Diesel Truck Exhaust Mitigation

Portland, Oregon

Portland Clean Air

While diesel powered vehicles are only 6% of vehicles on the road in Oregon, they emit 60-70% of all particulate emissions from all vehicles, according to Oregon Department of Environmental Quality (DEQ). A 2004 study by Barbara Zielinka et al. in *Journal of the Air and Waste Management Association* found that diesel exhaust is 100 times more toxic than gasoline engine exhaust. Diesel particulate is the most hazardous airborne carcinogen according to published California risk assessments.

Downtown Portland, Upper Waterfront, Pearl District, and parts of Cully are in the worst 2% of precincts in the nation for airborne diesel particulate concentrations according to the most recent Environmental Protection Agency (EPA) *National Air Toxics Assessment* (NATA) which used 2011 data and was released December 2015. This is primarily due to industrial, unfiltered, short haul truck exhaust from nearby highways. NATA also ranks Portland as the worst city in the nation for respiratory distress from air pollution.

Diesel particulate is primarily made of carbon. These carbon particles attract and adhere to polycyclic aromatic hydrocarbons and other carcinogens in diesel exhaust, and also to airborne carcinogenic chemicals from other sources. In 2015 DEQ reported that 80-95% of diesel exhaust is ultra-fine particulate "easily inhaled and left in the lower area of the lungs... capable of entering the bloodstream, allowing them to be circulated to all parts of the body." Clean Air Task Force in Boston calculated EPA data and, using State of California published risk assessments, found diesel particulate emissions in Portland cause residents more than 5.8 times as many cancers as all other inhaled carcinogens combined.

The EPA reported that diesel exhaust can cause eye, throat, and bronchial irritation, nausea, lightheadedness, as well as coughing and phlegm. In 2015 the *Oregonian* reported that other health effects of diesel exhaust include "heart attacks, pre-term and low-weight births, and asthma." The World Health Organization classifies diesel exhaust as a carcinogen, causing lung and bladder cancer. The States of Washington and California as well as the Oregon Environmental Quality Commission have named diesel particulate as a carcinogen. A 2012 study by Susan Peters et al. of 1,256 families published in the *International Journal of Cancer* reported an association between childhood brain tumors and prenatal exposure to diesel exhaust.

The *Portland Tribune* reported in 2014 that:

> "California led the nation by branding diesel a carcinogen back in 1998... Oregon's Environmental Quality Commission, the volunteer board that guides the DEQ and sets state policies, declared diesel emissions a carcinogen in 2006. But the board adopted a more lenient state standard for diesel pollution — allowing concentrations 33 times higher than California or Washington before it's deemed a health concern."

The 2015 *Oregonian* diesel investigation found that "Oregon has become a dumping ground for California's old, polluting big diesel rigs." The Oregonian reported that California is phasing out 350,000 trucks with stricter diesel standards. These trucks end up in Oregon where they are still legal.

By 2015 nearly all California trucks were required to have a diesel particulate filter installed. These filters remove 90% of diesel particulate from truck exhaust. Oregon's lack of air pollution regulation has resulted in an increase in litigation and negative media attention focused on industry. Neighborhood reaction to harmful chemical exposure makes voluntary mitigation of diesel truck fleets a cost-effective business practice.

