Source: City Manager

Agenda Item No: REP 131-13

To: City Council
From: City Manager and Staff

Council Meeting Date: Aug 19, 2013

Re: CNG Report: Fracking, Safety, and Alternative Fuels Comparison

EXECUTIVE SUMMARY:

This report is intended to provide Council with information regarding the extraction of natural gas, safety of using CNG vehicles for the City's fleet, and a comparison of CNG with other alternative fuels.

DISCUSSION:

CNG Background and History

Physical Properties of CNG

Natural gas used in CNG vehicles is 80-90% methane (CH4). The remaining contents are composed of other hydrocarbons (propane, butane, etc.), various inert gases, and an additive for odor. The gas is stored at 3000 to 3600 psi to allow for the storage of enough fuel for driving ranges comparable to gas and diesel. Natural gas is lighter than air and dissipates rapidly when released from a container. (Table 1, Alternative Fuels Data Center - Fuels Properties).

History

Knowledge and use of natural gas from naturally occurring seeps or springs is thousands of years old, but it was not until the 19th century that natural gas became commercially viable. Gas was pumped from shallow wells and used mainly for lighting cities until the advent of electric lighting. Gas continued to be used for heating and generating electricity. In the early years of automobile production a host of alternative fuels including natural gas were being used. The abundance of petroleum and the demand for fuel during WWII effectively tied the automobile industry to the use of gasoline and diesel. Starting in the late 80's and early 90's increases in the price of petroleum have spurred interest in using natural gas for transportation.

Uses

Natural Gas is currently used is a variety ways. It is used to generate electricity with gas and steam turbines, domestically for heat and appliances, for transportation, in the production of several agricultural fertilizers, and for the production of Hydrogen which is in turned used for chemical manufacturing and the production of hydrogen fuel cells.

Extraction

In 2011 gas from shale wells accounted for approximately 30% of gas withdrawn (extracted) in the US. Other major sources for gas include oil wells, traditional gas wells, and coalbed wells. Extraction from shale beds has been increasing steadily, almost doubling from 2009 to 2011 (EIA). By 2035, EIA projects that shale gas production will rise to 13.6 trillion cubic feet, representing nearly half of all U.S. natural gas production. The increase in extraction from shale beds is made possible by the rise in demand for natural gas and improved technology (hydraulic fracturing). Hydraulic fracturing has been used since the late 1940's for natural gas and oil extraction, but the method has not been used heavily until the last 10 years.

Responsible development of America's oil and gas resources offers a myriad of economic benefits, however concerns have arisen in regards to environmental safety. Hydraulic fracturing also known as "fracking" is a procedure used in the extraction of natural gas and oil. "Fracking" is a well stimulation technique used to maximize production of oil and natural gas in unconventional reservoirs, such as shale, coal beds, and tight sands. These fractures increase the exposed surface of rock in the formation and in turn, stimulate the flow of

natural gas or oil to the wellbore. As the demand for natural gas increases, so does concern for potential risks to drinking water supplies.

In response to the U.S. House of Representatives Appropriations Conference Committee, the U.S. Environmental Protection Agency is conducting a comprehensive study to investigate the potential adverse effects of fracking on water quality and public health.

In the Study of the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources: Progress Report, the EPA has collected data from multiple sources for review and analysis. Much of the data came directly from states with high levels of oil and gas activity. Information on the chemicals and practices used in fracking was collected from nine companies that used the hydraulic fracturing process which totaled 24,925 wells between September 2009 and October 2010. Recent evidence suggest fracking may have contributed to groundwater contamination with methane in some instances and that proprietary chemicals used in the procedure could theoretically pose a public health threat. However, because groundwater supplies and natural gas deposits are often separated by thousands of feet of rock and earth, and groundwater can be contaminated by many sources, it is difficult to establish a definitive connection between contaminated drinking water and fracking. The EPA also received additional data on chemicals and water use for hydraulic fracturing by utilizing the registry operated by the Ground Water Protection Council and the Interstate Oil and Gas Compact Commission. In the study, the EPA used scenario evaluations, laboratory studies, toxicity assessments, and case studies. In the scenario evaluations, computer models are being used to identify conditions that may lead to impacts on drinking water resources from hydraulic fracturing. Case studies sampling at five locations in Colorado, North Dakota, Pennsylvania and Texas have been completed for the study. Over 70 domestic water wells, 15 monitoring wells, and 13 surface water sources among others are being used in the study. This research will help to identify the source of any contamination if any exist. A draft of the report is expected to be released in 2014.

