-548-1548
Susquehanna Motor Co Inc	370 Old Route 15 West Milton, PA 17886-6005	570-568-6941
Erie Truck Center	3900 Depot Rd Erie, PA 16510-0590	814-898-8396
Triple Cities Mack Parts Store	118 Brown Rd Pittston, PA 18640-0372	800-234-2665
Lesher Mack Sales & Service, Inc.	2700 Cumberland St Lebanon, PA 17042-2256	717-273-4535
W W Engine & Supply Inc. Bedford Division	170 Transport St Bedford, PA 15522-2773	814-623-5191
Bergey's Truck Centers	446 Harleysville Pike Souderton, PA 18964-4219	215-721-3400
Transedge Truck Center	1501 Beaver Ave Pittsburgh, PA 15233-3220	412-237-6000
Transedge Truck Center	247 Route 61 S Schuylkill Haven, PA 17972-2970	570-385-2540
Bergey's Truck Centers	1003 W Ridge Pike Conshohocken, PA 19428-8101	610-825-3333
R & R Inc Of Pa	3015 New Butler Rd New Castle, PA 16101-1323	724-658-4594
Triple Cities Mack	319 Green Ridge St Scranton, PA 18509-9181	570-342-0208

Navistar Inc. (International)

Formed in 1902, International is a leading producer of medium trucks, heavy trucks, severe service vehicles. Their products, parts and services are sold through a network of nearly 1,000 dealer outlets in the United States, Canada, Brazil, and Mexico and more than 60 dealers in 90 countries throughout the world.

Website www.internationaltrucks.com

Contact Stephen Gilligan, Vice President, Product and Vocational Marketing, Navistar
331-332-5000 | stephen.gilligan@navistar.com

PA Dealer	***Address***	***Phone Number***
Five Star International	2751 Mccoy Street Williamsport, PA 17701	855-287-8481
Noerr's International	700 US Highway 22 Lewistown, PA 17044	855-313-1966
Allegheny Trucks, Inc.	49A Greenwood Road Altoona, PA 16602	855-297-7451
Five Star International LLC	1810 S. 19Th Street Harrisburg, PA 17104	855-314-8967
Kovatch Mobile Equipment	44 Mountain Avenue Nesquehoning, PA 18240	855-287-9443
Five Star International LLC	1846 North 5Th Street Reading, PA 19612	855-293-7081
Stadium International Sales and Service, LLC	1006 Underwood Road Scranton (Olyphant), PA 18447	855-288-3455
Lowe & Moyer Garage	731 CHURCH ST FOGELSVILLE, PA 18051	855-294-3782

Five Star International, LLC	1294 Strickler Rd. Mount Joy, PA 17552-8889	855-314-8966
Five Star International, LLC	1294 Stricker Road Mt Joy, PA 17552	855-313-2690
Five Star International LLC	2818 W. Market Street York, PA 17404	855-313-7780
Zacherl Motor Truck Sales, Inc.	795 Greenville Pike Clarion, PA 16214	855-332-1017
Tri-County Motor Sales	1575 Ferndale Ave Johnstown, PA 15905	855-297-6460
Five Star International, LLC	2131 Hanover Ave. Allentown, PA 18109	855-294-4051
Hunter Truck Sales & Service, Inc.	101 East Main Street Eau Claire, PA 16030	855-320-7571
Del-Val International Trucks	1034 Bethlehem Pike (Rte. 309) Montgomeryville, PA 18936	855-242-0010
G.L. Sayre, Inc.	1231 W. Ridge Pike Conshohocken, PA 19428	855-293-7077
Hunter Truck Sales & Service, Inc.	519 Pittsburgh Rd Butler, PA 16002	855-317-9266
Bucks County International, Inc.	134 Old Oxford Valley Road Langhorne, PA 19047	855-252-8944
Hunter Truck Sales, Inc.	4637 Campbell's Run Road Pittsburgh, PA 15205	855-276-1502
Hill International Trucks N.A., LLC	300 Alton Hill Drive Eighty Four, PA 15330	855-317-7881
Hunter Truck Sales, Inc.	100 Hunters Way Smithfield, PA 15478	855-317-9245
Five Star International, LLC	6100 Wattsburg Road Erie, PA 16509	855-297-7436

Peterbilt

Based in Denton, Texas, Peterbilt Motors Company combines world renowned design, innovative engineering and fuel efficiency solutions, with superior quality to build a custom-engineered truck that stands as the "Class" of the industry.

Website www.peterbilt.com

Contact Steve Weiner
940-594-9651 | Steve.Weiner@PACCAR.com

PA Dealer	*Address*	*Phone Number / Website*
Pocono Peterbilt	1328 Golden Slipper Road Bartonsville, Pennsylvania 18321	570-688-2400 www.poconopeterbilt.com
Hunter Keystone Peterbilt	9981 Old Route 22 Breinigsville, Pennsylvania 18031	610-285-2244 www.huntertrucksales.com
Hunter Peterbilt	519 Pittsburgh Road Butler, Pennsylvania 16002	724-586-7744 www.huntertrucksales.com/butler.php
G. L. Sayre Peterbilt, Inc.	1231 West Ridge Pike Conshohocken, Pennsylvania 19428	610-277-2000 www.glsayretrucks.com

Hunter Peterbilt	101 E Main — PO Box H Eau Claire, Pennsylvania 16030	724-791-2525 www.huntertrucksales.com
Hunter Erie Peterbilt	8125 Wattsburg Road Erie, Pennsylvania 16509	814-825-3330 www.huntertrucksales.com/erie.php
Hunter Keystone Peterbilt	1463 Manheim Pike Lancaster, Pennsylvania 17601	717-299-6630 www.huntertrucksales.com/lancaster.php
Hunter Peterbilt	100 Hunter's Way Smithfield, Pennsylvania 15478	724-564-4292 www.huntertrucksales.com/smithfield.php

Appendix C. *Local Utilities in Pennsylvania*

Columbia Gas of Pennsylvania

Columbia Gas of Pennsylvania is one of the seven energy companies associated with NiSource Inc. It serves more than 419,000 customers in 26 counties throughout Pennsylvania. It mostly operates in western Pennsylvania, but it does have some customers in the outer lying counties of southeastern Pennsylvania.

Website https://www.columbiagaspa.com

Contact New Business Line

Phone 1-888-460-4332

PECO Gas (Exelon Corporation)

PECO is an electricity and natural gas utility subsidiary of the Exelon Corporation based in Philadelphia, PA. It provides electricity to approximately 1.6 million customers using 500 power substations and 29,000 miles of distribution and transmission lines. It provides natural gas to more than 500,000 customers using 31 gas gate stations and 6,600 miles of underground gas mains. PECO services about 2,100 square miles of southeastern Pennsylvania.

Website https://www.peco.com

Contact Mr. Dane Stokes

Phone (215) 841-5304

Email Dane.stokes@exeloncorp.com

Philadelphia Gas Works (PGW)

Philadelphia Gas Works (PGW) is a natural gas utility company servicing Philadelphia, PA. It is the largest municipally owned gas utility in the nation. It delivers 78 billion cubic feet of natural gas to 500,000 customers annually, utilizing over 6,000 miles of gas mains and service pipes.

