Western Governors' Association

Transportation Fuels for the Future

Natural Gas and Propane

WGA Hydrogen Team
January 8, 2008
Final Report

The following report is based on the contributions of the individuals and organizations listed below. The Team members were chosen for their breadth of knowledge and industry or policy experience. The group was assembled with the goal of having a wide scope of interests including industry, academia and environmental analysis. The group also worked towards consensus viewpoints on the critical issues impacting the development of natural gas and propane as commercially available alternative fuels. This consensus model helped to achieve a balanced perspective on the challenges and potential solutions to further commercial development of this alternative transportation fuel.

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EXECUTIVE SUMMARY

Natural gas and propane offer substantial environmental and economic benefits to Western states and the country through reducing our dependence on imported oil. Natural gas used as a transportation fuel is the same clean burning fuel used for cooking and heating many U.S. homes. Comprised of 90-95 percent methane, natural gas has the lowest carbon content of all the fossil fuels (the methane molecule consists of one carbon atom and four hydrogen atoms) and is a clean, high energy, high-octane fuel (130+) ideal for use in vehicles.

One of the largest barriers to market penetration of both natural gas vehicles (NGVs) and propane vehicles is the small number of Original Equipment Manufacturer (OEM) vehicles. With little to no OEM product to sell, market penetration becomes extremely difficult. Small volume manufacturers' certification efforts are necessarily directed to the most frequently requested higher-sales volume fleet vehicles.

The NGV fueling industry frequently finds success by following the anchor tenant model. In this model, a partnership is created between a large "anchor" fleet and a fuel provider that constructs a new fueling station to service the anchor fleet. This station can be opened and marketed to the public, expanding the available refueling infrastructure to local fleet operators, such as taxis, limos and shuttles, and increasing alternative fuel usage in the area. Development of public infrastructure encourages consumer acceptance of NGVs, including small fleets that cannot justify building their own fuel stations.

Like natural gas, propane is an ideal fuel for vehicles that are centrally garaged, fueled at a single point once a day or every several days and may be of the same vehicle type. An outstanding example is taxicab fleets such as Yellow Checker Star Transportation Company in Las Vegas which operates its entire combined fleet of 550 vehicles on propane. Both natural gas and propane are favored by centrally fueled local fleet operations. Propane favors light- to medium-duty fleet vehicles and those operating across a wider area.

In as much as propane is widely distributed today, most barriers to entry are that of market perception. Stored under pressure, propane is considered unsafe in many regulatory environments. Past engine fuel system technology has attempted to implement products essentially developed in the 1950s to today's modern fuel-injected engines with less than stellar success. Local jurisdictions make placement of refueling sites difficult to impossible. Nonetheless, the demand for propane as an engine fuel is increasing.

KEY RECOMMENDATIONS

Near-term (within 3 years)

- Encourage review of state alternative fuel incentives to determine if they enhance niche market deployment of natural gas and propane vehicles and fueling infrastructure. Also, review to determine if end users from public and private sector are able to realize the intended benefits of state incentives. This can frequently be facilitated by contacting a state's Clean Cities coalition(s).

- Encourage support of state legislation that presents the same opportunities for key interests across the alternative fuels spectrum. If a state provides incentives for ethanol while not providing similar incentives for biodiesel or natural gas, it will ultimately harm the overall alternative fuels market. A level playing field will help ensure a maximum number of new alternative fuel projects.

- Encourage governors to support the creation of state grant funds that can be used to offset the cost of adding alternative fuel vehicles to public and private sector fleets or constructing an alternative fueling station. These programs must be well funded in order to have the desired impact.

- Encourage governors to support and encourage local and state decisions to use natural gas and propane vehicles where they are most effective and economical.

Mid-term (3-10 years)

- Encourage continued review of funding programs and tax credits. These will be critical to the success of fleet replacement programs beyond the first three years. Funding sources should target successful markets and vehicle types to ensure momentum is carried forward.

Federal

- Encourage all energy uses of renewable biogas. Specifically, encourage support of incentives or credits at both state and federal levels for biogas used or gathered for all energy applications including biogas converted to pipeline quality methane.

- Encourage and support federal legislation that will provide incentives or credits to vehicle manufacturers, many of whom build natural gas and propane vehicles for the international market, to develop and deploy those vehicles for the North American market.

- Encourage and support the extension of federal financial incentives for alternative fuels, alternative fuel vehicles (AFVs) and the installation of alternative fueling stations.

- Encourage and support federal financial incentives for alternative fuel off-road vehicles.

Market and Deployment Opportunities for CNG, LNG, and LPG

Niche Markets vs. General Deployment

Compressed natural gas (CNG), liquefied natural gas (LNG) and liquefied petroleum gas (LPG or propane) are used as clean-burning alternatives to gasoline and diesel fuel in the transportation sector. Over the past 15 years, CNG and LNG as transportation fuels have found their biggest successes in fleet applications. Limiting factors to general deployment include the incremental cost of vehicles over their conventional fuel counterparts; sparse fueling infrastructure compared to the nationwide network of gasoline stations, and station site considerations. Space limitations, codes and regulations frequently make it difficult for the corner gasoline station to accommodate an added large capacity, public-access CNG compressor and additional dispensers.

Market and Deployment Opportunities

The primary cost effective markets for natural gas vehicles are in the following high fuel use fleet applications: transit, airport, taxi, shuttle, municipal, refuse, ports (i.e., drayage trucks), delivery and distribution, and long haul Class 8 trucks. Any fleet that operates in a defined geographic area where fueling infrastructure exists is an excellent candidate. Any large, centrally fueled fleet that returns to a home base is an excellent candidate for constructing its own on-site fueling station. Most natural gas infrastructure providers will build fueling stations for fleets at no cost to the customer in return for a long term fueling contract. This provides the host fleet with substantial savings over petroleum fuels. Additionally, there are significant federal tax credits for the purchase of heavy-duty NGVs and installation of fueling stations. For private companies, these credits can provide further incentive to switch to natural gas. Some states also have tax credits that can provide additional savings.

LPG or propane is a product of natural gas processing and petroleum refining. The market and deployment opportunities and challenges for propane as a transportation fuel parallel those of CNG for the most part. Additionally, many of the same barriers exist for LPG transportation fueling infrastructure as exist for CNG, including siting requirements, and various state codes and regulations.

LNG applications have been limited to heavy-duty vehicles, and most of those vehicles are deployed in California, Arizona and Texas.

The U.S. Department of Energy's Alternative Fuel Data Center Web site (www.eere.energy.gov/afdc) states there are more than 150,000 light-, medium-, and heavy-duty NGVs and more than 200,000 light- and medium-duty propane vehicles on U.S. roads today, and more than 5 million and 9 million of these vehicles, respectively, worldwide. According to a November 1, 2004 press release from R. Polk & Co, the total number of light-duty vehicles in the United States is projected to reach 234.4 million units by July 1, 2008.

The cost to install LPG fueling infrastructure is less than that of CNG or LNG. According to the DOE's Alternative Fuel Data Center, there are approximately three times as many refueling sites for propane vehicles (2,442) than CNG sites (732) in the United States. This ratio holds true in

the Western states as well, with 1,382 vehicular LPG refueling sites and 450 CNG refueling sites.

There are 36 LNG stations listed nationwide, 29 of which are in California. The remaining seven LNG stations are located in other Western states.

To put these station numbers in perspective, there were 167,476 retail gasoline stations reported in the National Petroleum News Annual Station Count in 2006.

Barriers and Challenges

A near-term challenge for OEMs is to design and build vehicles that are significantly more fuel-efficient. This challenge, when looking at natural gas vehicle and propane vehicle production, is compounded by limited demand and increased cost as economies of scale are lost and additional EPA certification requirements for each fuel and engine family are encountered.

To date, the largest incentives for alternative fuel vehicle sales have been those contained in the Clean Air Act Amendments of 1990, the Energy Policy Act of 1992 and Executive Order 13149 (signed April 2000; revoked January 2007).

EPAct 1992 mandated the purchase of increasing percentages of alternative fuel vehicles (though not the use of alternative fuels) in state, federal and fuel provider fleets. E.O. 13149 directed Federal agencies to reduce petroleum consumption by 20 percent and required the use of alternative fuels in agency alternative fuel vehicles.

Tax incentives for the purchase of alternative fuel vehicles, fueling infrastructure and alternative fuel use at both federal and state levels are important tools to help maintain and increase the number of alternative fuel vehicles. However, more needs to be done to allow small businesses and non-profit organizations to take advantage of the credits.

