Alternative Fuels for Fleet Vehicles (LPG Vehicles)

A paper from [JordanFire.Net]

Introduction

The development and use of the internal combustion engine has been an economic and developmental boon to the United States. It is now easy to go across the country in our own vehicles at a rate literally unheard of 100 years ago. However, using petroleum for transportation is not without environmental costs. When petroleum is burned, carbon monoxide (CO), carbon dioxide (CO_2), nitrogen oxides (NOx), sulfur oxides (SOx), volatile organic compounds (VOCs,) also known as reactive hydrocarbons), hydroxyl ions (OH^-), and particulate matter (PM) are emitted. Additionally, NOx and reactive hydrocarbons form low level ozone (O_3) (a major component of smog) in the presence of sunlight.

These pollutants have numerous health and environmental impacts, including urban smog and, perhaps most worrisome, global climate change (also known as global warming). Burning the fuels is not the only environmental risk. The extraction and transportation of petroleum can also have significant environmental impact. There are few, if any, people who have forgotten the vast environmental impact of the Exxon Valdez oil spill in Prince William Sound. Although this spill has not, thankfully, been repeated in U.S. waters, there are many smaller spills that happen on a more "regular" basis that also have a detrimental effect on the environment, albeit in a smaller impact area. The grounding of the New Carissa off the Oregon coast is only the most recent, well-publicized oil spill in the Pacific Northwest.

It is important to remember that many products basic to modern life, in addition to transportation, are dependent upon petroleum. Most of the chemicals and other products that we use daily are made from petroleum: plastics, fibers, solvents, fertilizers, engine fluids and detergents are just a few examples. According to a July 1997 report by the U.S. Department of Energy ("Summary of the Technical and Policy Analysis conducted by The Department of Energy in partial fulfillment of the requirements of Section 506 of the Energy Policy Act of 1992"):

Petroleum used in transportation alone exceeds total domestic oil production by 2 million barrels per day. This gap is growing, and is projected to reach nearly 6 million barrels per day by the year 2010… .

As noted by the Energy Information Administration, Office of Energy Markets and End Use, DOE, in "Describing Current and Potential Markets for Alternative-Fuel Vehicles" March 1996:

The transportation sector [in the United States] consumes 65 percent of the total petroleum products supplied, and, by far, the largest share of product supplied to the transportation sector is motor gasoline. In the United States, the transportation sector contributes:

- about one-third of CO_2 emissions
- about one-third of NOx emissions
- fewer than 1 percent of anthropogenic methane emissions
- 77 percent of CO emissions
- 45 percent of nitrogen oxide (NO_2)emissions
- more than one-third of non-methane VOCs

What can be done to reduce our reliance on burning petroleum for fuel? There is at least one option: alternative fuels. Although the use of alternative fuels for personal cars hasn't advanced much beyond the curiosity level (for the wealthy and/or environmentally conscious out there), fleets are a whole other story.

What is prompting fleet managers to look at alternative fuels? Federal requirements are one driver. As noted on the Office of Government Policy's (OGP) Federal Vehicle Policy Division (MTV) website,

The alternative fuel acquisition requirements of the Energy Policy Act of 1992 apply to Federal, State, and fuel provider fleets located in certain geographical areas. These geographical areas are metropolitan statistical areas or consolidated metropolitan statistical areas, as established by the Bureau of Census, with a 1980 population of more than 250,000 people.

There are other drivers being placed on fleet managers in individual states. California has regulatory requirements regarding a reduction in emissions based upon a fleet average for manufacturers (Low-Emission Vehicle Program). At least 10% of the cars sold in the state must meet zero emission standards by 2003. Massachusetts, New York, Maine and Vermont have adapted these "California standards" and requirements for low and zero emission vehicles, although the implementation date for the LEVs may differ by state. In areas where regulations have not yet mandated alternative fuels, the change has been induced by managers interested in efficiency and a desire to get ahead of the game as far as environmental management is concerned.

