Fleets Run Cleaner on Natural Gas

Emissions and Environmental Benefits of Natural Gas Vehicles

NGVAMERICA
Natural Gas Vehicles for America

Explanation of Terms

To assist in better understanding the key terms used in this document, the following definitions are provided:

Global Warming Potential (GWP) and Timeframe

The relative warming of a greenhouse gas over a specified period of time as compared to carbon dioxide (GWP of 1). GWP allows for the conversion of different greenhouse gas emissions into the same emissions unit, carbon dioxide equivalents (CO_2e) [1]. The GWP timeframe is based on the energy absorbed over a certain time period, for example a GWP with 100 years is based on the energy absorbed over 100 years [2].

Carbon Dioxide (CO_2)

A naturally occurring gas, and also a by-product of burning fossil fuels and biomass, as well as land-use changes and other industrial processes. It is the principal human caused greenhouse gas that affects the earth's radiative balance. It is the reference gas against which other greenhouse gases are measured and therefore has a Global Warming Potential of 1 [3].

Nitrogen Oxide (NO_x)

Gases consisting of molecules with one nitrogen atom and varying numbers of oxygen atoms. Nitrogen oxides are produced in the emissions of vehicle exhausts and from power stations. In the atmosphere, nitrogen oxides can contribute to formation of photochemical ozone (smog), can impair visibility, and have health consequences; they are thus considered pollutants [3].

Particulate Matter (PM)

A small, discrete mass of solid or liquid matter that remains individually dispersed in gas or liquid emissions. Particulates take the form of aerosol, dust, fume, mist, smoke, or spray. Each of these forms has different properties [4].

Greenhouse Gases (GHGs)

Any gas that absorbs infrared radiation in the atmosphere. Greenhouse gases include, carbon dioxide, methane, nitrous oxide, ozone, chlorofluorocarbons, hydrochlorofluorocarbons, hydrofluorocarbons, perfluorocarbons, sulfur hexafluoride. Each gas has a CO_2e to allow them to sum to create the GWP value [3].

Carbon Intensity

The amount of carbon by weight emitted per unit of energy consumed. A common measure of carbon intensity is weight of carbon per British thermal unit (Btu) of energy. When there is only one fossil fuel under consideration, the carbon intensity and the emissions coefficient are identical. When there are several fuels, carbon intensity is based on their combined emissions coefficients weighted by their energy consumption levels [4].

Low Carbon Fuel Standard (LCFS)

A LCFS is a regulation requiring fuel providers to reduce the carbon intensity (greenhouse gas emissions per unit of energy in the fuel) of transportation fuels. This is done on a life cycle emissions basis using a model similar to GREET. While California is the most visible state to have such a regulation, Oregon also implemented an LCFS is 2016 and Washington is considering a similar regulation. Outside of the US, British Columbia has a similar regulation for fuels as well.

Global Temperature Potential (GTP)

GTP is an alternate climate impact metric to GWP. GTP measures the temperature change at the end of a time period relative to CO_2. Modeling is required to calculate GTP to determine how much climate responds to increases in greenhouse gases and how quickly the system responds. GTP is not the primary metric for calculating emissions and environmental issues, but its use is growing [5].

The market for natural gas vehicles was largely founded on the need to improve air quality in America's urban areas in the early '90's. Natural gas offered reduced emissions at the core of its value proposition as a transportation fuel. **Those benefits are even stronger today.**

Lower greenhouse gas and environmental related emissions are priorities for shippers, trucking fleets, municipal refuse vehicles and transit buses across the country. Natural gas provides clear advantages among alternative transportation fuels. This document was created to explain the emission and environmental benefits associated with CNG and LNG, as well as the technical reasons behind the calculations and inputs that were chosen.

NGVAmerica members represent the full marketplace of the natural gas vehicle industry. This document is designed for fleets, businesses, and governmental entities already invested in NGVs and those contemplating the switch to natural gas. It presents short and concise talking points to communicate the environmental benefits and explains how natural gas vehicles satisfy a variety of sustainability goals.