One of the largest barriers to market penetration of both NGVs and propane vehicles is the small number of Original Equipment Manufacturer (OEM) vehicles. While there are several small volume manufacturers producing quality conversion systems, product selection remains limited. EPA certification requirements are very expensive and time consuming for small volume manufacturers.

With little to no OEM product to sell, market penetration becomes extremely difficult. Small volume manufacturers' certification efforts are necessarily directed to the most frequently requested high sales volume fleet vehicles.

Tax incentives alone are not enough to stimulate widespread market growth of natural gas and propane as transportation fuels, even in niche markets. If demand drives product development, then additional funding in the form of grants and rebates to alleviate the high cost of initial fleet investment in these alternative fuel vehicles and fueling infrastructure must be made available.

Key challenges facing the adoption of natural gas vehicles, were identified in the February 2007 United States Government Accountability Office Report to Congressional Requesters entitled "Crude Oil: Uncertainty about Future Oil Supply Makes It Important to Develop a Strategy for Addressing a Peak and Decline in Oil Production". Those challenges include: 1) the higher cost of high-pressure fuel tanks for consumers, 2) the costly upgrades to the existing refueling infrastructure, and 3) the availability and cost of natural gas.

Fossil Fuel Perceptions: Fuel Supply

A specter hanging over expanded development, production and wide scale deployment of natural gas and propane vehicles is the uncertainty of fuel price and supply. In its recently released global oil and gas study, "Facing the Hard Truths about Energy," the National Petroleum Council states, "Over the next 25 years the United States and the world face hard truths about the global energy future." Four important points the Council makes are:

- The world is not running out of energy resources, but there are accumulating risks to continuing expansion of oil and natural gas production from the conventional sources relied upon historically. These risks create significant challenges to meeting projected total energy demand.

- To mitigate these risks, expansion of all economic energy sources will be required, including coal, nuclear, biomass, other renewables, and unconventional oil and natural gas. Each of these sources face significant challenges, including safety, environmental, political or economic hurdles and imposes infrastructure requirements for development and delivery.

- U.S. oil production has declined steadily over the past 35 years. U.S. natural gas production has been more stable, but demand for both oil and natural gas has increased steadily, creating a gap that is filled by imports. Many forecasts project that the gap between supply and demand for domestic oil and natural gas will widen over the next 25 years and beyond.

- Policies aimed at curbing carbon dioxide emissions will alter the energy mix, increase energy related costs and require reductions in demand growth.

Fuel price volatility, or a perception that prices may become volatile, does not lend budgetary security to a fleet manager looking at alternative fuel vehicle costs, the cost of adding fueling infrastructure to accommodate those vehicles, and his or her break-even point. Again, tax incentives and grants coupled with the significantly lower price per gasoline gallon equivalent (GGE) currently enjoyed by natural gas and propane can help to make these fuels and vehicles very attractive alternatives for many fleets and can help to make a business case for fleet investment in this technology.

The previously cited GAO report goes on to reveal that "there is currently no federal funding or research focusing on natural gas vehicles." However, the National Petroleum Council in its July 18, 2007 report states that to adequately meet the energy demands of the country over the next 25

years, “expansion of all economic energy sources will be required, including coal, nuclear, biomass, other renewables and unconventional oil and natural gas.”

Increasing the use of natural gas vehicles can: (1) reduce America’s dependence on foreign oil, (2) improve air quality in urban areas, (3) reduce emissions of greenhouse gases, and (4) pave the way for a more rapid introduction of hydrogen transportation technologies.

Natural Gas, Compressed Natural Gas (CNG) and Liquid Natural Gas (LNG)

Description and Definition

Natural gas used as a transportation fuel is the same clean burning fuel used for cooking and heating in many US homes. Comprised of 90-95 percent methane, natural gas has the lowest carbon content of all the fossil fuels (the methane molecule consists of one carbon atom and four hydrogen atoms) and is a clean, high energy, high-octane fuel (130+) ideal for use in vehicles.

CNG fueling stations tap into the existing natural gas distribution system in the U.S., compress the gas on-site, and dispense it into vehicles. Very little on-site storage of natural gas is needed for station operation. For residential consumers, a home CNG refueling appliance that allows NGV owners to fuel their vehicles from their home natural gas line is now available. (See www.myphill.com.)

LNG is natural gas that is stored as a cryogenic liquid. LNG is created at liquefaction plants by cooling natural gas to -260 degrees Fahrenheit. This fuel is then trucked from the liquefaction plant to the fueling station, where it is stored in an insulated tank and dispensed into vehicles as liquid. LNG can also be vaporized at the fuel station and dispensed as CNG. This allows natural gas to be used in locations that do not have access to pipeline natural gas.

CNG is used successfully in light-, medium- and heavy-duty vehicles. LNG is generally only used as a fuel for heavy-duty vehicles (over-the-road truck and trailers, transit buses, trash trucks, yard hostlers, etc.). CNG and LNG are sold in Gasoline Gallon Equivalents (GGEs) or Diesel Gallon Equivalents (DGEs), which have the same energy content as gasoline and diesel. Selling fuel on an equivalent gallon basis allows the user to directly compare fuel prices.

There are renewable forms of natural gas now entering the market. Renewable forms of natural gas provide additional supplies of natural gas and expand the carbon benefits of an already abundant, domestic and clean fuel. Renewable natural gas involves capturing and processing biogas from landfills, sewage treatment processes, anaerobic digestion of manure at dairy farms, and gasification of biomass. The natural gas from these processes is stripped of impurities and refined into biomethane that can be used to produce CNG or LNG for vehicles.

Potential

Supply sources that include consideration of unique Western attributes/opportunities on a state and regional basis

Natural gas is a domestic resource with 98 percent of U.S. supply coming from North America and proven domestic reserves exceeding 75 years. CNG supply comes from the existing extensive network of natural gas pipelines already in place in most areas of the country. LNG can be manufactured at liquefaction plants located on natural gas pipelines. The LNG produced can then be trucked to the fueling station. It is important that new LNG liquefaction plants be located within 200 miles of urban areas to minimize transportation costs to stations. Several of the largest gas producing states, such as Oklahoma and Colorado, are located in the West.

Technology

The focus of NGV market development today is the heavy-duty vehicle sector: truck and trailers, transit buses, trash trucks, cargo handling, and pickup and delivery trucks. The emphasis on heavy-duty is based on the large amount of emissions reductions achievable with heavy duty natural gas engines, as well as the large reductions in particulate matter (PM) emissions known to cause health problems. Natural gas engines are available for heavy-duty applications as OEM product directly through automotive dealers or engine manufacturers.

The NGV industry focuses on all high-fuel-use fleet applications, regardless of whether they are light-duty or heavy-duty vehicles.

Development efforts for heavy-duty vehicles must be made to engineer existing heavy-duty natural gas engines into more heavy-duty truck platforms and to demonstrate and advertise the availability of these products to the marketplace. State-level sponsored research and demonstrations will go a long way to improve product availability and encourage use of natural gas in the transportation sector.

Hybrid-electric vehicles are a significant focus in today's market. These vehicles combine the best of electric drive technologies with a gasoline or diesel fueled engine. However, hybrids are not limited to gasoline vehicles. Hybrids can also be fueled with natural gas. For example, the Denver RTD currently operates a fleet of 36 hybrid-electric CNG buses. It is important to note that heavy-duty NGVs can also take advantage of hybridization. Hybridizing NGVs should become a high priority in order to maximize the benefit of the fuel.

Markets

With the market entry of the home refueling appliance, Phill, consumers can now take advantage of the convenience of home fueling at rates even more cost effective than retail natural gas rates at public infrastructure. The appliance retail cost is about $3,500 plus $1,000 to $2,000 for installation. Significant rebates and/or tax credits can substantially reduce the cost with current natural gas prices; consumers can fill their NGV at home for about $1.40 per GGE. The home refueling appliance is a garage-mounted appliance that allows one car to fill up overnight by

connecting to the existing home natural gas line. The Phill appliance has an expected lifetime of seven years. Home refueling is ideal for multi-car families, with a dedicated commuter car that does not leave the area. Many states offer HOV lane access for alternative fuel vehicles as an additional incentive to drive NGVs. Some cities also provide free parking for NGVs. Public refueling infrastructure in states such as California is sufficient to support extended travel needs. The home refueling appliance aims to remove the need to visit refueling stations as the vehicle has a full tank every morning. Federal tax credits are available to consumers for both the refueling appliance and the vehicle.