Fleet managers are in an ideal situation to consider vehicles using alternatives to petroleum fuels. Transportation fleets generally have refueling facilities on site (regardless of the fuel used); often the vehicles used in the fleets have a "set" mileage day in and day out (for example, delivery of baby diapers, local print shop deliveries, postal services). There is rarely a requirement to carry more than four passengers (and even that may be a large number of passengers for a fleet vehicle). The fleet managers have complete control over the maintenance and upkeep of their fleets and facilities.

There are a number of different fuels that fall under the heading "alternative fuels" for fleet vehicles. For this report, these include:

- **natural gas** (both compressed and liquefied);
- **liquefied petroleum gas** (commonly called propane);
- **methanol**;
- **ethanol**;
- **electricity** from batteries;
- **hydrogen** including the use of fuel cells; and
- **biodiesel**.

A comprehensive lifecycle environmental impact analysis of the production and use of alternative fuels is beyond the scope of this report. A brief overview of these fuel types is provided below, with information given about reductions in emissions as compared to gasoline and diesel powered vehicles. For comparison, a similar overview of **gasoline** and **diesel** is also provided. Most of the information found in this section was gathered from the sources listed at the end of the document.

Natural Gas - Compressed Natural Gas and Liquefied Natural Gas

What it is: Natural gas is a mixture of hydrocarbons - mainly methane (CH_4). As indicated by its name, natural gas is in gaseous form. It can be stored on a vehicle either in a compressed gaseous state (CNG) or in a liquefied state (LNG). When found as LNG, it is super-cooled to a temperature of minus 260 F and contained in insulated, pressurized tanks. For the remainder of this discussion, information that applies to both CNG and LNG will be presented as information about natural gas vehicles (NGVs); information that is specific to either CNG or LNG will be noted as such.

How it is produced: Natural gas is primarily extracted from gas wells or in conjunction with crude oil production; it can also be produced as a "by-product" of landfill operations.

Environmental Characteristics: Natural gas has low CO emissions, virtually no PM emissions, and reduced VOCs. Per unit of energy, natural gas contains less carbon than any other fossil fuel, leading to lower CO_2 emissions per vehicle mile traveled. Specific emission reductions for NGVs compared to gasoline are:

- CO, 65-90 percent;
- Non-methane organic gas (NMOG), 87 percent;
- NOx, 87 percent;
- CO_2, by almost 20 percent.

Another emission reduction is achieved when fueling NGVs. Gasoline vehicles have evaporative emissions during both fueling and use, which, according to the Natural Gas Vehicle Coalition, can account for at least 50 percent of a gasoline vehicle's total hydrocarbon emissions. Finally, the ozone-producing reactivity of natural gas is up to 80-90 percent below gasoline.

Economics: Because natural gas burns cleaner, there is a reduction in the vehicle maintenance needed, including a longer time between oil changes, and an increase in the life of spark plugs.

Many utilities and other sources note the lower cost of natural gas as a fuel. According to the Natural Gas Vehicle Forum (**http://www.ngv.org/**), specifically, **http://www.ngv.org/ngv/ngvorg01.nsf/bytitle/EconomicBenefitsofNGVs.htm**,

"... As of October 1998 natural gas cost between $0.95 and $1.041 compared to an equivalent gallon of gasoline, in the Southern California region."

In the Puget Sound region natural gas costs $0.80 per gallon gasoline equivalent (gge) (when purchased through Puget Sound Energy). It can be considerably less if an individual fleet owns their own station: $0.45 per gge. It can be even cheaper if the fleet manager decides to purchase the natural gas directly from the producers themselves.

The California Energy Commission has also identified some costs for natural gas. In March 1997, the cost was estimated at $0.70 to $1.00, also in California. Although prices are dependent upon the local natural gas utility, these numbers are good estimates for the cost of natural gas for fleets. The March 1997 estimate for installing fast-fill compressor facilities for a small private or public fleet of about ten vehicles, (in California) was between $180,000 to $250,000.

