# CNG 101

Presented by ampCNG

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# Table of Contents

This educational text on natural gas in the Class-8 trucking industry is categorized into five sections.



# About CNG 101

In 2010, our focus was to research and develop ways to solve environmental problems that also create economic opportunities. For us, this meant finding a business solution that did not rely on subsidies or incentives to be sustainable.

Our search brought us to Fair Oaks, IN where we invested in and built an anerobic digester at Fair Oaks Dairy Farm that utilizes excess on-site cow manure to manufacture methane, a form of renewable natural gas. In addition to powering a nat gas generator and selling excess methane to local utilities, we also had the idea to compress the gas and run the farm's fleet of 42-milk haulers using CNG.

Now although we had a strong collective background in energy, finance and agriculture, we did not know much about commercial trucking. Realizing this hurdle, we hired some terriffic people with tremendous experience and set-out to educate ourselves as best as possible. The more we learned, the more we realized the impact that the adoption of CNG could have on the Class-8, heavy-duty trucking sector.

We pushed forward and built two CNG stations along I-75 in Indiana and began saving the supply chain hundreds of thousands of dollars in fuel costs and were reducing CO2 emissions equal to removing tens of thousands of cars from the road. And along the way we started ampCNG, to use the knowledge we had developed to help fleets understand and execute on the major financial and environmental opportunities associated with switching to CNG.

Without further explanation, we are excited to now distill that research and present it to you in this educational manual called "CNG 101".

Nate Laurell

*CEO + Founder of ampCNG*

For more information on compressed natural gas and ampCNG, visit our website at www.ampCNG.com.

# From Diesel to Natural Gas

## *A Changing of the Guards*

Although natural gas has been available as a transportation fuel for decades, the economic and social benefits of switching the Class-8 trucking industry away from diesel has only recently gained traction.

Natural gas is up to 40% less expensive than diesel, it produces 30% less CO2 emissions, produces up to 94% less particulate emissions, and is a domestic fuel source that promotes US job creation, the US economy and national security.

# A Economic Advantage of Natural Gas Fuel

The immense cost savings of natural gas over diesel is a direct result of natural gas being a domestically produced fuel that utilizes existing natural gas pipelines without expensive refining processes.


**Left**
Oil tanker designed to tranport large amounts of crude-oil

**Right**
Gasoline and Diesel prices during a price spike.

## Domestic Product = Less Travel

Natural gas is a fuel that is 90% domestically produced in the United States. By contrast, 40% of crude-oil based fuels come from foreign sources. Additionally, natural gas travels efficiently across existing pipeline infrastructure in the United States. CNG stations tap into those pipelines to supply fuel to users. Diesel travels by truck, train or boat to stations where it is stored on-site in underground tanks.

## Simplified Refining

Compared to diesel fuels, natural gas requires less refining to be viable for truck engines. It is cleaned and compressed into either a gas (CNG) or liquid (LNG).

Diesel fuels are refined in oil refineries where crude-oil is boiled at temperatures between 482 and 662 degrees Fahrenheit and mixed with additional chemicals. This process costs up to $0.52 cents per gallon to produce diesel fuel (source: EIA).

+200%

Rise in average diesel prices over since 2000.

## Price Stability

Natural gas is domestically abundant, has enhanced pipeline and storage infrastructure, is geographically diverse and has less exposure to weather-related disasters. This results in greater price stability for natural gas.

Diesel prices are sensitive to shifts in foreign oil prices caused by oftentimes uncontrollable events. Foreign political predicaments, such as wars or sanctions in major oil producing countries cause crude-oil prices to spike erratically. Weather related incidents, such as hurricanes that shut-down oil refineries, cause shortages of diesel fuel. Both of these effect short and long-term diesel prices at the pump.

## Shale Reserves in the U.S.

Shale gas refers to natural gas that is trapped within shale formations. Over the past decade, the combination of horizontal drilling and hydraulic fracturing has allowed access to large volumes of shale gas that were previously uneconomical to produce. The production of natural gas from shale formations has created major opportunities for natural gas use both domestically and internationally.

**90+years**

The EIA estimates a 90+ year supply of domestic natural gas in the U.S.

The U.S. Energy Information Administration's Annual Energy Outlook 2013 Early Release projects U.S. natural gas production to increase from 23.0 trillion cubic feet in 2011 to 33.1 trillion cubic feet in 2040, a 44% increase. Almost all of this increase in domestic natural gas production is due to projected growth in shale gas production, which grows from 7.8 trillion cubic feet in 2011 to 16.7 trillion cubic feet in 2040.

The availability of large quantities of shale gas should enable the United States to consume a predominantly domestic supply of gas for many years and produce more natural gas than it consumes.