Technology Progression and Influential Factors

The differential or incremental cost of NGVs over their gasoline or diesel counterparts has always been an issue. All manufacturers of NGVs indicate that the way to lower the differential cost is to achieve a greater sales volume and better economies of scale, not only on the production line, but also from the supply chain for parts and components.

For instance, the vehicle incremental cost of CNG vehicles, ranges from $6K for a passenger car to $40K for a heavy-duty truck and is primarily based on the large amounts of carbon fiber used to make the fuel tanks. Currently, the cost of carbon fiber is extremely high due to its military demand as well as use in the new generation of commercial aircraft. A greater number of NGVs on the road worldwide will stimulate the construction of more carbon fiber production facilities to alleviate the current supply constraints and drive the cost of carbon fiber CNG fuel tanks down, significantly reducing the incremental cost of CNG vehicles.

As discussed earlier, hybrid or plug-in hybrid applications to a NGV platform could help extend the NGV range and/or reduce the amount of on-board fuel storage necessary. Supportive and consistent long-term governmental policies also would help the technological evolution of such vehicles.

The technological evolution of the fuel itself could involve a transition from fossil fuel natural gas to renewable biomethane, and further to reformed hydrogen made from natural gas. Future projects might also involve the reforming of biomethane into hydrogen, providing a source of renewable hydrogen. While all of these technologies are available in some form today, fossil fuel natural gas remains the most cost effective and realistic option for large-scale vehicle deployment. As cost effective methods of biogas collection and production come to market, the economic case for fleet implementation can be made and its use in fleets will increase. Similarly, once a cost effective method of producing renewable hydrogen and fuel cell vehicles becomes available, companies will be able to harness existing natural gas stations to create hydrogen fuel.

Predicted Deployment and Use Timeline in the near term (within 3 years), mid-term (3-10 years), and long term (>10 years)

Acknowledging a need to improve its energy security, advance greenhouse gas goals and reduce urban air pollution generated from mobile sources, the California Energy Commission (CEC) through its AB 1007 fuel diversity process has made several projections of potential NGV penetration in the state's public and private vehicle fleets. The CEC's estimates show that 125

million gallons of petroleum were displaced by NGVs in 2006. Their moderate forecast predicts that natural gas will displace over 500 million gasoline gallons in California by 2017 and about 1 billion gallons by 2022. The CEC believes that these projections are supported by the existing need to expand the country's fuel supply to alternative fuels. Natural gas provides inherent reductions of carbon emissions by as much as 27 percent for passenger cars, and 21 percent for heavy-duty vehicles. Currently, tax credits made available through 2009 via the Energy Policy Act of 2005 help private companies buy down the incremental cost of NGVs and further reduce fuel costs, making NGVs a very attractive option. These federal policies should be extended through 2017 to provide greater certainty to fleets and to help the country achieve its goal of 35 billion gallons per year for alternative fuels.

Other policies to consider include fleet incentives for targeted sectors. High-volume fuel use, return-to-base fleets can maximize the economic and environmental benefits of natural gas use. CNG and LNG applications for transit and refuse, for example, are ideal. Natural gas is a realistic alternative to petroleum that can complement other alternative fuels. This is important as ethanol is largely a light-duty application and biodiesel production cannot provide the supply needed for the West to meet its future energy needs. Government leaders should consider NGV incentives for industries that greatly impact neighboring communities via mobile sources of pollution. Prime examples of such operations are airports, solid waste collection, transit buses, and ports and trade corridors that make up the goods movement industry. Mandates have been used in the LA metro area to require non-diesel trucks and buses in several fleet applications.

Advantages and Disadvantages of Fuel

Advantages

Emissions: Natural gas is one of the cleanest burning fuels on the market today. Natural gas has the lowest carbon content of all the traditional fossil fuels. Emissions reductions are significant in every major category. Using natural gas in light-duty vehicles reduces greenhouse gases (GHGs) by 27 percent on a well-to-wheels basis when compared to a similar gasoline vehicle. Light duty NGVs are also playing an increasing role in the European GHG reduction strategy.

Comparing a 2006 heavy-duty diesel transit bus to one that operates on natural gas provides a 50 percent reduction in smog-forming oxides of nitrogen (NOx), and a 90 percent reduction in carcinogenic particulate matter (PM) or black soot. New heavy-duty NGVs will be certified to the 2010 EPA Emissions Standards this year, meaning their NOx reduction increases to 83 percent when compared to their 2007 diesel counterparts. Carbon dioxide (CO2) and GHG emissions in heavy-duty NGVs are reduced by 21% according to the California Energy Commission's well-to-wheels assessment of alternative fuels vehicles. Vehicles fueled with renewable biomethane can reduce GHGs by 100 percent.

These emissions reductions mean that replacing one diesel-powered trash truck with one that operates on natural gas has the same benefit as removing 325 passenger cars from the road, forever.

Domestically Produced: Using natural gas in vehicles provides a gallon-for-gallon displacement of fuels derived from foreign oil. A fleet of 100 natural gas powered transit buses will displace 1,000,000 gallons of diesel fuel every year.

Economical: Natural gas remains the single most affordable vehicle fuel in the market today. CNG and LNG prices typically fall 20-50 percent below gasoline and diesel prices, with many customers realizing savings of over $1.00 per gallon. To large fleets, these savings can easily add up to millions in fuel savings each year. These prices do not take into account the current federal tax credit for alternative fuels. Combined with these credits, the fuel is even more economical.

Quiet: Heavy-duty NGVs are significantly quieter than their diesel counterparts resulting in a noise abatement benefit. Noise decibels are reduced 50 percent behind the truck, 90 percent inside the truck, and 98 percent beside the truck. One diesel trash truck at idle generates the same decibel level as 10 natural gas trash trucks at idle.

Renewable: Renewable forms of natural gas are now being developed. Natural gas is composed of 90-95 percent methane, and methane can be collected from numerous renewable resources including landfill gas, sewage treatment facilities, dairy farms and gasification of biomass. Renewable CNG and LNG are used extensively abroad. Iceland, completely without fossil fuel natural gas, powers 100 percent of their NGV fleet with biomethane. Sweden and Switzerland both power more than 50 percent of their NGV fleets with biomethane. Capturing and collecting land fill methane and using it to power refuse haulers represents a GHG reduction of 100 percent as it eliminates both the GHGs produced by the vehicle itself, as well as the landfill methane, which is normally released into the atmosphere. These technologies are currently being developed and deployed in the United States.

Disadvantages

Infrastructure: A national infrastructure is not yet available. California has shown through an Interstate Clean Transportation Corridor concept, in place for nearly 10 years, that viable strategic fueling infrastructure can be developed to permit intrastate trucking operations. This concept can be adapted to the Western states to allow interstate trucking within the western region.

Infrastructure Cost: Natural gas fueling stations are expensive. The cost of constructing a new fueling station can easy exceed $1 million (USD). Most fuel providers focus on the anchor tenant fleet model, where new stations are constructed at no cost to the user in return for a reasonable minimum fuel volume commitment. The user agrees to purchase a certain amount of fuel for a specified number of years in return for a no cost fueling station on their property. Customers, even with the cost of the station factored into the fuel price, are able to realize multi-year fixed priced fuel contracts that save them substantial amounts of money on fuel. For transit buses, trash trucks, airports and municipal fleets, a commitment of 250,000 gallons per year is sufficient for fuel providers to build a new state-of-the-art fueling station. Within three years, the company or agency then only needs to purchase the vehicles and the fuel.

Vehicle Cost: All natural gas vehicles carry an incremental cost, which makes them more expensive than their diesel or gasoline counterparts. This cost can range from $6,000 - $10,000 for passenger vehicles and up to $40,000 to purchase a CNG trash truck or transit bus from the manufacturer. There are significant federal and state tax credits to cover these costs. However, many buyers of NGVs are tax-exempt government agencies that cannot use the credits. Additional grant funding and financial support is often necessary to help large government natural gas fleet projects offset this capital burden. California has an Alternative and Renewable Fuel and Vehicle Technology Program (AB 188 signed into law by Gov. Arnold Schwarzenegger on October 14, 2007) that offers financial incentives for customers wishing to purchase alternative fueled vehicles.