A recent study by several researchers at Duke noted directional drilling and hydraulic fracturing may have a potential impact on increased methane gas levels near shallow groundwater sites. Concerns for impacts to groundwater resources are based on the flow and discharge of water and gas due to the high pressure of the injected fracturing fluids in the gas wells, the toxicity and radioactivity of water from a mixture of fracturing fluids, and the large number of private wells in rural areas that rely on shallow groundwater for household and agricultural use. There are at least three possible reasons to explain the higher concentration of methane near the gas wells: physical displacement of gas-rich deep solutions from the target formation, leaky gas-well casings, or the reduced pressure following fracturing activities could allow methane gas to migrate into ground water. The study found no evidence of contamination in drinking water samples with deep saline brines or fracturing fluids. Although the study does suggest greater stewardship, more research, and increasing regulations to improve public confidence in its use.

Sources:

EPA, Plan to Study the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources, EPA/600/R-11/122, November 2011
http://www2.epa.gov/sites/production/files/documents/hf_study_plan_110211_final_508.pdf

Osborn, S. G., Vengosh, A., Warner, N. R., & Jackson, R. B. (2011). Methane contamination of drinking water accompanying gas-well drilling and hydraulic fracturing. proceedings of the National Academy of Sciences, 108(20), 8172-8176.

http://www.eia.gov/dnav/ng/ng_prod_sum_dcu_NUS_a.htm

CNG Vehicle Safety

Summary

CNG and LNG vehicles are required to adhere to the same safety standards as gas and diesel vehicles. There have been very few recorded incidents involving CNG vehicles in the past 30 years. Training, regular inspections, maintenance, and scheduled replacement of tanks are the key to safety for any fuel system. The vast majority of CNG incidents are the result of gross negligence, human error, and have occurred with gas/diesel vehicles that were converted to CNG.

Regulations

There are numerous international, federal, state, and industry codes, standards, and regulations for all aspects of CNG usage for transportation, as well as, numerous sources for best practices and policies for maintenance of CNG vehicles, fueling stations, and maintenance areas. National Fire Protection Agency Codes and Standards, SAE International-best practices, Federal Transit Authority, International Fire Code, American National Standards Institute, and Code of Federal Regulations are some of the organizations and codes used to regulate the use of CNG. (Table 2-Codes, Standards and Advisories Applicable to Natural Gas Vehicles and Infrastructure). Many of these regulations have existed since CNG started being used in vehicles.

CNG as a Fuel

The gaseous and compressed state of methane used for CNG vehicles can create a perception that is less safe than liquid fuels. It is hard to determine if gas or liquid fuels are safer, as it depends on the environment, situation, and human element (error). A natural gas leak is very noticeable because of an additive (usually mercaptan) that gives off a strong odor. Methane (gas used for CNG vehicles) not only disperses quickly once introduced to the open air, it also takes a higher concentration in the air to become flammable when compared to vaporized gasoline and diesel.

Fuel Tanks

Vehicles using natural gas must compress the gas at a high pressure to store enough fuel to have a comparable range to gas and diesel vehicles. To accomplish this gas is stored in special tanks at 3000 to 3600 psi. The tanks are designed and placed within the vehicle to minimize the impact of a fire or collision. There are four types tanks employed in CNG vehicles:

Type 1: All metal construction. Very durable and very few tank failures reported worldwide. Can be too heavy for use in commercial fleets.
Type 2: Metal liner with a composite (fiberglass or carbon fiber) wrap. Lighter and more expensive than Type 1. Only a few reported failures in the US.
Type 3: Similar construction to Type 2 but lighter. Only a few reported failures in the US.
Type 4: Plastic liner and full wrapped with a composite material. The lightest tank available and is becoming much stronger as carbon fiber technology improves. Few reported failures in the US.

Most reported tank failures occur on private vehicles that were converted to run on CNG. Almost all tank failures were due to gross negligence: tanks repeatedly filled above the recommended psi, failure to visually inspect tanks on a periodic basis (recommend every 3 years or 36,000 miles), and tanks used well beyond expiration date (tank life is usually between 15 and 25 years depending on type).

While the tank is responsible for keeping the pressurized gas from getting out in the case of a fire or collision, other CNG safety devices are designed to empty the tanks of the gas as quickly as possible. Methane quickly dissipates into the atmosphere and thus emptying the tanks rapidly in the event of a fire or collision greatly improves the safety of a CNG vehicle. CNG tanks are required to have at least one Pressure Relief Device (PRD), most have two one on either end of a tank. The PRD is vented to blow gas out of the vehicle and into the atmosphere. There are numerous other features and devices that provide safety for the use of CNG as a fuel, but the tank and the PRD are the main components. As with any safety features these devices must be maintained and inspected on a regular basis.

Fueling Stations

There are two kinds of filling stations: time fill which slowly fills a tank over a long period of time and fast fill which fills a tank in a matter of minutes. The design, installation, and operation of both stations are regulated by the National Fire Association Code. As with CNG vehicles most incidents with fueling stations have been a result of stations not built to code or as a result of human error. Stations are required to have overpressure devices that keep a fueling station from overfilling a tank. It is also important to be careful with stations that fill both 3000 and 3600 psi tanks and insure that the proper tanks are filled at the right pump.

