The Definitive Guide for LNG IN FLEETS

KINDER MORGAN

Abstract

The emergence of natural gas as an abundant, inexpensive, near zero NOx emission and domestic fuel is revolutionizing the delivery of energy used for transportation fleets. The economics of natural gas compared to diesel is mostly appealing for vehicles with high over the road travel and fuel use. With unpredictable and volatile fuel costs and pressure to lower carbon footprint, the transportation industry has been searching for an alternative fuel that will address these two concerns. LNG – or Liquefied Natural Gas – is now establishing itself as the low emission fuel of choice for transportation fleets. In this guide, we will explain how liquified natural gas can be utilized to provide fuel cost savings and environmental benefits for the class 8 trucking sector.

What is LNG

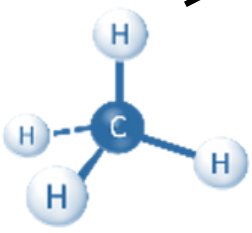
Liquefied Natural Gas (LNG) is manufactured by sourcing natural gas from pipelines, and then purifying the gas during liquefaction. LNG is a consistent, clean, refined fuel.

he gas is pulled from the natural gas pipeline and brought into the manufacturing plant for pre-treatment. Pre-treatment cleans up the gas by removing debris found in the pipeline, water, and the heavy hydrocarbons. This refinement process yields a 95% Methane content. As a result, LNG has a higher and more stable Methane content than when the gas was in its natural state; resulting is a greener and more stable fuel.

Cummins Westport uses LNG to test its natural gas-powered engines due to the higher methane content, stability and reliability of LNG. Accurate engine performance testing requires a stable and specific composition of natural gas. Raw pipeline natural gas composition varies and can contain variable levels of heavy hydrocarbons, such as ethane, which leads to poor engine performance.

After pre-treatment, the cleaner gas is liquefied. The gas is cooled to negative 260 degrees Fahrenheit. As a liquid, LNG is 1/600th of its volume as a gas. This density allows LNG to be efficiently stored, which makes it an ideal fuel to transport. LNG is transported to the end-user by cryogenic transport trucks.