**93% Crude-Oil**

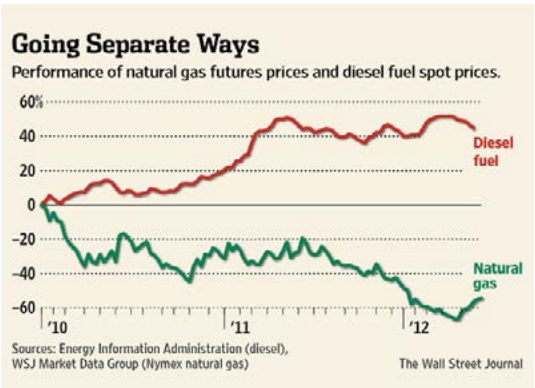
The fuel consumption in the transportation industry 93% dependent on crude-oil fuels compare to just 1% in the electricity industry

## Price Divorce Between Natural Gas and Crude-Oil

Due in large part to expanded natural gas extraction domestic natural gas prices have become independent from global petroleum prices and have become far more stable as a result.

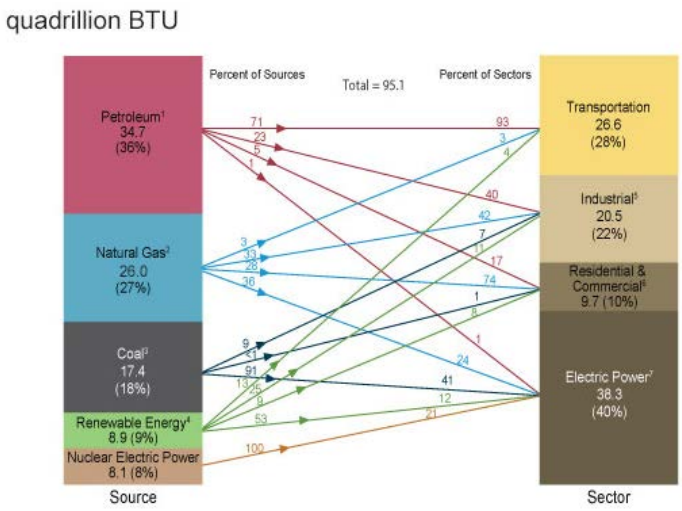
## Case Study: Electricity Industry

Increased natural gas production has made a tremendous effect on the electricity industry that has seen a major switch away from coal-fired power plants mainly to combined-cycle natural gas plants, which produce nearly 50% less CO2 and produces power much more economically.




**Above**
Wall Street Journal graph showing prive divorce between natural gas and diesel

Primary energy consumption by source and sector, 2012




**Right**
Primary energy consumption by source and sector

# Environmental and Public Health Benefits A

Of the roughly 2 million Class-8 trucks in service, more than half are model year 2009 or older. The following environmental benefits of a shift to CNG from diesel relate to these older trucks and percentage reductions in life-cycle and direct emissions:

-25%

Reduction in CO2 emissions when natural gas is burned compared to diesel

-94%

Reduction in smog producing particulate emissions

## Public Health

Unlike the industrial pollutants released from smokestacks, diesel engine exhaust is emitted at ground level, where Americans breathe it every day—whether we walk, ride bicycles, drive cars, take the subway, or commute via train, ferry, or transit bus. Diesel exhaust is comprised of microscopic carbon soot particles that act to absorb metals and other toxic substances in the exhaust. When inhaled by humans, these tiny, toxic-laden particles cross the blood barrier from lungs into the bloodstream, delivering the toxics to internal organs and leading to inflammation and cardiovascular and respiratory diseases such as cancer, stroke, and heart attacks. In fact, particulate pollution from diesel shortens the lives of 21,000 people per year due to respiratory and cardiovascular disease, including about 3,000 from lung cancer. In addition, diesel takes its toll in cardiovascular disease with an estimated 27,000 heart attacks annually, and is responsible for approximately 400,000 asthma attacks a year. The nationwide diesel cancer risk is more than 200 times the one-in-one-million level that EPA considers acceptable. Diesel pollution also affects our nation's productivity, with more than two million work days a year estimated lost due to diesel pollution health effects. CATF project estimates that diesel fine particle pollution will account for approximately $139 billion in monetized damages or losses in 2010 (Source: US Clean Air Task Force).

## Driver Safety

The California Air Resources Board (CARB) has identified 41 toxic constituents of diesel exhaust that pose potential health threats. The risk of health issues associated with diesel pollutants increases dramatically for those who are repeatedly and regularly exposed to diesel exhaust, namely workers who spend long days inside or behind diesel trucks.

**Below**
Layer of smog covering Los Angeles mainly caused by NOx, SOx and particulate emissions

| *Impact* | *Pollutant* | *% Reduction w/ Natural Gas* |
|---|---|---|
| Greenhouse Gas Emission | CO2 Equivalent | 20%-25% |
| Air Pollution | Particulate Matter | 67%-94% |
| Air Pollution | Nitrogen Oxides (NOx) | 32%-73% |
| Air Pollution | Non-Methane Hydrocarbons | 69%-83% |
| Noise | Decibels | 50% (behind)<br>90% (inside)<br>98% (beside) |

**Above**
Table with pollutant reduction percentages associated with burning natural gas over diesel

# A National Security

The production and use of natural gas as a transportation fuel does not pose the geopolitical risks associated with continued reliance on foreign oil, nor does it result in an ongoing outflow of capital to foreign nations.