Website http://www.pgworks.com

Contact Ms. Caroline McCallum

Phone (215) 684-6701

Email caroline.mccallum@pgworks.com

UGI Utilities, Inc.

UGI Utilities, Inc. is a natural gas and electricity utility servicing 660,000 customers in 45 counties in Pennsylvania and one county in Maryland. UGI Utilities, Inc. and its wholly owned subsidiary UGI Central Penn Gas provide natural gas service to southeastern Pennsylvania.

Website http://www.ugi.com/portal/page/portal/UGI/Business_Gas/NGV

Phone UGI Utilities, Inc. (Gas)
800-276-2722

UGI Central Penn Gas
800-652-0550

UGI Penn Natural Gas
800-276-2722

Peoples Natural Gas Company

Peoples provides natural gas service to approximately 700,000 homes and businesses in western Pennsylvania, West Virginia and Kentucky.

Website http://www.peoples-gas.com/NaturalGasVehicles.aspx

Contact Lutitia Clipper, PhD

Phone 412-244-2583

National Fuel Gas Distribution, Pennsylvania Division

National Fuel Gas Distribution Corporation sells or transports natural gas to more than 732,000 customers through a local distribution system located in western New York and northwestern Pennsylvania.

Website http://www.natfuel.com/Default.aspx

Contact Mr. Paul White

Phone 716-827-2345

Valley Energy

Valley Energy is an investor owned company regulated by the Pennsylvania Public Utility Commission and the New York Public Service Commission. Service is provided to 11 communities in Bradford County, Pennsylvania and Chemung and Tioga Counties in New York. Natural gas is supplied to more than 8,000 residential, commercial and industrial customers through a 165-mile pipeline distribution system.

Website http://www.valley-energy.com/index.htm

Contact Mr. Ed Rogers

Phone 570-888-9664

Appendix D. *Vendors for Natural Gas Equipment and Services*

Equipment Providers

Name	Location	Phone	Website
ANGI Energy Systems	Wisconsin	800-955-4626	www.angienergy.com
Air& Gas Technologies	New Jersey	800-716-5550	www.airgastech.com
Cobey Energy	New York	716-362-9550	www.cobey.com
Quantum Technologies	California	404-977-8374	www.qtww.com

Fuel Providers

Name	Location	Phone	Website
Hess	New York	212-997-8500	www.hess.com
American Natural Gas	New York	631-293-4700	www.americannaturalgas.com
Sprague Energy	New Hampshire	800-225-1560	www.spragueenergy.com

Infrastructure Providers

Name	Location	Phone	Website
Air& Gas Technologies	New Jersey	203-374-1795	www.airgastech.com
American Natural Gas	New York	866-264-6220	www.americannaturalgas.com
ANGI Energy Systems	Wisconsin	800-955-4626	www.angienergy.com
Beavers Petroleum	New York	607-739-1790	www.beaverspetroleum.com
Clean Energy Fuels Corp	California	562-493-2804	www.cleanenergyfuels.com
Clean Fuel Connection, Inc.	California	888-890-4638	www.cleanfuelconnection.com
CNG Source, Inc.	Pennsylvania	814-673-4980	www.cngsource.com
CNGasGroup	Florida	866-403-0102	www.cngasusa.com
Cobey Energy	New York	716-362-9550	www.cobey.com
Integrys/Trillium	Utah	800-920-1166	www.trilliumusa.com
P.C. McKenzie Company	Pennsylvania	877-244-4883	www.mckenziecorp.com
TruStar Energy	California	909-793-3700	www.trustarenergy.com

Other Contacts

Name	Location	Phone	Website
Agility Fuel Systems	California	949-236-5520	www.agilityfuelsystems.com
Chautauqua Energy Management	New York	716-326-4977	www.cemny.com
Clean Vehicle Solutions	New Jersey	800-495-2270	www.cleanvehiclesolutions.com
Cummins Power System, LLC	New York	855-812-2278	www.powersystems.cummins.com
Gannett Fleming	Pennsylvania	717-763-7211	www.gannettfleming.com
North American Equipment Upfitters	New Hampshire / New York	603-624-6288	www.naeuinc.com
Oxford Engineering	New Jersey	856-541-0700	www.oxfordengineering.com
Wendel	New York	716-688-0766	www.wendelcompanies.com

Refuse Body Contacts

Name	Location	Phone	Website
Heil Environmental	Tennessee	866-367-4345	www.heil.com
McNeilus	Minnesota	507-374-6321	www.mcneilusgarbagetrucks.com

Appendix E. *Resources for Additional Information*

Alternative Fuels and Advanced Vehicles Data Center

The Alternative Fuels and Advanced Vehicles Data Center (AFDC) provides information, data, and tools to help fleets and other transportation decision makers find ways to reduce petroleum consumption through the use of alternative and renewable fuels, advanced vehicles, and other fuel-saving measures.

Website www.afdc.energy.gov

America's Natural Gas Alliance

America's Natural Gas Alliance promotes the economic, environmental and national security benefits of greater use of domestic natural gas. The Alliance represents 30 of North America's largest independent natural gas exploration and production companies and the leading developers of the shale plays now transforming the clean energy landscape.

Website www.anga.us

American Clean Skies Foundation

American Clean Skies Foundation (ACSF) was founded in 2007 to advance America's energy independence and a cleaner, low-carbon environment through expanded use of natural gas, renewables and efficiency.

Website www.cleanskies.org

American Gas Association

The American Gas Association (AGA) represents more than 200 companies delivering natural gas to customers. AGA provides information and services promoting efficient demand and supply growth, and operational excellence, in the safe, reliable and efficient delivery of natural gas.

Website www.aga.org

American Trucking Associations

The American Trucking Associations (ATA), founded in 1933, is the largest national trade association for the trucking industry. Through a federation of other trucking groups, industry-related conferences, and its 50 affiliated state trucking associations, ATA represents more than 37,000 members covering every type of motor carrier in the United States.

Website www.trucking.org

American National Standards Institute

The American National Standards Institute (ANSI) oversees the creation, promulgation and use of thousands of norms and guidelines that directly impact businesses in nearly every sector, including natural gas vehicles and infrastructure. ANSI is also actively engaged in accrediting programs that assess conformance to standards – including globally-recognized cross-sector programs such as the ISO 9000 (quality) and ISO 14000 (environmental) management systems

Website www.ansi.org

Clean Cities

Clean Cities is the U.S. Department of Energy's (DOE) flagship alternative-transportation deployment initiative, sponsored by the Vehicle Technologies Program. Clean Cities has saved more than 3 billion gallons of petroleum since its inception in 1993.More than 10,400 stakeholders contribute to Clean Cities' goals and accomplishments through participation in nearly 100 Clean Cities coalitions across the country. Private companies, fuel suppliers, local governments, vehicle manufacturers, national laboratories, state and federal government agencies, and other organizations join together under Clean Cities to implement alternative-transportation solutions in their communities.

