Heavy Duty Engines:

Market Development Opportunity

Market Development

The World LPG Association

The World LPG Association (WLPGA) was established in 1987 in Dublin, Ireland, under the initial name of The World LPG Forum.

The World LPG unites the broad interests of the vast worldwide LPG industry in one organization. It was granted Category II Consultative Status with the United Nations Economic and Social Council in 1989.

The World LPG Association exists to provide representation of LPG use through leadership of the industry worldwide.

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There could be views expressed in this document that are not necessarily shared by all contributors.

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LPG & Heavy Duty Engines

Heavy Duty Engines as market development opportunity

Contents

Chapter One

Introduction

Liquefied Petroleum Gas (LPG) is the third most widely used automotive fuel in the world. That simple fact may surprise the reader who may consider Autogas an "alternative fuel." Observers familiar with the global automotive market understand that various LPG options are available for light-duty, medium-duty and heavy-duty vehicles that have both on-road and off-road applications.

What is LPG?

In some regions it is called propane or LP Gas. LPG is produced when natural gas is processed and when crude oil is refined. The majority of global LPG production is a result of capturing LPG when processing natural gas.

Advantages of LPG as an automotive fuel

Regulators and government officials around the globe are aware of the polluting effects of gasoline and diesel vehicles. In the United States, numerous studies have concluded that the number one source of the smog precursor Nitrogen Oxide (NOx)[1] in metropolitan areas are diesel medium-duty and heavy-duty trucks. Autogas vehicles are proven to be safe; they combat climate change, improve public health, provide clean energy for a low carbon world and meets or exceed environmental standards. The use of Autogas is also a good business decision as the fuel is high in energy content but generally lower in cost than diesel and gasoline[2]. Autogas fleets also have substantially lower preventative maintenance costs than their gasoline and diesel counterparts[3].

Millions of motorists globally use Autogas daily and each of these vehicles contributes to cleaner air and reduces pollution. Imagine the air quality improvements in your area that would be achieved by wider adoption of Autogas.

For example:

- Autogas has 40% less Hydrocarbon (HC) emissions[4].
- Autogas reduces Nitrogen Oxide (NOx) emissions by 35%[5].
- Compared to gasoline, Autogas has 50% less ozone-forming potential[6].
- Particulate Matter (PM) is virtually eliminated[7].
- The use of Autogas reduces Green House Gases (GHG) by 5% to 26%[8].

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1 "Nitrogen Oxides (NOx) Control Regulations." U.S. Environmental Protection Agency. September 1, 2017. https://www3.epa.gov/region1/airquality/nox.html. Accessed June 18, 2018.
2 "Clean Cities Alternative Fuel Price Report." U.S. Department of Energy. April 2018. https://www.afdc.energy.gov/uploads/publication/alternative_fuel_price_report_april_2018.pdf. Accessed June 18, 2018.
3 "Financing Models: Propane Autogas Vehicles and Infrastructure". North Carolina Clean Tech, North Carolina State University. 2015. https://nccleantech.ncsu.edu/wp-content/uploads/Propane-Finance-Models.pdf. Accessed June 18, 2018.
4 "LPG for Heavy Duty Engines, Buses, Trucks, Marine and Other Applications ". World LP Gas Association. Issue 2017. https://www.wlpga.org/wp-content/uploads/2017/11/LPG-for-Heavy-Duty-Engines-2017.pdf. Accessed June 18, 2018.
5 "LPG for Heavy Duty Engines, Buses, Trucks, Marine and Other Applications ". World LP Gas Association. Issue 2017. https://www.wlpga.org/wp-content/uploads/2017/11/LPG-for-Heavy-Duty-Engines-2017.pdf. Accessed June 18, 2018.
6 "LPG Exceptional Energy – Fact Sheet". World LP Gas Association. June 2010. https://www.primagas.cz/media/tinyManager/files/52.pdf. Accessed June 18, 2018.
7 "LPG for Heavy Duty Engines, Buses, Trucks, Marine and Other Applications ". World LP Gas Association. Issue 2017. https://www.wlpga.org/wp-content/uploads/2017/11/LPG-for-Heavy-Duty-Engines-2017.pdf. Accessed June 18, 2018.