**$845M**

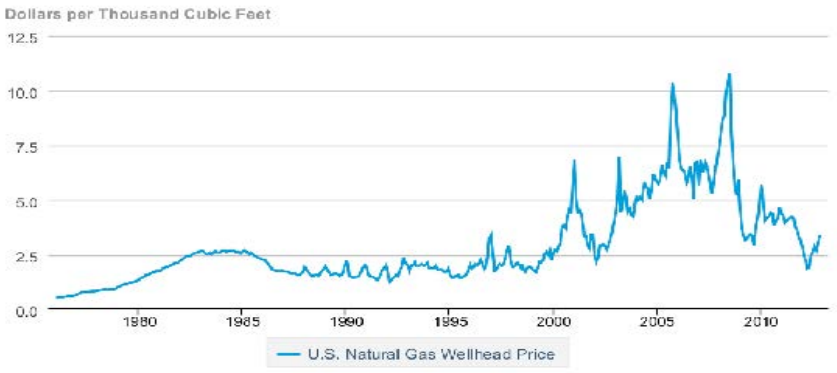
Average dollars spent each day on OPEC oil into the U.S.

## Consumption of Foreign Oil

In 2011, the U.S. imported approximately 45% of the petroleum it consumed, of which 46% of which came from OPEC countries, spending close to $845 million a day to import OPEC oil, of which $110 million a day goes toward the 38 billion gallons of diesel fuel used in on-road transportation annually.

Based on U.S. Energy Information Administration (EIA) and Federal Trade Commission (FTC) estimates:

- *$362 billion of the total $560 billion U.S. trade deficit in 2011 (65%) went toward net imports of crude oil.*
- *The average retail price for diesel in 2011 was $3.85 per gallon, of which 60%, or $2.35 per gallon, was the total cost of crude oil.*
- *The cost of crude oil used for diesel fuel by the Class-8 truck sector (24.4 billion gallons x $2.35/gallon) represents $56 billion a year spent on diesel.*





eia Source: U.S. Energy Information Administration

## Price Volatility of Oil

Petroleum is a globally traded commodity that is at risk to supply disruptions resulting from political conflict, pipeline and trade route blockage, fuel embargoes, etc., volatile price swings are not uncommon.

## Price Stability of Natural Gas

Advancements in extraction techniques (hydraulic fracturing) have tapped immense natural gas in the US. Estimates by the EIA and the Potential Gas Committee suggest a 90+ year supply of natural gas based on current rates of consumption. Close to 90% of the natural gas consumed in this country is produced domestically.

B

# CNG vs. LNG

## *Storage, Transportation and Safety*

CNG and LNG are both viable options to fuel transportation vehicles. Each is sourced and hit dedicated natural gas engines identically. The major difference is the way that they are stored.

When considering switching a fleet to natural gas it is important to understand the advantages and disadvantages of CNG and LNG technology in the commercial trucking industry. Most significantly, the breakdown in production, transmission and distribution of both and how those differences effect cost and functionality of natural gas.

# B Physical Differences

CNG and LNG are both natural gas. One is stored in the form of a gas the other in the form of a liquid.


### Compressed Natural Gas

Compressed natural gas (CNG) is a form of natural gas storage that is used in the transportation industry. CNG stations pull natural gas directly from the natural gas pipeline and compress it on-site to 4,500 psi. CNG is then transferred into CNG outfitted trucks at the pump.


### Liquefied Natural Gas

Liquefied natural gas (LNG) is a form of natural gas storage. First, natural gas goes through a process called cryogenic liquefaction, where it is cooled to -260 degrees Fahrenheit at a liquefaction plant. Then, LNG is transported via insulated truck or boat, and is either transferred to LNG stations, and stored in on-site thermos tanks, or shipped and sold overseas.

## CNG


## LNG

# Price Gap

B

At the pump, the average fuel price for CNG is $2.30/DGE (diesel gallon equivalent), and the average cost for LNG is $2.78/DGE. The cost difference between CNG and LNG is mainly due to the expenses incurred in the necessary cryogenic freezing of natural gas into LNG and transporting it at -260 degrees Fahrenheit.

**$.48/DGE**

Average price advantage of CNG over LNG per diesel gallon equivalent

### Tranportation Costs

CNG transportation costs are minimal because natural gas used to produce CNG comes directly from natural gas pipelines. LNG is transported via specially insulated boats, trains and trucks

### Processing Costs

CNG has no processing costs because it is taken directly out of the US natural gas pipeline. For LNG, natural gas has to be transported to a liquefaction plant where it is cleaned and processed into a liquid by cooling it to -260 degrees, adding $0.70 cents per DGE to its bottom line.

