Fact Sheet

Natural Gas Vehicles' Emissions Data and Comparisons

Introduction

Reducing greenhouse gas (GHG), nitrogen oxides (NOx) and particulate matter (PM) emissions from medium and large trucks and buses is crucial to cleaning up the Pacific Northwest's air quality and helping states and provinces meet GHG goals for the transportation sector. When targeting emission reductions in this sector, it is important to fully understand the differences between alternative fuel technologies – including their availability, emissions reduction capabilities, and cost – and how those technologies can help the state reach its goals.

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In this fact sheet, we address how Natural Gas Vehicles (NGVs) are well positioned to cost-effectively reduce GHG emissions compared to their diesel and electric counterparts.

New technology coming on the market is making NGVs even more attractive from an environmental and cost perspective. Using "near-zero" natural gas engines – EPA-certified to a 0.02 grams per brake horsepower-hour [g/bhp-hr] Optional Low NOx Standard – NGV NOx emissions are reduced 90% when replacing older diesel engines.[1] When compared with new technology diesel engines (NTDEs), also built to meet the 0.02 g/bhp-hr standard (as of Jan. 1, 2010), or to electric vehicles (EVs), ***NGV NO_X emissions are comparable to or lower when factoring in upstream ("lifecycle") emissions*** (those from drilling and transportation activities or operations of the average electrical grid)[2] and – according to recent tests – **much lower in NO_X emissions compared to real-world experience with NTDEs** (see box on next page). NGVs also have significant advantages in terms of purchase price and range (vs. EVs) and fuel and maintenance costs (vs. NTDEs).

The new NGV engines are already being manufactured in the U.S., both new trucks and engine replacement. In fact, medium- and heavy-duty NGVs are the only alternative-fueled vehicles widely available from manufacturers today. For availability, see the *Alternative Fuel and Advanced Vehicle Search*[3] or the *Clean Cities 2015 Vehicle Buyers Guide (PDF)*.[3]

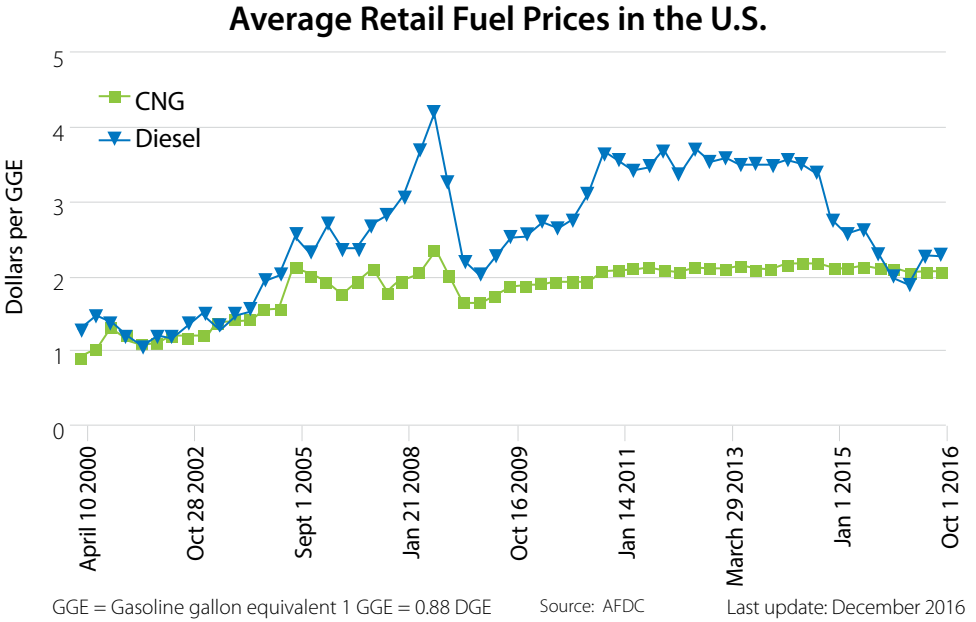
[1]http://www.cumminswestport.com/press-releases/2015/isl-g-near-zero-natural-gas-engine-certified-to-near-zero
[2]http://www.afdc.energy.gov/vehicles/natural_gas_emissions.html
[3]http://www.afdc.energy.gov/vehicles/search/; http://www.afdc.energy.gov/uploads/publication/2015_vehicle_buyers_guide.pdf