During its organizing sessions, the NGVAmerica Technology & Development Committee identified promoting the awareness of the emissions and environmental benefits of natural gas vehicles as a focus area for the committee. A working group was formed and has since reviewed a variety of ways to evaluate the environmental benefits of using natural gas as a transportation fuel. The working group is made up of NGVAmerica members — utilities, fleets, LNG, station developers, engine manufacturers, component and system suppliers, US government agencies, associations, and industry consultants. The working group developed a set of emission benefits and this white paper was developed to provide the industry with a broader explanation.

Environmental Benefits of Natural Gas

Combusting natural gas produces **27% fewer CO_2 emissions** than diesel fuel on energy equivalent basis [6]

CNG in heavy duty vehicles has **13%–17% fewer** greenhouse gas emissions compared to diesel on a well-to-wheel basis

- Carbon intensity values from the California Low Carbon Fuel Standard
- A GWP of 25 on a 100 year timeframe per the *Intergovernmental Panel on Climate Change's Fourth Assessment Report.*
- A fuel economy reduction between 7% and 12%
- Calculated using CA GREET 2.0

LNG in heavy duty vehicles has **6%–11% fewer** greenhouse gas emissions over diesel on a well-to-wheel basis

- Carbon intensity values from the California Low Carbon Fuel Standard
- A GWP of 25 on a 100 year timeframe per the *Intergovernmental Panel on Climate Change's Fourth Assessment Report.*
- A fuel economy reduction between 7% and 12%
- Calculated using CA GREET 2.0

Near-Zero natural gas engines produce
95% fewer Nitrogen Oxide (NO_X) emissions
than the current standards.

Carbon Dioxide

Carbon dioxide (CO_2) is the dominant greenhouse gas emitted by human beings, and transportation is the second largest contributor to CO_2 emissions [7]. Burning natural gas produces 27% less CO_2 emissions than burning diesel fuel. Natural gas, consisting mostly of methane (CH_4), is a less carbon intensive fuel than diesel and gasoline. Methane has a chemical makeup that is 4:1 hydrogen to carbon, while gasoline and diesel have 8 and 16 carbon atoms, respectively.

CO_2 is the primary long lived pollutant, with the potential to remain in the atmosphere for hundreds of years. Methane on the other hand is a short lived climate pollutant, which during its lifetime has a greater potential to capture heat but remains in the atmosphere for a much shorter amount of time.

Carbon Dioxide Equivalent (CO_2e)

When comparing the greenhouse gas emissions impacts of producing and burning different fuels it is important to look at not only carbon dioxide emissions but also to consider other greenhouse gas emission such as methane and nitrous oxides. It is also important to provide a means of comparing the relative impact of these different gases. Since CO_2 is the dominant greenhouse gas many organizations assign a CO_2 equivalent or CO_2e factor to the other greenhouse gases. The California Low Carbon Fuel Standard (LCFS) assigns a life cycle carbon intensity factor of 78.36 gCO_2e/MJ for compressed natural gas and 84.55gCO_2e/MJ for liquefied natural gas. While gasoline has factor of 98.47 gCO_2e/MJ and diesel has a factor of 102.01 gCO_2e/MJ [8].

Greenhouse Gas Emission Comparisons

When looking at a well-to-wheel comparison of natural gas versus diesel, compressed natural gas (CNG) reduces greenhouse gas emissions by 13%–17% and liquefied natural gas (LNG) reduces GHG emissions by 6%–11%. This advantage assumes a fuel economy reduction of 7% to 12%, depending on the vehicle application and drive cycle. Natural gas engine manufacturers have made great strides in developing engines that provide significant environmental benefits, and are now working to improve the fuel economy of these same engines. The carbon intensity used for these calculations is taken from the *California Low Carbon Fuel Standard*. Global warming potential (GWP) is measured on different periods of time. For the analysis in this paper, a long term measurement was used — GWP of 25 CO_2e over 100 year timeframe for methane. The GWP and timeframe used is per the *Intergovernmental Panel on Climate Change's Fourth Assessment Report*, and the timeframe is the same value used by the US Environmental Protection Agency (EPA). Different GWPs and timeframes will give varying benefits:

	CNG Well-to-Wheels Benefit	LNG Well-to-Wheels Benefit
GWP of 25 over 100 years	13%–17%	6%–11%
GWP of 34 over 100 years	8%–13%	1%–6%

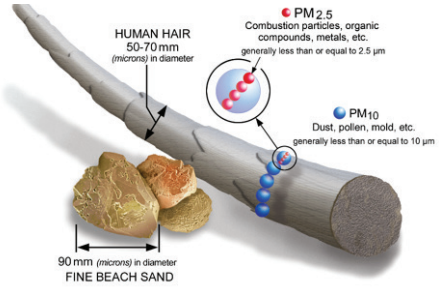
Nitrogen Oxides (NO_x)

The nitrogen oxide (NO_x) family of compounds contributes to ozone-forming criteria pollutants. Ground level ozone can affect lung functions, breathing passages and cause coughing. On days when ozone levels are at their highest, children, the elderly and persons with respiratory issues are encouraged to remain indoors and limit outdoor activities. Natural gas engines that have begun to enter the market reduce NO_x by 95% over current standards without incurring any additional losses in fuel efficiency. This technology is able to far exceed today's emission standards, without expensive aftertreatment solutions (i.e. diesel exhaust fluid). The Cummins Westport NearZero natural gas engines are spark-ignited with a maintenance free three-way catalyst and also feature closed crankcase ventilation, which is able to reduce engine related methane emissions by as much as 70%.

Particulate Matter

Particulate matter (PM) is particles created from the combustion of fuel. These particles are extremely small and measured in microns (µm). The smaller the particle, the more likely it will be inhaled and potentially cause health problems. Combustion particles are generally less than or equal to 2.5 µm. The small size of particulate matter and its ability to penetrate the lungs and even get into the bloodstream makes it an even greater health concern than ozone pollution. The NearZero natural gas engine technology mentioned above is certified to a PM value 90% below today's standard.

Figure 1 [9]



Technology Advancements

Natural gas vehicle technology continues to move forward with constant innovation in engines, storage, fuel system development, etc. The industry continues to look for ways to enhance the environmental value proposition of natural gas vehicles. The NGV industry is already benefiting from an influx of renewable natural gas, and it is expected that this recent development will expand in the future.

Natural gas engine manufacturers are continuing to make improvements in the design and operation of natural gas engines, looking for ways to not only improve emissions, but advance efficiency when using spark ignited and high pressure direct injection fuel delivery systems. To be cost competitive, most natural gas engines in the market are built off of existing gasoline or diesel engine blocks, resulting in some performance differences. Natural gas engine manufacturers continue to make strides to narrow the gap between existing gasoline and diesel engine technology. High Pressure Direct Injection (HPDI) is an engine technology in which a small amount of diesel fuel is used as the pilot ignition with natural gas as the primary fuel. The fuel is directed at high pressure directly into the combustion chamber. HPDI technology is able to maintain equal horsepower, torque and efficiency as a comparable diesel engine.

Natural Gas Sources & Infrastructure

As with most vehicle and fuel types, vehicles are not the only source of emissions; the refueling station can also produce emissions. The industry is continuing to make significant strides to reduce these emissions. CNG station manufacturers are using advanced materials and component designs to limit fugitive emissions, along with enhanced sealing methods for gas tubing and fittings. Major components such as compressors are also equipped with methane detectors which will shut down the station should a pre-determined methane level be reached.

Much like CNG, LNG stations have utilized technology to reduce the emissions profiles as well. There are existing LNG stations which utilize various boil-off gas management systems in order to manage operational venting events and, like the CNG application, methane sensors are utilized to detect small leakages from pumps, flanges, etc. When activated, the methane sensors initiate system shut-downs, so the deficiency can be addressed by maintenance technicians. Also, systems which manage the venting of the delivery hose are now being implemented to further reduce fugitive methane release.