Range: NGV range is limited only by the amount of on-board fuel storage. Typical CNG transit buses have a range in excess of 500 miles before needing to refuel, which is more than enough fuel to complete duty cycles. Refuse collection trucks have more than enough natural gas fuel capacity to complete daily duty cycles. Transit and refuse fleets normally have on-site refueling and fuel at night before the next shift. Fueling for these types of vehicles with natural gas is therefore very similar to diesel fleets. Light-duty vehicles, such as taxicabs and shuttle buses, have a range of 200+ miles. In many cases these kinds of vehicles fuel at or near airports, the source of most fares. Typical taxi and shuttle fares do not exceed 100 miles one way, so natural gas range is sufficient to meet daily requirements.

Facility Modifications: Maintaining NGV fleets indoors requires a facility to undergo some modifications. Modifications involve upgrades to handle lighter than air fuels and include such items such as methane detection, lighting modifications and installation of ventilation systems.

Oil/Gasoline/Diesel Displaced: Unlike blended alternative fuels, natural gas provides a gallon-for-gallon displacement of fuels derived from oil. One thousand transit buses operating on natural gas will displace 10 million gallons of diesel fuel every year. If the current U.S. refuse fleet of approximately 150,000 trash trucks were replaced with natural gas trash trucks, it would displace approximately 1.2 billion gallons per year of diesel fuel.

Barriers and Challenges

National, Regional and State Challenges

One of the most important challenges for the NGV industry remains as simple as policy support and promotion. Despite natural gas being a clean, domestically produced fuel that can realistically combat rising fuel costs, policy-makers continue to give it limited attention. Perhaps this is due to the fact that natural gas is a fossil fuel and its potential as a renewable resource and a bridge to hydrogen fuel is not properly understood. There are large NGV fleets operating in many states today that have eliminated thousands of tons of harmful emissions from the air, reduced fuel costs by millions of dollars, and displaced millions of gallons of gasoline and diesel fuel derived from imported oil. Yet, they receive limited recognition and support from their policy-makers. NGVs are often referred to as the best kept secret in the alternative fuel world, and this needs to change. Renewed support for the industry through tax incentives and grant programs aimed at promoting the use of alternative fuels is essential to further industry success.

Infrastructure Requirements (feedstock, feedstock transportation, fuel distribution, grid impact, quality assurance)

Natural gas fueling stations have limited requirements in regards to feedstock, distribution and grid impact. Quality control occurs downstream when the gas is actually injected into pipelines, ensuring high quality fuel. CNG fueling stations can typically be constructed at any location that has access to natural gas and electric utilities. LNG stations can be constructed anywhere that has access to an electric utility. LNG is produced at a liquefaction facility and trucked to the fueling location where it is stored on site in cryogenic form.

Financing/ Economics (scalability to market, life cycle costs and financial risks)

The actual fueling stations are typically financed by the station provider/builder. These providers will build, operate and maintain the station in return for a multi-year fueling commitment from the fleet consumer. Even with the financing, the anchor fleet typically enjoys fuel savings of 20% or more below current gasoline and diesel prices. This provides an incentive for large fleets to enter the market by removing the need to finance and operate the station themselves. With the recent EPA-required changes to diesel engines and their associated costs, the life cycle costs of owning and operating heavy-duty NGVs are now comparable or superior to diesel fleets. The financial challenge for most operators is finding the additional funding to cover the incremental cost of the vehicles themselves.

Regulatory (siting/permitting)

Natural gas fueling stations must adhere to the same process for siting and permitting that most fueling stations do, taking into account civil improvements, access, fire code etc. These requirements are minimal in impact to both station builders and consumers.

Synergies with Other Fuels and/or Energy Production

Natural gas has synergies with biomethane and hydrogen.

Biogas is gas collected from landfills, sewage treatment processes, dairy farms, etc. This gas is cleaned and refined into biomethane, which can be injected into pipelines or used to produce CNG or LNG for use in vehicles on-site. In both cases, biomethane is a fully renewable resource that will increase in use over time. Natural gas shares most of its physical properties with hydrogen. This means hydrogen and natural gas fueling stations use similar dispensers, storage systems, safety requirements, etc. Hydrogen internal combustion engines and fuel cells use similar vehicle fuel storage systems, injectors, etc. Experience with natural gas can easily be leveraged to implement hydrogen fueling projects. Blending hydrogen with natural gas at the fueling station produces HCNG, which can provide even greater emissions reductions than natural gas alone. Typically, fueling stations that provide HCNG can be modified to fuel CNG vehicles, HCNG vehicles, hydrogen vehicles and fuel cell vehicles. This means that investment in natural gas infrastructure today lays the foundation for tomorrow’s hydrogen infrastructure. As these technologies become cost effective, natural gas fueling stations can be modified or expanded to support this new market.

Suggested State, Regional and Federal Actions to Accelerate Deployment/Use

Near-term (within 3 years)

Many states already have policies in place to promote the use of natural gas technologies. However, many of these polices are outdated and need to be updated or expanded in order for the users to claim credits or rebates.

- Review state alternative fuel incentives to determine if they enhance niche market deployment of natural gas and propane vehicles and fueling infrastructure.

- Review to determine if end users from the public and private sectors are able to realize the intended benefits of state incentives. This can frequently be facilitated by contacting a state's Clean Cities coalitions(s).

If a state provides incentives for ethanol while not providing similar incentives for biodiesel or natural gas, it will ultimately harm the overall alternative fuels market. A level playing field will help ensure a maximum number of new alternative fuel projects and will allow consumers to choose the fuel that best fits their needs or the needs of their businesses. Each alternative fuel has advantages and disadvantages; a fuel that works well for one fleet may not make sense for another. CNG may be used more economically and feasibly for some fleets, whereas biodiesel or ethanol blends might be a better economic option for another.

- Support and encourage state legislation that presents the same opportunities for key interests across the alternative fuels spectrum.

If a tax-exempt entity or agency wishes to add 30 alternative fuel vehicles to its fleet, state grant funds are often the only available mechanism that can ensure an alternative fuel project will remain in a department's budget. These grant funds help make the economics of using large numbers of alternative fuel vehicles attractive to both government and private fleets.

- Support the creation of state grant funds that can be used to offset the cost of adding alternative fuel vehicles to public and private sector fleets or of constructing an alternative fueling station. Grant programs must be well funded in order to have the desired impact.

California has shown that niche markets, such as transit, school buses, refuse trucks, taxis, shuttles, street sweepers, etc, are viable markets for NGV introduction. NGV projects in these key sectors provide maximum emissions reductions, foreign oil displacement and fuel savings.

- Support and encourage local and state decisions to use natural gas for transportation in the sectors where it will be most effective and most economical. Focus on transit bus fleets, airports and solid waste fleets.

Mid-term (3-10 years)

California has grown its heavy-duty NGV fleet by over 4,000 vehicles in the last 5 years. The state's 6,000-plus heavy-duty vehicles are displacing more than 100 million gallons of petroleum per year. This type of growth can be economically replicated in other areas where there are concerns about petroleum dependence, price fluctuations of gasoline and diesel fuel, air quality, health risks associated with vehicle emissions, and global warming.

Within the next few years, the market will have begun to select which alternative fuels work best for specific needs. During this time, most will likely be determined through economic experience. These needs will lead vehicle manufacturers and upfitters to produce necessary models to fill market demand. Models currently not available in the United States but that are available in other regions, such as Europe and South America, may be modified to suit the U.S. market. Fuel selection may also be partly determined by geographic availability of fuel types. Many vehicles will need to be replaced during this important time of change, including heavy-duty vehicles that typically have very long life cycles.

Funding programs and tax credits will be critical to the success of replacing many more vehicles than in the first three years. Funding sources should target successful markets and vehicle types to ensure momentum is carried forward. As more and more vehicles are replaced, the economies of scale will begin to be reflected in reduced alternative fuel vehicle costs. However, the volume of alternative fuel vehicles will need to grow by thousands to make it profitable for vehicle manufacturers.

- Continue periodic review of state funding programs and tax credits. These will be critical to the success of fleet replacement programs in the mid-term.

- Target funding to successful markets, vehicle types, and fuels.

- Encourage all energy uses of renewable biogas. Specifically, encourage support of incentives or credits at both state and federal levels for biogas used or gathered for all energy applications including biogas converted to pipeline quality methane.

- Encourage and support federal legislation that will provide incentives or credits to vehicle manufacturers, many of whom build natural gas and propane vehicles for the international market, to develop and deploy those vehicles for the North American market.

- Encourage and support continued federal financial incentives for alternative fuels, alternative fuel vehicles (AFVs) and the installation of alternative fueling stations.

- Encourage and support federal financial incentives for alternative fuel off-road vehicles.