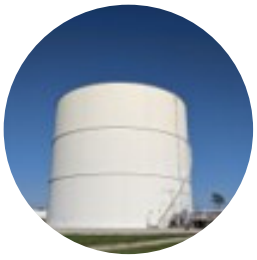
LNG Production Process



Natural Gas Supply

Pre-Treatment

Turns to Liquid at-260 F

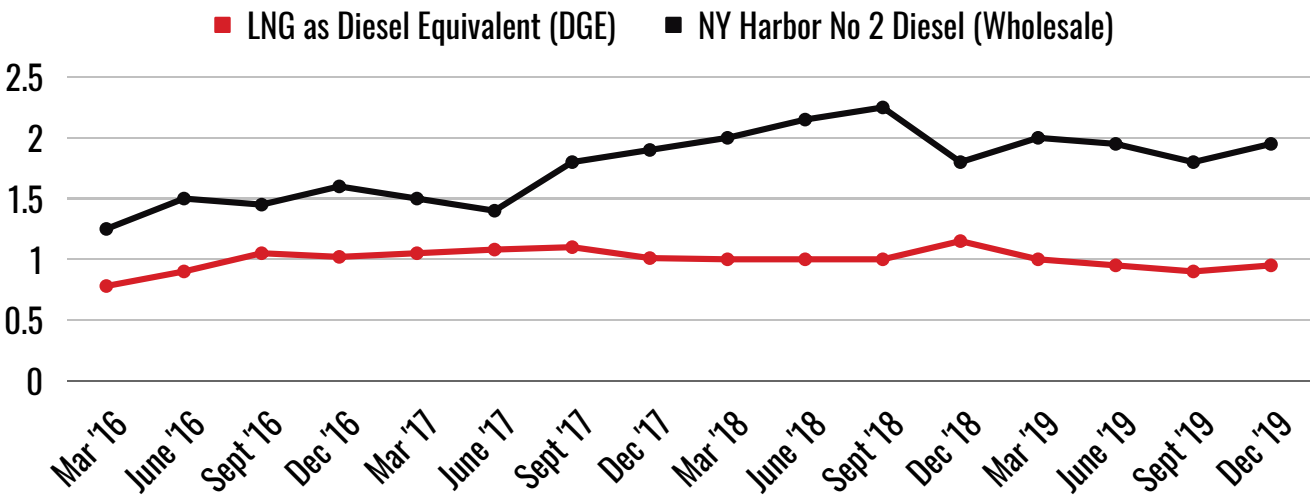


Storage Reduced 600x Compared to PNG

LNG Pricing

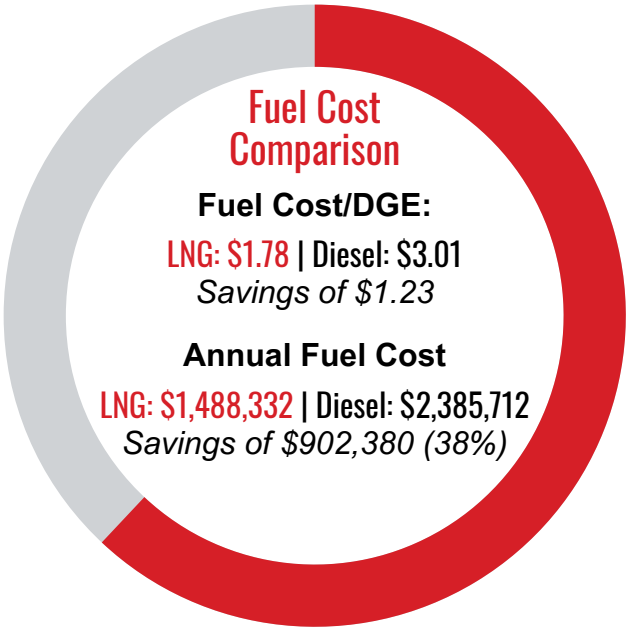
Wholesale merchant LNG cost is approximately $1 per Diesel Gallon Equivalent (DGE). LNG is a domestic low-emission fuel that offers price stability and the opportunity for long-term hedging. Natural gas is traded on the New York Mercantile Exchange (NYMEX). The First of the Month (FOM) NYMEX cost of natural gas makes up only approximately 35% of the wholesale cost of LNG. As a result, LNG pricing is stable and consistent especially when compared to wholesale No. 2 diesel.

Pricing: Diesel vs LNG



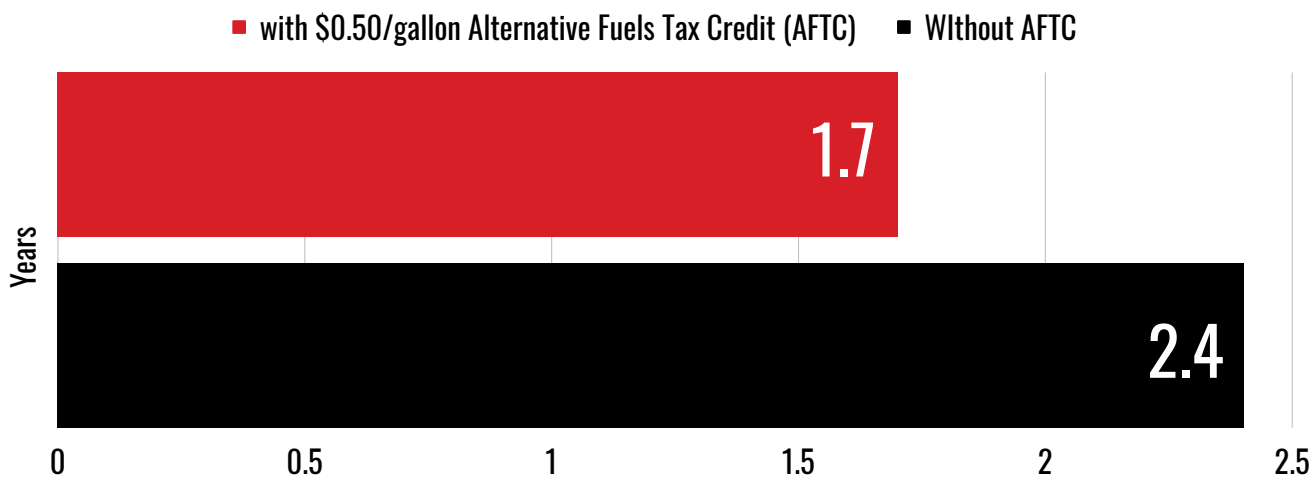
Hypothetical ROI Analysis

The significant price advantage of LNG over diesel (approximately $1.23 a fully delivered diesel gallon equivalent) allows fleets to receive a very fast return on the invest (ROI) they make in the additional capital expenses needed when converting to LNG. These expenses include natural gas engine trucks, fueling stations and possible maintenance upgrades. Typically, the ROI is two years or less for the average trucking fleet. From a corporate perspective, this payoff is extremely attractive. The ROI Analysis below enables fleet owners to make the case for an economic and sustainable transportation solution for their fleet.