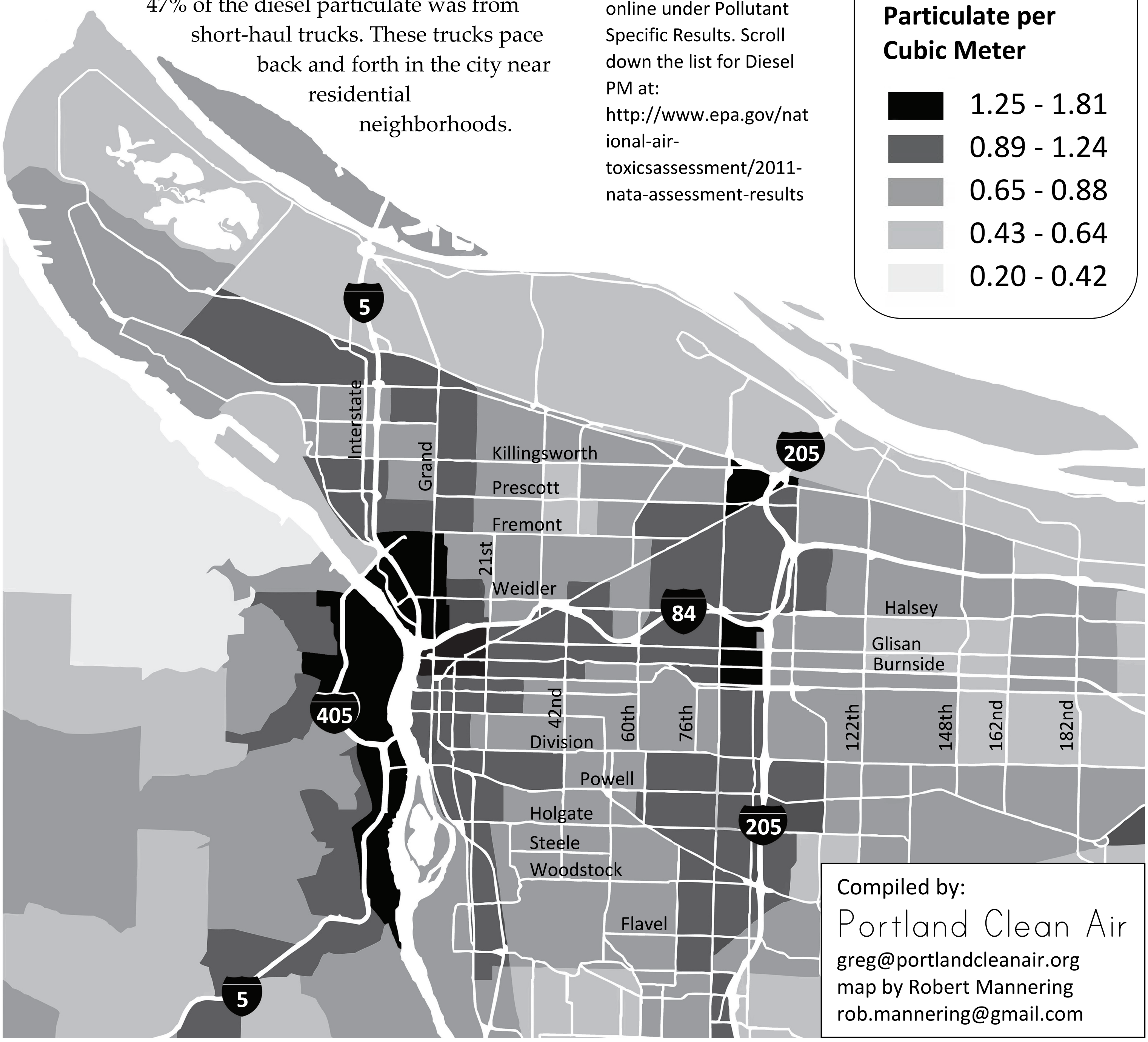
Diesel Particulate Concentrations

In Multnomah County

The most recent Environmental Protection Agency (EPA) *National Air Toxics Assessment* was released in December 2015. In that study Multnomah County ranked in the worst 1% of counties nationwide for diesel particulate matter concentrations. The areas in black below ranked in the worst 1-2% of precincts in the nation for airborne diesel particulate. According to the EPA National Emissions Inventory, also using 2011 data for Multnomah, Washington, and Clackamas Counties, 47% of the diesel particulate was from short-haul trucks. These trucks pace back and forth in the city near residential neighborhoods.

EPA reported high diesel particulate concentrations along freeway corridors. Portland Clean Air is currently modeling more accurate diesel particulate concentrations using Oregon Department of Transportation and Portland Bureau of Transportation 24-hour truck counts as well as an optical carbon aerosol particulate analysis monitor.