Long term (> 10 years)

California is projecting that its heavy-duty NGV market will grow to nearly 70,000 vehicles by 2022 and more than 200,000 vehicles by 2050. Light-duty vehicle populations will also grow as petroleum pricing continues to pose hardships on the consumer market.

- Encourage both interstate and intrastate regional cooperation where possible to effect coordinated annual vehicle orders among agencies so that prices for the most frequently needed NGVs among state, county and municipal government fleets may be reduced.

- Support and encourage federal- and state-level RD&D funding for advanced natural gas engines, and advanced natural gas storage and delivery systems.

- Support and encourage federal- and state-level RD&D to enhance domestic recovery of natural gas from unconventional and renewable resources, and potential new resources such as methane hydrates.

A cohesive energy plan with consistent funding for development of alternative transportation fuels across technologies, including vehicle fuel efficiency, is essential at the federal level and within the programs of the U.S. Department of Energy.

From a local, Clean Cities perspective, federal alternative fuel policies and emphasis across the board appear to be ever changing as are funding directions and grant opportunities. A perceived "alternative fuel du jour" approach discourages commitment to the adoption of these fuels and technologies.

Stakeholders participating in the U.S. Department of Energy's Clean Cities program represent the entire alternative transportation fuels industry, and both mandated and voluntary fleets. Stakeholder fleets have been heavily invested in various alternative fuels and corresponding fueling infrastructures for the past 15 years. These fleets pursue alternative fuels for various reasons including cost benefits, mandates, clean air and EPA non-attainment woes, and a desire to diversify fuel reliance – especially in the case of local governments that must provide basic services even in the face of conventional fuel shortages, should they occur.

The adoption of alternative fuels does not happen overnight. It is frequently a long process requiring a number of years to reach the correct decision makers and educate enough people to get an alternative fuel project off the ground and lay the groundwork for its ongoing success. This cannot happen when fuel emphasis is consistently shifting. All alternative transportation fuels need consistent and ongoing support at the federal level. Because of regional differences in natural resources and in fuel transport and distribution, some fuels make more economic sense in one area, fleet or region, than another. Part of the Clean Cities mission is to help fleets find and implement the alternative fuels that are most suited for the application. One fuel, group of fuels, or technology cannot be ignored at the expense of others as it will take every resource we have available to make a dent in the 179 billion gallons of gasoline and diesel fuel consumed by U.S. cars and trucks each year.

- Support and encourage federal policy that maintains long-term emphasis on developing all alternative transportation fuels and alternative fuel vehicles. Consistency across altfuel platforms in research dollars and deployment demonstrations are crucial to their development.

Recommendations and Potential Funding for Regional Demonstration Projects

WGA Project Recommendation

Project Background: In mid-1999, an alternative fuels team made up of Clean Cities coordinators from coalitions along the I-35/I-29/I-94 international trade corridor, project consultants Gladstein, Neandross & Associates, and others embarked on an as-yet-unfunded alternative transportation fuels International Clean Transportation Corridor (ICTC-3) project intended to stretch from Monterrey, Nuevo Leon, Mexico, to Winnipeg, Manitoba, Canada. Initial support for the project was provided by the DOE's Clean Cities Program, the Texas General Land Office, the Texas General Service Commission's State Energy Conservation Office, and Brookhaven National Laboratory.

A similar project, the I-80/I-5/I-10/I-15/CA Route 99 Interstate Clean Transportation Corridor, was established in California beginning in 1996 assisted by Gladstein, Neandross & Associates. The Interstate Clean Transportation Corridor is a planned network of alternative fuel dispensing stations along key roadways serving associated alternative fuel vehicle (AFV) fleets that move freight between cities and states in the Western United States. It is the first economically sustainable and most successful, planned clean-fuel corridor of its kind in the nation.

The goal of the ICTC Project is to mobilize and concentrate public and private resources to maximize the commercial viability of clean, alternative fuel trucks in goods movement. The ICTC Project links truck fleet operators to engine, chassis and fuel providers, as well as to public agencies that provide technical and financial assistance in order to facilitate the deployment of alternative fuel trucks and development of alternative fuel infrastructure along the corridor.

The U.S. Department of Energy, U.S. Environmental Protection Agency, California Air Resources Board (CARB), South Coast Air Quality Management District (SCAQMD), California Energy Commission (CEC), San Bernardino Associated Governments (SANBAG), Mojave Desert Air Quality Management District (MDAQMD), Riverside County Transportation Commission (RCTC), and the Antelope Valley Air Pollution Control District (AVAPCD) have mutually funded the Project and are members of the Project's Steering Committee. The ICTC Project provides a unique opportunity for these agencies to coordinate their respective air quality and energy agendas through this single collaborative effort.

Since 1996, more than $25 million in federal, state, and local grant funding has been awarded to ICTC projects including:

- building twenty-three (23) public access natural gas fueling stations in California and Nevada;
- deploying 514 heavy-duty and 160 light duty natural gas and LPG vehicles to use these stations;
- reducing emissions of NOx by over 350 tons and diesel consumption by 5.5 million gallons annually; and
- generating over $75 million in public and private investment

Project Recommendation: Revitalize the International Clean Transportation Corridor Project (ICTC-3)

The successes of the ICTC Interstate Clean Transportation Corridor can serve as a model for the already conceptualized ICTC-3 International Clean Transportation Corridor.
By tapping into already established alliances, such as the Western Governors' Association, the Clean Cities program and its local coalitions and stakeholder fleets, the National Association of State Energy Offices, regional EPA collaboratives, EPA's Smart Way Transport Partnership and others, federal grant funding that emphasizes interstate partnerships can be sought. More and more frequently, federal grants of the type that fund alternative fuel development seek multipoint and/or multi-state projects.

DOE and EPA are the two main federal sources for grant funding for alternative fuel projects with requests for proposals released periodically. Grant funded-projects are frequently augmented with CMAQ project funding. Required funding matches may come from individual partners, from state funds especially environmental penalty funds, and from non-federal grant funding, such as foundation funding. DOE and EPA requests for proposals that could help fund this project include Mobile Source Outreach funding, Clean School Bus USA funding, Market Transformation - Clean Energy and Air Quality Integration funding for state and multi-state initiatives, Diesel and Emissions Reductions, Source Reduction, Renewable Energy Demonstrations, and Biofuel Initiatives.

While this report focuses on CNG, LNG and LPG, these fuels and others could all be part of a revitalized ICTC-3 project. A goal for a diverse ICTC-3 alternative transportation fuel project would be multi-fuel refueling islands along the trade corridor.

The overall goal of an ICTC-3 project would be to mobilize and concentrate public and private resources to maximize the commercial viability of clean, alternative fuel trucks in goods movement. Like the ICTC project that went before it in California, an ICTC-3 International Trade Corridor project would link truck fleet operators to engine, chassis and fuel providers, as well as to public agencies that provide technical and financial assistance in order to facilitate the deployment of alternative fuel trucks and development of alternative fuel infrastructure along the corridor. A project of this scope requires ongoing effort and coordination so that each piece of the project builds on the success that precedes it.

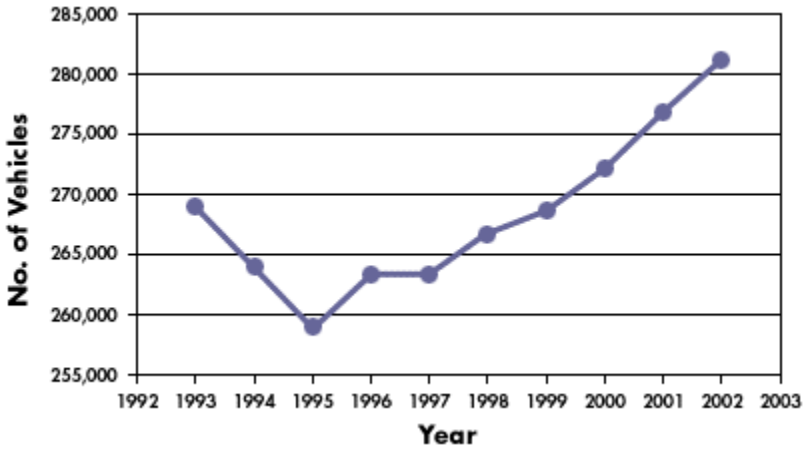
Propane as a Transportation Fuel

Description

Propane is a molecularly simple hydrocarbon fuel (C_3H_8). It can be derived from the processing of natural gas into pipeline quality product. Propane is also manufactured as a result of cracking crude oil into finished products, including gasoline, aviation gas and diesel fuel. It is also a natural occurring by-product of synthetic diesel (Nestle Oil Corporation, Finland). Over 90 percent of propane marketed in the United States is domestically produced. As an energy source, propane provides approximately 4 percent of U.S. energy needs, primarily as a home heating fuel. Over 45 percent of propane available to the United States is not used as energy, but rather as feedstock for plastics manufacture.