LNG Pricing

Return on Investment



Inputs and Assumptions

- Total Trucks: 50
- Annual Mileage/Truck: 100,000
- Annual Diesel Gallons for Tractors: 793,650
- Diesel fuel economy: 6.3 mpg
- 5% fuel economy degradation for LNG
- No truck residual values included
- Diesel: $3.006 (2/18/19 EIA national retail average diesel)
- RINs Value: 2.5%, $0.04/gallon
- Both fuels shown at fully delivered, fully taxed price
- LNG IN taxes: $0.714/gallon
- Incremental cost for LNG Truck: $43,971
- Kinder Morgan provides the Fueling Station
- Natural Gas Maintenance Center Upgrades included at $100,000

LNG Technology

The latest LNG tank technology provides a lightweight fuel system with the range capacity for a regional transportation network.

Chart Tank Models	HLNG-150 'Lite'	HLNG-150	HLNG-158 'Bonus'	HLNG-206
Dimensions	26"x86"	26"x90"	26"x90"	26"x120"
Capacity	69 DGE	69 DGE	72 DGE	94 DGE
Empty Weight	625 lbs	635 lbs	675 lbs	830 lbs
Full Weight	1041 lbs	1051 lbs	1112 lbs	1400 lbs

** Available in custom sizes from 13" to 34" diameter up to 280 gross gallon capacity. Full weight calculations are based on 3.08 lb./gal. density LNG.*

For class 8 vehicles, the most economic method of storage for natural gas is as a liquid. The gas is cooled to temperatures as low as negative 164° Celsius, compressing it to 1/600th of its original volume. As a result, LNG has a much greater energy density than CNG.

The initial cost of an LNG fuel system is less expensive than a CNG system because fewer tanks are needed to store the fuel needed for an equivalent range. LNG tanks are similar to diesel, in that the fuel is stored in two saddle tanks and fueled on one side of the vehicle.

Since LNG is compressed, LNG fuel systems are lightweight; up to 500 lbs. lighter than diesel, and 1,000 lbs. lighter than CNG fuel systems. This lightweight system reduces fuel economy loss to only 5-8% less than diesel.

An LNG fuel system enables an 800+ mile range for a day-cab. This range is ideal for hub-and-spoke transportation networks, where trucks are domiciled and return to their hub after one to two days.

LNG tanks have a durable cryogenic insulation that does not have a maximum service life and only require a visual inspection once a year. CNG tanks require off road service technician inspection every 36,000 miles thus increasing down-time.

LNG is the safest fuel on the market. Natural gas as a liquid will not explode. LNG tanks have a low operating pressure of 50-150 psi. If spilled, LNG will evaporate and not impact the environment. LNG is colorless, odorless, non-toxic and non-corrosive. Drivers have reported higher satisfaction using LNG in their trucks rather than diesel. Drivers have a quieter ride and do not experience any residual smell while fueling or operating the LNG trucks. LNG's performance rivals diesel on a torque and miles per gallon basis.

Natural Gas Engines

The latest Cummins Westport engine for Class-8 trucks is the ISX12N. Certified to the California Air Resources Board and Environmental Protection Agency's (EPA) Optional Low NOx emissions standard of 0.02 g/bhp-hr, it has 90% fewer NOx emissions than the current North American EPA standard. With 400 hp / 1,450 lb-ft torque, and near-zero emissions. [1]