This EPA dataset is online under Pollutant Specific Results. Scroll down the list for Diesel PM at: http://www.epa.gov/national-air-toxicsassessment/2011-nata-assessment-results



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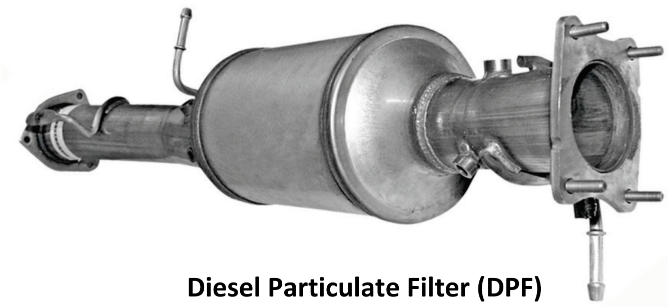
Technology Answers for Diesel Exhaust

This report examines five modern technologies that either reduce dangerous exhaust emissions or increase fuel efficiency for diesel trucks.

Diesel Particulate Filter (DPF) Retrofit

Pollution control through diesel retrofits brings older diesel vehicles in line with modern expectations and technology. Diesel Particulate Filters (DPF) work by trapping particulate matter in the exhaust system. The filter retains the ultrafine particulate from the emissions and later burns it so that it is kept out of the air. DPFs remove up to 90% of harmful particulate from exhaust.



Diesel Particulate Filter (DPF)

> "The DPF needs to be cleaned regularly, through a process called regeneration, either active, passive or forced regeneration; the accumulated soot is burnt off at high temperature, around 600°c, to leave only a residue of ash," as reported by JLM Lubricants. "Active regeneration happens while the vehicle is not in use and takes ten minutes on average to complete. Passive regeneration takes place while driving using the heat of the exhaust. This works well for vehicles that drive longer distances with few stops compared to those that perform short trips with many starts and stops. If the filter develops too much pressure then the last type of regeneration must be used - a forced regeneration. This involves a garage using a computer program to run the car, initiating a regeneration of the DPF manually," according to Kevin Sanders of DPF Remedy.

All new on-highway engines in the United States are sold with DPFs already installed. DPFs were required by federal law in all new engines starting in 2007; these engines were implemented in all new vehicles starting in 2008. For earlier vehicles, a DPF retrofit can provide the same benefit. DPFs are for vehicles using Ultra Low Sulfur Diesel Fuel (ULSD). The right DPF for your vehicle is determined based primarily on your expected use and your engine specifications. Diesel Particulate Filters require an inspection, data logging, and a backpressure monitoring system, which are typically included in the cost of the DPF. You should clean your DPF to remove the accumulated ash every 6 to 12 months. If filters are not cleaned regularly, they can clog and cause backpressure, ultimately causing decreased fuel efficiency and engine stalling.

Diesel Oxidation Catalysts, also known as DOCs, work by sending exhaust through a chamber filled with honeycombed precious metals which react with the exhaust and break it down into generally less harmful pollutants. DOCs reduce PM emissions 20-40%. They are not nearly as effective as DPFs at reducing particulates.

DPF/ DOC Cost: DPFs range in cost from $5,000 to $15,000 for a passive filter which relies solely on the inherent heat of the exhaust or up to $50,000 for an active filter which burns the PM with added fuel, heat, or driver action. 2010 DOC prices typically ranged from $600 to $2,000.

DPF/ DOC Vendors:

Brattain International (800) 452-5302
brattain.com

Cummins Northwest (800) 283-0336
locator.cummins.com

Diesel Emissions Service (503) 473-8108
dieselemissionsservice.com

DSU Peterbilt & GMC (800) 556-4998
dsutrucks.com

McCoy Freightliner (800) 831-2208
mccoyftl.com

Papé Kenworth (503) 240-6282
papekenworth.com

Papé Machinery, Inc. (800) 452-5346
machinerytrader.com/dealers/detail.aspx?cid=2861172

Peterson Machinery Co. (800) 452-7676
petersoncat.com/services/service/emissions

Water Diesel Fuel Emulsions (WiDE)