Health & Safety information: Natural gas is lighter than air; a spill would disperse into the air, as opposed to pooling on the ground or entering sewer or water systems. However, in an enclosed area, natural gas will rise to the ceiling, which could be a potential fire and ignition risk.

Natural gas has a higher ignition temperature than gasoline, and also a narrower range of flammability. As a result, natural gas is less risky than gasoline in terms of accidental ignition or combustion.

LNG has some additional safety issues that CNG does not have. Since LNG is cooled to -260F, all bodily contact with liquid fuel, cold metals or cold gas should be avoided; frost bite can occur. Also, methane gas detectors must be installed at facilities, because odorants cannot be added to LNG.

Additional information: Natural gas has played a minor role historically in the U.S. transportation market, perhaps partly because it is more difficult to store than liquid fuels. Natural gas is a North American resource, delivered continuously through a gas pipeline network in the United States to end users. Much of the natural gas used in the Northwest is imported from Canada.

NGVs are more common in other countries. Italy, New Zealand, and the former Soviet Union all have more than 150,000 NGVs in operation. Australia and Canada are also significant users, although Canada uses fewer than the U.S. According to numbers available on the Department of Energy, Energy Information Administration website

(**http://www.eia.doe.gov/cneaf/solar.renewables/alt_trans_fuel97/table1.html**), there were over 85,000 NGVs operating in the United States in 1998.

Chuck Dougherty, Program Manager - Alternative Fuel Vehicles, Puget Sound Energy, notes that one of the advantages of natural gas is that is it "provides an answer today," one that allows both the fuel provider and its customers to do business exactly the way they are currently operating. Natural gas allows a change to an alternative fuel without requiring an immediate switch away from internal combustion engines and the investment supporting their production. Just as important as the availability and ease of transition to natural gas is the fact that the vehicle technology is available and ready now for commercialization.

There are two different methods of filling NGVs. The "fast fill" method is completed in approximately five to six minutes, and uses compressed gas stored in cascades of cylinders. There is also a "timed fill" method completed in five to eight hours, which is usually performed overnight. One concern for the storage and transmission is that water content in the natural gas can be an issue when storing in pipes and tanks that could be rusted by the water. However, this is not an issue in the Pacific Northwest, where the average water content is 0.5 pounds per million feet of gas. As a comparison, the National Society of Automotive Engineers (SAE) standard calls for not more than 7 pounds per million feet of gas.

The performance of NGVs is comparable to those of gasoline-powered vehicles. NGVs experience no loss of power, and may have greater power and efficiency. One reason has to do with the nature of fuel itself: natural gas has a 130 octane rating, compared with 87 to 94 octane rating of gasoline. (Octane rating refers to the fuel's ability to resist uncontrolled combustion or "knock.")

A unit volume of CNG has less than one-fourth of the energy content of gasoline, requiring a greater storage requirement for the vehicle. Based upon the physical state of the fuel, approximately two to four times more LNG than CNG can be stored on a vehicle.

Compressed Natural Gas

Depending on make and model, 1999 model year CNG vehicles have a driving range of approximately 120-180 miles, with a low of 70 miles and a high of 210 miles. Another way to increase the driving range is to use bi-fueled vehicles that can switch from natural gas to gasoline (for example, EPA Region 10, as noted above). However, there are significant losses in emission benefits once the vehicle is no longer a dedicated NGV.

The emissions of aftermarket CNG conversions are of particular concern. Fleet operators need to make sure that all vehicle conversions meet EPA Memorandum 1-A Requirements and are installed by a qualified aftermarket installer.