In 2005, 18.8 billion gallons of propane was consumed in the United States. Roughly 564 million gallons of that total was used in the transportation sector, powering over 200,000 trucks, taxicabs, school buses and shuttles across America's streets. Propane is the fuel of choice for over 600,000 forklifts in U.S. factories and distribution centers. Worldwide, propane powers over 10 million vehicles, making it the third most widely used engine fuel in the world. [(1)]

Number of Propane Vehicle's in Use in the US 1993-2002



Source: Alternative Fuels Data Center, U.S. Energy Information Administration
Note: Estimates for 2001 are preliminary and estimates for 2002 are based on plans or projections.

Propane is non-toxic, naturally odorless (an odorant is added at the time propane is first purchased), stable, and can be stored for long periods of time. This makes propane an ideal fuel for emergency standby generation. Exhaust emissions from propane engines are fundamentally below that of gasoline or diesel and once processed through typical engine control systems, result in far fewer toxins than traditional transportation fuels. Recent studies indicate that propane powered engines are a low carbon content producer, that is, greenhouse gas production is lower from propane powered engines.

Potential

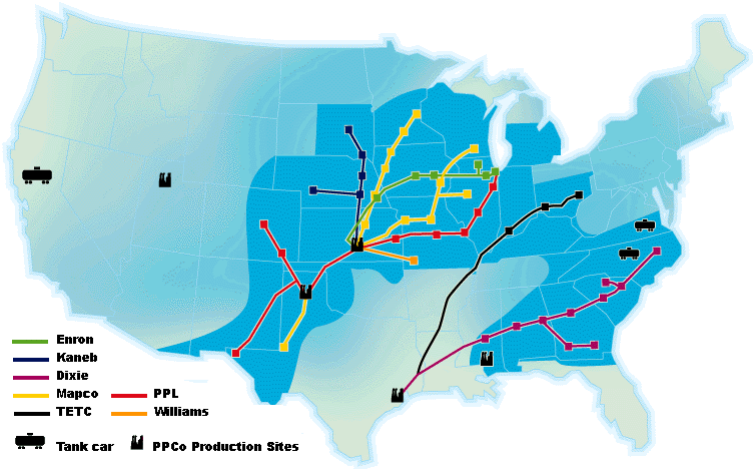
Draft results from the recent TIAX study for the California Energy Commission predict that propane could power enough vehicles to achieve up to a 4.3 percent market penetration of annual vehicle sales in the state by 2027. This could result in a gasoline gallon-equivalent displacement of over 400 million gallons. TIAX considered this result "aggressive" for the state of California. A moderate case predicts the displacement of 268 million gallons while a conservative approach resulted in a displacement of 134 million gallons. (2)

At the height of the propane engine fuel market in 1983, the United States consumed 1.36 billion gallons of propane as engine fuel according to the American Petroleum Institute. The state of California contributed to nearly 200 million of those gallons, while the remaining Western states provided an additional 150 million gallons of consumption.(3) However, history indicates that propane as an engine fuel was supported both in distribution and storage at much higher levels 25 years ago than is utilized today. That supply and distribution chain remains in place, but has been redirected towards today's markets.

A recent report to the Propane Education and Research Council by Energy and Environmental Analysis, a Washington D.C. based consulting group, concluded that propane in the transportation sector could displace 1 billion gallons of gasoline and diesel in the United States by 2017. In light of governmental interest in use of alternative fuels to supplant traditional transportation fuels, it appears that propane is a viable solution for a strong portion of the region's domestic needs.

Supply

Propane to the Western states is primarily supplied via rail and truck transport from natural gas production facilities in Canada, Wyoming and the San Joaquin Valley of California. Refinery derived propane is also produced in most of the Western states. The remaining supply, typically provided during the winter heating season, is transported into the West via rail car from Canada, Texas and Kansas.



THE U.S. LPG PIPELINE NETWORK

Note that 66 percent of U.S. propane supply is served by pipeline from the major storage hubs of Texas and Louisiana. There are no pipelines serving the Western states, and all products are, therefore, transported by rail or truck. In the high demand season, rail service can be especially problematic.

The Energy Information Administration (EIA) publishes monthly data on Propane/Propylene supply by districts. Individual data by state is unavailable. Supply of propane apart from propylene, also, is not separated by product. However, propylene is not a naturally occurring product and only results from the refinery process. Propylene is considered a good feedstock in the alkylation process of gasoline manufacture and most of it never hits the propane supply chain. Therefore, an analysis of EIA data regarding supply can generally be considered a "primarily propane" affair.

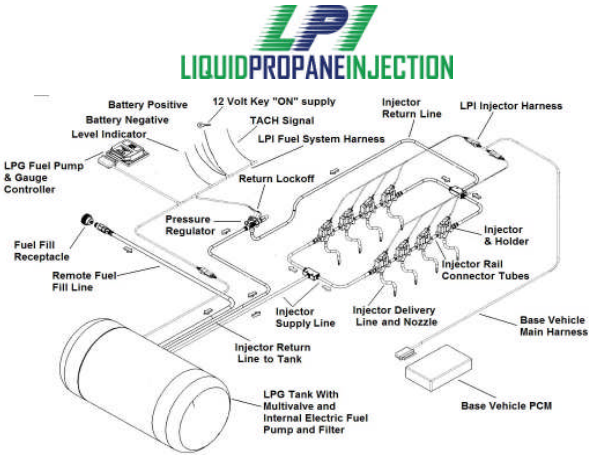
The eleven Western states make up both PADD 4 and PADD 5. A quick look at EIA data as of 2005 (the latest published figures) shows 32.5 million barrels (1.36 billion gallons) of product were produced in the West. Contrasting American Petroleum Institute (API) data for the same PADDs and year, sales of propane were at 1.74 billion gallons. Therefore, approximately 380 million gallons or 22 percent of total sales were imported into the combined PADDs from other parts of the country, including and most likely, predominantly from Canada.

Purvin and Gertz Inc., a well-known consultancy group that studies LPG (propane) on a worldwide scale, stated in March 2007, "A growing spate of new LPG production projects around the world, including many associated with LNG projects, has moved LPG into a supply driven market relationship." [(4)] It is projected that as more LNG imports arrive in North America, "entrained" LPG will arrive alongside, suppressing prices and providing opportunities for growth in new propane markets, especially engine fuel. Most of that propane will arrive in the United States into the Gulf Coast. However, if LNG import terminals along the West Coast can be constructed, supply of associated LPG could increase.

One such facility in northern Mexico is scheduled for completion in 2008. Energia Costa Azul is a development of Sempra Energy, which may ultimately import up to 2.5 billion cubic feet per day of LNG, 50 percent of which is destined for the U.S. market. It is unknown at this time how much LPG might be entrained in the import gas.

Technology

Sequential port-injection products have been recently introduced into the market. This technology allows the distribution of propane into an engine precisely and uniformly, allowing the engine control system that once was designed for gasoline to control the flow of propane to the cylinders. This has resulted in much better, "gasoline-like" power, performance and fuel economy compared with older "air valve" propane fuel systems. Tailpipe emissions are significantly reduced over gasoline powered vehicles in most applications.



THE LPi LIQUID PROPANE FUEL INJECTION SYSTEM

All propane-powered vehicles are conversions of either gasoline-powered or diesel-powered engines and vehicles. OEMs do not participate in manufacturing vehicles for the North American market that operate on fuels other than gasoline, diesel, and E85 with the exception of one OEM-produced natural gas model. The distinction of OEM-like propane systems is a function of where the vehicle is converted and at what point in the vehicle supply chain.

Manufacturers of engine fuel systems market their product to installers in a controlled manner. EPA and CARB both require the manufacturer to warranty their systems for up to 120,000 miles of the propane vehicle life. Developing and maintaining relationships with quality installers is paramount to a manufacturer's success.

Manufacturers have developed commercial relationships with American automobile dealers. A customer orders a propane-equipped vehicle from the dealer, and the system is installed at a "Tier 2 Upfitter" in Detroit prior to its delivery to the dealer and ultimately to the customer.

