



NATURAL GAS' ROLE IN DECARBONIZING TRUCKING

Natural gas (NG) is a fuel that has the potential to help reduce total greenhouse gas (GHG) emissions, but also has significant advantages in reducing the more immediate and local health effects caused by air pollutants like nitrogen oxides (NO_x) and particulate matter (PM). PM filters are very efficient and the actual difference in PM output between diesel and NG is very small. The big difference between natural gas and diesel is NO_x. Replacing diesels with spark-ignited natural gas engines could improve a fleet's ability to meet upcoming more stringent emission standards.

The net CO₂ benefit of a natural gas engine is in the range of 13% to 18% compared to diesel fuel. Natural gas produces approximately 27% less CO₂ per unit of energy on a fuel-comparison basis compared with No. 2 diesel fuel. However, the natural gas engine is less efficient than a diesel and natural gas needs to be compressed for storage on the vehicle. Methane leakage that occurs primarily in the upstream process in the natural gas supply system (pipelines and local distribution systems) also must be considered. The Environmental Protection Agency (EPA) estimates the leakage to be 1.4%, and there are some higher estimates.

According to the American Petroleum Institute (API), natural gas is a form of petroleum most often found

accompanying crude oil in oil wells. Most of the natural gas in the US is considered a fossil fuel because it is made from underground sources formed over millions of years by the action of heat and pressure on organic materials. Alternatively, renewable natural gas (RNG), also known as biomethane, is a pipeline-quality vehicle fuel produced by purifying biogas. RNG offers a significant environmental benefit: it has negative carbon intensity when derived from animal waste such as dairy. Currently most of the natural gas used in transportation, around 70%, is RNG.

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While natural gas has been used in combustion engines for decades, currently there is a renewed interest in using it in transportation because it is a lower-carbon fuel than diesel and is cleaner-burning. In the past few years, the capacity to produce RNG has grown significantly and RNG represents 69% of the natural gas used in transportation in 2022.

Fleets' experience with natural gas falls into the following four categories.

1. No desire to experiment or invest.
2. Made investment with no success.
3. Invested and had some success.
4. Invested heavily with success and will continue to do so.

In the first type are carriers that don't have the time or resources necessary to jump into something they know or that they believe is unproven. The second group of carriers is mostly made up of those that tested natural gas tractors when they gained popularity in the early-to mid-2010s. Unfortunately, that generation of natural gas tractors was plagued with a plethora of failures that are common with new technologies. The third bucket is carriers — like Paper Transport — that found a way to operate natural gas equipment, albeit at an operational cost increase over diesel, but it expanded their total