Liquefied Natural Gas

There are some areas where LNG vehicles differ from CNG vehicles. These include:

- Higher energy density. A greater volume of LNG can be stored in a smaller space. This allows vehicle designers and engineers to increase range while decreasing weight, where a real advantage can be had in long-haul high fuel volume use vehicle.
- Speed of fueling. Large vehicles can often be filled in the "fast fill" time of four to six minutes.
- Control over fuel composition. The composition of LNG can be determined with a high degree of

accuracy since most LNG produced for vehicles is 99+ percent methane. By having this control, the vehicle is able to have a more finely tuned fuel system and engine, leading to optimization of engine performance, greater fuel economy, and lower emissions.
- Delivery and availability. LNG is similar to gasoline, in that it can be transported in trailer trucks, railcars, barges and ships. The delivery infrastructure is already in place.
- It is possible to have liquids develop in LNG fuels. These liquid "slugs" won't gassify, and reduce the efficiency of the fuel.
- The boil-off factor of LNG as a fuel needs to be maintained.

Liquefied Petroleum Gas / Propane

What it is: Generally, liquefied petroleum gas (LPG) consists of various hydrocarbons, mainly of propane, propylene, butane, and butylene in various mixtures. However, for fuels in the United States, the mixture is mainly propane a relatively simple molecule (C_3H_8) compared to gasoline, which undergoes more complete combustion when used as a fuel.

How it is produced: LPG is a byproduct of natural gas processing and petroleum refining.

Environmental Characteristics: The propane vehicles can have lower emission of reactive hydrocarbons (about one-third less), NOx (20 percent less), and CO (60 percent less) than gasoline vehicles. However, if the vehicle is an aftermarket conversion, emission performance will varies widely depending on the type and quality of the conversion.

Economics: Propane retail prices are, on average, about the same as unleaded gasoline prices. According to information available from the Energy Information Administration, in January 1999, propane cost Commercial/Institutional Consumers $0.769 per gallon and cost $0.757 through retail outlets. Neither one of these prices include taxes. It is important to remember that propane is used in several different sectors, which can make a direct comparison to gasoline at the pump a bit more difficult.

Health & Safety information: If LPG leaks or is spilled, it will remain on the ground or enter water systems.

Additional information: Propane is used in all major end-use sectors as a heating fuel, engine fuel, cooking fuel, and chemical feedstock. The components of LPG are gases at normal temperatures and pressures. With moderate pressure (100 to 300 psi), they condense to liquids, making them easy to store and transport. When LPG is used in a vehicle, it is stored as a liquid and changes back to a gas before it is burned in the engine. With the fuel in a gaseous state, it mixes readily with air to allow for nearly complete combustion (thereby reducing some exhaust emissions such as carbon monoxide) and it has few cold-weather starting problems. LPG has many of the storage and transportation advantages of liquids, along with the fuel advantages of gases.

LPG/propane has been extensively used as a road fuel for several decades, and was in relatively widespread automotive use (mainly fleets) prior to the enactment of Energy Policy Act of 1992 (EPACT). In fact, it appears to be the primary alternative fuel in use today. Propane is used mostly in delivery vehicles, especially those that are used to deliver propane.

LPG in the storage tank has an energy density that is about 73 percent of the energy density of gasoline, by volume. [Energy density affects the volume and weight of fuel contained in onboard storage tanks; it can used as a measure of energy content.] It requires slightly larger fuel tanks or more frequent fill-ups in order to maintain an equivalent gasoline range. However, survey data available in a 1996 DOE Energy Information Administration report indicated that propane vehicles had more fuel storage capacity than conventional-fuel vehicles. The average fuel storage capacity for dedicated vehicles in the light-duty category was approximately 91 percent higher for propane vehicles than for conventional-fuel vehicles.

Propane vehicles have been shown to have less carbon build-up than conventionally fueled vehicles. According to the National Propane Gas Association, spark plugs from a propane vehicle last from 80,000 to 100,000 miles and propane engines can last two to three times longer. Currently, only one automobile manufacturer offers an LPG vehicle. The majority of propane powered vehicles are converting using aftermarket kits. As with CNG conversions, fleet operators converting vehicles to propane must comply with EPA Memorandum 1-A.

How safe are natural gas alternative fuels?