Website www.cleancities.energy.gov

Contacts

Position	Name	Phone Number	E-mail/Website
National Clean Cities Director	Dennis A. Smith	202-586-1791	dennis.a.smith@ee.doe.gov
Mid-Atlantic Region	Darren Stevenson	412-386-4726	darren.stevenson@netl.doe.gov
Eastern Pennsylvania Alliance for Clean Transportation	Tony Bandiero	215-990-8200	www.ep-act.org
Pittsburgh Region Clean Cities	Rick Price	412-418-4594	www.pgh-cleancities.org

CNG Now

CNG Now is a leading internet site for information, news, and blogs advocating the use of compressed natural gas.

Website www.cngnow.com

Clean Vehicle Education Foundation

The Clean Vehicle Education Foundation coordinates and implements a variety of public awareness, education, market research, codes and standards and technology programs at the national level. The Clean Vehicle Education Foundation activities help achieve national goals of cleaner air, reduced dependence on imported oil and accelerated development and deployment of alternative fuel vehicles.

Website www.cleanvehicle.org
Douglas Horne, President | dbhorne@cleanvehicle.org

Energy Information Administration

The U.S. Energy Information Administration (EIA) collects, analyzes, and disseminates independent and impartial energy information to promote sound policymaking, efficient markets, and public understanding of energy and its interaction with the economy and the environment.

Website www.eia.gov

Environmental Protection Agency

The mission of the Environmental Protection Agency (EPA) is to protect human health and the environment by regulating air pollution from motor vehicles, engines, and the fuels used to operate them, and by encouraging travel choices that minimize emissions. These "mobile sources" include cars and light trucks, heavy trucks and buses, nonroad engines, equipment, and vehicles. EPA also has authority over natural gas conversion kits, and maintains a listing of kits that are approved for sale in the United States.

Website www.epa.gov/otaq

National Alternative Fuels Training Consortium

The National Alternative Fuels Training Consortium (NAFTC) is a pioneer and national leader in developing, managing, and promoting programs and activities that desire to cure America's addiction to oil, lead to energy independence, and encourage the greater use of cleaner transportation. The NAFTC is the only nationwide alternative fuel vehicle and advanced technology vehicle training organization in the United States.

Website www.naftc.wvu.edu

National Fire Protection Association

The mission of the National Fire Protection Association (NFPA) is to reduce the worldwide burden of fire and other hazards on the quality of life by providing and advocating consensus codes and standards, research, training, and education. NFPA develops, publishes, and disseminates more than 300 consensus codes and standards intended to minimize the possibility and effects of fire and other risks.

Website www.nfpa.org

National Institute for Automotive Service Excellence

The non-profit National Institute for Automotive Service Excellence (ASE) works to improve the quality of vehicle repair and service by testing and certifying automotive professionals. Auto technicians and other professionals who want to become ASE certified can take one or more of ASE's 40-plus exams. The Alternate Fuels Certification Test (F1) is used to identify and recognize those Technicians who can demonstrate knowledge of the skills necessary to diagnose, service, and repair compressed natural gas vehicles. The Compressed Natural Gas Vehicle (F1) test contains 55 scored questions on vehicle inspection, equipment installation, leak testing and repairs, emissions, system diagnosis, maintenance and repair, and cylinder safety. Technicians must retest every five years to retain their certification. The Alternate Fuels CNG Vehicle recertification test (F1R) is about half as long as the initial certification test.

Website www.ase.com

NaturalGas.org

Naturalgas.org is presented as an educational website covering a variety of topics related to the natural gas industry. The purpose of this website is to provide visitors with a comprehensive information source for topics related to natural gas, and present an unbiased learning tool for students, teachers, industry, media, and government.

Website www.naturalgas.org

Natural Gas Vehicle Journal

The Natural Gas Vehicle Journal (NGVJournal) is the new portal of NGV Communications Group. It presents the latest news on the NGV industry, multimedia content, statistics and all the journalistic material produced by the Group, in addition to their institutional data and contact information.

Website www.ngvjournal.com

Natural Gas Vehicles for America

Natural Gas Vehicles for America (NGVAmerica) is a national organization dedicated to the development of a growing, profitable, and sustainable market for vehicles powered by natural gas or biomethane. NGVAmerica represents more than 100 companies, environmental groups, and government organizations interested in the promotion and use of natural gas and biomethane as transportation fuels. NGVAmerica member companies are those that produce, distribute, and market natural gas and biomethane across the country; manufacture and service natural gas vehicles, engines, and equipment; and operate fleets powered by clean-burning gaseous fuels.

Website www.ngvamerica.org

NTEA, the Association for the Work Truck Industry

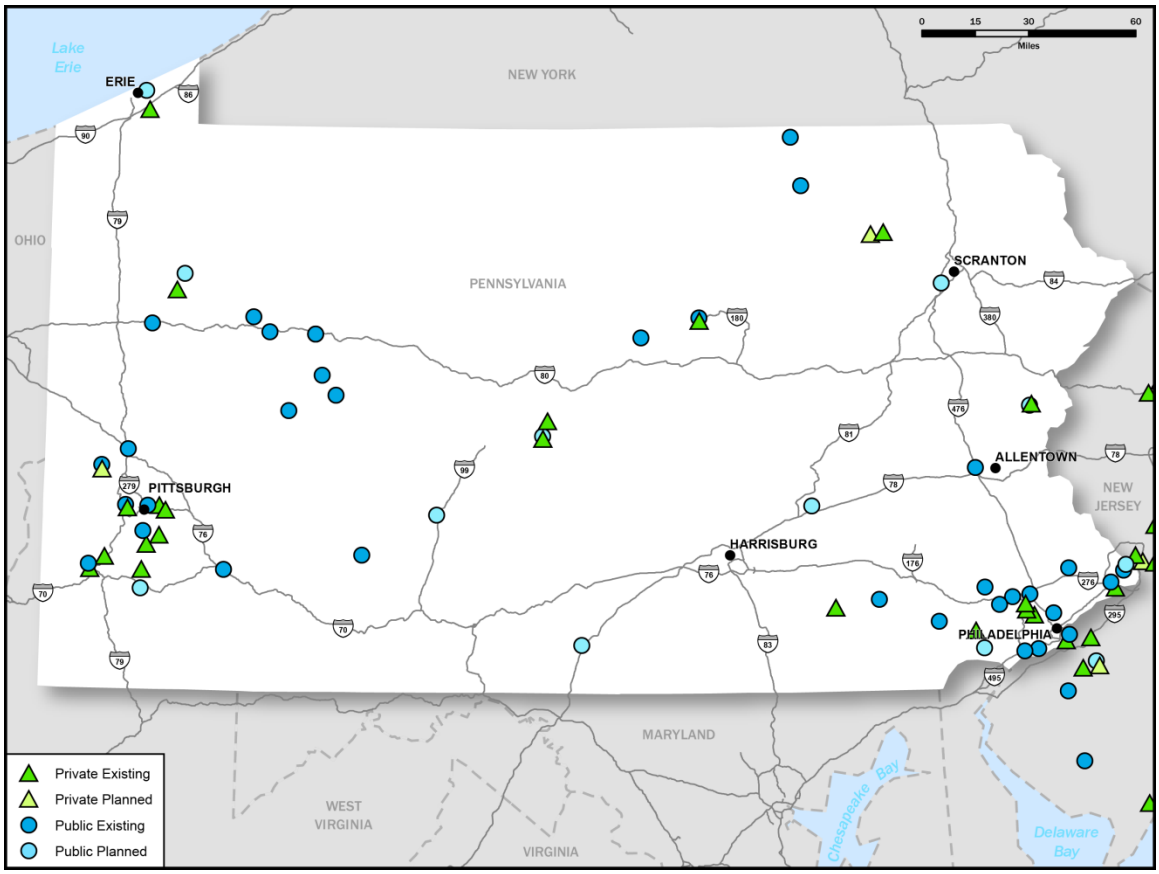
Established in 1964, NTEA, the Association for the Work Truck Industry, represents nearly 1,600 companies that manufacture, distribute, install, sell and repair commercial trucks, truck bodies, truck equipment, trailers and accessories. Buyers of work trucks and the major commercial truck chassis manufacturers also belong to the Association. NTEA provides in-depth technical information, education, and member programs and services, and produces The Work Truck Show. The Association maintains its administrative headquarters in suburban Detroit and a government relations office in Washington, DC.