Maintenance Facilities

The main safety concern for buildings used for maintenance of vehicles using liquid fuels, such as gasoline and diesel, is fuel pooling on the floor. The main safety concern for buildings used for working on CNG vehicles is gas accumulating in pockets in the ceiling. Maintenance facilities dealing with CNG vehicles require proper ventilation usually achieved with ceiling or attic fans that pull air out of the building. Most existing fleet maintenance buildings can be modified to allow leaked natural gas to be vented out of the building.

Sources:

NFPA, Vehicular Gaseous Fuel Systems Code 2010 Edition
http://files.dep.state.pa.us/OilGas/BOGM/BOGMPortalFiles/Act13/NGVProgram/NFPA_52_2010_Vehicular_Gaseous_Fuel_Systems.pdf

Overview of Safety Issues Associated with the CNG Fuel System and..., Oak Ridge National Lab, DOE, 2002
http://web.ornl.gov/~webworks/cppr/y2001/rpt/115272.pdf

Clean Vehicles Education Foundation, Presentation Oct. 2010
http://www1.eere.energy.gov/cleancities/pdfs/ngvtf10_cyl_safety.pdf

Alternative Fuels Comparison

Table 3 (attached) provides a summary of the comparison of alternative fuels for transit buses, as well as the sources of information used to make the comparison. The information found in this table is not specific to Columbia, but instead reflects a more global comparison of these fuels and their use for transit buses. It is important when examining any aspect of comparing alternative fuels to look at the most recent reports and analysis. Changes in methodologies, such as accounting for methane leakage at wells, regulations, such as the 2010 emissions regulations, and technology all have a major impact on the comparison of fuel economy, emissions, capital cost, and operating cost.

Cost of Fuel

Historical data and forecasts from various sources show that natural gas prices will most likely remain significantly lower than gasoline, diesel, and bio-fuels. The Clean Cities Alternative Fuel Price Report by the US Department of Energy and the most recent Annual Energy Outlook reports by the US Energy Information Administration forecast that natural gas prices will remain more stable and significantly lower than gasoline and diesel.

Fuel Economy

CNG buses have been shown to have less fuel economy than other fuels over the years. The gap between CNG and diesel has closed somewhat. This is in part aided by new emissions restrictions that reduce the fuel economy of new diesel buses and new technology for CNG buses. Bio-fuels as well are starting to close the gap. Fuel economy for any particular fleet will be dependent upon the routes, topography, elevation, and other local characteristics.

Emissions

Most reports indicate that CNG vehicles produce less greenhouse gas emissions than new clean diesel buses. The difference is sometimes minimal and can depend on how emissions are measured. CNG is typically measured to have less tailpipe and less life cycle emissions too (from the well to use in the vehicle). Life cycle or well to wheel measurements of CNG emissions will vary depending on the factor used to calculate leaked methane from natural gas wells. Similarly bio-fuels have less tailpipe emissions than diesel, but their life cycle emissions can be far greater. After reviewing numerous studies it seems that CNG produces slightly less green house emissions than new diesel vehicles, and at the least does not produce more.

Cost of Vehicles

Cost from least to most: New Diesel, CNG, Hybrid. These cost difference will most likely remain significant in the near future. It is important to note that new diesel buses are becoming more expensive.

Operation and Maintenance

Many CNG providers claim that CNG vehicles require less maintenance than diesel, bio-fuels, and hybrids. What is clear from some early CNG adopters (before 2007) is that CNG fleets require different kinds of maintenance and that they may be about the same as diesel buses. Newer CNG buses may indeed require less maintenance but there are no long term studies available for maintenance cost yet. The maintenance for B-100 depends on the local weather, as B-100 has to be pumped out of vehicles during the winter months.

Current Use for Heavy Vehicle Fleets

The use of alternative fuels for transit is growing and natural gas is leading the way with about 19% of transit fleets in the US using CNG or LNG (majority are CNG). CNG is also growing in solid waste fleets. Across the world CNG is used heavily in Iran, Pakistan, Brazil, India, and China. Table 4 (attached) displays the number of cities participating in the 2012 ICMA Performance Measurement Survey that reported using various alternative fuels for their fleets during 2012.