NGV Trucks vs. Diesel Trucks

According to the U.S. Department of Energy's Alternative Fuels Data Center (AFDC), while "the gap has narrowed between tailpipe emissions benefits from NGVs and conventional vehicles (due to increasingly stringent emissions regulations), NGVs continue to provide emissions benefits – especially when replacing older conventional vehicles or when considering lifecycle emissions." Indeed, the devil is in the details. According to Argonne National Laboratory's *Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) model,* light-duty vehicles running on compressed natural gas (CNG) can reduce lifecycle GHG emissions by 11% (83% if running on RNG)[4] compared to new diesel engines. Stated differently, Oregon's Department of Environmental Quality calculates CNG's carbon intensity[5] score at 79.93 compared to diesel at 98.48 – indicating CNG lifecycle GHG emissions are 19% lower. In addition, because CNG fuel systems are completely sealed, NGVs produce no evaporative emissions.

Other advantages of NVG trucks over new diesel trucks:

- **Substantial fuel cost savings.** At 2017 prices, natural gas costs $2.06 per diesel gallon equivalent (DGE), compared to $2.48/gallon for diesel. Due to current low oil prices, this cost differential is significantly narrower than usual (see chart below), and is already widening as oil prices rise. There is a general consensus that oil prices will return to historical norms in the medium- and long-term. Based on fuel cost savings alone, NGV trucks have a much shorter payback period.[6]



GGE = Gasoline gallon equivalent 1 GGE = 0.88 DGE Source: AFDC Last update: December 2016

[4]When renewable natural gas (RNG) is available in Oregon, NGVs will see an additional, substantial reduction in GHG emissions. RNG is biogas (methane) sourced from landfills, wastewater treatment digesters, anaerobic digesters at dairies and the like. It is produced without fugitive emissions and, in fact, has a negative emissions value as a result of the sequestration of methane that would be otherwise emitted.

[5]Carbon intensity is lifecycle emissions (sometimes called "well-to-wheels") and refers to how much total pollution is generated in the production, transport, storage and use of a fuel in a vehicle. http://www.deq.state.or.us/aq/cleanFuel/qa.htm

[6]Based on the average cost of diesel in 2011-2015, when it cost $1.30 more per DGE than natural gas, fuel cost savings would exceed $40,000 using natural gas instead of diesel over a truck's 200,000 mile lifespan.

- **Fuel price stability.** While the price of natural gas is expected to remain relatively low and stable for the foreseeable future – given plentiful U.S. domestic natural gas supply (and reserves) – the same cannot be said for the world's oil prices. The U.S. still depends on petroleum imports, much of which comes from politically unstable countries, making oil prices historically volatile. (The OPEC cartel's agreement on Nov. 30, 2016 to cut oil production immediately sent crude oil prices soaring.) The U.S. Energy Information Administration (EIA) predicts the price of crude will more than triple by 2040, while the increase in natural gas prices, already much lower per DGE, would be less than double. (Freightliner has created a calculator[7] to show how much money could be saved by switching trucks to natural gas.)
- **Maintenance costs (CNG engines).** The difference between the new technologies providing near-zero emissions from natural gas or diesel engines is significant: the newest diesel engines require sophisticated emission control equipment, including diesel particulate filters, selective catalytic reduction (SCR) systems and the continuous use of diesel exhaust fluid (DEF), while comparable natural gas engines can meet the same NOx standards with a simple, maintenance-free catalytic converter. Fewer emissions components, and the fact that CNG is a cleaner-burning fuel that generates less wear-and-tear on some engine components, translates to less vehicle maintenance and downtime.[8]
- **Quiet engines.** Natural gas engines on average are 10 decibels quieter than even the newest diesel engines of a comparable size. This is important for vehicle fleets that operate in noise-sensitive neighborhoods and/or at night.
- **Performance.** NGVs are similar to gasoline or diesel vehicles with regard to power, acceleration, and cruising speed. The driving range of NGVs is marginally less than that of comparable gasoline and diesel vehicles, but this can be mitigated with extra storage tanks or the use of liquefied natural gas (LNG), which increase range for larger vehicles.

NTDEs struggle to meet NO_X standard

While built to meet new EPA NOx emission standards, new technology diesel engines have struggled to meet those performance standards. According to a 2014 In-Use Emissions Technology Assessment by the California Air Resources Board (CARB), heavy-duty trucks with the new engines averaged NO_X emissions of 0.4 g/bhp-hr, or twice the new EPA standard. Causes cited were "cold starts, low-load/low-speed operations and overall engine deterioration."