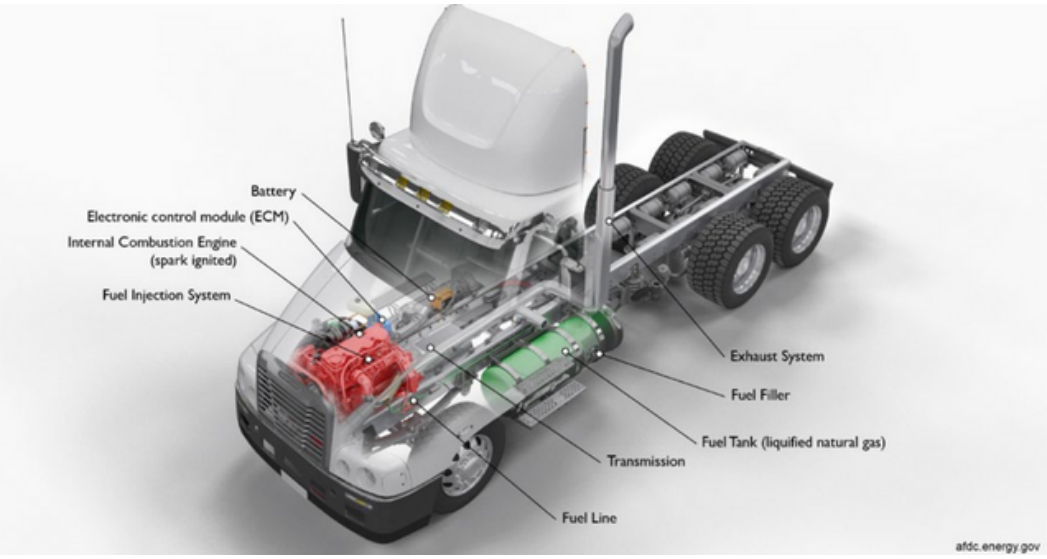
Cummins Westport engines feature the same factory base warranty coverage as Cummins diesel engines. For truck applications, this comprehensive warranty includes parts, labor and progressive damage on virtually everything from the block casting to fuel system for 2 years / 250,000 miles (402,336 kilometers). Major components coverage is also available. Extended Coverage Cummins Westport Inc. also offers a variety of extended coverage plans. [2]

The ISX12N features a new ECM, which offers faster processing to support heavy-duty On-Board Diagnostics (OBD) and is telematics capable. The OBD monitors the engine and after-treatment system. The latest after-treatment system is an enhanced Three-Way Catalyst (TWC) that provides consistent emissions control performance, is maintenance-free, and can be mounted vertically or horizontally on the vehicle. [2]

How do LNG trucks work?

Heavy-duty liquefied natural gas (LNG) vehicles work much like gasoline-powered vehicles with a spark-ignited internal combustion engine. The natural gas is super-cooled and cryogenically stored in liquid form in tanks on each side of the truck. LNG is most often used in heavy-duty vehicles to meet range requirements. Because it is a liquid, the energy density of LNG is greater than CNG, so more fuel can be stored on board the vehicle. This makes LNG well-suited for Class 7 and 8 trucks traveling longer distances.

Key Components of a Liquefied Natural Gas Truck



- **Battery**: The battery provides electricity to start the engine and power vehicle electronics/accessories.
- **Electronic** control module (ECM): The ECM controls the fuel mixture, ignition timing, and emissions system; monitors the operation of the vehicle; safeguards the engine from abuse; and detects and troubleshoots problems.
- **Exhaust system**: The exhaust system channels the exhaust gases from the engine out through the tailpipe.
- **Fuel filler**: This is a filler or “nozzle” used to add fuel to the tank.
- **Fuel injection system**: This system introduces fuel into the engine’s combustion chambers for ignition.
- **Fuel line**: A metal tube or flexible hose (or a combination of these) allows for transferring fuel from the tank to the engine’s fuel injection system.
- **Fuel tank (liquefied natural gas)**: Stores liquefied natural gas on board the vehicle until it’s needed by the engine.
- **Internal combustion engine (spark-ignited)**: In this configuration, fuel is injected into either the intake manifold or the combustion chamber, where it is combined with air, and the air/fuel mix is ignited by the spark from a spark plug.
- **Transmission**: The transmission transfers mechanical power from the engine and/or electric traction motor to drive the wheels. [4]

Fueling Infrastructure

Mobile Fueling Station

LNG fleets can choose to build a permanent fueling station or choose to use a mobile onsite fueling station. A mobile fueling station allows you to try LNG with zero capital investment up front, which may work well as fleets transition from diesel to LNG. Some LNG providers will manage the construction of fueling stations and even fund the capital costs with a commitment to a long-range fuel agreement. Also, Cummins Westport and Chart provide on-site training for the maintenance facilities and drivers. LNG tank fill time is 48-50 gallons per minute which is equal to diesel. To fill an LNG tank, the operator must wear proper PPE, which consists of a face mask, gloves, long-sleeves, and pants.

