# A Comparison of Compressed Natural Gas and Propane

For General Background Purposes

## Compressed Natural Gas (CNG) vs. Propane (LPG)

### The Basics

<table>
<thead>
<tr>
<th>Compressed Natural Gas (CNG)</th>
<th>Propane (LPG)</th>
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<tbody>
<tr>
<td>Methane is the primary component of natural gas. It is the simplest hydrocarbon with a chemical formula of CH₄.</td>
<td>Propane is the primary component of LPG and is derived from the processing of crude oil or natural gas. Propane is a three carbon alkane with a chemical formula of C₃H₈.</td>
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</tbody>
</table>

- Natural gas has the highest energy to carbon ratio (4:1) of any fossil fuel and thus produces less carbon dioxide per unit of energy than any other fossil fuel.
- Natural gas is compressed to 3,600 psi to become CNG, which is stored inside high pressure cylinders onboard natural gas vehicles (NGV).
- One gasoline gallon equivalent (GGE) is the amount of alternative fuel it takes to equal the energy content of one liquid gallon of gasoline.
- One GGE of CNG contains 114,898 Btu’s.
- One GGE of CNG will power a vehicle the same number of miles as one gallon of gasoline.

- With only 3 carbon atoms per molecule, propane is a cleaner burning fossil fuel than gasoline or diesel.
- Propane is compressed to 120 psi and stored as a liquid inside steel tanks onboard LPG vehicles.
- One gallon of propane contains about 28% less energy than one gallon of gasoline or one GGE of CNG.
- One gallon of propane contains about 83,500 Btu’s.
- One gallon of propane will power a vehicle about 28% fewer miles than one gallon of gasoline.

### Fuel Safety

- Natural gas is lighter than air with a specific gravity of 0.5537.
- When present in the environment, natural gas will dissipate into the atmosphere quickly, minimizing fire potential.
- Very narrow flammability range: 5% to 15%
- Auto-ignition temperature: 1,004°F

- Propane is heavier than air with a specific gravity of 1.5219.
- When present in the environment, propane does not puddle in liquid form but will pool near the ground similar to gasoline vapors.
- Very narrow flammability range: 2% to 9.5%
- Auto-ignition temperature: 850°F to 950°F
### Economics

#### Station Construction
- Stations require greater initial investment of $500K–$750K to build a standard fast-fill station.
- Investment partners are often willing to install private/public stations when fleet demand exists.
- CNG offers a second option, called time-fill. Time-fill stations provide concurrent fueling of multiple vehicles (up to 100’s) at a slower rate per vehicle.
  - Example: A station can fill one truck at 8 GGE/minute on fast-fill or 100 trucks at 480 GGE/hour on time-fill.
  - If a fleet’s vehicles sit in a parking lot overnight, every night, this is the most cost and time effective method of fueling.

Time-fill stations are considerably less expensive than fast-fill stations, which reduces costs and increases convenience where applicable.

#### Automobile Purchase/Conversion

**Light & Medium Duty Vehicles**
- OEM options from
  - GM
  - Chrysler
  - Honda
  - (Ford offers a conversion/upfitting process)
- Conversions available across multiple platforms for the end user to find the best vehicle options. For a complete listing, click here.
- Incremental costs range from ~$7k–$15k per vehicle. The Drive Natural Gas Initiative “Add Natural Gas” project has created six bi-fuel NGVs at an additional cost of ~$2,600-$4,800 per vehicle to demonstrate lower incremental price feasibility.

**Station Construction**
- Fueling facilities are less expensive to install than CNG stations—about $45k–$175k to build an LPG filling station. A very simple dispensing system can be as low as $25K.
- Propane suppliers will often install private stations when fleet demand exists.

**Automobile Purchase/Conversion**
- No OEM options exist through GM (except noted immediately below) or Ford—only aftermarket options. Roush Clean Tech is a QVM of Ford product, not able to OEM. There are no Chrysler or Honda OEM products or certified conversion kits available.
- One Class 4 available (Collins Nex Bus – Express/school bus)
- Conversions available on several platforms. Less vehicle choices when compared to NGVs. A complete listing can be found here.
- Incremental costs range from ~$5k–$12k per vehicle.
Multiple options exist across many platforms, including transit buses, waste management, and Class 8 over-the-road tractors. Examples of a variety of OEM heavy-duty vehicles is available here.

**Fuel Costs\(^1\)**
- National average price: $2.09/GGE.
- National average retail price: $2.20/GGE.
- National average private price: $1.80/GGE
- Price fluctuations are rare.
- Seasonal price fluctuations are non-existent, due to gas utility buying patterns. Gas utility profits are regulated.