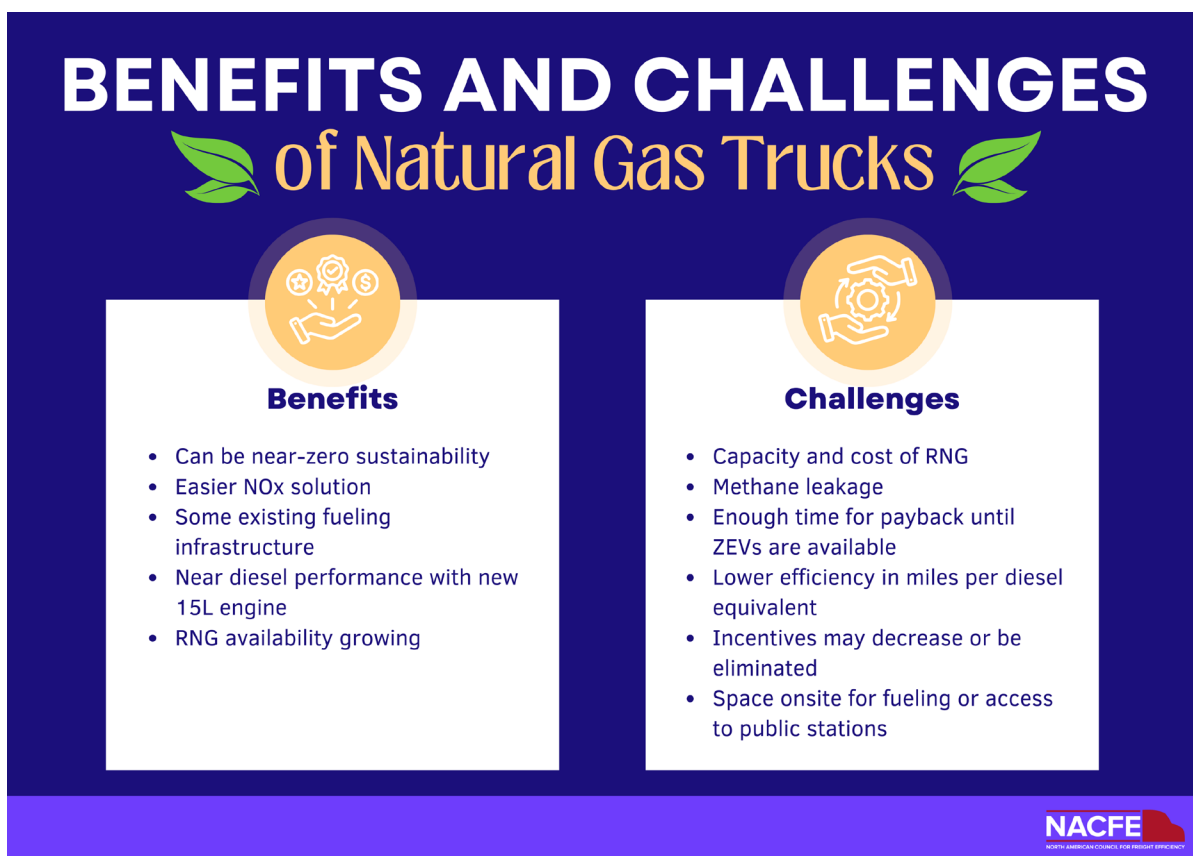
portfolio offerings, decreasing dependency on diesel. The last group of fleets have gone “big” on CNG and are making it affordable in their operations. This is a short list, but it includes UPS, WM (Waste Management) and Frito-Lay.

When evaluating the natural gas option, there are many financial considerations. More specifically, fleets should consider and compare natural gas to diesel and other alternatives, including battery electric, from a variety of standpoints. It can take five to 10 years for fleets to see payback from their investment in natural gas vehicles and infrastructure. During that time there are likely to be significant improvements in battery electric vehicles which will offer many benefits to fleets. Having invested in natural gas, they may not be able to pivot to take advantage of the benefits of battery electric vehicles.

As with any technology there are both benefits and challenges for fleets when it comes to natural gas as a power source for their trucks. Perhaps the biggest benefit is that natural gas vehicles can be a near-zero solution. Plus, there is already some fueling infrastructure in place. On the challenge side is the fact that they are lower in efficiency in miles per diesel equivalent and there may not be incentives to purchase them. Figure ES 1 presents a more complete picture of the benefits and challenges of natural gas trucks.

FIGURE ES1

THERE ARE BENEFITS AND CHALLENGES FOR FLEETS WHEN IT COMES TO NATURAL GAS AS A POWER SOURCE



Concerns About Natural Gas

Because natural gas is lighter than air, there are some concerns about maintenance. Maintenance facilities historically have been designed to handle vehicles using fuels (gasoline/diesel) that are heavier than air. Because natural gas is lighter than air, it rises to the ceiling which means that it might be necessary to modify some areas of the shop. There are some issues that need to be addressed as shops convert to natural gas capabilities, and shops need to review their specific building safety codes surrounding natural gas.

Tanks for natural gas are significantly more costly and complex than that of a diesel fuel tank. Due to lower volumetric energy density of natural gas, they are larger and consume more space on the vehicle.