Maintenance

LNG trucks do not have an SCR system, but instead a Three-Way Catalyst (TWC). The TWC is maintenance-free and does not require diesel exhaust fluid (DEF). LNG trucks do not have diesel particulate filters and will never require a DPF regeneration. Unlike a diesel truck, an LNG truck can operate in cold weather without the fuel gelling.

Overall, maintenance for the ISX12 G is similar to that of diesel engines, but there are a few key differences:

- The spark plugs will need to be replaced per the maintenance schedule at 1,000 hours (50,000 miles/80,000 km).
- Motor oil specifically formulated for natural gas engines is required. Do not use diesel engine oil in a natural gas engine. If diesel engine oil is used, valve torching, piston scuffing and reduction in spark-plug life will occur.
- For more information, see the links below or visit Cummins QuickServe Online.
  - New Natural Gas Engine Oil Specification (CES 20092)
  - Extended Oil Drain Intervals with CES 20092 Natural Gas Engine Oils
  - List of Cummins approved CES oils

ISX12 G Maintenance Intervals

Based on Heavy Duty Truck < 80,000 lb (36,287 kg) GCVW

Maintenance Item	Hours	Distance	Months
Spin-on Fuel Filter	Daily Check	N/A	N/A
Oil and Filter*	500	25,000 mi (40,000 km)	6
Coolant Filter	1,500	75,000 mi (120,000 km)	12
Spin-on Fuel Filter	1,000	50,000 mi (80,000 km)	9
SPark Plugs	1,000	50,000 mi (80,000 km)	12
Overhead Set Adjustment**	3,000	150,000 mi (240,000 km)	24
Enginge Brake Adjustment	6,000	300,000 mi (480,000 km)	24
Cooling System Flush	6,000	300,000 mi (480,000 km)	24
Ignition Coil Extension	10,000	500,000 mi (800,000 km)	5 years
Air Cleaner/element	Follow vehicle manufacturers' published recommendations		

^Assuming normal line haul duty cycle based on 50 mph/80 kph average speed. Maintenance intervals must be reduced for slower average speed applications.

**Requires Natural Gas Engine Oil. For customers using CES 20092 natural gas engine oils only, the recommended interval is 40,000 mi (64,000 km) for vehicles with average road speeds greater than 25 mph (40 kph).*

***Initial overhead set adjustment at 1,000 hours. [5*

Maintenance Facility Modifications

LNG has the best safety record of any current fuel on the market and is used widely across the transportation industry. It has a high ignition temperature, so it is much less likely to ignite than diesel and other common fuels. Nevertheless, facilities that maintain vehicles fueled by natural gas require implementation of different safety measures.

Liquefied Natural Gas is composed of mostly methane (CH4) with slight amounts of other hydrocarbons. In the event of a release or spill of LNG, natural gas is lighter than air and will therefore rise to the ceiling of the maintenance facility and quickly dissipate rather than remaining at or near floor level like liquid fuel vapors. If concentrations of 5%-15% by volume of natural gas encounter an ignition source, natural gas may ignite, therefore it is important to modify your maintenance facility to insure the highest standards of safety.

The codes that dictate the minimum requirements are NFPA 30, NFPA 70, NFPA 88A. The five key garage modifications required to meet the minimum codes are as follows.

1. Ventilation must provide sufficient air flow to reduce the concentration of the released gas and at the same time evacuate the gas from the structure.
2. Paths of migration must be controlled to prevent the released gas from entering unprotected areas of the structure.
3. Space heating must be designed in accordance with guidelines so that open flames or hot surfaces do not provide an ignition source.
4. Electrical wiring and equipment must be installed in such a manner that they do not provide sources of ignition due to sparking. The equipment itself can be designed to be “explosion proof.”
5. Methane detection and control systems and alarms must provide defense against dangerous concentrations of natural gas by alerting personnel and disabling potential electrical ignition sources. [6]

All are accompanied by the need to establish specific protocols and training to ensure safety. Each of these are discussed in the Compressed Natural Gas Vehicle Maintenance Facility Modification Handbook.