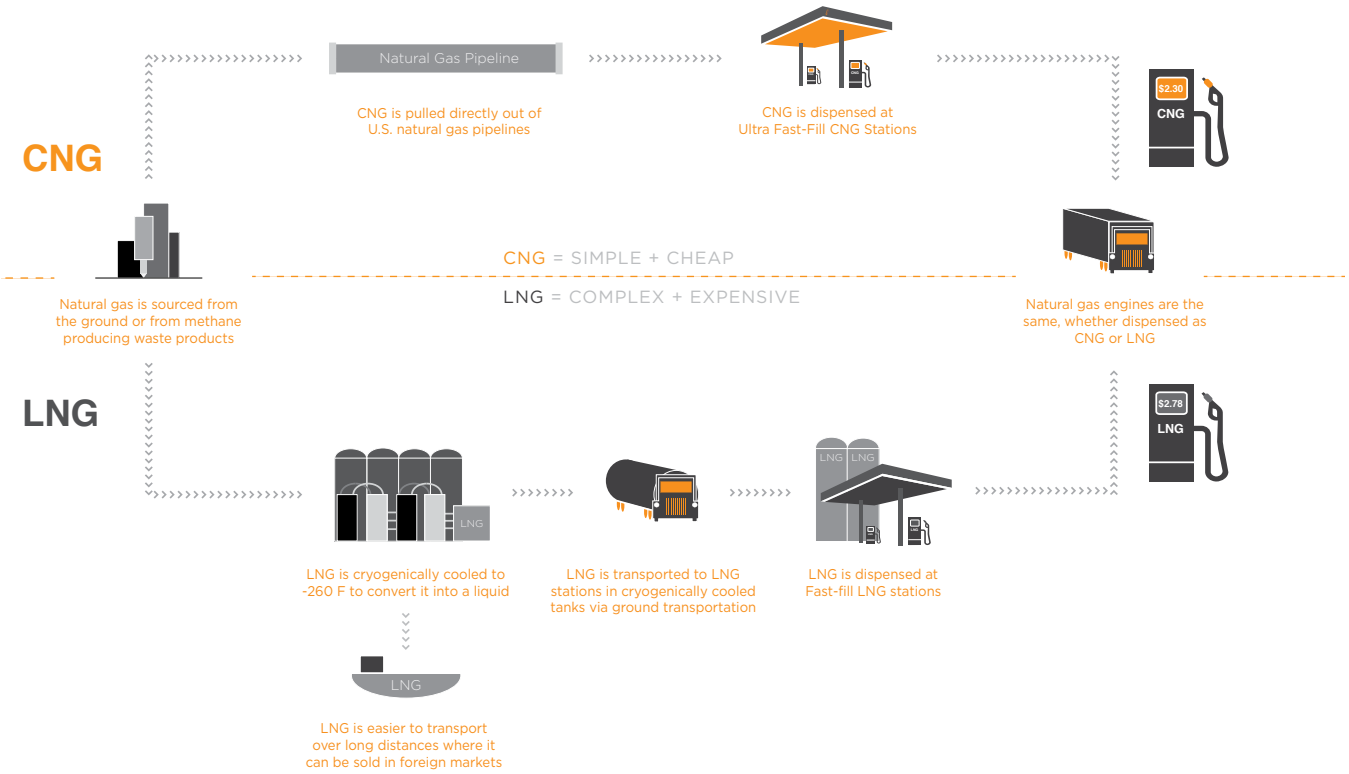
| | Commodity Cost | Processing | Transportation | Station + Service | Federal Tax | State Tax | TOTAL COST PER DGE |
|---|---|---|---|---|---|---|---|
| **CNG** | $.50 Henry Hub $ | $.00 | $.15 Transport via Nat Gas Pipeline | $1.25 On-site Compression | $.20 Fixed | $.20 Variable by State | $2.30 |
| **LNG** | $.50 Henry Hub $ | $.70 Cryogenic Liquefaction | $.18 Ground Transport | $.80 Cryogenic Storage | $.40 Fixed | $.20 Variable by State | $2.78 |
| **DIESEL** | $2.38 Brent/WTI $ | $.52 Crude Oil Processing | $.15 Ground Transport | $.25 Fueling Infrastructure | $.24 Fixed | $.20 Variable by State | $3.74 |

*Numbers based on Diesel Gallon equivalent fuel costs.

**Statistics sourced from the US Energy Information Association (EIA) & the National Petroleum Council (NPC).

# B Storage and Transportation

CNG and LNG are not different fuels, but simply different ways to store natural gas. Therefore, they each have unique modes of production, transmission and distribution that make the changes the effect the process and costs of each.




**3600PSI**

Average storage pressure of a CNG tank

## CNG Process

A Natural gas exits ground
B Natural gas enters pipeline
C Natural gas is compressed from a pipeline and stored at 3600 PSI
D CNG is transferred from storage to a CNG vehicle through a fuel pump

**-260°F**

Temperature LNG must be cooled to to store as a liquid

## LNG Process

A Natural gas exits the ground
B Natural gas is transported to a cryogenic liquefaction plant and turned into LNG
C LNG is transported via insulated trucks to LNG stations
D LNG is stored on-site in thermos bottles that help prevent LNG from boiling-off
E LNG is transferred into an LNG vehicle through a fuel pump

# Tank and Maintenance Differences



Tank packages come in different shapes and sizes depending on the miles needes to run and highway weight restrictions. The major maintenance difference between a CNG and LNG truck is the cryogenic tanks required to keep LNG at -260 degrees Fahrenheit.