Autogas around the globe

Of the 26.8 million global Autogas vehicles many are in the light-duty to medium-duty category (cars and mid-size trucks). Some heavy-duty trucks and buses are in service. Countries like Italy, Poland, and South Korea have up to 15% of their car fleet running on Autogas. Turkey has close to 40% of its car fleet on Autogas. In Guangzhou, the capital of the Guangdong province of China, they operate about 7,200 of 8,000 buses on LPG and 100% of their taxi fleet of 18,000 runs on LPG. To view a list of Autogas vehicles by country visit: https://auto-gas.net/about-Autogas/the-Autogas-market/.

Fuel infrastructure

LPG fuel-dispensing infrastructure is available in many locations throughout the globe. LPG dispenser systems are scalable and relatively inexpensive. Fleets generally start with small above-ground or underground tanks and as their fleets expand, they either place larger tanks on site or add tanks to their existing infrastructure. The cost-effective aspect of LPG dispensers is well-documented. For example, in the US one could install nearly ten Autogas dispenser systems for the cost of a single fast-fill compressed natural gas station.

Autogas fleets may lease or own the equipment used to dispense fuel into their vehicles. There are many factors in determining final costs, including the size of the storage tank and technology such as credit card readers. Local permitting and regulations also can make cost vary between different regions. The U.S. Department of Energy estimates that the purchase of a 1,000 gallon dispensing system is $45,000 to $60,000 USD and the initial cost to lease the equipment is between $3,000 to $10,000 USD. For a large installation with a 30,000 gallon tank, the system purchase costs are estimated to be between $225,000 to $300,000 USD. Initial leasing expense of such a large system can be estimated between $15,000 to $50,000 USD.[9]

Cost Savings

Typically, the initial attraction to LPG as a vehicle fuel is lower fuel costs. While globally pricing varies widely, in some areas LPG fleet customers may pay half as much for their LPG as they would for their diesel or gasoline[10]. Preventative maintenance costs are lower LPG than on gasoline or diesel. The Railroad Commission is the Texas state agency that regulates the oil and gas industry in their state. The Commission has a history of using LPG vehicles and according to their data, the preventative maintenance costs of LPG vehicles are 50% less than gasoline vehicles. A North American bus fleet featured in a case study in this report realises a 40% cost reduction for preventative maintenance on their LPG fleet versus their diesel buses.

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[8] "LPG for Heavy Duty Engines, Buses, Trucks, Marine and Other Applications ". World LP Gas Association. Issue 2017. https://www.wlpga.org/wp-content/uploads/2017/11/LPG-for-Heavy-Duty-Engines-2017.pdf. Accessed June 18, 2018.

[9] "Costs associated with Propane Vehicle Fueling Infrastructure". U.S. Department of Energy. https://www.afdc.energy.gov/uploads/publication/propane_costs.pdf. Accessed July 22, 2018.

[10] "LPG for Heavy Duty Engines, Buses, Trucks, Marine and Other Applications ". World LP Gas Association. Issue 2017. https://www.wlpga.org/wp-content/uploads/2017/11/LPG-for-Heavy-Duty-Engines-2017.pdf. Accessed June 18, 2018.

Chapter Two

European Fleet Case Study

Fleet Name: Régie des Transports du Territoire de Belfort (RTTB), France

The Territoire de Belfort in northeastern France is home to about 144,000 residents nestled against the Swiss border. As with many communities across France, public transportation is critical to moving the people of the region. That duty falls to the RTTB.

RTTB operates approximately 150 buses in their fleet. According to RTTB Director Jean Louis Lager, until mid-June 2017 they operated 38 Scania Citywide transit buses fueled by Autogas. The Scania buses were typical 12-meter long buses with a seating capacity between 40 and 42 depending on the configuration. The RTTB served seven of their urban routes with the LPG powered buses. Due to a lack of engine availability, they have entirely transitioned to diesel buses to serve their suburban and rural routes.

RTTB documented cost reduction on fuel cost for their LPG buses compared to the diesel portion of their fleet. According to Director Lager, they also spent about half as much to perform regular preventative maintenance on LPG buses.