Natural Gas fuels are as safe, if not safer, than traditional petroleum based fuels. However, being that most people are familiar with gasoline or diesel, their safety is rarely questioned. People unaccustomed to alternative fuels may have misconceptions or doubts about their safety in vehicle applications. Note that as with any fuel, the safety of natural gas is associated with the training and proper handling of the fuel. Below you will find information regarding the safety of natural gas fuels.

CNG

The fuel is odorless, and odorants are added to detect leaks and spills. In the event of a leak, the gas will rise to the ceiling and create a potential risk for enclosed areas. Sturdy, heavy storage tanks must be used to avoid possible hazards from the high-pressure storage.

LNG

The fuel is cooled cryogenically to -260°F. At this temperature, bodily contact with the liquid fuel, cold metals, or cold gas can cause cryogenic burns (frostbite). Methane gas detectors must be installed to detect leaks, because odorants cannot be added to LNG.

What is the definition of an alternative fuel?

U.S. Department of Energy: Alternative fuels are substantially non-petroleum and yield energy security and environmental benefits. DOE currently recognizes the following as alternative fuels: methanol and denatured ethanol as alcohol fuels (alcohol mixtures that contain no less than 70% of the alcohol fuel), natural gas (compressed or liquefied), liquefied petroleum gas, hydrogen, coal-derived liquid fuels, fuels derived from biological materials, and electricity (including solar energy). DOE can expand this list when new fuels are developed and approved as meeting this definition.

For more information on Ozone visit: http://www.epa.gov/oar/oaqps/gooduphigh/

Natural Gas Vehicle Standards

A large number of mandatory and voluntary standards cover the varying facets of natural gas vehicle components, conversion, and manufacture, and the fueling stations, repair facilities and garages that service them. Following is a list and short description of the " NGV" series of American National Standards, developed through the Natural Gas Vehicle Coalition with support from the Gas Research Institute, the Canadian Gas Association and CSA International.

These voluntary standards represent natural gas vehicle industry "good practice" for the safety and durability of essential elements in CNG vehicle fueling stations and vehicle fuel systems.

NGV1-1994 (includes addenda 1a-1997 and 1b-1998) **Compressed Natural Gas Vehicle (NGV) Fueling Connection Devices**	Covers the examination, construction, performance, testing, safe operation and certification of NGV fueling nozzles and receptacles.
NGV2-2000 **Basic Requirements for Compressed Natural Gas Vehicle (NGV) Fuel Containers**	Covers the construction, performance, testing, inspection and safe operation of vehicle on-board compressed natural gas storage containers (" cylinders").
PRD1-1998 (including addendum 1a-1999) **Basic Requirements for Pressure Relief Devices for Natural Gas Vehicle (NGV) Fuel Containers**	A standard for the safe operation, substantial and durable construction, performance and testing of pressure relief valves for on-board natural gas vehicle fuel containers.
NGV3.1-1995 **Fuel System Components for Natural Gas Powered Vehicles**	Applies to the design, construction, testing and approval to assure safe performance of newly produced compressed natural gas fuel system components (e.g., valves, pressure regulators, sensors) intended for use on NG powered vehicles.
NGV4.1-1999	A standard for the safe

NGV Dispensing Systems	operation, substantial and durable construction, performance and testing of components (e.g., housings, filters, electrical equipment, overfill protection) for CNG vehicle fuel dispensing systems.
NGV4.2-1999 **Hoses for Natural Gas Vehicles and Dispensing Systems**	Covers the safe operation, substantial and durable construction, performance and testing of components for hoses for CNG vehicles and dispensing systems.
NGV4.4-1999 **Breakaway Devices for Natural Gas Dispensing Hoses and Systems**	A standard for the safe operation, substantial and durable construction, performance and testing of breakaway devices (components to shut off gas flow in the event a vehicle hits a dispenser or drives away with a fueling hose still attached) for vehicular CNG dispensers and dispensing hoses.
NGV4.6-1999 **Manually Operated Valves for Natural Gas Dispensing Systems**	A standard for the safe operation, substantial and durable construction, performance and testing of manually operated valves for CNG vehicle dispensing systems.
NGV4.8 - 2002 **Natural Gas Vehicle Fueling Station Compressor Guidelines**	General requirements for compressor packages containing reciprocating compressors used in CNG fueling station service.