**600+mi**

Number of Miles a CNG truck can run on a standard 120DGE fuel tank configuration

## CNG Tank Packages

CNG tank packages are mounted either on the side rail of a truck or back-of-cab. Updated tank packages allow CNG vehicles to travel 600 plus miles without refueling.

## LNG Tank Packages

LNG fuel tanks are more difficult to maintain because of cryogenic insulation that keeps LNG from boiling off overtime. The trade-off is a smaller tank package with a driving range of 800 plus miles.

**Right**
Fleet of 11.9L Kenworth trucks with a 125 DGE back-of-cab CNG tank system

**Below**
Overview of CNG vs. LNG tank differences (source: Agility Fuel Systems)

| *CNG TANK ADVANTAGES* | *CNG TANK DISADVANTAGES* |
|---|---|
| • Unlimited hold times with no fuel loss<br>• More mature technology<br>• Gas / vapor instead of cryogenic<br>• Simple fuel tanks and pressure management<br>• System design can be customized for application | • Cost of compression - energy and maintenance with a compression station<br>• Size of storage tanks |

| *LNG TANK ADVANTAGES* | *LNG TANK DISADVANTAGES* |
|---|---|
| • Fewer tanks / less space requirements<br>• Greater fuel density<br>• Lower weight storage | • The complexity of tanks<br>• Pressure and temperature management of fuel to engine is more complex<br>• High maintenance cost of cryogenic parts<br>• Use the fuel or lose it to evaporation as it boils off |

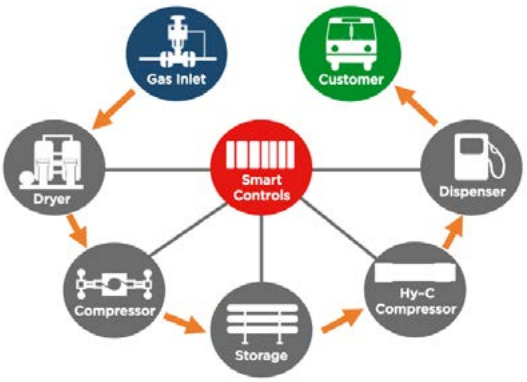
# CNG Technology + Financing

## *Game Changing Advancements*

Technology for CNG stations, engines and storage have rapidly matured over the past decade. CNG capabilities have evolved from private cars, vans and buses to commercial trucks with larger engines and heavier loads. Although beneficial for private vehicles, the Class-8 trucking industry has the most to gain by switching to CNG fuel.

# C Ultra-Fast-Fill Station Technology

Although CNG stations have existed for a long time, the technology used to compress and store CNG fuel has evolved tremendously over the past decade to allow comparable fill times to gasoline and diesel fueling stations. Ultra-fast-fill CNG stations utilize storage technology that equalizes CNG on-site. State-of-the-art Hydraulic Intensifier (Hy-C) systems act like a super-efficient bike pump to pull fuel from storage vessels at a rate of 7–12 gallons per minute, allowing stations to use 90% of the fuel stored on-site, versus 30% with older technology. Additionally, the Hy-C system operates with fewer moving parts, resulting in less maintenance and electricity use.


**Left**
CNG Station + CNG tractor-trailer in Fair Oaks, Indiana.

**Right**
Workflow of an "Ultra-Fast-Fill" CNG station

## Hydraulic Intensifier Compressors (Hy-C)

The hydraulic intensifier (Hy-C) system employs an innovative architecture that splits gas compression into two phases: a multi-stage reciprocating compressor and a proprietary two-stage, non-lubricated hydraulic intensifier compressor that delivers a fast and full fill every time. The Hy-C system is suitable for any location, even those with low suction pressure or intermittent fueling patterns.

**Hy-Flow**: The Hy-C system uses the compressed gas in storage to provide faster fills than a typical CNG station design, with flow rates from 7 to 12 gallons per minute.

**Hy-Efficiency**: Typical stations are only able to use about 30% of the gas in storage, making very inefficient use of expensive high-pressure storage vessels. In contrast, the Hy-C system can use up to 90% of the gas in storage.

**Hy-Reliability**: Because the Hy-C system operates at a slow speed, 25 RPM versus 1800 RPM for a reciprocating compressor, there is less equipment wear and ultimately less maintenance required. The slower speed also results in lower gas temperatures, which mean a fuller fill for your vehicles. Hy-C systems use significanlty less electricity than competing fast-fill systems.

90%

The rate of efficiency at which natural gas is pulled from storage as a result of the highly efficient Hy-C system

## Smart Controls

The key to efficient CNG fueling at stations comes from smart control systems that make sure CNG machinery is working at maximum efficiency. These controls help save electrical usage, manage fueling operations and obtain important management and operational data.

**7-12**

Gallons per minute is the speed at which "Ultra-Fast-Fill" stations can pump CNG.

- The key to fast and consistent CNG fueling comes from smart control systems that ensure machinery is working at maximum efficiency. Smart control save electricity, manage operations of mechanics and obtain important operational data
- Manage compressor lead/lag operations that balance usage of the equipment.
- Prioritizing actually ensures that trucks that show up first have priority in filling first-come, first-serve. This ensures that when other trucks pull up and start fueling, the process is not slowed-down for the first truck due to even distribution of fueling resources.
- Track and record management operation statistics including average fill times per vehicle and compressor operation.
- Automatically log all station alarms and shutdowns
- Provide detailed real-time system information that can be viewed via a standard web browser.