**Fuel Costs\(^1\)**
- National average price: $4.31/GGE.
- National average retail price: $4.39/GGE
- National average private price: $3.35/GGE
- Prices fluctuate similar to gasoline and diesel, albeit improving as a result of propane being produced from U.S. natural gas reserves.
- Prices prone to seasonal fluctuation, due to large home heating demand in colder months (Compare propane prices above to last July's (2013) pricing as an example.)

**Tailpipe Emissions/Environmental**
Natural gas is the cleanest burning fossil fuel and consequently has the emissions advantage over diesel and gasoline. It can be argued that because of this inherent environmental quality, the EPA has been able to set stricter emission mandates (particularly with NOx and PM reductions) that forced expensive diesel emission technology to be created to be as environmental as natural gas. Natural gas was compliant with 2010 EPA emission requirements in 2007.

Both natural gas and propane provide environmental advantages as these vehicles all must be certified to new demanding emission limits that require today’s motor vehicles to be 90% cleaner for most pollutants than was the case just a few years ago. The biggest benefit in both cases—natural gas and propane—is to introduce them to replace older, dirtier diesel vehicles. For emission benefits of particular vehicles, potential purchasers should obtain copies of actual certification data and consider the emission certification levels (e.g., Tier 2, 4, or ULEV, SULEV).

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### Infrastructure: Public vs. Private

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<th>Public</th>
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<tbody>
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<td>Up to $3/4 billion currently being invested in creating U.S. natural gas fueling stations and fueling corridors:</td>
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<td>- Since 2009, the amount of CNG fueling infrastructure has grown by 73%.</td>
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<td>- Since mid-2010, the number of planned CNG fueling stations has grown 396%.</td>
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<tr>
<td>There are more than 1,362 CNG stations nationwide, of which 50% are open to the public.</td>
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<td>Natural gas is a consistent fuel provided by local, regulated utilities nationwide.</td>
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<tr>
<td>Investment in U.S. propane fueling infrastructure pales in comparison to natural gas.</td>
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<td>More than 2,986 fueling locations nationwide with an additional 28 planned to be built.</td>
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<td>HD5 propane is required for vehicular use; cannot use “barbecue grade” propane.</td>
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<tr>
<td>HD10 propane could void engine warranty and damage fuel systems.</td>
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### Safety

National Fire Protection Agency (NFPA) guidelines for both CNG and propane conversions are strictly enforced. CNG and propane systems are tested to meet or exceed all safety requirements for gasoline and diesel equivalents. (Question: If gasoline and diesel transportation fuels were introduced today, would they hold up under the same scrutiny as CNG?)

### Long-Term Price Stability

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<td>Natural gas is currently estimated to have over 100 years of stable supply.</td>
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<td>Reserves of natural gas are estimated to keep prices stable through at least 2030, even assuming significant gains in power generation and vehicular use.</td>
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<tr>
<td>The price at the pump is expected to remain significantly lower than gasoline and diesel, and the price differential is expected to widen as gasoline and diesel prices continue to increase.</td>
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<tr>
<td>Over 98% of natural gas is produced within U.S. borders, providing long term, reliable resources.</td>
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<td>Propane is a by-product of natural gas and crude oil (foreign &amp; domestic) production.</td>
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<tr>
<td>Propane prices vary, similar to gasoline and diesel.</td>
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<tr>
<td>Propane prices are expected to remain lower than gasoline and diesel, but fleet managers can still expect fluctuating prices, especially during the home heating months.</td>
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<tr>
<td>More than 90% of propane is produced inside the U.S., which makes pricing more stable than before as a direct result to decreases in refining propane through foreign oil imports.</td>
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Pricing and Market Share Trends

Any effort to compare the price of natural gas and propane with the price of gasoline should start by ensuring that the consumer is making an apples-to-apples comparison. CNG sold at retail is already converted to GGE units so consumers can figure out quickly if they are getting a good deal. For propane, it is generally sold in liquid gallons and must be converted to GGE units in order to put it on a level playing field for comparison sake (i.e., paying more or less for the same amount of energy). The formula to convert a gallon of propane to a GGE of propane:

\[
\frac{\text{Gasoline Btu}}{\text{Propane Btu}} \frac{115,400}{83,500} = 1.38
\]

The answer nets a conversion factor of 1.38 gallons of propane to 1 GGE. Therefore, the cost of a GGE of propane is 1.38 times greater than the cost of a gallon of propane.