Website www.ntea.com

Appendix F. *CNG Stations in Pennsylvania*

CNG Stations in Pennsylvania

According to the Department of Energy's Alternative Fuels Data Center's (AFDC) Alternative Fueling Station Locator (www.afdc.energy.gov/locator/stations), there are 68 public, private, and planned CNG fueling stations throughout the state of Pennsylvania, as shown in the map below (including 8 that are temporarily unavailable). These stations are located throughout the state, with concentrations around Pittsburgh and Philadelphia, and in areas of natural gas production. The maps and tables that follow list the refueling stations available in these metropolitan areas, and include key information such as station address and equipment characteristics. The reader is encouraged to visit the AFDC Station Locator for up-to-date information on the stations that are available in the state: www.afdc.energy.gov/afdc/locator/stations/

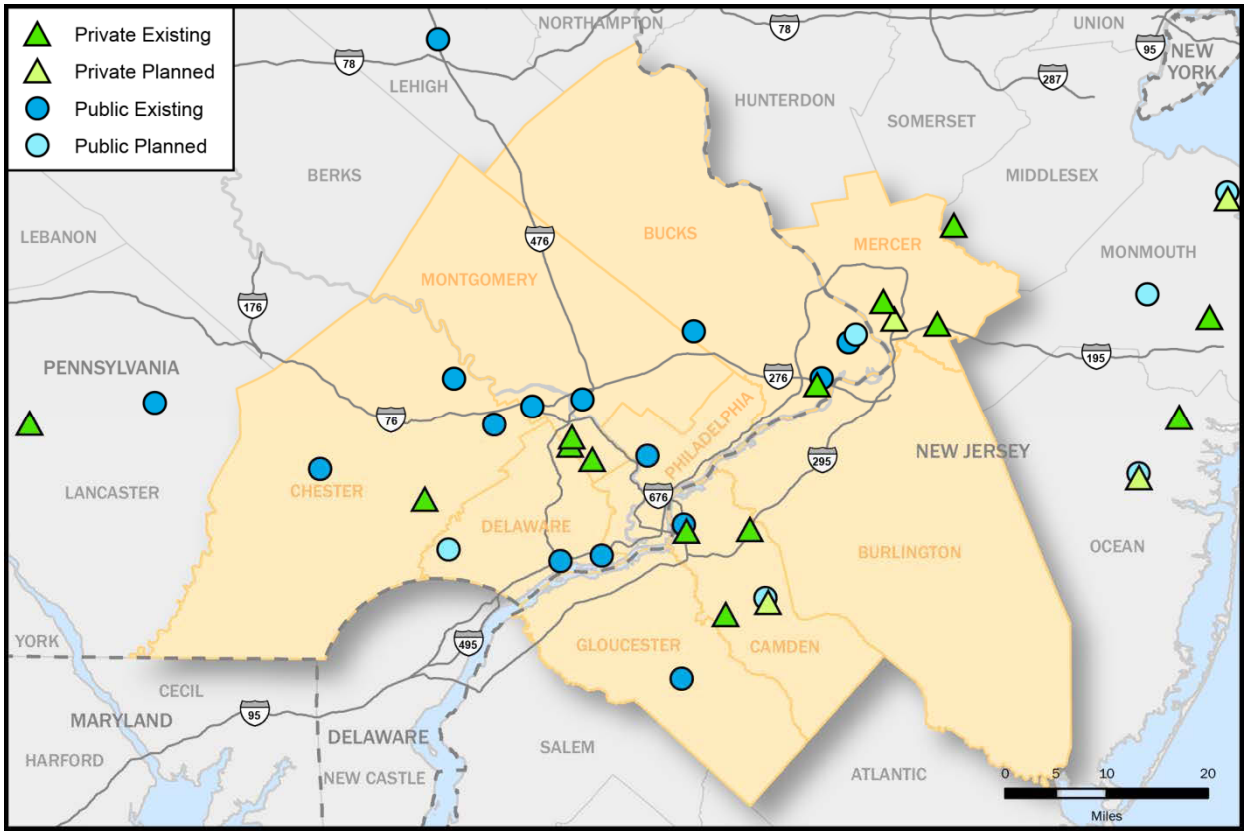


The breakdown of stations by type in Pennsylvania is:

Public stations	44: 25 open, 7 temporarily unavailable, 12 planned
Private stations	24: 21 open, 1 temporarily unavailable, 2 planned
Time-fill	6
Fast fill	62 (includes stations offering both time fill and fast fill)

APPENDIX F

CNG Stations: Philadelphia Area



The highlighted area on the map indicates the DVRPC region.

Public CNG Stations in the DVRPC Region (Sorted by Status, then by Municipality Name)