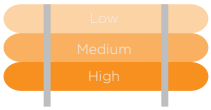
*Information from Trillium CNG*

**Below**
In-depth overview of "Ultra-Fast-Fill" station technology


1. Natural Gas Pipeline
CNG is different from all other transportation fuels, including diesel, gasoline and LNG because it is not stored on-site. CNG utilizes the US's pre-existing network of natural gas pipelines to cheaply and safely transport natural gas to stations. This means no underground storage tanks and no expensive transportation costs.


2. Gas Meter + Dryer
Local gas utilities supply a meter for the CNG station to measure the amount of gas used. The utility determines the pressures and flow rates that are available on-site and if any service upgrades will be needed. In the dryer, gas flows through filters and a drying bed to remove moisture and contaminants. Only clean, dry gas flows to the compressors.

3. Compressor
Compressor systems are the workhorses of every CNG station and must withstand heavy-duty use over many years. To meet this demand, only best-in-class compressors are installed; they have an unmatched record of service, a long life, and superior factory support. Compressors are housed in sound-attenuated enclosures that minimize noise to an average of 70 decibels from a 10-foot distance.




4. High Pressure Storage
From the compressors, advanced control systems manage the flow of gas and determine whether to send it to storage or to bypass storage sending the gas directly to the dispensers. CNG is stored at up to 5000 psi. All CNG storage tanks are above ground, which makes them easy to maintain and nontoxic to the ground the way that underground gasoline or diesel tanks often contaminate soil.

5. Hy-C Compressors
The Hydraulic Intensifier (Hy-C) system employs an innovative architecture that splits gas compression into two phases: a multi-stage reciprocating compressor and a proprietary two-stage, nonlubricated hydraulic intensifier compressor, which delivers a fast and full fill every time. The Hy-C system is proprietary architecture that fills at up to 90% efficiency using a non-lubricated compressor system.

6. CNG Fuel Dispenser
Fuel can be dispensed through ultra fast-fill systems that provide fill times similar to gasoline and diesel fuel dispensing and that include fuel management and credit-card payment systems. Stations also utilize RFID systems that allow fleets to charge fuel directly to an account and track fueling statistics. New color screen displays allow drivers simple functionality.

# C Natural Gas Engines

All major heavy-duty truck OEMs have factory-built models available for sale, including Freightliner, Peterbilt, and Kenworth. Existing fleets of 40+ trucks are currently operating CNG tractors pulling 80,000 lbs more than 20,000 miles per day.

The Cummins Westport 8.9L ISL-G has been installed in trucks since 2007 with the 13,000th engine having shipped in December 2012. The Cummins Westport 11.9L ISX-G was released in 2013 with an estimated 4,000 units allocated among the major truck OEMs. With up to 400hp and 1450 ft-lb of torque, this opens up the heaviest trucking hauls to CNG tractors. Current CNG heavy-duty truck engines are fully EPA-certified and require no DEF or diesel particulate filters.

ISX G ENGINE

- 4 cycle, spark ignited, in-line 6 cylinder, turbocharged, CAC
- Displacement – 8.9 litres (540 cu in)
- Peak rating: 320hp, 1000 lb-ft
- EPA/CARB certified at or below EPA10 emission levels
- Dedicated natural gas engine
- Will operate on CNG or LNG
- Capable of using up to 100% Biomethane
- Three Way Catalyst after-treatment
- Engine braking
- Manual/Automatic Transmission capable
- No AMT at launch
- *Ideal for Bus / Transit / Shuttle, Refuse, Pick-up and Delivery, Last Mile Operations, Beverage Distributors, Home Fuel Delivery, Specialty Vehicles*

ISX12 G ENGINE

- 4 cycle, spark ignited, in-line 6 cylinder, turbocharged, CAC
- Displacement – 11.9 litres (726.2 cu in)
- Peak rating: 400 hp, 1450 lb-ft
- EPA/CARB certified at or below EPA10 emission levels
- Dedicated natural gas engine
- Will operate on CNG or LNG
- Capable of using up to 100% Biomethane
- Three Way Catalyst after-treatment–Engine braking–Manual/Automatic Transmission capable
- No AMT at launch
- *Ideal for Regional Haul, Bulk Hauler less than or equal to 80,000 GVW, Less than loaded, Dedicated Carrier Services, Expedited Freight, Feed Trucks, Mixer/Vocational, Specialty Vehicles*

**Above**
Source: Cummins-Westport

# Purchasing CNG Trucks

Technological advancement has made CNG equipment for Class-8 trucks easier to insure, less expensive to maintain and more widely adopted. This has made investing and securing debt in CNG equipment less risky and subsequently easier and less expensive to finance.