FISCAL IMPACT:

VISION IMPACT:
http://www.gocolumbiamo.com/Council/Meetings/visionimpact.php

SUGGESTED COUNCIL ACTIONS:

Informational

FISCAL and VISION NOTES:					
City Fiscal Impact Enter all that apply		**Program Impact**		**Mandates**	
City's current net FY cost	$0.00	New Program/ Agency?		Federal or State mandated?	
Amount of funds already appropriated	$0.00	Duplicates/Expands an existing program?		**Vision Implementation impact**	
Amount of budget amendment needed	$0.00	Fiscal Impact on any local political subdivision?		Enter all that apply: Refer to Web site	
Estimated 2 year net costs:		**Resources Required**		Vision Impact?	
One Time	$0.00	Requires add'l FTE Personnel?		Primary Vision, Strategy and/or Goal Item #	
Operating/ Ongoing	$0.00	Requires add'l facilities?		Secondary Vision, Strategy and/or Goal Item #	
		Requires add'l capital equipment?		Fiscal year implementation Task #	

Table 1

Alternative Fuels Data Center – Fuel Properties Comparison

	Gasoline	Diesel (No. 2)	Biodiesel	Propane (LPG)	Compressed Natural Gas (CNG)	Liquefied Natural Gas (LNG)	Ethanol	Methanol	Hydrogen	Electricity
Chemical Structure	C_4 to C_{12}	C_8 to C_{25}	Methyl esters of C_{12} to C_{22} fatty acids	C_3H_8 (majority) and C_4H_{10} (minority)	CH_4 (83-99%), C_2H_6 (1-13%)	CH_4	CH_3CH_2OH	CH_3OH	H_2	N/A
Fuel Material (feedstocks)	Crude Oil	Crude Oil	Fats and oils from sources such as soy beans, waste cooking oil, animal fats, and rapeseed	A by-product of petroleum refining or natural gas processing	Underground reserves	Underground reserves	Corn, grains, or agricultural waste (cellulose)	Natural gas, coal, or, woody biomass	Natural gas, methanol, and electrolysis of water	Coal, nuclear, natural gas, hydroelectric, and small percentages of wind and solar
Gasoline Gallon Equivalent	100%	1 gallon of diesel has 113% of the energy of one gallon of gasoline.	B100 has 103% of the energy in one gallon of gasoline or 93% of the energy of one gallon of diesel. B20 has 109% of the energy of one gallon of gasoline or 99% of the energy of one gallon of diesel.	1 gallon of propane has 73% of the energy of one gallon of gasoline.	5.66 pounds or 126.67 cu. ft. of CNG has 100% of the energy of one gallon of gasoline. [1]	1 gallon of LNG has 64% of the energy of one gallon of gasoline.	1 gallon of E85 has 73% to 83% of the energy of one gallon gasoline (variation due to ethanol content in E85). 1 gallon of E10 has 96.7% if the energy of one gallon of gasoline. [2]	1 gallon of methanol has 49% of the energy of one gallon of gasoline.	1 kg or 2.198 lbs. of H_2 has 100% of the energy of one gallon of gasoline.	33.70 kWh has 100% of the energy of one gallon of gasoline.
Energy Content (Lower heating value)	116,090 Btu/gal (g)	128,450 Btu/gal (g)	119,550 Btu/gal for B100 (g)	84,950 Btu/gal (g)	20,268 Btu/lb (g) [1]	74,720 Btu/gal (g)	76,330 Btu/gal for E100 (g)	57,250 Btu/gal (g)	51,585 Btu/lb (g)	3,414 Btu/kWh

Alternative Fuels Data Center – Fuel Properties Comparison

	Gasoline	Diesel (No. 2)	Biodiesel	Propane (LPG)	Compressed Natural Gas (CNG)	Liquefied Natural Gas (LNG)	Ethanol	Methanol	Hydrogen	Electricity
Energy Content (Higher heating value)	124,340 Btu/gal (g)	137,380 Btu/gal (g)	127,960 Btu/gal for B100 (g)	91,410 Btu/gal (g)	22,453 Btu/lb (g) [1]	84,820 Btu/gal (g)	84,530 Btu/gal for E100 (g)	65,200 Btu/gal (g)	61,013 Btu/lb (g)	3,414 Btu/kWh
Physical State	Liquid	Liquid	Liquid	Pressurized Liquid	Compressed Gas	Cryogenic Liquid	Liquid	Liquid	Compressed Gas or Liquid	Electricity
Cetane Number	N/A	40-55 (a)	48-65 (a)	N/A	N/A	N/A	0-54 (b)	N/A	N/A	N/A
Pump Octane Number	84-93 (c)	N/A	N/A	105 (f)	120+ (d)	120+ (d)	110 (e)	112 (e)	130+ (f)	N/A
Flash Point	-45 °F (o)	165 °F (o)	212 to 338 °F (a)	-100 to -150 °F (o)	-300 °F (o)	-306 °F (p)	55 °F (o)	52 °F (o)	N/A	N/A
Autoignition Temperature	495 °F (o)	~600 °F (o)	~300 °F (a)	850 to 950 °F (o)	1,004 °F (o)	1,004 °F (p)	793 °F (o)	897 °F (o)	1,050 to 1,080 °F (o)	N/A
Maintenance Issues			Hoses and seals may be affected by higher-percent blend. Lubricity is improved over that of conventional diesel fuel.	Some fleets report service lives that are 2-3 years longer, as well as extended intervals between required maintenance.	High-pressure tanks require periodic inspection and certification.	High-pressure tanks require periodic inspection and certification.	Special lubricants may be required. Practices are very similar, if not identical, to those for conventionally fueled operations.	Special lubricants must be used as directed by the supplier and M-85-compatible replacement parts must be used.	When hydrogen is used in fuel cell applications, maintenance should be very minimal.	Service requirements are less than with gasoline or diesel. No tune-ups, oil changes, timing belts, water pumps, radiators, or fuel injectors are required. It is likely that the battery will need replacement before the vehicle is retired.