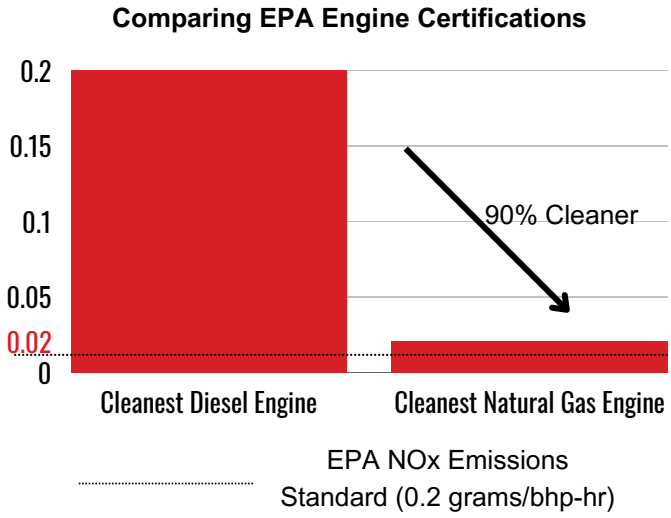
Environmental Sustainability

The focus on environmental sustainability has become a priority for many companies and consumers in the United States. Implementing NGV’s into your fleet provides your business with an opportunity to be good stewards of the environment, mitigate risk, and reduce total cost of operations.

Heavy duty vehicles total 7% of all vehicles on America's roadways, however, they account for upwards of 50 percent of all smog-precursor emissions and 20 percent of all transportation-related greenhouse gases (GHGs). [7] Cleaner burning than other fossil fuels, the combustion of natural gas produces negligible amounts of sulfur, mercury, and particulates. Burning natural gas produces lower levels of nitrogen oxides (NOx), which are precursors to smog, than gasoline and diesel used for motor vehicles. Reductions in these emissions translate into public health benefits, as these pollutants have been linked with problems such as asthma, bronchitis, lung cancer, and heart disease for millions of Americans.

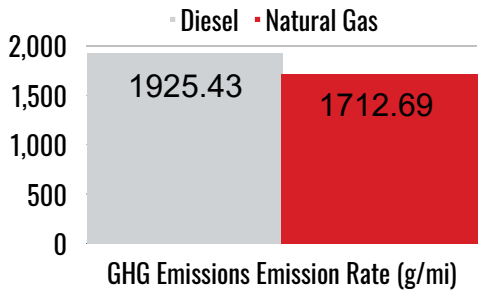
Emissions and GHG Emissions Reductions with Cummins Westport Engine

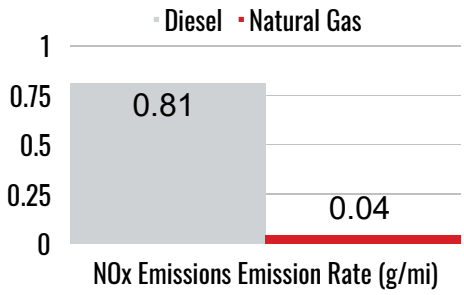
The Cummins-Westport engines are 90% cleaner than the EPA's current NOx standard and emit up to 21% fewer GHG emissions than comparable gas and diesel vehicles. When fueling with Renewable Natural Gas, GHG emissions can be reduced up to 125%.



Case Study - Emissions Reduction

- 540 Class-8 trucks
- 45,092.6 LNG gallons/truck at 6.5 miles per gallon





By implementing natural gas in their fleet, this customer reduced GHG emissions by 11% and reduced NOx emissions by over 95%.