There is some concern about the availability of natural gas fueling stations. As of 2022, there were more than 1,400 (772 of which were public) CNG fueling stations in the US. There are approximately 97 (51 public) LNG fueling stations, mostly in areas that service the long-haul trucking industry.

Manufacturers and Suppliers

Cummins is the primary supplier of natural gas engines. Hylion also provided a powertrain solution, however, they have discontinued their natural gas-based product. In early 2024, Cummins will be introducing a new X15N, the first of the fuel-agnostic versions of the next generation 15-liter engine. Westport offers a high pressure direct injection (HPDI) natural gas combustion system. It is a direct injection system which injects both diesel fuel (as a pilot for ignition) and natural gas. This fuel system allows



METHODOLOGY

This report was written from interviews with subject matter experts at fleets, OEMs, research groups and industry organizations. Available public information has been referenced to support findings and conclusions.

engines to run with late cycle direct injection, meaning the timing of the fuel injection is similar to what occurs in a diesel engine, so the efficiency is closer to that of a diesel engine.

In October 2023, Daimler announced plans to offer the Cummins X15N in both the day cab and sleeper version of its Cascadia models. Kenworth offers natural gas engines in their product portfolio and indicated they will offer the Cummins X15N in the T680 in the future. The Mack Granite is available with the Cummins L9N and an Allison 4500 fully automatic 6-speed transmission. Peterbilt introduced natural gas engines in 2007 with the