## Return on Investment

Although all types of CNG vehicles displace CO2 and see fuel savings, commercial truck fleets with long, consistent routes stand to benefit the most by transitioning. At an average of $2.30 per diesel Gallon Equivalent ("DGE") for CNG versus $3.74 for diesel, fleets have the opportunity to save up to $170,000 for a single truck over the course of its lifetime.

**17.50%**

Internal Rate of Return advantage in fuel savings over diesel in an average CNG truck configuration.

## Subsidies and Economic Incentives

Many municipal, state, regional and national public agencies have developed grant programs that incentivize the use of CNG vehicles. The combination of economic and environmental benefits associated with transitioning transportation fuels to CNG makes it one of the most readily accessible alternative fueling incentive opportunities.
Public Entities that offer CNG Financing Programs include:

- US Department of Energy Clean Cities Clean Fleets Program
- US Department of Transportation
- Environmental Protection Agency (Smartway Finance Program)

**Below**
(1) Priced 12L Cummins Kenworth Trucks / Trilogy Tank System
(2) Based on $50k for maintenance bay for 20 trucks
(3) 10% fuel efficiency haircut for CNG
(4) $2.30 assumption for CNG

| Fuel Type | Diesel | LNG | CNG |
|---|---|---|---|
| Miles Per Year Per Truck | 130,000 | 130,000 | 130,000 |
| Additional Truck Costs | N/A | ($70,000) | ($80,000) |
| Fuel Costs (Gallon Equivalent) | $3.74 | $2.78 | $2.30 |
| Miles Per Gallon | 6.5 MPG | 6 MPG | 6 MPG |
| Total Annual Fuel Costs | $74,800.00 | $60,233.33 | $49,833.33 |
| Additional Residual Value | N/A | $17,500 | $20,000 |
| Additional Maintenance Costs | N/A | ($2,500) | ($2,500) |
| Annual Savings | $0.00 | $12,066.67 | $22,466.67 |
| Payback in Months | N/A | 69.61 Months | 42.72 Months |
| IRR | N/A | 3.16% | 17.50% |

# C Leasing CNG Trucks

Leasing arms of national truck manufacturers now provide unique financing options for leasing trucks that allow haulers to realize no additional capital costs when leasing a CNG trucks compared to diesel trucks by working with fueling companies to house additional truck costs in fuel charges, rather than up-front. This allows growth in the natural gas fuel market to fleets of any size.

Truck Lease Example:

- *Kenworth T-660, Cummins ISX12 G natural gas engine, 400 HP, Fuller 10-Speed, Tank Package Trilogy RM120 DGE Rail Mount System*
- *48-Month TRAC Lease, 125K miles per year allowance, 32.5% residual value*
- *Full service maintenance program $550 / month and $0.09 / mile (variable)*

**$1.01/mi**

All-in cost of a CNG lease for a standard CNG truck configuration

Cost Per Mile

Substantially reduced fuel costs save fleets that lease trucks a considerable variable advantage with “all-in” per mile leasing costs of $1.01.

| CNG | LNG | DIESEL |
|---|---|---|
| • $1.01 / mile (“all-in”)<br>• Includes full service maintenance<br>• Includes fuel @ $2.30 / DGE<br>• 600 Mile Range<br>• 5.75 MPG | • $1.11 / mile (“all-in”)<br>• Includes full service maintenance<br>• Includes fuel @ $2.78 / Gallon<br>• 782 Mile Range<br>• 5.75 MPG | • $1.07 / mile (“all-in”)<br>• Includes full service maintenance<br>• Includes fuel @ $3.75 / Gallon<br>• 777 Mile Range<br>• 6.40 MPG |
| Total Annual Cost Per Truck<br>$85,109.53 | Total Annual Cost Per Truck<br>$93,582.57 | Total Annual Cost Per Truck<br>$90,251.40 |

## R-CNG

CNG can be produced into a renewable bio-methane through manure or land-fill waste

CNG (Compressed Natural Gas)
CNG is a fossil fuel substitute for gasoline, diesel fuel, and propane. Although CNG's combustion does produce greenhouse gases, it is widely considered a cleaner alternative to conventional fuels as it produces, on average, 30% less CO2 emissions than gasoline or diesel. CNG is classified by the US Department of Energy as a "Clean Fuel." Additionally, in the event of a spill it is safer than other fuels, as natural gas is lighter than air, and disperses quickly when released. CNG can also be created from biogas, produced from landfills, wastewater or manure.

CNG is made by compressing natural gas, which is mainly composed of methane to less than 1% of the volume it occupies at standard atmospheric pressure. It is stored and distributed in hard containers at a pressure of 2,900–3,600 psi, usually in cylindrical or spherical shapes containers.

LNG (Liquefied Natural Gas)
LNG is natural gas that has been converted to liquid form for condensed storage or transport. The liquefaction process involves removal of certain components, such as dust, acid gases, helium, water, and heavy hydrocarbons, which cause difficulty downstream. The natural gas is then condensed into a liquid by cooling it to approximately –260 degrees Fahrenheit. Liquefied natural gas takes up about 1/600th the volume of natural gas in the gaseous state.

