Is Natural Gas a Viable Alternative to Diesel for the Trucking Industry?[1]

This white paper was created for ATA's fleet members to provide an educational overview of natural gas fuel as an alternative to diesel fuel for the trucking industry. Natural gas is a fuel comprised mostly of methane, with small amounts of propane, ethane, helium and water. Like certain other alternative fuels, natural gas could be an acceptable fuel choice for certain applications within an industry as diverse as trucking.

Natural gas engines can either be spark-ignition or compression-ignition with pilot injection (*i.e.*, ~5% diesel injection to initiate combustion), with the later retaining the general properties of a diesel engine but requiring a second fueling system.

The transition to natural gas presents several significant challenges from economics to operability and poses significant refueling infrastructure hurdles. Until a competitive natural gas refueling infrastructure can evolve, this alternative fuel is problematic for long haul trucking operations, but may be a viable alternative for some regional and local trucking applications.

Natural gas may be used as a transportation fuel in its compressed form (CNG) or liquefied form (LNG). Because of lower energy density, CNG is not practical for long-distance, heavy-duty truck applications. CNG is being successfully used in short and medium range, heavy-duty applications such as refuse trucks, concrete mixers, straight trucks, and municipal buses.

LNG may present a viable alternative for certain trucking applications. LNG is cryogenically liquefied (*i.e.*, converted to a liquid by reducing its temperature to approximately –260º F) and has higher energy content per volume than CNG (although still significantly lower than diesel). LNG's energy density makes it more acceptable for longer-range routes, although the lack of a competitive refueling infrastructure suggests that this alternative is not currently viable for long-haul applications. Some LNG vehicles are being used on local routes with dedicated refueling infrastructure (*e.g.*, refuse transfer trucks, port drayage trucks).

Economic Factors:

Truck Costs – Natural gas trucks sell at a large premium ($45,000 - $75,000) compared to diesel-powered heavy duty Class 8 trucks.[2] Federal (and state) tax incentives may be available to purchasers of natural gas trucks to reduce the price differential between diesel and natural gas trucks; however, these incentives generally are not sufficient to offset the price differential.

Fuel Price – Natural gas prices fluctuate as do diesel fuel prices - LNG sold at a significant discount to ultra low sulfur diesel (ULSD) throughout 2009 (approximately 75 cents to

[1] The information contained herein was provided by ATA members with experience using natural gas, natural gas vehicle manufacturers, and natural gas fuel providers.

[2] There are currently two natural gas engine classes: (1) a truck equipped with a spark-ignition 250-320 horsepower 8.9 liter engine sells at a $45,000 premium to its diesel counterpart and can operate on stored CNG or LNG; and (2) a truck equipped with a 400-550 horsepower compression-ignition 15 liter engine sells at a $75,000 premium to its diesel counterpart and operates on LNG. Extra LNG fuel tanks could increase the premium to $90,000 for an LNG truck.

$1.50/gallon cheaper than ULSD on a diesel gallon BTU equivalent basis). CNG prices also fluctuate and ranged from 95 cents to $2.59 per diesel gallon equivalent through 2009, with significant differences depending upon the region of the country.[3]

Fuel Economy Penalty – Spark ignited natural gas trucks are less fuel efficient than their diesel counterparts. Spark-ignited natural gas engines have a reduced fuel economy of 7% to 10%, while compression-ignition natural gas engines have about a 1% fuel economy penalty.

Weight Penalty – Fuel tanks used to store both LNG and CNG are heavy and reduce the amount of freight that a truck can legally carry. LNG fuel tanks are constructed from ¼" thick stainless steel. Each 119 gallon LNG tank adds approximately 500 lbs., while a 72 gallon tank adds about 270 lbs. to the weight of a truck. A CNG truck equipped with five 15 gallon tanks (300-350 mile operating range) would add 1,200 pounds compared to its diesel counterpart.

Engine Durability – Natural gas engine durability is equivalent to diesel fuel engines.

Operational Factors:

Operating Range – An LNG truck equipped with two 119 gallon tanks has an operating range of approximately 775 miles depending on route and load characteristics. A typical 119 gallon tank can hold 97 gallons of LNG. The difference in rated capacity and actual capacity is a result of the need to maintain vapor space in the tank. CNG fueled trucks have a more limited operating range - the sweet spot for a CNG vehicle is a daily route of 250 miles.