THE FOLLOWING STANDARDS ARE UNDER DEVELOPMENT:

NGV4.3 - Temperature Compensation Devices for Natural Gas Dispensing Systems

NGV4.5 - Priority and Sequencing for Natural Gas Dispensing Systems

NGV4.7 - Automatic Pressure Operated Valves for Natural Gas Dispensing Systems

United States of America Standards

ANSI

Email: info@ansi.org

National Fire Protection Association Standards:

NFPA 52 - Compressed Natural Gas Vehicular Fuel Systems Code - 1998
NFPA 57 - Liquefied Natural Gas Vehicular Fuel System Code - 1999
NFPA 88A - Standard for Parking Structures - 1998
NFPA 30A - Motor Fuel Dispensing Facilities and Repair Garages - 2003
NFPA 59A - Standard for the Production, Storage, and Handling of Liquefied Natural Gas - 2001

Available from:

National Fire Protection Association,

1 Batterymarch Park,
PO Box 9101,
Quincy,
MA 02269-9101,
USA
Ph:1-800-344-3555
http://catalog.nfpa.org

SAE (Society of Automotive Engineers) Standards:

SAE J1616 - Recommended Practice for Compressed Natural Gas Vehicle Fuel
SAE J2323 - Recommended Practices for LNG Powered Heavy Duty Trucks

SAE J2406 - Recommended Practices for CNG Powered Medium and Heavy-Duty Trucks - 2002

SAE J2645 - Liquefied Natural Gas (LNG) Vehicle Metering and Dispensing Systems - 2003

Available from:

SAE (Society of Automotive Engineers),
400 Commonwealth Drive,
Warrendale,
PA 15096-0001,
USA
Ph: 1-774-726-0790
http://www.sae.org/products

ANSI (American National Standards Institute) Standards:

ANSI/AGA NGV1 -1994 (with 1997 and 1998 addenda) - Compressed Natural Gas Vehicle Fueling Connection Devices
ANSI/CSA NGV2 - 2000 - Basic Requirements for Compressed Natural Gas Vehicle Fuel Containers
ANSI/AGA NGV3.1 -1995 - Fuel System Components for Natural Gas Powered Vehicles
ANSI/IAS NGV4.1 -1999 - NGV Dispensing Systems
ANSI/IAS NGV4.2 -1999 - Hoses for Natural Gas Vehicles and Dispensing Systems
ANSI/IAS NGV4.4 -1999 - Breakaway Devices for Natural Gas Dispensing Hoses and Systems
ANSI/IAS NGV4.6 - 1999 - Manually Operated Valves for Natural Gas Dispensing Systems
ANSI/IAS PRD1 - 1998 (with 1999 addendum) - Basic Requirements for Pressure Relief Devices for Natural Gas Vehicle Fuel Containers

Available from:

CSA America, Inc.
8501 E. Pleasant Valley Rd
Cleveland, OH 44131

(216) 524-4990
www.csa-america.org
Sales: 1-800-463-6727

CGA (Compressed Gas Association) Standards:

CGA C-6.4-1998 - Methods for External Visual Inspection of Natural Gas Vehicle Fuel Containers and Their Installations

Available from:

Compressed Gas Association,
4221 Walney Road, 5th Floor
Chantilly, VA 20151-2923
USA
1-703-788-7361
http://www.cganet.com

US Department of Transportation Standards

49 CFR 571.304, FMVSS 304 - Compressed Natural Gas Fuel Container Integrity
49 CFR 571.303, FMVSS 303 - Fuel System Integrity of Compressed Natural Gas Vehicles
49 CFR 393.65, FMCSR - All Fuel Systems

Availability:

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http://www.access.gpo.gov