Alternative Fuels Data Center – Fuel Properties Comparison

	Gasoline	Diesel (No. 2)	Biodiesel	Propane (LPG)	Compressed Natural Gas (CNG)	Liquefied Natural Gas (LNG)	Ethanol	Methanol	Hydrogen	Electricity
Energy Security Impacts	Manufactured using oil, of which nearly 2/3 is imported (n).	Manufactured using oil, of which nearly 2/3 is imported (n).	Biodiesel is domestically produced, renewable, and reduces petroleum use 95% throughout its lifecycle (i).	Approximately half of the LPG in the U.S. is derived from oil, but no oil is imported specifically for LPG production.	CNG is domestically produced. The United States has vast natural gas reserves.	LNG is domestically produced.	Ethanol is produced domestically. E85 reduces lifecycle petroleum use by 70% and E10 reduces petroleum use by 6.3% (l).	Methanol is domestically produced, sometimes from renewable resources.	Hydrogen is produced domestically and can be produced from renewable sources.	Electricity is generated mainly through coal fired power plants. Coal is the United States' most plentiful and price-stable fossil energy resource.

Notes

[1] Due to the infinite temperature and pressure combinations of gaseous fuels and their effect on fuel density, ft^3 units are not given. Most of these fuels are dispensed by Coriolis flow meters, which track fuel mass and report fuel dispensed on a "gallon of gasoline-equivalent" (GGE) basis.

[2] E85 is a high-level gasoline-ethanol blend containing 51% to 83% ethanol, depending on geography and season. Ethanol content is lower in winter months in cold climates to ensure a vehicle starts. Based on composition, E85's lower heating value varies from 83,950 to 95,450 Btu/gal. This equates to 73% to 83% the heat content of gasoline.

Sources

(a) R.L. McCormick. Biodiesel Handling and Use Guidelines—Fourth Edition, National Renewable Energy Laboratory, 2009.

(b) American Petroleum Institute (API), Alcohols and Ethers, Publication No. 4261, 3rd ed. (Washington, DC, June 2001), Table 2.

(c) Petroleum Product Surveys: Motor Gasoline, Summer 1986, Winter 1986/1987. National Institute for Petroleum and Energy Research.

(d) K. Owen and T. Coley. 1995. Automotive Fuels Reference Book: Second Edition. Society of Automotive Engineers, Inc. Warrendale, PA.

(e) J. Heywood. 1988. Internal Combustion Engine Fundamentals. McGraw-Hill Inc. New York.

(f) American Petroleum Institute (API), Alcohols and Ethers, Publication No. 4261, 3rd ed. (Washington, DC, June 2001), Table B-1.

(g) Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) Model, version 1.7. 2007. Input Fuel Specifications. Argonne National Laboratory. Chicago, IL.

(h) The National Biodiesel Board website reports that "most major engine companies have stated formally that the use of blends up to B20 will not void their parts and workmanship warranties." Accessed 11/15/12 at http://www.biodiesel.org/using-biodiesel/oem-information/oem-statement-summary-chart

(i) J. Sheehan, V. Camobreco, J. Duffield, M. Graboski, and H. Shapouri. 1998. An Overview of Biodiesel and Petroleum Diesel Life Cycles. Report of National Renewable Energy Laboratory (NREL) and US-Department of Energy (DOE).

(j) R.L. McCormick, A. Williams, J. Ireland, M. Brimhall, and R.R. Hayes. 2006. Effects of Biodiesel Blends on Vehicle Emissions. NREL Milestone Report NREL/MP-540-40554.

(k) K. Kelly, L. Eudy, and T. Coburn. 1999. Light-Duty Alternative Fuel Vehicles: Federal Test Procedure Emissions Results. Report of National Renewable Energy Laboratory (NREL), NREL/TP-540-25818.

(l) M. Wang. 2005. Energy and Greenhouse Gas Emissions Impacts of Fuel Ethanol. Presentation to the NGCA Renewable Fuels Forum, August 23, 2005. Argonne National Laboratory. Chicago, IL.

(m) J. Murray, Ben Lane, K. Lillie, and J. McCallum. 2000. An Assessment of the Emissions Performance of Alternative and Conventional Fuels. Report of the Alternative Fuels Group of the Cleaner Vehicles Task Force. Norwich, UK.

(n) Energy Information Administration. Monthly Energy Review. Summary for 2006.