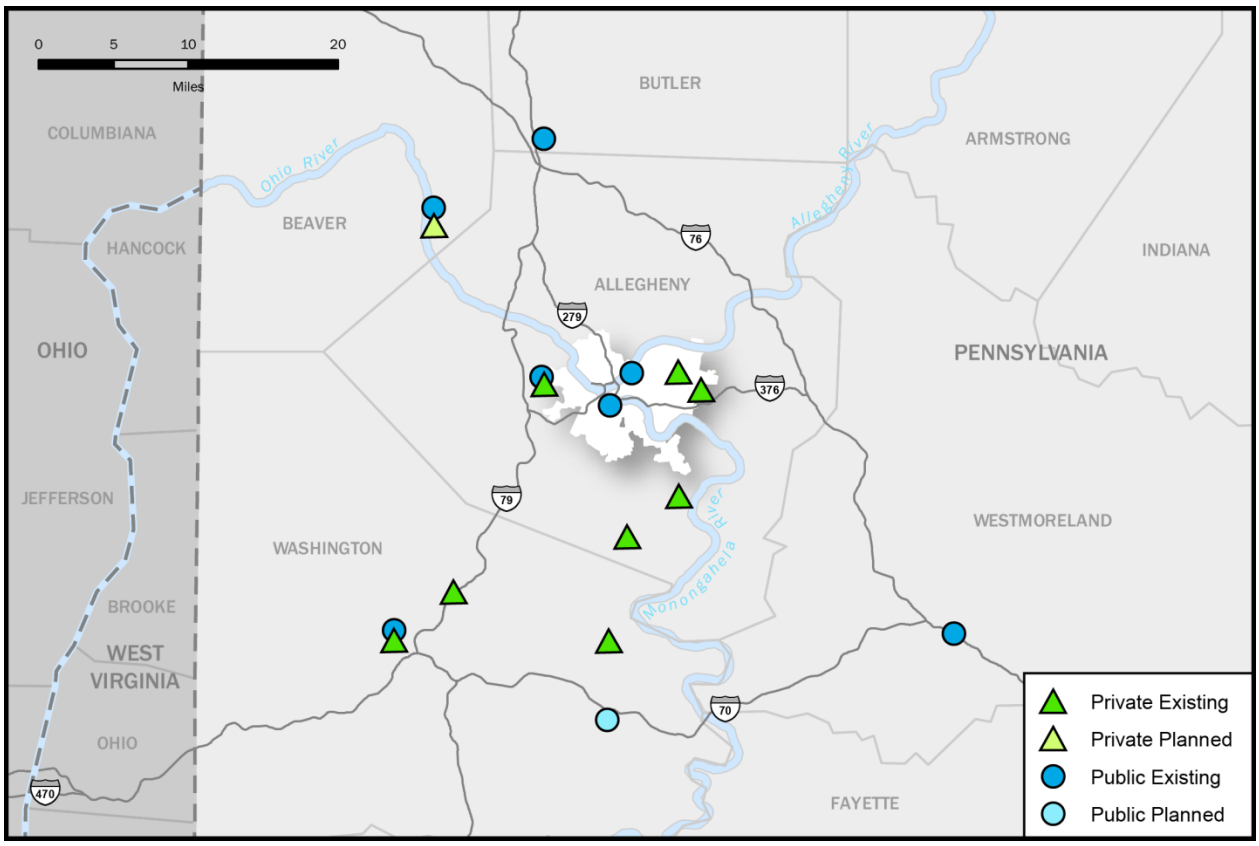
Station Name	Location	Status
Clean N' Green	1224 Hayes Blvd Bristol, PA 19007	Open
Clean N' Green	1001 Fairview St Camden, NJ 8104	Open
Clean Energy - Tyburn LLC	451 Tyburn Rd Fairless Hills, PA 19030	Open
Clean Energy - South Jersey Gas	142 S Main St (Grove and Academy Streets) Glassboro, NJ 8028	Open
Clean Energy - Philadelphia International Airport - Wally Park	1 Scott Way Lester, PA 19113	Open
VNG	2901 W Abbottsford Ave Philadelphia, PA 19129	Open
Clean Energy - Berwyn	1050 Swedesford Rd Berwyn, PA 19312	Temporarily Closed
Clean Energy - Coatesville	175 N Caln Rd (Caln Rd and Rt 30) Coatesville, PA 19320	Temporarily Closed
Clean Energy - Eddystone	1510 Chester Pike Eddystone, PA 19022	Temporarily Closed
Clean Energy - King of Prussia	113 N Gulph Rd King of Prussia, PA 19406	Temporarily Closed

Station Name	Location	Status
Clean Energy - Phoenixville	1101 W Bridge St Phoenixville, PA 19460	Temporarily Closed
Clean Energy - Plymouth	680 Ridge Pike Plymouth Meeting, PA 19462	Temporarily Closed
Clean Energy - Warminster	388 Park Ave Warminster, PA 18974	Temporarily Closed
GAIN Clean Fuel	355 Newbold Rd Fairless Hills, PA 19030	Planned
Clean Energy - Glen Mills	1130 Baltimore Pike (Rt 202 and Rt1) Glen Mills, PA 19342	Planned
South Jersey Gas	2500 Old Egg Harbor Rd Lindenwold, NJ 8021	Planned

Private CNG Stations in the DVRPC Region (Sorted by Status, then by Municipality Name)

Station Name	Location	Status
Lower Merion High School	301 E Montgomery Ave Ardmore, PA 19003	Open
Waste Management - Delaware Valley North	1224 Hayes Blvd Bristol, PA 19007	Open
Bryn Mawr College	300 Airdale Rd Bryn Mawr, PA 19010	Open
Waste Management - Camden	1001 Fairview St Camden, NJ 8104	Open
New Jersey Department of Transportation - Cherry Hill Facility	Route 70 & Frontage Rd (at NJ Turnpike) Cherry Hill, NJ 8034	Open
Gloucester Township Station	1729 Erial Rd Gloucester Township, NJ 8012	Open
New Jersey Department of Transportation - Hamilton Facility	2779 Kuser Rd (at Route 130) Hamilton Township, NJ 8691	Open
Harriton High School	600 N Ithan Ave Rosemont, PA 19010	Open
Clean Energy - Central Jersey Waste	500 Breunig Ave Trenton, NJ 8638	Open
West Chester University	821 S Matlack St West Chester, PA 19382	Open
Waste Management - Trenton Hauling	208 Patterson Ave Hamilton Township, NJ 8610	Planned
South Jersey Gas	2500 Old Egg Harbor Rd Lindenwold, NJ 8021	Planned

CNG Stations: Pittsburgh Area



The highlighted area on the map indicates the City of Pittsburgh.

Pittsburgh Area Public CNG Stations (Sorted by Status, then by Municipality Name)

Station Name	Location	Status
Bee Green CNG	3099 Duss Ave (Duss Ave and Legionville Rd) Ambridge, PA 15003	Open
Get-Go Cranberry	1737 State Route 228 (I79 and Route 228) Cranberry Township, PA 16066	Open
Sunoco	734 New Stanton Service Plaza Hunker, PA 15639	Open
EQT - Strip District	2926 Smallman St Pittsburgh, PA 15201	Open
Giant Eagle GetGo	755 Beechnut Dr Pittsburgh, PA 15205	Open
American Natural Energy Centre	73 E Carson St Pittsburgh, PA 15219	Open
Clean N' Green	200 Rangos Ln Washington, PA 15301	Open
US 1	Rt 917 (Goasia Drive and Rt 917) Bentleyville, PA 15314	Planned

Pittsburgh Area Private CNG Stations (Sorted by Status, then by Municipality Name)

Station Name	Location	Status
FYDA Freightliner of Pittsburgh	20 Fyda Dr (PA SR 519 and I-79) Canonsburg, PA 15317	Open

Station Name	Location	Status
Peoples Natural Gas	65 Ginger Hill Rd Finleyville, PA 15332	Open
Giant Eagle Warehouse	755 Beechnut Dr Pittsburgh, PA 15205	Open
Iron City Uniform	6440 Frankstown Rd Pittsburgh, PA 15206	Open
National Energy Technology Laboratory	626 Cochrans Mill Rd Pittsburgh, PA 15236	Open
Waste Management - Washington	200 Rangos Ln Washington, PA 15301	Open
US Steel Corp - Mon Valley Works - Irvin Plant	Camp Hollow Rd West Mifflin, PA 15122	Open
Peoples Natural Gas	1201 Pitt St Wilkinsburg, PA 15221	Temporarily Closed
Waste Management - Pittsburgh (Ambridge)	2097 Duss Ave Ambridge, PA 15003	Planned