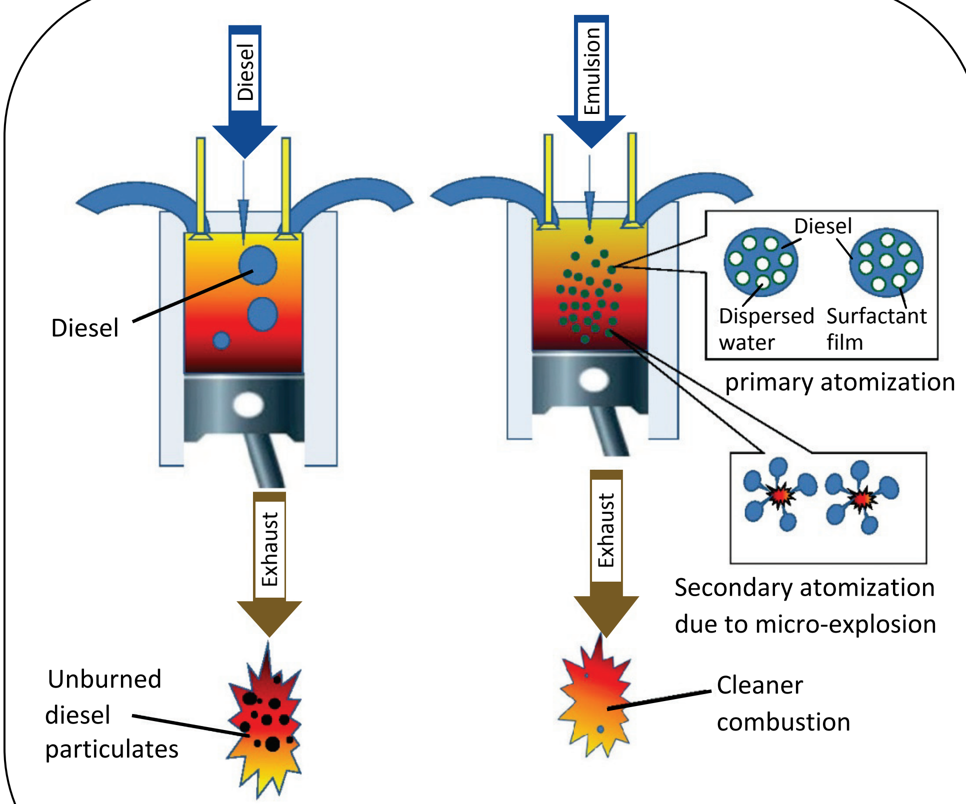
Modern Water Diesel Fuel Emulsions (WiDE) combine both easy pollution control and increased fuel efficiency. The fuel emulsion contains a blended mix of tiny water droplets encapsulated in a diesel fuel film which explode in the combustion process. Water boils at a lower temperature than diesel, so heated water droplets inside the water-diesel mix create micro-explosions and puffs of vapor. The water droplet micro-explosions and vapor improve the air/fuel mix, resulting in higher combustion efficiency.

The water droplet micro-explosions, along with puffs caused by water droplet vaporization, create a "secondary atomization" of the fuel. The micro explosions cause smaller droplets to intersperse within the fuel, thus spreading air throughout the fuel. There is a more complete combustion of fuel, which leads to greater fuel efficiency.

In addition, the presence of water in diesel fuel has a cooling effect on the engine which reduces emissions. According to the EPA, "because of its high heat of vaporization, low vapor pressure, and low boiling point, water [is] the ideal cooling substance." The water's cooling effect on the engine reduces nitrous oxide emissions, and the water reduces particulate matter formation.

It is important to understand that WiDE fuel is different from fuel which has water "entrained" in the form of large visible drops of water. Fuel with entrained water reduces energy output. Moreover, if the water settles to the bottom (becomes "free water") it causes injection wear, corrosion, and filter plugging. To prevent these problems, WiDE fuel involves small water droplets which are suspended in the fuel. Think of a cracked egg: the yolk in the egg before it is beaten is similar to entrained water while the beaten egg is similar to WiDE.

Emulsifying water with diesel fuel increases the fuel efficiency up to 1.2 times that of pure diesel fuel. In addition to pollution reduction from greater fuel efficiency, the exploding water droplets break into component chemicals which help oxidize and neutralize soot and other pollutants. Overall, diesel fuel mixed with water reduces nitrogen oxides, hydrocarbons, and exhaust smoke.