(o) Methanol Institute. Fuel Properties. Accessed 11/14/2012 at http://www.methanol.org/Energy/Resources/Alternative-Fuel/Alt-Fuel-Properties.aspx

(p) Foss, Michelle. 2012. LNG Safety and Security. Bureau of Economic Geology, Jackson School of Geosciences. University of Texas at Austin.

Table 2

CLEAN VEHICLE EDUCATION FOUNDATION

6011 Fords Lake Ct
Acworth GA 30101
770-424-8575
dbhorne@cleanvehicle.org
www.cleanvehicle.org

Codes, Standards and Advisories Applicable to Natural Gas Vehicles and Infrastructure

(N.B. This list is not all-inclusive)

Document	Applicability	Comments
NFPA 52 – Vehicular Gaseous Fuel Systems Code - 2010 – new edition approved for 2013	CNG LNG and L/CNG vehicles (incl. marine) and fueling facilities. Hydrogen vehicles are covered in this edition but will be transferred to NFPA 2 in the next edition.	Probably single best source of guidance for CNG, LNG and L/CNG vehicles and fueling facilities.
NFPA 88A – Standard for Parking Structures – 1998	Open, enclosed, basement and underground parking structures	No special requirements for NGVs other than reference to NFPA 52 and 57
NFPA 30A – Code for Motor Fuel Dispensing Facilities and Repair Garages - 2012	Facilities dispensing **both** gaseous **and** liquid fuels at the same facility	Includes requirements of old 88B on repair garages.
NFPA 59A – Standard for the Production, Storage, and Handling of Liquefied Natural Gas - 2013	Site selection, design, construction, and fire protection for LNG facilities.	
SAE J1616 – Recommended Practice for Compressed Natural Gas Vehicle Fuel - 1994	CNG motor vehicle fuel	Recommendations on vehicular fuel composition.
SAE J2343 – Recommended Practices for LNG Powered Heavy-Duty Trucks-2008	LNG powered heavy duty trucks	Primarily heavy truck recommendations but some maintenance facility equipment and procedures.
SAE J2406 – Recommended Practices for CNG Powered Medium and Heavy-Duty Trucks - 2002	CNG powered medium and heavy duty trucks (>14,000 gvwr)	Published in 2002.

Document	Applicability	Comments
SAE J2645 - Liquefied Natural Gas (LNG) Vehicle Metering and Dispensing Systems	LNG Vehicular Fuel Metering and Dispensing.	Published in 2009
Design Guidelines for Bus Transit Systems Using Liquefied Natural Gas (LNG) as an Alternative Fuel (3/97)	Transit Facilities but useful reference for other fleets	FTA Report - Not only references required codes (e.g., NFPA) but also suggests additional precautions and provides general information.
Design Guidelines for Bus Transit Systems Using Compressed Natural Gas as an Alternative Fuel (6/96)	ditto	ditto
Compressed Natural Gas Safety in Transit Operations (10/95)	ditto	ditto
Liquefied Natural Gas Safety in Transit Operations (3/96)	ditto	ditto
International Fire Code - 2012	International fire code	Check with local fire marshal on applicability.
CSA B108-99 Natural Gas Fuelling Stations Installation Code	Canadian Std. applicable to fleet and public stations	
CSA B108-99 Appendix B – Indoor Fuelling of Natural Gas Vehicles	Canadian Std. Fueling facilities w/i a building that has primary functions other than fueling. Does not cover public stations.	Published August 2001.
CSA B109-01 – Natural Gas for Vehicles Installation Code	Canadian Std. Applies to "installation, servicing and repair of NG fuel systems on self-propelled vehicles."	
ANSI NGV1-2006 – Compressed Natural Gas Vehicle Fueling Connection Devices	CNG vehicular fueling connection devices	Assures standardized nozzles and receptacles
ANSI NGV2-2007 – Basic Requirements for Compressed Natural Gas Vehicle Fuel Containers – Also see Addendums 2a and 2b published in 2012	CNG fuel containers	Container requirements in addition to FMVSS 304.
ANSI NGV3.1-1995 – Fuel System Components for Natural Gas Powered Vehicles	Fuel system components for NGVs (excludes LNG components upstream of vaporizer)	Primarily for converted vehicles.
ANSI NGV4.1/ CSA 12.5 -1999 – NGV Dispensing Systems	CNG vehicular fuel dispensing systems	