Refueling Issues (LNG) – LNG trucks must be refueled at specialized stations that are configured for the specific truck. Running out of fuel on the side of the road is a significant challenge as LNG mobile refueling typically is not an option and the truck would have to be towed to the refueling station. Since the product is dispensed at between -255 and -270 degrees Fahrenheit, employee training and the provision of personal protective equipment may be necessary. Compression-ignition versions require the operator to refuel with both LNG and diesel; although the diesel only needs to be refilled about 1 out of every 20 LNG refuelings.

Refueling Issues (CNG) – CNG trucks also require specialized refueling. Depending upon temperature, some members report that they have had to refuel 2 to 3 times to make sure the tank is full. A minimal amount of driver training is required, but specialized personal protective equipment should not be necessary.

Fuel Quality – As with all fuel (diesel, natural gas, or renewable fuels), operators must ensure that they refuel with high quality fuel. Using a reputable fuel vendor is an important component of ensuring that only high quality, clean fuel is dispensed into the truck. Consult the engine manufacturer to confirm that the available fuel supply meets the manufacturer's specifications.

Duty Cycle - As with diesel engines, operators should work with their truck dealer or manufacturer to select the appropriate engine for their expected duty cycle and durability expectations.

Natural Gas Re-Fueling Infrastructure Concerns:

Today, it is a challenge for over-the-road fleets to find CNG or LNG fueling outlets on the road without planning and scheduling routes. Many of the natural gas refueling stations in this country are owned and operated by municipalities. Prior arrangements must be made before "stopping by" for fuel.[4]

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[3] *See* www.cngprices.com

[4] The Department of Energy maintains a fuel locator: www.afdc.energy.gov/afdc/locator/stations

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New infrastructure is required for refueling, as truck stops and gas stations do not have the ability to dispense LNG or CNG. Building out a natural gas refueling infrastructure along key freight corridors will take time. A competitive fuel model would require the presence of multiple entities selling LNG/CNG in the same geographic area. While competition exists in the natural gas industry, the high barriers to entry for building retail refueling stations may slow the development of a competitive refueling infrastructure and could result in higher prices for natural gas at public refueling stations.

Permitting a natural gas refueling station (especially an LNG station) may be challenging, as most fire marshals are not yet familiar and comfortable with the construction and operation of these facilities. This is not an insurmountable problem, but will require some time and effort to make state and local officials comfortable with the project.

Natural gas may be a viable alternative for centrally-fueled fleets that return to their base of operations each day. A natural gas refueling station typically costs between $500,000 and $1.2 million dollars, depending upon its capacity.

- *LNG Refueling Station Costs* – Establishing a LNG station capable of handling Class 8 trucks can cost between $700,000 and $1.2 million. LNG fueling can be equivalent to diesel refueling in duration.

- *CNG Refueling Stations* – Refueling a CNG truck can take between 5 and 30 minutes depending upon the capacity of the refueling compressor. A CNG refueling station can cost $1.2 million for a system capable of refueling 4 trucks simultaneously. A CNG fast fill station ($1.2M) can generally fuel vehicles in 5 minutes each at a steady rate depending on the amount of storage and size of compressor. There also is a slow fill option for fleets that can refuel overnight.

Environmental Implications:

Criteria Pollutants – PM and NOx emissions from LNG-fueled trucks are similar to post 2007 diesel trucks. Some natural gas engines comply with the EPA 2010 emission standards without the use of a diesel particulate filter or selective catalytic reduction emissions aftertreatment system.

Ultra Fine Particulates – There is insufficient data to compare the emissions of ultra-fine particulate matter between natural gas and diesel engines.

Greenhouse Gas (GHG) Emissions – On a "well-to-wheel" basis, natural gas engines emit fewer carbon (GHG) emissions than comparable diesel engines; however, the magnitude of this advantage for natural gas varies depends upon the fuel's processing method. CNG typically has the best GHG performance, with carbon emission levels up to 28% lower than diesel. While higher than CNG, carbon emission levels for LNG are still 1% to 18% lower than diesel. LNG tends to have higher carbon emission levels than CNG as a result of the energy expended to cool gas temperatures to - 260 F.