Primary and secondary atomization of emulsified fuel

The EPA reports that "reductions in particulate emissions (PM) tend to be on the order of two to three times the amount of water added to the fuel." Fierce Fuel uses a WiDE formula that reduces PM up to 80% and nitrous oxide up to 55%. Other formulas may have even better benefits. A 25.6% water formula has been reported to reduce nitrous oxide by up to 50% and PM by up to 94%. Generally, studies are showing reductions of nitrous oxide by up to 37% and reductions of PM by up to 90% when compared with pure diesel fuel.

A low amount of surfactant can help increase the micro-explosions. Surfactants also stabilize the saturation of water droplets in the fuel mixture to prevent settling. Other factors that optimize emulsified fuel are ambient temperature, droplet size, and engine timing.

Water percentages ranging from 5 to 40% can successfully work as fuel mixtures. Different water drop sizes result in different engine efficiency and different air quality benefits. Diesel fuel emulsions using small water drops improve engine efficiency at all engine loads, though the greatest benefits are at engine loads more than 75%.

One of the best known brands of emulsified fuel is PuriNOx. A draft EPA report on PuriNOx shows that PuriNOx gives significant pollution reduction. The EPA studied the summer version of PuriNOx, which contains 20% water. In 2002 the EPA forecast that using PuriNOx in target year 2007, would reduce PM by 16.8% to 55.6%, with highest reductions among typical highway fleets, and PuriNOx usage would reduce Nitrous Oxide emissions by 9% to as much as 20.2%, with highest reductions among typical off-road fleets. Environment Canada's test use of PuriNOx for Houston, Texas, demonstrated even better results: reductions of PM by up to 69% and reductions of nitrous oxide emission by up to 41%.

Water Diesel Emulsions can be used by standard diesel engines without any prior modifications to the engine. Emulsions may also be used with other pollution control devices. A corrosion inhibitor is part of the emulsifier. However, fuel emulsions are not as corrosive as direct water injections.

Emulsified fuels can result in a loss of peak power, though normal usage will only require greater pressure on the accelerator. Continuing studies on power show conflicting results, with some studies showing an increase and some a decrease in power. A recent study by Fierce Fuel Systems showed minor decreases in horsepower so long as water did not exceed 20%. Additionally, initial engine startups may be more difficult than with pure diesel. However, a water diesel ratio of approximately 20/80 provides only "negligible changes" in horsepower and torque.

Under some conditions, diesel fuel emulsions may cause an increase in other pollutants such as hydrocarbons. Other studies have shown up to a 90% reduction in hydrocarbons when using a 13% water emulsion. Regardless, even when studies show an increase in other pollutants, the increases do not exceed engine certification standards.

Overall, water diesel emulsions provide immediate pollution reduction and fuel efficiency without installation of special equipment.

Diesel Fuel Pre-Treatment System

Water diesel fuel emulsion is not available at Oregon fueling stations. To fill this void, an onboard emulsifier can create emulsified fuel on the truck. Onboard pretreatment systems have computer-monitored storage and filtration programs which ensure that only diesel is stored in the engine and that only diesel is used at the initial startup. Pre-treatment systems thus reduce any possible corrosion from water and also provide typical full-power engine startup. The device monitors air temperature to use more emulsified fuel during warmer weather and less emulsified fuel during freezing conditions. Alternatively, an onboard system can use water heating equipment or antifreeze additives.

Fierce Fuel System reports the following results from X_2O, their onboard emulsification system, available for injector fuel engines made in 2015 or earlier:

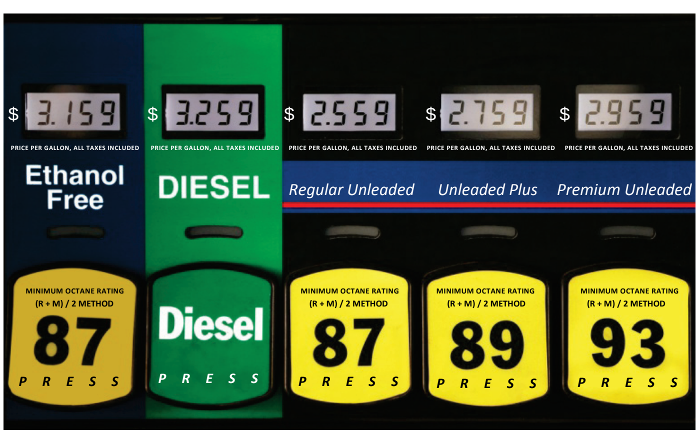
> "Independent dynamometer tests with a class eight truck confirm that a 17.3% fuel savings occurs when using 20% water in the diesel water emulsion at 65 mph with 80,000 gross vehicle weight under constant load. Reduction of particulate, nitrogen oxides, and carbon monoxide will be realized at all load conditions due to low temperature combustion resulting in lower exhaust. A 30% water emulsion saves up to 27% in fuel. Drivers can select water ratios from 10 to 40%, depending on load and demand, with near linear savings."

No engine modification is needed to install Fierce Fuels' X_2O. Using standard shop supplies, installation typically takes two people four hours to complete. The X_2O uses a "precisely tailored filtration system for individual engine types."

Onboard emulsification system

Cost: $16,995.

Vendors: Fierce Fuel Systems
fiercefuelsystems.com
(248) 977-4722



Natural Gas

According to a report by the International Council on Clean Transportation, natural gas fueled trucks' emissions are similar to gas and diesel powered trucks.

> "Natural gas engines can be either stoichiometric, spark ignited (SI) or lean-burn, compression-ignited, high-pressure direct injection (HDPI). A third technology... is lean-burn SI; this technology is currently being adopted elsewhere in the world but is not under consideration for use in the US heavy-duty transportation sector. SI natural gas engines operate similarly to gasoline engines and in turn produce similar engine-out emissions that require a three-way catalyst for after-treatment. HDPI engines, which use compression ignition along with a small (around 5 %) amount of diesel fuel to pilot the ignition, operate similarly to diesel engines and require after-treatment systems composed of a diesel particulate filter (DPF) and selective catalytic reduction (SCR). "

Natural gas fueled trucks are responsible for large quantities of methane gas pollution. Methane is a greenhouse gas and is emitted in every stage — from fracking extraction to refining, through the transportation and refilling processes, and as truck exhaust. Ninety percent of natural gas consists of methane, and methane's effect as a greenhouse gas is up to 20 times more detrimental than carbon dioxide.

In addition to methane pollution, natural gas has multiple drawbacks when compared with diesel:

- Power: Gas engines produce only 60% to 75% of horsepower of comparable diesel engines.
- Lack of infrastructure and range: Current natural gas trucks offer up to about a 550-mile range, close to what a driver can do in a day. Some long combination vehicles can only obtain a 450-mile range. While progress is being made, the costs of setting up refueling stations is high and typically being underwritten by the industry as they develop the network. Some gas fleet owners, such as UPS, are having to build their own CNG fueling terminals.

- Quality of fuel: The quality of fuel grade gas is somewhat sporadic and engines are not highly tolerant of variation. This can cause emission issues, mileage issues and, in some cases, severe damage to the engine internals. Some engine types are designed to burn gas with varying levels of air to reduce emissions; however, they have reduced fuel efficiency and can cause engine issues such as misfiring or knocking. Knock can cause extreme damage to an engine. Careful control of temperature and gas supply is needed even with duel gas/diesel systems to prevent knock damage.
- Safety: Natural gas poses special safety concerns. Leaks of Liquid Natural Gas (LNG) in enclosed spaces may cause pressure to build and be easily ignited. Additionally, LNG is stored at temperatures that are so cold that it can cause cryogenic burns. Compressed Natural Gas (CNG) poses its own usage concerns which requires trained and certified technicians.

Cost: Natural gas trucks have a cost similar to diesel trucks according to America's Commercial Transportation Research Truck Fuel Calculator: under $88,000 per year. Gasoline, fuel cell, and electric trucks cost from $91,000 up to $103,500 annually. Natural gas conversion kits range from $15,000 to $30,000; refitting of engine internals are not included in the conversion costs. Natural gas trucks may have higher maintenance costs in some areas. Mechanics must spend $50,00 to $150,000 per bay in upgrades to repair natural gas vehicles.

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