Other Public CNG Stations in Pennsylvania (Sorted by Status, then by Municipality Name)

Station Name	Location	Status
Heath Oil CNG	5609 State Route 8 (I-80 and Route 8) Barkeyville, PA 16038	Open
"O" Ring Fueling Systems	228 Allegheny Blvd (Route 36 and 180.) Brookville, PA 15825	Open
Palo CNG	12600 State Route 66 Clarion, PA 16214	Open
"O" Ring CNG Fuels Systems - Innovative Entrepreneurs Inc	5363 Route 36 Coolspring, PA 15730	Open
White Oak Farms Inc	1009 State Route 839 Dayton, PA 16222	Open
GAIN Clean Fuel	153 Macridge Ave Johnstown, PA 15904	Open
Wayne Township Landfill	267 Fritz Rd Lock Haven, PA 17745	Open
"O" Ring CNG Fuels Systems - Innovative Entrepreneurs Inc	601 S Main St Ext Punxsutawney, PA 15767	Open
Dandy Mini-Mart	1131 Elmira St (Off Route 220) Sayre, PA 18840	Open
CNG Fuel LLC	20511 Paint Blvd Shippenville, PA 16254	Open
Dandy Mini-Mart	474 Reuter Blvd Towanda, PA 18848	Open
River Valley Transit	1550 W 3rd St (at Streets & Parks Building.) Williamsport, PA 17701	Open
CNG One Source	Allegheny Blvd Brookville, PA 15825	Planned
Sunoco	1490 S Main St Chambersburg, PA 17201	Planned
AR Natural Gas Fueling Systems	329 Theater Dr Duncansville, PA 16635	Planned
Knox Western CNG	1111 Bacon St Erie, PA 16511	Planned

Station Name	Location	Status
CNG One Source	Route 8 and Front St Franklin, PA 16323	Planned
GAIN Clean Fuel	713 Legionnaire Dr Fredericksburg, PA 17026	Planned
L T Verrastro Inc	700 Moosic Rd Old Forge, PA 18518	Planned
Clean N' Green	910 W Pennsylvania Ave Pen Argyl, PA 18072	Planned
Clean Energy - State College PA	3180 W College Ave State College, PA 16801	Planned

Other Private CNG Stations in Pennsylvania (Sorted by Status, then by Municipality Name)

Station Name	Location	Status
Waste Management - Erie Hauling	975 Robison Rd E Erie, PA 16509	Open
Fort Monmouth	Murphy Dr (Building 812.) Fort Monmouth, NJ 7703	Open
CNG One Source	190 Oak Grove Cir Franklin, PA 16323	Open
Trillium CNG - Proctor & Gamble	1807 US-6 Meshoppen, PA 18630	Open
Town of Montclair - Department of Community Services Yard	219 N Fullerton Ave Montclair, NJ 7042	Open
Waste Management - Grand Central Sanitation	910 W Pennsylvania Ave Pen Argyl, PA 18072	Open
Centre Area Transit Authority (CATA)	2081 W Whitehall Rd State College, PA 16801	Open
Pennsylvania State University	Park Ave University Park, PA 16802	Open
River Valley Transit	1550 W 3rd St (at Streets & Parks Building.) Williamsport, PA 17701	Open
Proctor & Gamble Warehouse 2	TBD (Pennsylvania 87) Mehoopany, PA 18629	Planned

Appendix G. *Cost Evaluation Tool for Fleet Analysis*

A simple cost evaluation tool has been developed as a companion tool to this guidebook. The tool allows a fleet user to enter basic information about a fleet vehicle (or set of similar vehicles), including average annual mileage and fuel efficiency, and determine simple payback if these vehicles were to be converted to natural gas based on incremental capital cost of the vehicle and fuel costs for diesel and natural gas. The tool also allows the user to choose whether or not to include the capital cost of a refueling station in their project, and will provide broad order-of-magnitude estimates of fueling station capital cost based on the natural gas throughput estimated from the number of vehicles.

This tool is not intended to replace a fleet's own financial decision-making tools, nor is it intended to supplant vehicle cost/payback tools available through truck dealers and OEMs. Rather, the tool is intended to assist a fleet in making the initial determination for whether or not to pursue a potential CNG project based on rough estimates of payback.

A sample screen shot of the tool is illustrated on the next page – the complete Excel tool is available at www.dvrpc.org/EnergyClimate/CNG.htm.

NATURAL GAS TRUCK COST CALCULATOR

INPUTS

FLEET CHARACTERISTICS

Number of Diesel Trucks to be Replaced with CNG	100	(1)
Planned Lifetime of Trucks (years)	10	
Average Daily Mileage per Truck (miles per day)	90	
Average Annual Usage per Truck (days used per year)	300	
Average Fuel Economy of Diesel Truck (miles per diesel gallon)	5.00	
Average Fuel Economy of Natural Gas Truck (miles per diesel gallon	4.50	(2)

VEHICLE AND FUEL COST

Initial Capital Cost of Conventional Truck	$75,000	
Initial Capital Cost of Natural Gas Truck	$125,000	
Fuel Cost for Diesel ($/gallon)	$3.85	(3)
Source for Natural Gas Cost	Use CNG COST tab price for onsite fueling	
User Entered Natural Gas Cost ($/diesel gallon equivalent)	$2.35	(3)
Natural Gas Cost for Calculations ($/diesel gallon equivalent)	$1.88	(4) (5)

INCENTIVES FOR CNG VEHICLES

Federal Purchase Incentive (per vehicle)	$0	
State Purchase Incentive (per vehicle)	$0	
Other Purchase Incentives (per vehicle)	$10,000	

FUELING STATION OPTIONS (FOR ONSITE, OWNED STATIONS) — *Station costs part of CNG price*

Include purchase of stations in payback calculations?	No	(6)
Stations needed to serve this fleet of natural gas trucks based on fueling	1	(7)
Total **estimated** cost per station based on natural gas truck fueling needs	$1,520,000	(7)
User-entered number of stations	1	
User-entered station cost (per station)	$750,000	
Which station costs should be used in calculation?	Use the costs estimated by the tool	
Number of stations to be constructed	0	
Average cost per station	$0	

INCENTIVES FOR CNG STATIONS

Federal Incentive (per station)	$0	
State Incentive (per station)	$0	
Other Incentives (per station)	$50,000	

OUTPUTS

SIMPLE PAYBACK

Simple Payback of Natural Gas Incremental Costs Without Incentives	5.3
Simple Payback of Natural Gas Incremental Cost With Incentives (years)	4.2

LIFE CYCLE COST

Total Life Cycle Cost of Diesel Trucks	$28,290,000	
Total Life Cycle Cost of Natural Gas Trucks (No Incentives)	$23,787,632	
Life Cycle Cost Differential (No Incentives)	-$4,502,368	(8)
Total Life Cycle Cost of Natural Gas Trucks (With Incentives)	$22,787,632	
Life Cycle Cost Differential (With Incentives)	-$5,502,368	(8)