Renewable Natural Gas (RNG) is produced by taking biogas and cleaning it up. Biogas in turn is produced through various methods that accelerate the process whereby organic matter is broken down to produce methane. RNG can be produced from a wide range of sources where organic materials are present — landfills, dairy farms, waste-water treatment facilities, and animal and crop waste systems. Different sources of RNG have different carbon intensity factors but all RNG provide substantial reductions in overall greenhouse gas emissions compared to petroleum motor fuels. Dairy biogas and biogas from some food and green waste actually have a negative carbon intensity [10]. The transportation sector is poised to benefit from RNG where it can be used to directly replace conventional fuels and can be used without any changes to CNG or LNG fuel systems. When using RNG in transportation, well-to-wheel greenhouse gas emissions can be reduced by 80% to 115%, depending on the source. Today, it is estimated that about 20% of all natural gas for on-road transportation is RNG, and half of natural gas used for road transportation in California is RNG; this number will continue to grow as innovation seeks for new and efficient ways to develop RNG [11].

Life Cycle Analysis Tools

There are several tools available for calculating the emissions from different transportation fuels. One of the most widely used tools is produced by Argonne National Laboratory and funded by the US Department of Energy — Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET). California GREET is another model that is widely used in the transportation sector. Corporations often use the GHG Protocol in which transportation is simply one portion of the full analysis. Tools such as GREET or CA GREET often feed into corporate sustainability models.

Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET)

The GREET model [12] was developed by Argonne National Laboratory with funding from the US Department of Energy. The GREET model is used to estimate the well-to-wheels and vehicle cycle energy and emissions for conventional and alternative transportation fuels. The model is updated annually to incorporate new data which is available and to augment the model for more applications (the 2015 GREET model added a heavy duty vehicle module). GREET includes inputs for more than 100 fuel production pathways. These pathways take into account upstream emissions from the production, processing, transmission & storage, and distribution phases. Argonne follows an informal but collaborative process of updating its model.

CA GREET

CA GREET [13] is a modified version of GREET specified for use in California. The CA GREET model calculates the fuel pathways for the Low Carbon Fuel Standard (LCFS). CA GREET includes a rigorous assessment of upstream petroleum emissions. Recent updates to the California GREET have included extensive consultations with affected stakeholders and an opportunity for public comment. For the calculations in this document, CA GREET was used.

Greenhouse Gas Protocol

Greenhouse Gas (GHG) Protocol [14] was developed by the World Resources Institute (WRI) and World Business Council on Sustainable Development (WBCSD). The purpose of the GHG Protocol is to set standards on how to measure, manage and report greenhouse gas emissions. GHG Protocol is widely used by corporations to analyze their emissions, of which transportation is a part of.

Footnotes:

1. http://www.arb.ca.gov/html/gloss.htm#C
2. https://www.epa.gov/ghgemissions/understanding-global-warming-potentials#Learnwhy
3. https://www3.epa.gov/climatechange/glossary.html#L
4. http://www.eia.gov/tools/glossary/index.cfm
5. https://www.epa.gov/ghgemissions/understanding-global-warming-potentials
6. https://www.eia.gov/tools/faqs/faq.cfm?id=73&t=11
7. https://www3.epa.gov/climatechange/ghgemissions/gases/co2.html)
8. http://steps.ucdavis.edu/files/09-17-2015-Table-for-UCDavis_LCFS-Illustrative-CIs_FINAL.pdf
9. https://www.epa.gov/pm-pollution/particulate-matter-pm
10. http://www.arb.ca.gov/fuels/lcfs/fuelpathways/pathwaytable.htm
11. www.rngcoalition.com
12. http://greet.es.anl.gov
13. http://www.arb.ca.gov/fuels/lcfs/ca-greet/ca-greet.htm
14. http://www.ghgprotocol.org/

NGVAMERICA

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400 N. Capitol St. NW STE 450, Washington, D.C. 20001

ngvamerica.org