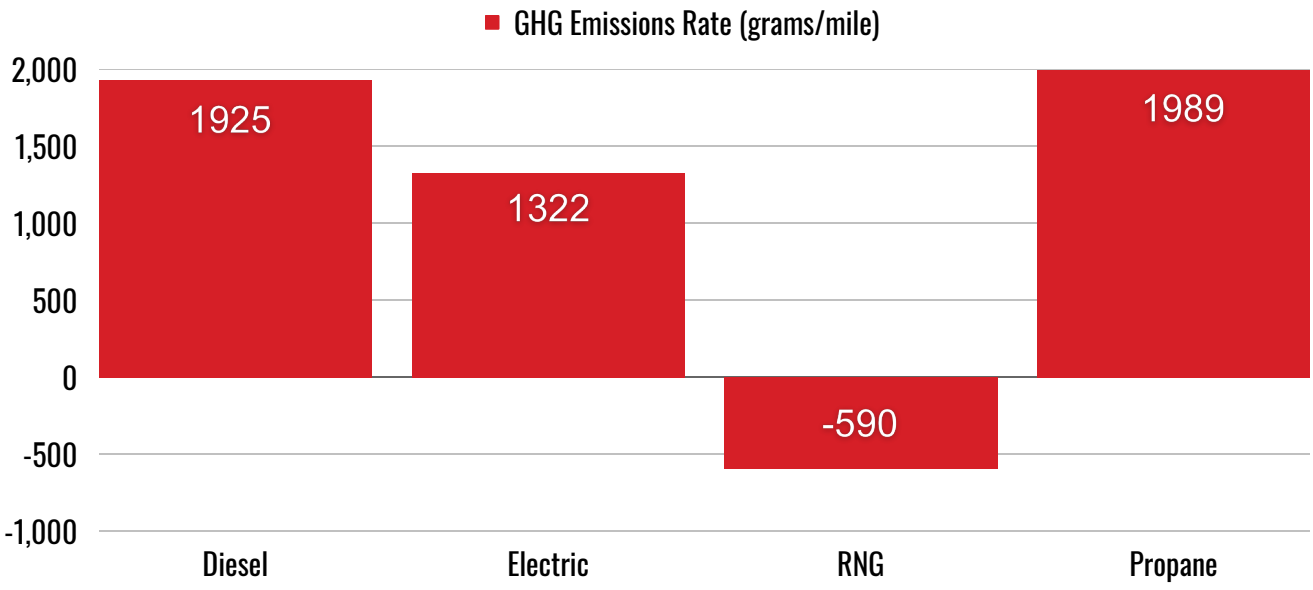
Renewable Natural Gas

Providing LNG as a diesel replacement is the first step in revolutionizing the alternative fuel industry. By demonstrating the commercial viability of LNG at scale, LNG providers are making additional investments into even cleaner fuels such as bio-methane developed from renewable natural gas projects.

Renewable Natural Gas (RNG) is an ultra-clean and ultra-low-carbon natural gas alternative. It is produced by capturing and refining fugitive methane, called biogas, produced from municipal wastewater treatment systems, animal waste and landfills. RNG can be processed to meet natural gas pipeline quality specifications.

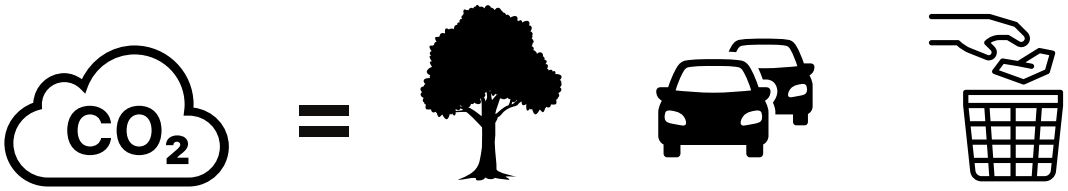
Use of RNG versus natural gas further reduces CO2 emissions by an additional 75% resulting in a carbon negative fuel. A carbon negative footprint is possible because absent the process to capture and refine the biogas, it would otherwise escape into the atmosphere. Raw biogas typically contains a 50%/50% methane/CO2 content mix.

RNG is delivered via LNG (Liquefied Renewable Natural Gas) and is the cleanest and highest quality transportation fuel available. RNG is cleaner than electric and offers additional per gallon savings. The data below is gathered from Argonne National Laboratory and compares the GHG emissions (grams per mile) of Renewable Natural Gas, Diesel, Electric, and propane long-haul heavy-duty trucks.



Environmental Impact of a Green Fleet

1,000,000 gallons of diesel fuel replaced by Liquefied Renewable Natural Gas (LRNG) is equivalent to:



10,180 metrics tons of CO2 reduced

169,667 new trees grown

2,161 cars off the road

3,547 tons of waste recycled, not landfilled

To calculate your fleet's environmental impact, check out our emissions calculator.