In the future it is expected that RTTB could again have a LPG bus option[11]. In Spain, an innovative project is working to create a next generation liquid LPG injected engine and bus for use in the European market. This Euro VI engine is under development by Spanish engine manufacturer Begas in cooperation with the Chinese bus manufacturer King Long United Automotive Industry Company.

The Begas/King Long powered bus has a 7.4L supercharged, 8-cylinder, multi-port LPG injection engine. The engine is OBD II HD compliant and has horsepower and torque similar to its diesel counterparts. The manufacturers expect that the unit cost of the bus will be similar to diesel buses. The vehicle is designed to service urban and suburban bus routes in mid-size and large cities throughout Europe.

By using the Begas/King Long bus the RTTB could reenter the LPG bus segment and save substantial money.

In France in June of 2018 Autogas was selling to a typical discount to diesel[12].

	Minimum price	Maximum price
LPG	0.609 €/L	0.979 €/L
Unleaded	1.208 €/L	1.758 €/L
Diesel	0.998 €/L	1.600 €/L

A single transit in bus in France could see fuel and maintenance costs savings by using LPG. Based on an average LPG price of 0.79 €/L and an average Diesel price of 1.30 €/L, a fleet could achieve the following:

[11] AEGPL Europe. "FIRST BUS POWERED 100% BY LPG UNDER DEVELOPMENT IN SPAIN".

http://www.aegpl.eu/newsroom/25th-april-2017/first-bus-powered-100-by-lpg-under-development-in-spain.aspx. Accessed July 22, 2018

[12] Matvoz, Matija. MyLPG.Eu. "Chart of Fuel Prices on France". https://www.mylpg.eu/stations/france/prices. Accessed June 19, 2018.

Example:

	LPG	Diesel
Average km traveled:	54,718	54,718
Average km per liter:	1.93	2.98
Total annual fuel usage:	28,287	18,386
Total annual fuel cost:	22,459.00 €	23,883.00 €
Average PM cost:	345.00 €	172.00 €
PM interval:	16,093 km	9,565 km
Annual PM cost:	1,173.51 €	1,955.85 €
Annual fuel savings:	1,424.24 €	
Annual PM savings:	782.34 €	
Annual savings per bus:	2,206.58 €	

If RTTB put the 38 Autogas buses back into operation they could achieve an annual savings of about €83,849.96. If half of their fleet (75 buses) operated on LPG, they would save in the range of €165,493.50 annually.

PRIMAGAZ France is an LPG distributor that serves over 27,000 communities throughout France. François Brunero serves at the Director of Business Development for Primagaz. He is a known expert in the Autogas market segment with over 20 years experience. Brunero says that in the recent past, France had over 2,000 LPG fueled transit buses operating across the country. If 2,000 Begas/King Long buses operated today in France it could result in a savings of €4,413,160 for public transportation authorities.

In France there may be as many as 90,000 registered buses[13]. Transitioning 25% to Autogas (22,500) buses could result in annual savings of over €49,648,050. The European Union has over 720,000 registered buses as of 2015[14].

French government policies for environmental protection, air quality, and combating climate change can be advanced by adopting policies that incentivise adoption of LPG medium-duty and heavy-duty vehicles in public and private sector fleets. With increased use of LPG in France, they would not only reduce carbon dioxide emissions, but also reduce nitrogen oxide and particulate matter.

[13] European Automobile Manufactures Association. "Vehicles in Use – Europe 2017". http://www.acea.be/statistics/article/vehicles-in-use-europe-2017. Accessed June 19, 2018.
[14] European Automobile Manufactures Association. "Vehicles in Use – Europe 2017". http://www.acea.be/statistics/article/vehicles-in-use-europe-2017. Accessed June 19, 2018.

Chapter Three

North American Fleet Case Study

Fleet Name: Leander Independent School District (LISD), Leander, Texas, USA

Central Texas is home to the metropolitan growth powerhouse of Austin. In 2017, over 1,000 people per day were moving to Texas and many of them were making the Austin area their home. In 2018 a similar trend continues. To northwest of Austin is the Leander Independent School District that serves more than 41,100 students from kindergarten to twelfth grade.