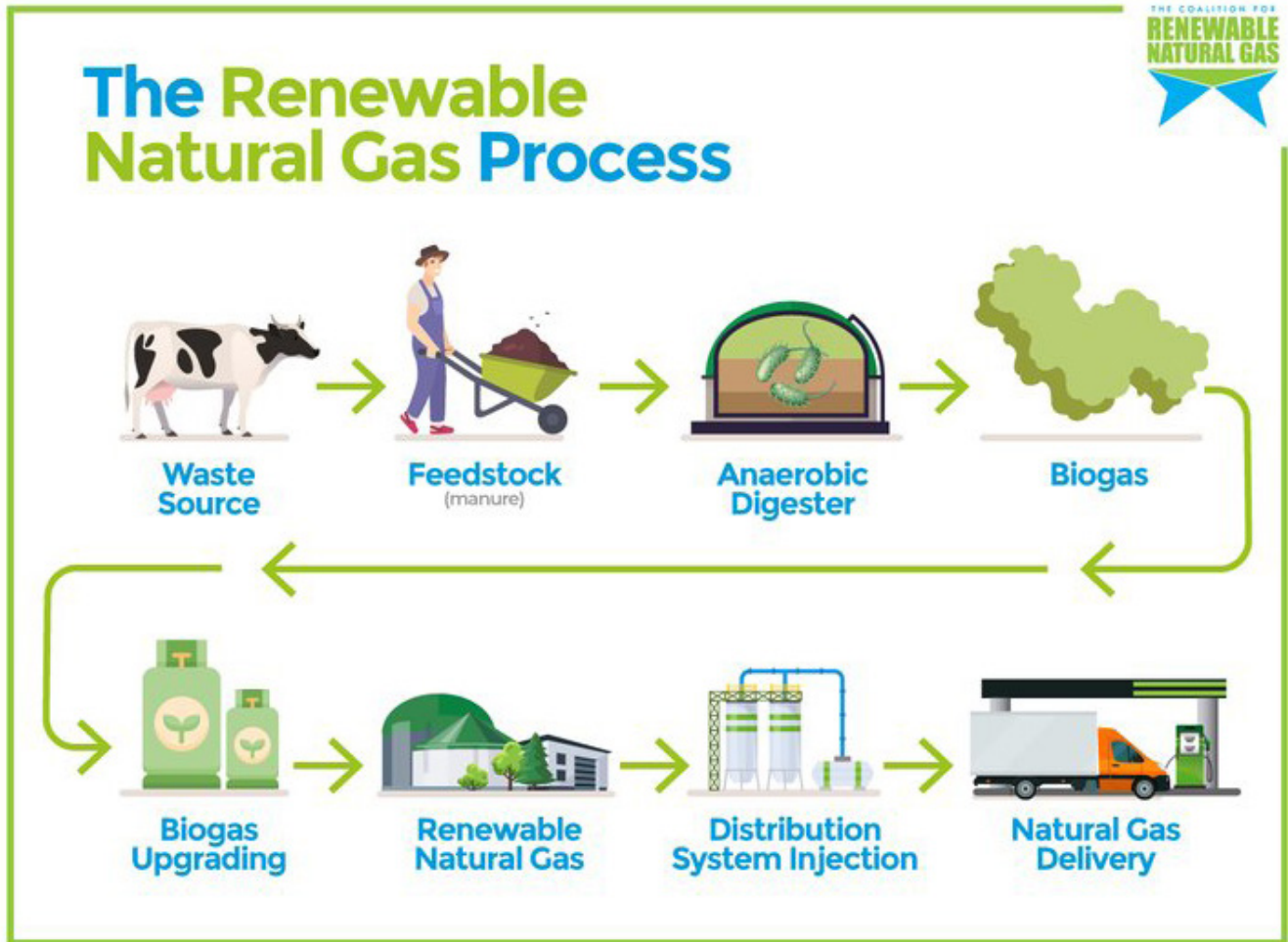


“Last year 69% of the natural gas that was dispensed as motor fuel was from a renewable source. That could be from landfill gas, waste water, food waste, or renewable nature gas from ag waste.”

— Daniel Gage, President, NGV America

FIGURE ES2

NEGATIVE CARBON INTENSITY CAN BE ACHIEVED THROUGH ANIMAL WASTE



Model 320. They currently have three engine platforms, the B6.7N, L9N, and ISX12N. Volvo has been using the Cummins ISX12N in the US.

Renewable Natural Gas

RNG is a form of natural gas that can be used as a fuel to power vehicles. It is fully interchangeable with conventional natural gas and has significant environmental benefits. RNG is generated from various feedstock sources such as livestock (e.g., animal manure), landfills, wastewater, and other sources. Negative carbon intensity (CI) can be achieved through animal waste. See Figure ES2. Feedstock through landfills and wastewater do not produce a negative CI but still offer an advantage over diesel and conventional natural gas.

Note that this opportunity will not go away in the near future. There always will be dairies, chicken farms, cattle,

garbage dumps, rotting, grasses, swamps, etc. All of this will decompose and emit methane into the atmosphere, so this opportunity needs to be seized and RNG is an excellent way to take advantage of it.

Emissions Mandates and Natural Gas

There is a tremendous amount of governmental regulation created over the last several years with the intention of providing cleaner air and decarbonizing the transportation industry. Natural gas engines can easily meet the Environmental Protection Agency's 2027 criteria pollutant regulations. Natural gas engines can be used as a tool to help truck manufacturers meet the GHG Phase 3 regulations. Natural gas engines will not comply with the zero-emission vehicle mandates. However, if a natural gas engine is combined with a hybrid, it can qualify as a near-zero emission vehicle.

Key Findings

After researching natural gas engines for use in commercial vehicles and speaking with fleets and other experts, the study team developed the following key findings.