NOTES

(1) Green cells are user-editable input fields.
(2) If CNG fuel economy is not known, assume 10-25% lower fuel economy than diesel truck
(3) Price estimates can be obtained from www.afdc.energy.gov/afdc/price_report.html. Use Central Atlantic pricing.
(4) See tab CNG COSTS for source of CNG pricing.
(5) To convert $/gasoline gallon equivalent to $/diesel gallon equivalent, multiply GGE price by 1.11
(6) If the calculation uses the CNG price built up from components on the CNG COST tab, the calculator will automatically zero out the station costs in these cells, since the CNG COST price already includes station cost amortization.
(7) Estimate based on "Business Case for Compressed Natural Gas in Municipal Fleets", NREL 2010
(8) For life cycle cost differentials, cost savings for the project are highlighted in green, while instances of cost increases for CNG are highlighted in red

Appendix H. *Natural Gas Vehicle Project Planning Checklist*

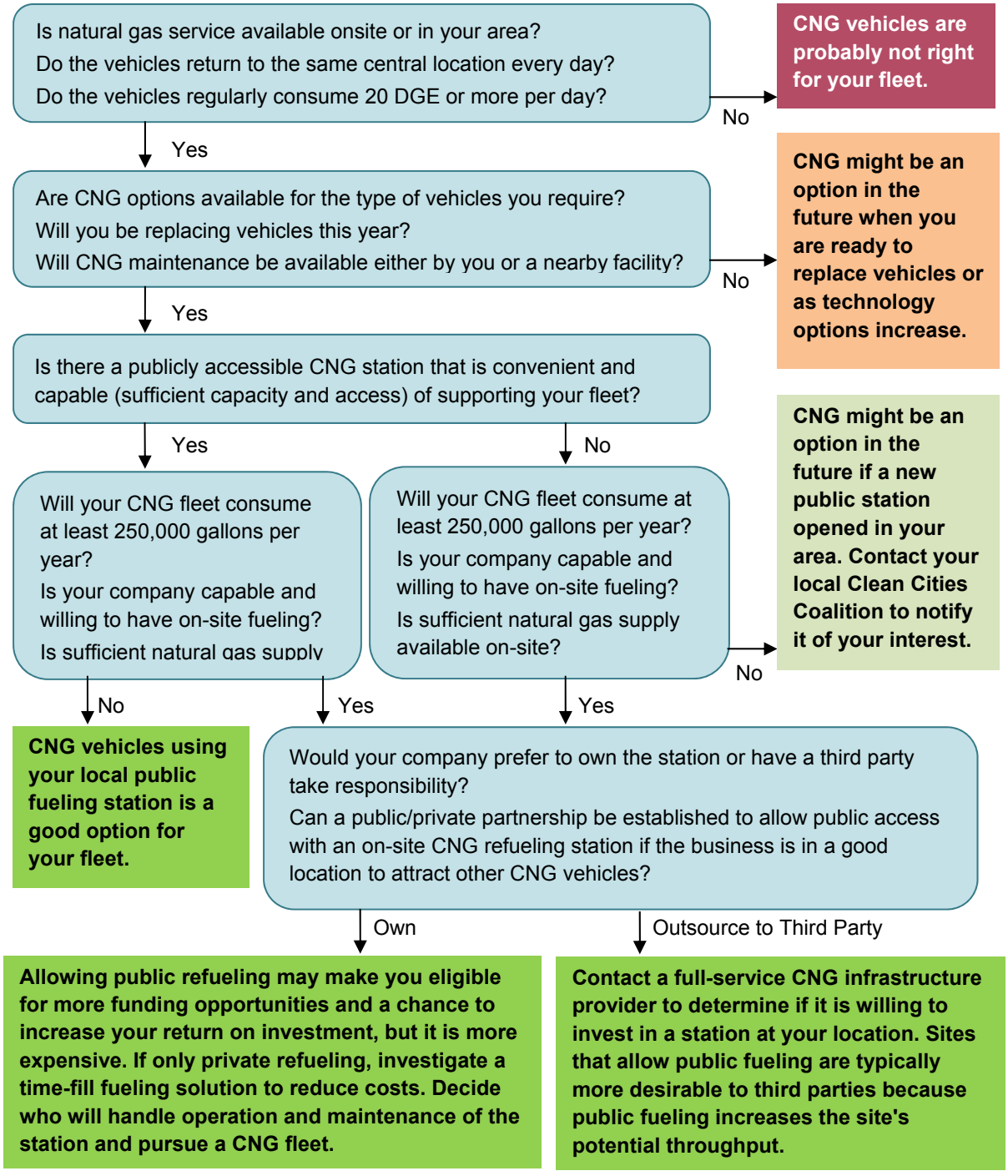
Checklist for Refuse Fleets Owning and Operating Vehicles

The checklist below is intended to serve as a guide for fleet managers in adopting natural gas as a fuel for fleet vehicles. This is not an exhaustive outline of the details necessary for a successful project: rather, it provides an overview of the basic steps involved. Fleet managers are encouraged to consult with experts in the natural gas industry for additional information.

	Understand the basics of natural gas and CNG vehicles (Section 3, page 13) • Be familiar with how natural gas is used as a fuel and what characteristics differ from conventional petroleum fuels.
	Assess fleet vehicle characteristics (Section 3, page 15) • Outline vehicle route characteristics and typical vehicle use (average annual miles per year), average vehicle age of the vehicles to be replaced, etc. Are there any special characteristics with these vehicles that would make them unsuitable for natural gas?
	Review CNG vehicle options (Section 3, page 16 and Appendix A) • What make and model of vehicle does the fleet prefer to purchase? Are there CNG options available in these truck models (or similar models)?
	Evaluate existing and planned CNG infrastructure (Section 3, page 17 and Appendix F) • Is fueling infrastructure available close to the fleet operation, or is a CNG station planned for somewhere nearby? Will the fleet need to construct its own refueling?
	Assess facility property (Section 3, Page 18) • If the fleet plans to build its own station, is there appropriate space available? Is there gas supply nearby? Would public access be viable?
	Understand the corporate or municipal business/operations strategy (Section 3, Page 20) • If the fleet plans onsite fueling, will it be owned or provided by a third party? Who will maintain the station? How will it be financed? What payback period is needed?
	Examine infrastructure requirements (Section 3, Page 20) • What will be needed to meet fleet infrastructure needs? These must be clearly understood to issue a RFP for station construction.
	Assess the business case (Section 3, Page 21) • How quickly will the fleet's investment in the CNG project be paid back with fuel cost savings? Does this fit with the fleet's typical business practices and preferences?
	Develop an implementation plan and act on it (Section 3, Page 22) • Plan carefully for the number of natural gas vehicles to be purchased, the financing to be arranged for the vehicles (and infrastructure if needed), and procurement of fuel (long-term fuel purchase agreements are best if possible).

Flow Chart of Decisions – Natural Gas Refuse Vehicle Projects

The flow chart below provides an alternative look at the steps and decisions to be made in planning for a natural gas vehicle project. This supplements the prior checklist.