Additional propane-to-gasoline analysis:

\[
\frac{\text{Propane Btu}}{\text{Gasoline Btu}} \frac{83,500}{115,400} = .72
\]

It is important to ensure that the GGE conversion is used when making comparisons because:

- A gallon of propane has 72% of the energy of a gallon of gasoline; or
- A gallon of propane contains 28% less energy than a gallon of gasoline

The aforementioned data is derived from the Transportation Energy Data Book (TEDB). The key point to this exercise is to calculate how much one is truly paying for the same amount of energy. That is why the Clean Cities Alternative Fuel Price Report (January 2014) provides exactly that type of analysis with charts that show the comparative price per GGE. Looking at the Clean Cities’ report, the price of CNG offers a much better economic value than gasoline or propane. Btu values vary slightly from U.S. regions and it is important to check with local fuel suppliers to provide these numbers whenever possible.

Also note that all fuels, including CNG and propane, have two different Btu numbers: an HHV (Higher Heating Value = Gross) and an LHV (Lower Heating Value = Net), both calculated based on heat of combustion, a term that measures the energy released as heat when a compound undergoes complete combustion with oxygen under standard conditions. HHV can have a significantly higher Btu value when compared to LHV due to the additional heat (transferred to energy) gained through the vaporization of residual water during the combustion process. The HHV Btu measurement can be employed when evaluating products like natural gas or propane home heating furnaces or hot water tanks because these technologies leverage additional heat (energy) gained through water vaporization. The internal combustion engine, however, cannot capture these efficiencies and so the LHV value must be used due to its inability to recover and utilize the net benefits of water vapor during the combustion process.

The following graphs and charts are taken from various government entities responsible for tracking transportation fuels. They serve to visually show historical, current and forecasted industry trends.
Average Retail Fuel Prices in the U.S.


AEO 2013 Transportation Fuels

The pie chart below shows that in 2011, natural gas accounted for 48% of the alternative fuels consumed; propane’s contribution was 24%. The next release date for the report of this market share data is April 2014 where it is estimated that natural gas will capture close to 60% of the market.

**Consumption of alternative fuels in vehicles by fuel type, 2011**

- Natural Gas: 245,409,000
- Propane: 124,457,000
- Ethanol (E85): 137,165,000
- Hydrogen: 174,200
- Electricity: 7,635,000

Source: U. S. Energy Information Administration


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Future: Scalability of Fuels and Infrastructure

One of the important factors to consider when evaluating all transportation fuels, particularly for those responsible in fleet management, is scalability. A key question is whether natural gas and propane production and infrastructure can be scaled up to serve a large part of the U.S. transportation market. The U.S. transportation fuels market is roughly a 185 billion GGE market. The U.S. market for natural gas at 24 quadrillion Btu per year is equivalent to roughly 192 billion GGEs. Thus, the natural gas market today is actually larger than the on-road transportation fuels market by 3.8%. Propane at about 15 billion annual gallons represents the equivalent of about 10.9 billion GGE’s and its total market size is less than 5.9% the size of the on-road transportation fuels market. The propane market is 5.7% of the size of the natural gas market.

To offset 5% to 10% of the total transportation fuel consumption (9.25 to 18.5 billion GGE), natural gas production would have to increase by about 4.8% to 9.6%, respectively. Propane production would have to increase by a staggering 84% to 169%, respectively. For propane, there is no reason to believe that domestic supply or infrastructure could possibly adjust to this level of demand without having a major impact on prices. Furthermore, there does not appear to be any effort in the propane industry to develop and expand the necessary infrastructure that would be required to service such an increase in demand. The natural gas industry on the other hand is investing hundreds of millions of dollars to expand its infrastructure to serve the transportation market. Thus, propane is most likely a niche market fuel at best that can help offset future transportation demand, but it will not have a substantial impact on the transportation fuels market or on petroleum imports.

Propane proponents’ talking points critique the lack of and cost of infrastructure in the NGV market and choose to ignore the fact—that since 2009 there has been massive growth in the number of fueling locations in the U.S.: 64% and 125% increases in CNG and LNG infrastructure, respectively. Currently, natural gas infrastructure investments total up to $750 million ($3/4 billion), and multiple stakeholders are actively engaged in its development:

- Local gas distribution companies
- Natural gas retailers
- Natural gas exploration & production companies
- Leasing companies
- Customers (existing users of NGVs)
- “Traditional” fuel retailers (Truck Stops and “C-Stores”)

Very simply put, both the capital and operating expenses of natural gas infrastructure, no matter how high or low, should be considered and weighed against revenue (or fuel savings) to determine investment worthiness (i.e., will the investor, whether it be a fleet or fuel provider, net a desirable return on their investment). Given the sheer volume of investments occurring in natural gas fueling infrastructure today, it appears that the answer is a resounding “yes” for a growing number of companies.