At less than highway speeds, new diesel engine NOx emissions were consistently higher. When accelerating from a stop, CARB found emissions averaged 4 g/bhp-hr, declining by half at 10 mph, and half again at 20 mph. The EPA standard was not met until a diesel truck was traveling 40 mph. By comparison, CARB stated, NGV trucks had much lower off-cycle (lower speed) NOx emissions.

Cumulatively, this means NO_X emissions were much higher on average for new diesel engines in drayage trucks with lots of starts and stops than for long-haul diesel trucks. Trucks with new natural gas engines had consistently low NOx emissions regardless of speed or usage.

[7]http://www.freightlinegreen.com/calculator

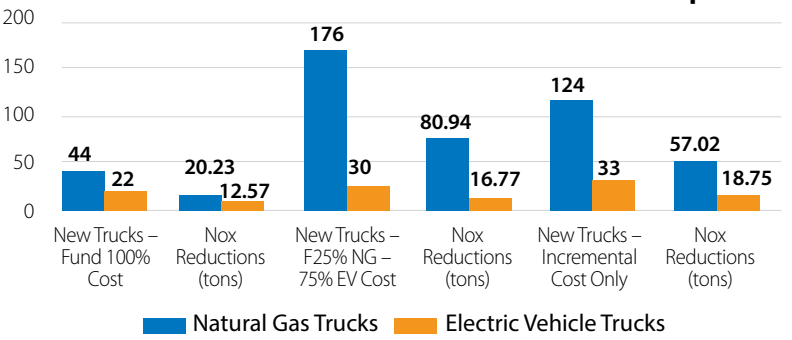
[8]http://auto.howstuffworks.com/fuel-efficiency/alternative-fuels/ngv4.htm; https://www.epa.gov/sites/production/files/2015-07/documents/catalog_of_chp_technologies_section_2._technology_characterization_-_reciprocating_internal_combustion_engines.pdf

NGV Trucks vs. Electric Trucks

Compared to electric trucks, the advantages of NGV trucks is clear: Substantial purchase price savings and much greater range. While actual cost depends on the application, an all-electric medium- or heavy-duty vehicle costs three to four times that of a comparable NGV. The following chart demonstrates, through one case study, how a sample $7.5 million investment could reduce NOx emissions – comparing replacement of short-haul trucks using either natural gas or electricity. The chart reflects how new low-NOx natural gas trucks can provide NOx reductions at a cost considerably lower than comparable all-electric trucks. Put another way, more NGVs could be deployed – and a greater number of higher-emitting vehicles taken off the road – for the same investment.

NGVs – Cost-effective NOx Reduction

VW $7.5 Million Short Haul Truck Example



NOx emissions are compared to emissions of new diesel vehicle; values will be larger for replacement projects

Data Source: Gladstein, Neandross & Associates *Game Changer Technical White Paper,* April 2016

The first two data sets, for example, indicate that 44 NGV short-haul trucks could be purchased for the same price as 22 electric trucks, resulting in 60% greater NOx emission reductions. (Numbers shown would hold to scale for larger investments.)

In addition, CNG-fueled trucks can travel, on average, 300 miles per fueling, vs. 60 miles per charge for an average (non-hybrid) electric truck, such as a garbage hauler. LNG-fueled heavy-duty trucks can be outfitted to have comparable driving ranges to their diesel equivalents.

Takeaways

- "Near-Zero" low-NOx natural gas engines deliver NOx emissions lower than the cleanest diesel engines and electric vehicles, when factoring in well-to-wheels emissions and consistently higher emissions from NTDEs in real-world experience.
- NGVs can be deployed in greater numbers and provide the most NOx reduction for the funds expended, compared to both "clean" diesel engines and electric trucks, because of their lower costs.
- Over time, NGV trucks offer greater cost savings over NTDEs because of lower fueling and maintenance costs.
- NGVs offer more vehicle choices already on the market.

In the U.S. today, NGVs are already serving 40 major airports, comprise 20% of transit buses and 60% of new garbage-hauling trucks ordered, and are being adopted in the long-haul truck market, rail industry and by marine shippers. ***Because natural gas is abundant domestically, cost-effective and already used in nearly all classes of vehicles, we must consider it as an alternative transportation fuel as we explore how to improve the region's air quality and meet our GHG goals.***

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