Document	Applicability	Comments
ANSI NGV4.2/CSA 12.52 -1999 – Hoses for NGVs and Dispensing Systems	CNG dispenser and vehicular hose assemblies	
ANSI NGV4.4/CSA 12.54 -1999 – Breakaway Devices for Natural Gas Dispensing Hoses and Systems	CNG dispenser shear valves and fueling hose emergency breakaway shutoff devices	
ANSI NGV4.6/CSA 12.56 -1999 – Manually Operated Valves for Natural Gas Dispensing Systems	Manually operated CNG valves, excluding cylinder shut-off valves	
ANSI NGV4.8 2012/CSA 12.8 -2002 – Natural Gas Vehicle Fueling Station Reciprocating Compressor Guidelines	Compressor packages containing reciprocating compressors used in CNG fueling station service.	
ANSI PRD1-1998 (with 1999 & 2007 addenda) – Basic Requirements for Pressure Relief Devices for Natural Gas Vehicle Fuel Containers	Pressure Relief Devices for CNG Fuel Containers	
CGA C-6.4-2007 – Methods for External Visual Inspection of Natural Gas Vehicle Fuel Containers and Their Installations	CNG vehicular fuel containers	Referenced in ANSI NGV2
49 CFR 178.56 – Specification 4AA welded steel cylinders	CNG cylinders for fueling stations.	Generally not used for new CNG fueling stations. ASME vessels now generally used.
49 CFR 178.57 – Specification 4L welded insulated cylinders	LNG vehicular fuel tank requirement called out in NFPA 57.	Option is meeting ASME Boiler and Pressure Vessel Code.
49 CFR 571.304, FMVSS 304 – Compressed Natural Gas Fuel Container Integrity	CNG motor vehicle fuel containers	DOT Federal Motor Vehicle Safety Standard for CNG motor vehicles.
49 CFR 571.303, FMVSS 303 – Fuel System Integrity of Compressed Natural Gas Vehicles	CNG vehicles ≤10,000 lbs. GVWR and school buses	DOT Federal Motor Vehicle Safety Standard for crash test of light duty vehicle and school bus CNG fuel systems.
49 CFR 393.65, FMCSR – All Fuel Systems	Commercial vehicles in interstate commerce	DOT Federal Motor Carrier Safety Regulations. May have been adopted by states for intrastate application. Wasn't written w NGVs in mind but may be legally applicable.

Document	Applicability	Comments
40 CFR 80.33 - Controls applicable to natural gas retailers and wholesale purchaser-consumers	Retailer and wholesale purchaser-consumers of NG	EPA 1.2 gm limit on atmospheric venting per refueling.
40 CFR 86.098-8 - Emission standards for 1998 and later model year light-duty vehicles	Light-Duty Vehicles	Requires NGV1 receptacles.
ASME Boiler and Pressure Vessel Code, Section VIII (Pressure Vessels)	Sections applicable to LNG containers used on vehicles and in fueling stations. Sections applicable to containers used in CNG fueling stations.	
CA Code of Regulations, Title 13, Div 2, Ch 4, Article 2	Fuel systems using LNG in 13 CCR 935, CNG in 13 CCR 934	CA vehicle requirements
CA Code of Regulations, Title 8, Div 1, Ch 4, Subchapter 1	CNG and LNG Storage Tanks	CA fuel storage requirements
CA Code of Regulations, Title 13, Div 3, Ch 5, Article 3, Sec 2292.5	CNG sold in CA	CA CNG composition requirements
TX Administrative Code, Title 16, Part 1	CNG regulations in Chapter 13, LNG regulations in Chapter 14	TX requirements

Availability:

National Fire Protection Association (NFPA) documents – contact NFPA at 1-800-344-3555 or http://catalog.nfpa.org

Society of Automotive Engineers (SAE) documents – contact SAE at 774-726-0790 or http://www.sae.org/products

Federal Transit Administration (FTA) documents – contact William Hathaway at 617-494-2081 or the National Technical Information Service at 703-605-6050 or http://www.ntis.gov

International Fire Code – Contact International Codes Council at 703-931-4533 or http://www.iccsafe.org

CSA Standards (CSA) documents – Contact CSA at 1-800-463-6727 or http://www.csa.ca

ANSI NGV documents – May be purchased from CSA at http://www.csa-intl.org/onlinestore/getcatalogdrilldown.asp?Parent=0&k=3&l=1 or ANSI at http://webstore.ansi.org/ansidocstore/default.asp

Compressed Gas Association (CGA) documents – Contact CGA at 703-788-2700 or http://www.cganet.com

Code of Federal Regulations (CFR) – Can be obtained on the web at http://www.gpo.gov/fdsys/browse/collectionCfr.action?collectionCode=CFR

California Code of Regulations (CCR) – Can be obtained on the web at http://ccr.oal.ca.gov

Texas Administrative Code – Can be obtained on the web at http://info.sos.state.tx.us

ASME Boiler and Pressure Vessel Code – Contact ASME at 800-843-2763 or www.asme.org