Although natural gas has favorable GHG emission levels when used as a fuel, it has a detrimental GHG impact if leaked directly to the atmosphere. Released directly into the atmosphere, methane is 20-times more potent than CO2 as a GHG. As LNG in fuel tanks warms, methane is released to the environment through a pressure relief valve. In fact, depending upon ambient temperatures and the age and condition of the fuel tanks, an LNG truck could vent significant amounts of natural gas after a few days. LNG tanks that are used daily should not have a venting issue. Venting should not be an issue with CNG tanks under normal operating conditions.

Maintenance Factors:

Oil Change – Spark-ignited natural gas engines use a different type of oil than diesel engines, while compression-ignited natural gas engines use the same type of oil as diesel engines. Spark ignited engines require more frequent oil changes, depending upon the truck duty cycle. In the case of compression-ignition natural gas engines, oil change intervals are comparable to similarly sized diesel engines.

Fuel Injector Replacement – While spark-ignited natural gas engines do not require injectors, compression-ignition natural gas engines may require injectors to be replaced more frequently than diesel engines, approximately every 220,000 to 300,000 miles.

Valve Adjustments – Spark-ignited natural gas engines require valve adjustments every 50,000 miles. Diesel engines and compression-ignited natural gas engines require valve adjustments at intervals ranging from 150,000 to 500,000 miles.

Ignition Systems – For spark-ignition natural gas engines, replacement of spark plugs after 37,500 miles are required (approximately $75 dollars for each of the 6 plugs). Ignition modules and various sensors (*e.g.*, O2, Manifold Absolute Pressure) add additional maintenance costs to the operation of natural gas engines.

Maintenance Intervals:

Maintenance Item	Diesel Cummins ISL9 (Miles)	CNG / LNG Cummins ISLG (Miles)	Diesel Cummins ISX15 (Miles)	LNG Westport ISXG (Miles)
Oil & Filter	15,000	12,500	25,000	25,000
Fuel Filter	15,000 (Primary) 30,000 (Secondary)	25,000	25,000	High Pressure Diesel 125,000 Low Pressure Diesel 31,250 High Pressure CNG 125,000
Spark Plugs	N/A	37,500	N/A	N/A
Coolant Filter	N/A	N/A	50,000	50,000
Change Coolant	80,000	50,000	250,000	250,000
Valve Adjustment	150,000	50,000	500,000	500,000
DPF (PM Trap)	200,000	N/A	300,000	300,000
DEF Dosing Filter	200,000	N/A	200,000	200,000

Training – Natural gas engines operate differently than diesel engines. In-house mechanics will require approximately 25-60 hours of additional specialized training for LNG engines and 20 hours training for spark-ignited engines. Finding a qualified natural gas mechanic is more difficult than finding a diesel mechanic. The local OEM may not have the requisite experience, tools or parts to quickly perform repairs. As a result, some fleets report that downtime for repairs are significantly longer for natural gas engines.

Methane Exposure – Maintenance shops that will work on natural gas-fueled vehicles may need a methane detection system and a methane evacuation system. Recommendations on the safe operation and maintenance of natural gas vehicles are available from the National Fire Protection

Association and the Society of Automotive Engineers. One ATA member reports spending over $150,000 on infrared sensors, modified lighting and electrical systems, and an air evacuation system. While all locations will need an air evacuation system, the Fire Marshall will determine whether a methane detection system is required.

Particulate Filters – Spark-ignited natural gas trucks do not require diesel particulate filters to meet EPA's PM emissions standards. Compression-ignition natural gas engines use all of the same aftertreatment systems as the base engines (*i.e.*, diesel particulate filters and selective catalytic reduction systems).