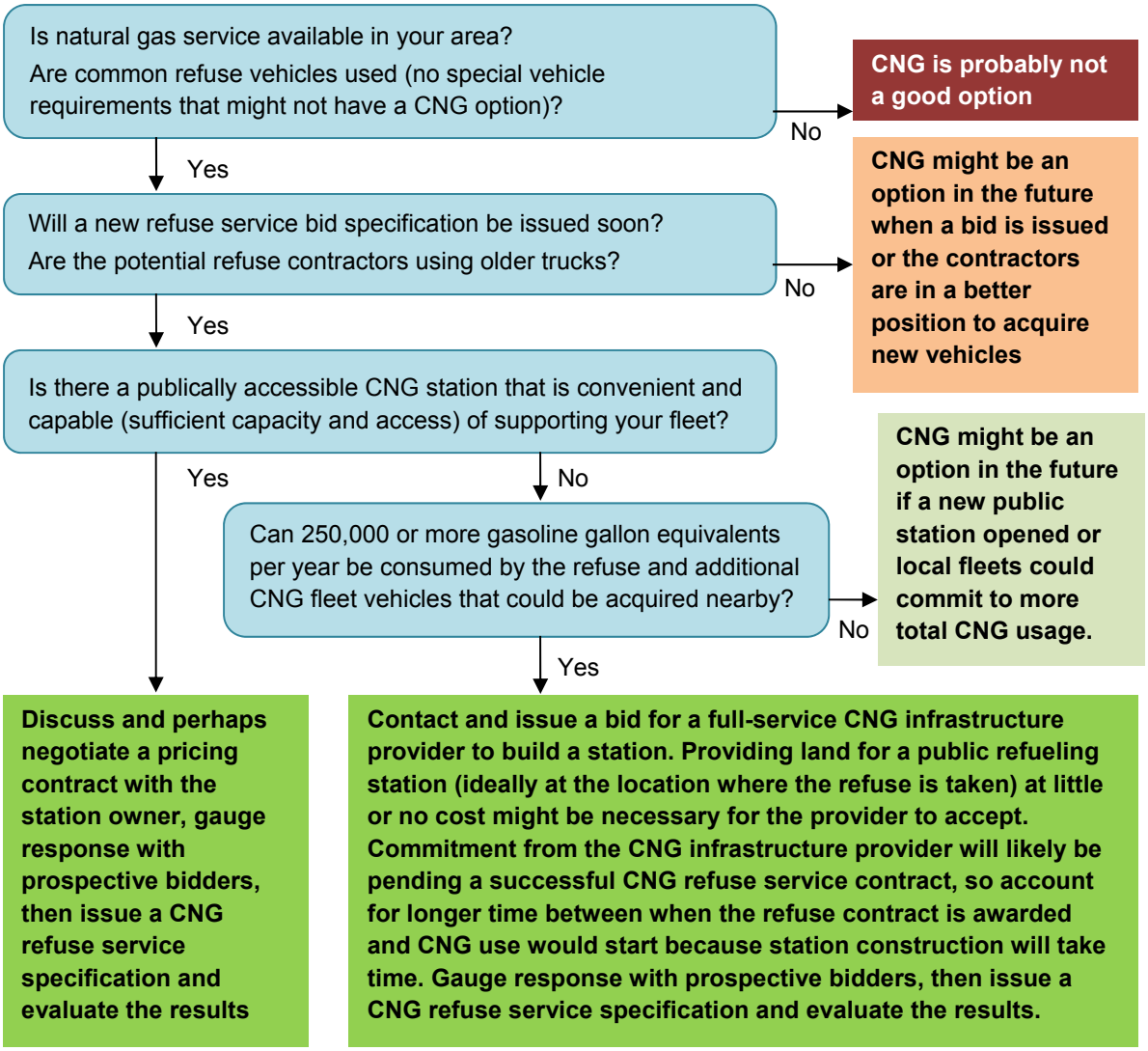
Checklist for Organizations Contracting for Refuse Services

The checklist below is intended to serve as a guide for municipalities in adopting a natural gas mandate for refuse services. This is not an exhaustive outline of the details necessary for a successful project: rather, it provides an overview of the basic steps involved. Municipalities are encouraged to consult with experts in the natural gas industry for additional information.

	Understand the basics of natural gas and CNG vehicles (Section 4, Page 25) • Be familiar with how natural gas is used as a fuel and what characteristics differ from conventional liquid petroleum fuels.
	Assess refuse operations (Section 4, Page 27) • Analyze whether route characteristics (distance, consistency, etc.), volume of refuse, and fleet practices of the prospective bidder pool, etc. are favorable for CNG use prior to considering a CNG requirement for refuse service contractors.
	Evaluate existing and planned CNG infrastructure (Section 4, Page 29 and Appendix F) • Is fueling infrastructure available close to the refuse operation, or is fueling planned for somewhere nearby?
	Investigate options for a new CNG station (Section 4, Page 31) • Will public refueling or private refueling be used? Is there enough CNG demand to interest a third-party fuel provider for a public station? Is there a site available that is appropriate for having a CNG station built?
	Examine bid specification details (Section 4, Page 32) • Collect enough information to issue an appropriate bid for both fuel procurement and CNG refuse services – review samples from other municipality bid documents for developing appropriate specifications.
	Develop an implementation plan and act on it (Section 4, Page 32) • Plan carefully for the implementation of a CNG mandate – discuss concept with potential bidders, plan for long-term fueling options, procure the refuse services with a CNG mandate, and execute the contracts.

Flow Chart of Decisions – Natural Gas Refuse Vehicle Projects

The flow chart below provides an alternative look at the steps and decisions to be made by a municipality in planning for a natural gas vehicle mandate for refuse services. This supplements the prior checklist.



Guidebook:
Natural Gas for Refuse Fleets in Pennsylvania

Publication Number: 13074

Date Published: April 2015

Geographic Area Covered: Commonwealth of Pennsyvlania

Key Words:

Natural gas, alternative fuel, refuse vehicle, trash truck, CNG, fueling station

Abstract:

This guidebook is intended to help municipalities and private companies in Pennsylvania understand how compressed natural gas (CNG) vehicles can be used in their refuse services to save money. The use of CNG to displace gasoline or diesel fuel assists Pennsylvania in achieving its broad energy security and environmental air quality goals. Both municipalities and private companies that own refuse trucks and municipalities that contract out refuse services will benefit from this guidebook. This document describes an overall approach and process for converting a fleet to CNG. While every fleet and operation is different and has its own unique features, this material provides an overview to assist an organization in determining if CNG vehicles are a viable option for refuse services and in locating the basic knowledge to start evaluating and implementing a CNG vehicle program.

This report was originally prepared by Antares Group Incorporated, Energetics Incorporated, and Modern Energy in the course of performing work contracted for and sponsored by the New York State Energy Research and Development Authority (NYSERDA). The original publication date was June 2012. The original NYSERDA document is available for download at:

http://www.nyserda.ny.gov/-/media/Files/EIBD/Research/Transportation/CNG/cng-refuse-fleets.pdf.

With permission from NYSERDA, DVRPC has modified this report for Pennsylvania, making minor changes to reflect local conditions, and updating information where feasible. The bulk of the document remains as DVRPC received it from NYSERDA. This is fundamentally their work

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