Updated 8/22/2012

Table 3

	CNG	New Diesel	B-20	B-99/B-100	Diesel-Electric
Fuel Price (in Diesel Gallon Equivalents or DGE)					
Current[1]	$2.34	$3.99	$4.19	$4.23	$3.99
Short term (2014)[2]	Slight increase	Slight decrease	Slight decrease	Slight decrease	Slight decrease
Long term (to 2040)[3]	Increasing but will remain significantly less than liquid fuels	Increasing	Increasing	?	Increasing
Fuel Economy (compared to old diesel)[4]	Lower	Higher	About Equal	Lower	Much Higher
Vehicle Cost (40 ft Bus)[5]	$475,000	$395,000	$395,000	$395,000	$500,000[6]
Annual Maintenance Cost Compared to Diesel[7]	Lower	N/A	Slightly Higher	Higher	Varies (depends if battery replacement is included)
Emissions Compared to New Diesel Bus[8]					
Tailpipe	Slightly less	N/A	Slightly less	Less	Much less
Life Cycle or Wells to Wheels	Less	N/A	Slightly less	Less	Less (depends on source of electricity)
Current Use in Transit Fleets (US)[9]	18.6% (includes LNG)	64.7% (includes old diesel)	7.9%		8.8%

1-Alternative Fuels Data Center, US Dept. of Energy, Nationwide Average Retail Price March 29-April 12 2013
2-Energy Information Administration (EIA), Short term Energy Outlook, Released July 9, 2013
3-EIA, Annual Energy Outlook 2013, with projections to 2040, Released April 2013
4-Fuel economy differs greatly depending on the year of the analysis, elevation, the transit fleet being measured, methodology, the particular technology used on the bus, and etc. This analysis **compares alternative fuels to new diesel buses** by summarizing the general trends found in various sources: Iowa Energy Center, Assessing the Cost for Hybrid vs Regular Transit Buses, Oct. 2012; Florida Dept of Transportation, Tracking the Cost of Alternatively Fueled Buses in Florida, Dec. 2011; US DOT, FTA, Alternative Fuels Study, Dec. 2006; US Dept of Energy, 100,000 Mile Evaluation of Transit Buses Operated on Biodiesel Blends (B20), 2006; FTA, Transit Bus Life Cycle Cost and Year 2007 Emissions Estimation, July 2007
5-Cost for Diesel and CNG buses are estimates used for the TIGER Grant and were provided by City of Columbia Fleet and Finance.
6-Cost for the Hybrid is an estimate from several sources.
7-The estimated maintenance cost are variable depending on the age of the report. Tech for buses has changed rapidly in the last few years. Sources: Iowa Energy Center, Assessing the Cost for Hybrid vs Regular Transit Buses, Oct. 2012; Florida Dept of Transportation, Tracking the Cost of Alternatively Fueled Buses in Florida, Dec. 2011; US DOT, FTA, Alternative Fuels Study, Dec. 2006; US Dept of Energy, 100,000 Mile Evaluation of Transit Buses Operated on Biodiesel Blends (B20), 2006; FTA, Transit Bus Life Cycle Cost and Year 2007 Emissions Estimation, July 2007
8-Emissions for alternative fuels were compared to emissions for new diesel buses. Emissions levels vary depending on what particular emission is in question, but this comparison takes a holistic look at the level of Greenhouse Gas Emissions (GHG). See 4 and 7 for sources, additionally: Hesterberg, T. W., Lapin, C. A., & Bunn, W. B. (2008). A comparison of emissions from vehicles fueled with diesel or compressed natural gas. *Environmental science & technology*, *42*(17), 6437-6445. Turrio-Baldassarri, L., Battistelli, C. L., Conti, L., Crebelli, R., De Berardis, B., Iamiceli, A. L., ... & Iannaccone, S. (2006). Evaluation of emission toxicity of urban bus engines: Compressed natural gas and comparison with liquid fuels.*Science of the Total Environment*, *355*(1), 64-77. Jayaratne, E. R., Ristovski, Z. D., Meyer, N., & Morawska, L. (2009). Particle and gaseous emissions from compressed natural gas and ultralow sulphur diesel-fuelled buses at four steady engine loads. *Science of the Total Environment*, *407*(8), 2845-2852. Yoon, S., Collins, J., Thiruvengadam, A., Gautam, M., Herner, J., & Ayala, A. (2013). Criteria Pollutant and Greenhouse Gas Emissions From Cng Transit Buses Equipped with Three-Way Catalysts Compared to Lean-Burn Engines and Oxidation Catalyst Technologies. *Journal of the Air & Waste Management Association*, (just-accepted). López, J. M., Gómez, Á., Aparicio, F., & Javier Sánchez, F. (2009). Comparison of GHG emissions from diesel, biodiesel and natural gas refuse trucks of the City of Madrid. *Applied Energy*, *86*(5), 610-615.
9-American Public Transportation Association, Transit News, 4/22/13, More than 35% of U.S. Public Transit Buses Use Alternative Fuels or Hybrid Technology

Table 4

Number of Cities Reporting Use of Alternative Fuel for Any Vehicles in Fleet, ICMA CPM 2012 (n=88)						
CNG	**LPG**	**Electric**	**Hydrogen**	**Propane**	**Ethanol (E95, E93, or E85, but not E10)**	**Biodiesel and Blends (B20 - B100)**
14	6	39	40	37	11	15