- 1. There appears to be a wide range in perception and results regarding the business case for natural gas.** Some fleets have been able to save money with natural gas fueled vehicles while others select them only for sustainability reasons. Some key factors to make a business case positive for natural gas are: Full utilization of fueling stations, utilizing both medium- and heavy-duty trucks, and taking advantage of all incentives.
 - 2. There are several positive environmental aspects of natural gas engines.** These include its ultra-low NOx capability, the fact that there is no need for a diesel particulate filter, and the well-to-wheels CO₂ reduction. Additionally, compared to conventional natural gas, RNG is the more attractive solution from an environmental standpoint, which can help fleets, shippers and customers meet their corporate ESG goals.
 - 3. There are environmental concerns with natural gas.** These include methane leaking from aging pipelines and natural gas infrastructure and outdated equipment.
 - 4. Sustainability goals, regulations, and the California conundrum.** The CO₂, NOx, and PM benefits of natural gas-powered vehicles allow fleets and shippers to improve the carbon footprint and reduce their Scope 2 and 3 emissions. Natural gas also helps OEMs and engine manufacturers meet GHG regulation and NOx and PM standards.
- However, in California and other states, ZEV mandates are being established, and natural gas does not qualify.
- 5. The new 15-liter Cummins X15N engine seems promising.** In the past, natural gas engines experienced reliability and performance issues, but many of these are believed to be fixed.
 - 6. Aftertreatment is simple and more reliable.** Natural gas engines do not require a DPF or SCR system, eliminating a major cause of downtime, warranty, and repairs.
 - 7. Natural gas is very abundant in the US.** The question is, how accessible is it for a given fleet's routes?
 - 8. There is a question as to whether there will be an ample supply of RNG.** Natural Gas Vehicles for America (NVGA) has projected significant increases in RNG over the next several years. Given the introduction of the Cummins X15N (and Cummins' projections), there could be a couple hundred thousand natural gas engines in heavy-duty applications later in the decade.
 - 9. Because of economics and the environment, there are a few points to consider when comparing BEV vs CNG.** Converting to natural gas is a long-term decision. Capital for fueling stations or charging stations, etc. is a 5 to 10+ year investment. From a CO₂ standpoint it is essential on a local level to consider the grid's dependence on fossil fuel vs. renewable/nuclear fuel. Local consideration of grid and CNG capacity also is a factor. CNG requires installing venting equipment, methane detection, and alarms in maintenance shops, which can be an expensive infrastructure investment.



“The latest big bore natural gas powertrain has power and torque curves almost identical to those of diesels, which will help long haul fleets see improved economic and environmental performance.”

— José Samperio, Vice President and General Manager for North America On-highway Operations, Cummins



ABOUT NACFE

The North American Council for Freight Efficiency (NACFE) works to drive the development and adoption of efficiency enhancing, environmentally beneficial, and cost-effective technologies, services, and operational practices in the movement of goods across North America. NACFE provides independent, unbiased research, including Confidence Reports on available technologies and Guidance Reports on emerging ones, which highlight the benefits and consequences of each, and deliver decision-making tools for fleets, manufacturers, and others. NACFE partners with RMI on a variety of projects including the Run on Less demonstration series, electric trucks, emissions reductions, and low-carbon supply chains. Visit NACFE.org or follow us on Twitter [@NACFE_Freight](https://twitter.com/NACFE_Freight).



ABOUT RUN ON LESS BY NACFE

Run on Less 2017 was a first-of-its-kind fuel efficiency roadshow that proved 10 MPG is possible with various combinations of commercially available technologies. Seven participating fleets hauled real freight on real routes during the three-week run across North America.

Run on Less Regional was conducted in October of 2019. Ten participating fleets demonstrated a variety of commercially available freight efficiency technologies in the three-week cross-country roadshow, proving that 8.3. MPG is possible in regional haul.

Run on Less – Electric was the first NACFE demonstration to focus on electric vehicles. Thirteen fleet-OEM pairs in the US and Canada participated in the three-week long event. If all US and Canadian medium- and heavy-duty trucks in the market segments — vans and step vans, medium-duty box trucks, terminal tractors and heavy-duty regional haul — studied in the Run became electric, about 100 million metric tons of CO₂ would be saved from entering the atmosphere. Visit runonless.com or follow us on Twitter [@RunOnLess](https://twitter.com/RunOnLess).

GET INVOLVED

NACFE could use the assistance of fleets, manufacturers and other trucking industry stakeholders in improving freight efficiency. Become a part of this exciting opportunity.

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