Alternative Fuel Tax Credit (AFTC)

A federal tax incentive has historically been available for alternative fuel that is sold for use as a fuel to operate a motor vehicle. A tax credit in the amount of $0.50 per gallon has been available for the following alternative fuels: natural gas, liquefied hydrogen, propane, P-Series fuel, liquid fuel derived from coal through the Fischer-Tropsch process, and compressed or liquefied gas derived from biomass. For propane and natural gas sold after December 31, 2015, the tax credit is based on the gasoline gallon equivalent (GGE) or diesel gallon equivalent (DGE). For taxation purposes, one GGE is equal to 5.75 pounds (lbs.) of propane and 5.66 lbs. of compressed natural gas. One DGE is equal to 6.06 lbs. of liquefied natural gas.

For an entity to be eligible to claim the credit they must be liable for reporting and paying the federal excise tax on the sale or use of the fuel in a motor vehicle. Tax exempt entities such as state and local governments that dispense qualified fuel from an on-site fueling station for use in vehicles qualify for the incentive. Eligible entities must be registered with the Internal Revenue Service (IRS). The incentive must first be taken as a credit against the entity's alternative fuel tax liability; any excess over this fuel tax liability may be claimed as a direct payment from the IRS. The tax credit is not allowed if an incentive for the same alternative fuel is also determined under the rules for the ethanol or biodiesel tax credits. For more information on the AFTC visit: afdc.energy.gov.

Government Funding/Incentives

The Clean Air Act (CAA) 2.0 liter partial settlement will require Volkswagen to fund a $2.7 billion mitigation trust fund. The mitigation trust fund will pay for defined eligible projects that reduce NOx (eligible mitigation actions). The total $2.7 billion funding for the mitigation trust fund is intended to fully mitigate the total, lifetime excess NOx emissions from the 2.0 liter vehicles. These funds have been distributed state by state to implement NOx reducing projects over the coming years. If you would like more information on your state's allocation, visit the EPA's Volkswagen Clean Air Act Civil Settlement webpage.

Kinder Morgan - We Make LNG Simple

Kinder Morgan provides LNG to the largest Class-8 LNG truck fleet in the United States. Kinder Morgan LNG supplies five UPS hubs, which fuel 540 Class-8 Trucks. This is the largest heavy-duty LNG fuel contract in the country. In addition to On-Road Transportation, Kinder Morgan also provides LNG to industries such as Agribusinesses, Asphalt Plants, E&P, Power Generation, and Utilities. Kinder Morgan is developing Renewable Natural Gas (RNG) projects. The RNG is delivered via LNG (LRNG) and is the cleanest transportation fuel available, cleaner than electric.

Kinder Morgan has two LNG plants with 24 million gallons of LNG storage capacity and 4 truck loading stations. The plants are connected to four interstate natural gas pipelines. This location is unique which gives Kinder Morgan the optionality of receiving gas from various supply basins. The supply creates redundancy of gas supply and enables Kinder Morgan to procure gas at the lowest possible cost, thereby reducing the overall cost of LNG.

Kinder Morgan is a Vertically Integrated Solutions Provider (VISP). Kinder Morgan buys gas at the wellhead, liquefies the gas in the two LNG plants, transports the gas 24/7/365 to customer locations, and manages the construction of mobile and permanent LNG fueling stations, storage and regassification systems. Managing these four steps enables Kinder Morgan to provide the lowest-cost LNG and eases the transition to LNG for an operation. They work closely with Cummins Westport and Chart to provide on-site training for the maintenance facilities and drivers.

For more information on LNG for fleets:

www.kindermorgan.com

KMIRNG@kindermorgan.com

(317) 886-8179

References

[1] Cummins Westport ISX12N Models. Retrieved from https://www.cumminswestport.com/models/isx12n [2] Move To Zero. Cummins Westport. Retrieved from https://www.cumminswestport.com/content/841/ISX12N_5544037_0418.pdf [4] Alternative Fuels Data Center: How Do Liquefied Natural Gas Trucks Work? U.S. Department of Energy. Retrieved from https://afdc.energy.gov/vehicles/how-do-lng-cars-work [5] Cummins Westport ISX12G Models. Retrieved from https://www.cumminswestport.com/models/isx12-g [6] Compressed Natural Gas Vehicle Maintenance Facility Modification Handbook. U.S. Department of Energy. Retrieved from https://afdc.energy.gov/files/u/publication/cng_maintenance_facility_mod.pdf [7] Game Changer Technical White Paper, Gladstein, Neandross & Associates, May 201