LNG is principally used for transporting natural gas to markets, where it is re gasified and distributed as pipeline natural gas. It can be used in natural gas vehicles, but requires specialized tank technology to keep LNG at -260 degrees Fahrenheit throughout transport. Its relatively high cost of production and the need to store it in expensive cryogenic tanks have made it more cost beneficial for large-scale transportation (such as boats or trains), rather than commercial car and truck markets.

Class-8 Trucking Sector
The Class-8 truck gross vehicle weight rating (GVWR) is any vehicle 33,000 pounds and above. This includes all tractor trailer trucks.

Back-of-Cab Tank Configuration
A tank configuration for natural gas vehicles where tanks ar stacked vertically behind a truck's cab. This allows larger tank packages that carry more natural gas to travel longer distances.

Diesel Gallon Equivalent (DGE)
Diesel Gallon Equivalent is another way to rate CNG vehicle storage. Since Diesel has a higher energy content than gasoline (129,500 BTUs standard), 1 DGE = 1.136 GGE and 1 GGE = 0.88 DGE. Since most CNG metrics are in GGEs if you want to calculate how many cubic feet would be required for an equivalent number of DGEs, just divide by 0.88 (in terms of Standard Cubic Feet, a DGE = 126.67/0.88 or 143.94 SCF and so forth). The reverse is also true. If, for example, you want to convert a cylinder capacity from GGE to DGE, you can multiply by 0.88. So, for example, a 24 GGE cylinder holds about 21 DGEs.

### Gasoline Gallon Equivalent (GGE)

Gallon of Gasoline Equivalent is the typical way CNG is sold at public fueling stations and the typical way that CNG tanks are rated. One standard GGE = 114,000 BTUs which equals 126.67 SCF (126.67). Now, the sharp reader will immediately notice that if an SCF has 1,020 BTUs then 126.67 scf should be 129,000 BTUs so something isn't adding up! That something known as "lower heating values" or LHV (also called net calorific value). You can read all about this here, but for the purpose of understanding CNG you need to know that an SCF of Natural Gas only yields 900 BTUs of useable gasoline equivalent energy.

CNG compresses the gas to 3,600 psi (some older vehicles were compressed at 2,400 psi). At this compression level, one GGE requires 0.51 cubic feet of space in a CNG tank. So the interior space of a 20 GGE tank is approximately 10 cubic feet (think roughly 42″ wide, 18″ deep, and 18″ tall).

### Hydraulic Intensifier Compressors (Hy-C)

The hydraulic intensifier (Hy-C) system employs an innovative architecture that splits gas compression into two phases: a multi-stage reciprocating compressor and a proprietary two-stage, non-lubricated hydraulic intensifier compressor that delivers a fast and full fill every time. The Hy-C system is suitable for any location, even those with low suction pressure or intermittent fueling patterns.

### MMBTU

One million British Thermal Units or BTUs. Natural gas is generally bought and sold in MMBTUs and future prices are generally quoted in this unit of measure.

### Henry Hub

Henry Hub (often abbreviated HH) is a natural gas pipeline hub in Earth, LA that interconnects with 13 interstate and regional pipelines. Most wholesale natural gas prices are quoted at this delivery point with an adder or discount based on local market dynamics and transportation cost. When you see the news reporting Natural Gas is at $3.50 that usually means 1 MMBTU, bought today, to be delivered to Henry Hub next month, costs $3.50.

### Standard Cubic Foot (SCF)

Standard Cubic Foot is one cubic foot of gas at standard temperature and pressure (60 degrees F and sea level). Since both temperature and air pressure affect the energy content of a cubic foot of natural gas, the SCF is a way of standardizing. One SCF = 1020 BTUs.

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# E About ampCNG

## Our Purpose

ampCNG helps haulers and corporations fuel with Compressed natural gas by educating and guiding customers through the financial and technological steps associated with switching to CNG. ampCNG takes an education-first approach to CNG, where we share our in-depth industry knowledge and experience with all interested parties.

## Our Story

ampCNG was started by a group of entrepreneurs with experience in the energy and transportation industries. ampCNG began CNG operations with the Renewable Dairy Fuels project at Fair Oaks Dairy Farm in Northern Indiana. ampCNG was brought in to research, fund, construct and implement an anaerobic digester using the manure from the farm's 12,000+ cows. ampCNG found that the most economical and environmentally friendly solution was to produce CNG from the manure to use as transportation fuel for the farm's fleet of 42 commercial trucks. ampCNG subsequently built CNG fueling stations at Fair Oaks and Sellersburg, Indiana. A huge success, the ampCNG team is now 100% focused on facilitating CNG opportunities for the commercial trucking industry from conception to completion.

## Our Research

The ampCNG team has the opportunity to research and test on the Class-8 trucking fleet with the most miles traveled on CNG in the country, our own fleet: ampHaulers, LLC. As a result, ampCNG has found that the long and consistent routes run by commercial trucks allow the greatest benefit from a transition to CNG. It provides the greatest aggregate cost savings, reduction in CO2 emissions and displacement of foreign oil in the transportation sector and is ampCNG's sole focus.


**Left**
ampCNG team at the Clean Cities Clean Fleets awards ceremony


ampCNG


ampCNG