Other manufacturers market their products through local installers or "Master Distributors" that provide the fuel system to the customer after the vehicle is purchased from the dealer. This is an important path to market as many potential propane engine fuel customers have already made a vehicle purchase decision and will not be an immediate candidate for the OEM strategy.

There are several fuel system manufacturers that provide a product line to partially fuel compression ignition engines with propane. The price differential from propane to diesel makes substitution of some diesel with propane in the engine fuel stream economically attractive. Substitution rates are advertised from 10 percent up to 50 percent propane for diesel in the engine. The Propane Education and Research Council has commissioned Mississippi State University to study the emissions effects of these engine fuel systems. Wide claims by manufacturers need to be substantiated in a laboratory environment as older technology has not always achieved environmental success. Test results and recommended paths forward are expected to be available in late 2007.

Unlike CNG, propane is stored under pressure of no more than 250 p.s.i. as an onboard liquid. The result is far greater range for a given propane-powered vehicle if utilizing the same volume space as a CNG tank. Conversely, the same amount of energy content can be stored in a vehicle space much smaller than a competing CNG-powered vehicle. Consequently, propane is utilized for fleets that operate greater distances from their refueling locations or that accumulate many miles per shift.

Propane fleet customers also expect to save a minimum of 25 percent over gasoline on a per mile basis. Typically, fleet owners will embrace not only propane but also any alternative when the added investment of implementing a strategy returns a significant savings in operating costs.

Markets

The propane industry typically targets fleet users as potential engine fuel customers. Fleets with vehicles using greater daily volumes of fuel have an easier time making a strong business case for alternative fuels, whether propane or natural gas. Like natural gas, propane is an ideal fuel for vehicles that are centrally garaged, fueled at a single point once a day or every several days, and may be of the same vehicle type.

Vehicles that currently have technology available to allow the use of propane as an engine fuel include mid-size sedans, vans, pickups and medium-duty trucks with Gross Vehicle Weight Ratings (GVWR) up to 33,000 lbs. Customers that use propane include bottled water delivery fleets, taxi fleets, tow truck operators, building trades, hotel shuttles, vanpools and school bus fleets.

Limitations to the use of propane include CARB certification requirements that force the system manufacturer to invest a significant amount of additional money over the cost of EPA certification for the same engine fuel system. California is currently limited to products available only from CleanFuel USA, Roush and Baytech.

Technology Progression

The propane conversion business is flourishing in most of the United States, but less so in California. Fuel system manufacturers continue to add engine families to their line up of products so that theirs might be the fuel system of choice when buyers select a vehicle.

Publicly accessible refueling infrastructure is being installed in selected areas of the West including southern California, Phoenix and Denver. Franchised by CleanFuel USA, these sites have the same imaging as comparable gasoline sites, are credit card driven, and are accessible 24/7. The cost of developing these types of refueling locations can reach $100,000 each. This compares to $200,000 for a gasoline station, and $750,000 or more for a natural gas refueling station. As more vehicles capable of refueling at these sites enter the market, more sites will be developed.

Size and Scalability

As mentioned above, the propane industry believes there are in excess of 200,000 propane-powered vehicles on the road today. The industry estimates that 70,000 of those vehicles are in the Western states. TIAX, in its report to California, predicts an additional 50,000 to 150,000 vehicles by 2020 depending upon market conditions and regulatory environment. Extrapolation of those figures indicates a market potential in the West of up to 370,000 propane-powered vehicles offsetting 740 million gallons of gasoline and diesel consumption by 2020. This represents a fivefold growth pattern over the next 13 years compared to 2005 API statistics of 143 million propane gallons consumed in vehicles. The industry believes this is a reasonable target to achieve.

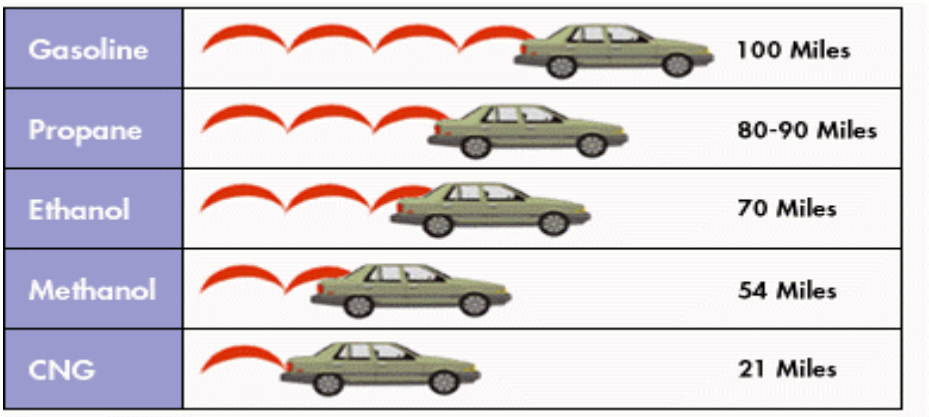
Advantages and Disadvantages of Fuel

Propane is easy to store and distribute. The fuel has been used in transportation since 1930. The cost of fuel systems for vehicles ranges from $5,000 to $10,000 per kit depending upon application and installation. Refueling infrastructure costs can range from a low of $7,500 per site up to $100,000, depending upon how elaborate the site needs to be. Propane gallon costs are easily 25 percent less than gasoline *before* taking federal tax credits into consideration. Propane-powered vehicles can be less expensive to purchase than diesel equivalents. However, the one diesel conversion currently available carries a $50,000 premium over its diesel counterpart. It uses older technology and delivers less power and lower fuel economy than its diesel counterpart. Emissions from gasoline-powered engines converted to propane-powered engines are typically lower than that of the base gasoline-powered vehicle.

When released into the atmosphere, raw propane evaporates at a rapid rate, lowering the surrounding area temperature below 32 degrees F. Therefore, if skin comes in contact with liquid propane, the rapid freezing effect can cause a painful minor burn similar to sunburn. Refueling systems are sealed from the atmosphere and less than 2 cc of propane can be released upon disconnect from the vehicle. However, industry practices recommend using gloves while refueling a propane-powered vehicle.

Gallon for gallon, the heat content of propane is 76 percent of gasoline. Although underhood technology reduces that physical disadvantage, fleet operators report a reduction in mileage per gallon for propane-powered vehicles of up to 10 percent. Propane can deliver up to 90 percent of gasoline's miles-per-gallon with significantly less environmental pollutants. Its fuel efficiency relative to gasoline surpasses those of all other alternative fuels: 70 percent for ethanol, 54 percent for methanol, and 21 percent for compressed natural gas (see chart below).

This comparison uses identical vehicles optimized for their specific fuel. The baseline is a gasoline-fueled vehicle with enough fuel to travel 100 miles. Distance shown is based on the relative energy content (British Thermal Units - BTUs) of each fuel gallon.



If all vehicles were fitted with equal volume tanks, propane gas would require the least fill-ups on a trip, followed by ethanol, methanol and CNG.

Source: Michigan Propane Gas Association

Propane for vehicles is readily available, but it takes some shopping to find it. Most refueling locations only operate during daylight hours, so refueling at night can be problematic. In addition, many operators of refueling sites tend to set prices per gallon at rates inconsistent with the use. Fleet operators refueling at locations outside of the "home zone" can experience fuel costs per gallon that significantly exceed those of gasoline. Most fleet users seek out propane suppliers who choose to support the engine fuel segment with lower prices that reflect the volumes fleets represent.

In an aggressive mode, propane fuel could displace 740 million gallons of gasoline and diesel by 2020 in the West. A more conservative approach might result in 400 million gallons of displacement.

Barriers and Challenges

In as much as propane is widely distributed today, most barriers to entry are that of market perception. Stored under pressure, propane is considered unsafe in many regulatory environments. Past engine fuel system technology has attempted to implement products essentially developed in the 1950s to today's modern fuel-injected engines with less than stellar success. Local jurisdictions make placement of refueling sites difficult to impossible. Nonetheless, the market for propane as an engine fuel is in a renaissance of sorts and demand for its use is increasing.

Deployment

Today's propane and natural gas-powered vehicles are generally very technically refined and competitive with their petroleum-based counterparts. There may be significant resistance to revisit natural gas or propane vehicles if fleets have had negative experiences with vehicles using older technologies.