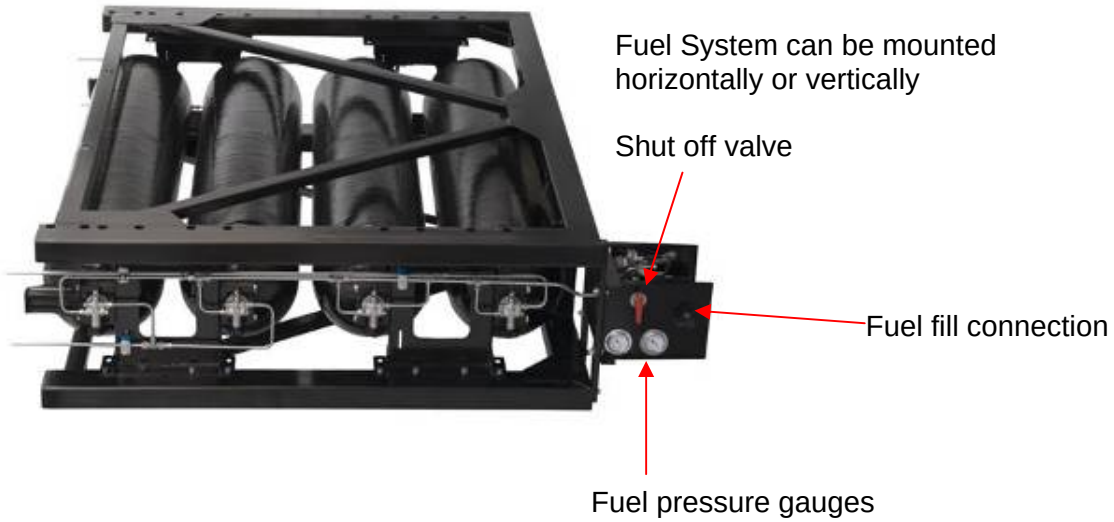
LNG On-Board Tanks – Some fleets have experienced significant problems with LNG fuel tanks. These tanks are double-walled construction with a vacuum between the two walls (like a giant thermos bottle). The vacuum serves as a temperature barrier. In some cases, fleets reported a loss of the vacuum due to tank manufacturing issues that manifest themselves months and even years after being placed into service. The vacuum can be recreated, but the process is costly and is not a permanent solution. Impacting a tank (such as during a collision or accident) can also result in a lost vacuum if the outer vessel is breached. As vacuum pressure decreases, fuel temperature rises, causing internal tank pressure to rise. The pressure relief valve built into the tank vents natural gas into the atmosphere, which affects the amount of fuel available for use and offsets some of the advantages of using LNG.

CNG On-Board Tanks – CNG is a high-pressure system operating at a storage pressure of up to 3600 pounds per square inch (psi). A truck CNG fuel system is comprised of tank storage, a high pressure fill system, fuel lines, engine compartment components (*i.e.*, filters) and regulators to reduce the fuel system pressure to 150 psi at the inlet connection to the engine. CNG tank inspections are required by the National Highway Traffic Safety Administration (NHTSA) every three years or 36,000 miles, whichever comes first. Tank inspections are external visual inspection only and the cylinder is not removed from the vehicle.

Crash Safety:

Natural gas vehicles are a safe alternative with a proven track record. LNG tanks usually replace the diesel saddle tanks on a truck. These tanks are constructed of stainless steel and very durable.

CNG tanks, as depicted below, are typically located behind the cab.



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LNG and CNG are about as flammable as diesel fuel. These gases pose a danger of ignition only when they are present in a 5% to 15% concentration. CNG and LNG will not pool when spilled, which reduces the probability of a fire if the tank is breached.

Natural Gas presents an asphyxiation hazard at concentrations exceeding 21%. These concentration levels are a concern in confined (indoor) environments.

Useful Links:

- **U.S. Department of Energy fuel locator at:** www.afdc.energy.gov/afdc/locator/stations
- **CNG Prices:** www.cngprices.com
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- **DOE-The Alternative Fuels and Advanced Vehicles Data Center:** http://www.afdc.energy.gov/afdc/fuels/natural_gas.html
- **DOE - The Alternative Fuels and Advanced Vehicles Data Center – State and Federal Incentives:** http://www.afdc.energy.gov/afdc/incentives_laws.html
- **Natural Gas Vehicle Institute (NGVi):** http://www.ngvi.com/
- **Natural Gas Vehicle for America (NGVAmerica):** http://www.ngvc.org/
- **American Gas Association (AGA):** http://www.aga.org/Legislative/issuesummaries/NaturalGasVehicles.htm
- **International Association for Natural Gas Vehicles (IANGV):** http://www.iangv.org/home.html
- **NGV Cost Analysis Toolkit for Fleets:** http://eerc.ra.utk.edu/etcfc/ngtoolkit/index.html

ATA will continually update this document as additional information becomes available. To provide comments on this document, contact Richard Moskowitz at: rmoskowitz@trucking.org.

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