Rolling out vehicles and refueling infrastructure for propane are a lock-step process. It is also highly ratable and dependent on the efforts of sales personnel. Fleet operators acquire a certain quantity of propane-powered vehicles either through new purchase or retrofit of existing vehicles. Propane suppliers follow up with refueling infrastructure to supply the specific need. Referring back to the TIAX work for California, in an aggressive mode, vehicle implementation will have to achieve 15,000 annual units by 2020. It is not difficult to extrapolate that work to 25,000 vehicles for the entire West during the same time period.

Certification and development costs for deploying the wider variety of engine families required to meet that volume could be as high as $6.25 million. At $250,000 per engine family, that amount provides for 25 different engine family platforms of which annual sales for each achieve 1,000 units. Recertification on an annual basis and development of new platforms as they roll out from manufacturers would likely cost an additional $1.5 million per year.

Entrepreneurial firms are leveraging common designs to minimize system development costs. One firm has developed its propane version of Ford's 5.4L V-8 knowing that it would be an incremental step to develop a propane version of Ford's 6.8L V-10. These engines can be used in a variety of potentially high fuel-volume applications from half-ton pickups and vans to 19,500 lb. trucks.

Infrastructure

A significant obstacle for both natural gas and propane is the existing petroleum refueling infrastructure. If one were to assume public refueling infrastructure to support 50 percent of the vehicles envisioned, an investment of approximately $80 million would provide 800 stations (at $100,000 each) with the capacity to serve 50 vehicles per day. Each station would have a maximum capacity to provide 500,000 gallons per year. An additional 3,400 private sites at an investment of ~ $15,000 each would likely supply the remaining demand for a total cost of $51 million.

In order to supply 740 million additional gallons for engine fuel into the marketplace, domestic production of propane will not be an issue. Storage and logistics are another story. Recent published estimates to provide refrigerated storage for propane in quantities of 18 million gallons reached upwards of $23 million. It is not hard to imagine the need to store 50 percent of the annual volumes, resulting in an investment of $511 million. Transportation from storage to distribution points will take approximately 75 to 100 transports with the capacity of 9,500 gallons each and an additional cost of $14.8 million.

Total capital cost for infrastructure is around $650 million, again ratable over the 13-year projection period.

Regional Challenges

Propane is easy to implement if the economics are sustained.

Financial Challenges

Costs to implement a transportation fuel replacement strategy have been noted above. Much of the cost can be borne by private industry seeking a strong return on their investment. In some cases, governmental assistance can lower the financial barrier to entry for vehicle development, purchase and refueling infrastructure installation.

Regulatory Issues

In the case for California, CARB has rejected acceptance of EPA certification for propane fuel systems. Larger industrial corporations have found that the only way to market is an OEM strategy, which lessens the financial burden of CARB requirements. This strategy may severely limit product availability to new vehicle purchases.

However, most of the fuel system providers are small entrepreneurs that are not capitalized well enough to shoulder the financial burden of both EPA and CARB certification requirements. In as much as an investment in EPA certification allows a given manufacturer access to 49 states in which to sell product, most have declined to even try to certify to CARB requirements. These manufacturers are quite content to sell as much product as they can outside of the state and bypass any opportunities the rather substantial added investment CARB certification would return. Therefore, a strategy to build a fleet of 370,000 vehicles in the western states is problematic without a resolution to the CARB issue.

Siting propane storage in gasoline stations can also be a huge hurdle. In California, many jurisdictions limit propane dispensers to a maximum of 500 gallons of storage. In order to break into a market where gasoline fuel storage containers are a minimum of 4,500 gallons, a strategy to allow vertical and/or underground storage of propane must be established. The variable politics of each jurisdiction in which a refueling station might be established is a challenge. Fire Marshals and Fire Departments at state conferences would assist in overcoming local siting issues.

Fuel Quality

Just as with gasoline, diesel, and natural gas, the quality of all fuels has become a critical element for today’s sophisticated engines. Fuel quality is critical for emissions and critical engine systems. Motor fuel grade propane should be HD-5. Lesser grades of propane will impact drivability and component durability.

Lifecycle and Environmental Impacts

Propane is a naturally occurring hydrocarbon associated with gas and oil extraction. While providing an economic benefit to those who participate in the energy sector of the United States, propane is not considered a primary product until it reaches the distribution layer of the economy. No oil or natural gas company seeks to manufacture propane; they deal with it in order to produce their primary products. Nonetheless, propane has its niche and can play a significant role in displacing conventional transportation fuel.

Greenhouse Gas Production: Propane is not a direct greenhouse gas when released into the air. "*Current measurements have not found a global climate impact from propane emissions*." [(5)] Compared to conventional fuel sources, propane generates fewer GHG emissions in almost every application. At the point of use, propane has a lower carbon content than gasoline, diesel, heavy fuel oil, or even biodiesel and ethanol.

Propane represents a small but important part of the U.S. energy supply – 4 percent of energy consumed in the U.S. in 2005. Because of propane's relatively low GHG emission rate, its share of GHG emissions is smaller than its share of energy supply. When quantifying the greenhouse gas emissions that result from the use of energy, it is important to distinguish between the emissions released at the location where the energy is consumed and the emissions released as a result of extracting, processing and delivering a refined and usable energy product to that location. The fuel lifecycle begins where the raw feedstock is extracted from the well or mine and ends where the fuel is consumed to power a vehicle, appliance, or other technology. Emissions released at the point of use are termed end-use emissions, while those emissions that occur along the delivery pathway are termed upstream emissions. Upstream emissions include all emissions resulting from the recovery, processing, and transport of fuel to the point of delivery to the end-user.

Energy use is not the only source of upstream emissions. Other production processes also release greenhouse gases. For example, biofuels crop production requires the application of nitrogen fertilizer which causes the formation of nitrous oxide, while natural gas refining causes the release of fugitive emissions of methane. The Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) model has quantified these processes, making it a valuable tool for comparative lifecycle analyses of fuel systems.

The inclusion of upstream emissions in an analytical comparison of different fuel options can have a significant impact on results. Limiting the comparison to end-use emissions only, for example, can give the impression that electricity, with zero end-use emissions, is an energy source with no greenhouse gas emissions. However, this limitation would mask the very large fraction of upstream emissions caused by the combustion of fossil fuels for electricity generation.

Water: Propane is not ground water contaminates nor is water utilized in the production process of the fuel

Land Use: Propane production, storage and distribution are not large users of land mass.

Tradeoffs: Propane is considered to be in a worldwide surplus condition beyond 2010. However, strong growth in propane use as a transportation fuel could impact supplies currently used for plastics manufacture. Fortunately, the chemical industry routinely offsets propane consumption by using other lower-priced hydrocarbons. Higher use of propane in energy environments results in better utilization of the product, but could lead to higher base prices for the product.

Mitigation Offsets: Increasing imports and/or future manufacture of bio-propane and dimethyl ether (DME) could become mitigating factors. Economics will dictate the emergence of either strategy.

Synergies with Other Fuels: Propane is a fuel unto its own and can be used in engines designed for gasoline without a lot of alterations. Propane may not lend itself to blending with hydrogen or other esoteric ingredients. Japan has studied the blending of DME with propane to produce a substitute for diesel in compression ignition engines. However, current manufacture of DME requires the conversion of natural gas, a product that is better used directly in its natural form. Dimethyl ether could be produced from so-called land-locked sources, but it appears other conversion techniques that deliver diesel products have more support. As discussed earlier, PERC is studying the benefits of injecting propane into diesel engines as a displacement fuel. It is too early to determine any benefits from this work.

Suggested Governmental Actions

Regional and State Actions

- Provide funding to assist with CARB engine certification and for refueling projects as needed or requested. Let the market take its course. Propane can be a self-sufficient alternative.

- Educate state and local fire marshals on appropriate siting of propane refueling infrastructure.

Federal Actions

- Encourage all energy uses of renewable biogas.

- Encourage and support federal legislation that will provide incentives or credits to vehicle manufacturers, many of whom build natural gas and propane vehicles for the international market, to develop and deploy those vehicles for the North American market.

- Encourage and support the extension of federal financial incentives for alternative fuels, alternative fuel vehicles (AFVs) and the installation of alternative fueling stations.

- Encourage and support federal financial incentives for alternative fuel off-road vehicles.

- Seek exemption from the Department of Homeland Security's chemical facility security regulations for small businesses and rural farms that use propane as a fuel or hold propane for sale as fuel in quantities of less than 100,800 pounds of 24,000 gallons. This would save thousands of rural propane customers and businesses that are not security risks from having to comply with an unnecessarily burdensome and expensive rule.

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