Rapid growth brings in new tax revenue, but the capital demand to build new schools, to purchase all the necessary equipment to outfit the school, and solve pupil transportation challenges always keeps pressure on the school district's budget. Innovation was required to keep up with the growth.

In 2009, the district began adoption of LPG powered school buses to save money and increase efficiency. With grant funding from the Texas Commission on Environmental Quality (TCEQ), the state-level version of the Environmental Protection Agency, they obtained dedicated LPG Blue Bird school buses. Under the terms of the grant, the TCEQ paid for 40% of the buses and the school district paid the remaining 60%. As part of the grant requirements, the district was required to take older, high-emission diesel buses out of service and destroy them to ensure the emission-reduction goal was achieved.

Each bus has a passenger capacity of 78 and has 362 HP and a gross vehicle weight of 33,000 lbs. (14,968 kg). The 2009 – 2012 models used a General Motors 8.1L engine with a CleanFuel USA LPG system. These dedicated LPG buses produced fuel cost savings and a reduction in costs on preventative maintenance and oil changes.

While this fleet has years of experience with Autogas, what is changing is that they are now able to purchase and deploy the most advanced low-emission LPG vehicles in the United States. Roush CleanTech manufactures the latest models they purchased and the environmental footprint exceeds the stringent US Environmental Protection Agency standards. These new buses are the first and only LPG engine in class 4-7 vehicles certified to the optional low nitrogen oxide (NOx) level of 0.05 grams per brake horsepower per hour. That is 75%cleaner than other manufacturers can offer.

In 2018, the school district has a total of 275 school buses, 78 of which operate on LPG. As is common in fleet vehicle acquisition, the district added vehicles over time as opposed to making one large purchase. In 2009, they started with 11 LPG buses. They added LPG in later years as follows: 2011 - 1, 2015 - 25, 2014 - 3, 2017 - 24, 2018 - 14. The newer model buses are also Blue Bird, but now have the Ford 6.1L V8 engine with the Roush CleanTech liquid injection LPG system.

The district expects the growth trend in LPG buses to continue. LISD Director of Transportation Ann Hatton plans to bring the fleet to 50% LPG in next two years. The district's long-term goal is to have 75% of their fleet on LPG and 25% on diesel.

This begs the question: why would they keep 25% of the fleet on diesel? The answer is to support long-range student field trips and sporting events. They consider diesel buses to be "trip buses" because they go beyond their proprietary LPG fuelling station range. The LPG buses used to have 60-gallon tanks with a range of about 100 miles. Their LPG new buses have 100-gallon tanks with a range of 200 miles. But Texas is a vast state and some trips could take them well beyond the fleet-based fueling station.

Billy Jackson is LISD's Vehicle Maintenance Supervisor. He says that the former director of transportation was always looking for ways to save money. Jackson became aware of the grant opportunity and started down the LPG path. Over time, the motivation to use LPG changed. The initial intent to save money as the primary concern is no longer the driving factor. Now the environmental benefits of the fuel are a top consideration. But of course, the cost savings are impressive.

In 2018, the district expects their buses to travel a combined 1.8 million miles. Mr. Jackson says that his LPG fuel costs are half compared to the diesel the school district purchases for other buses. In 2016-2017, the district's fuel budget was $1,190,000. Using LPG he saved $373,000. Jackson says he looks forward to the savings, and expects bigger savings this year.

Although they intend to maintain some diesel buses for very long-distance trips, the district knows their LPG buses have sufficient range to meet most of their mission requirements. In fact, they use their LPG buses on their some of their longest routes in order to maximise their cost savings.

LPG has the highest energy content, referred to as BTU content, of any alternative fuel. The district's diesel buses average seven miles per gallon. The LPG buses average 5 miles per gallon, but they are paying over $1.00 USD less per gallon for LPG.

"Diesel and gas prices have been up and down and LPG prices have been stable," said Jackson. "I work with my LPG supplier and occasionally I have the ability to lock in my price."

Like many LPG fleets, Leander ISD saves about half on the cost of their oil changes and regular preventative maintenances. Their average diesel preventative maintenance is done every 6,000 miles and costs between $300 - $400. The LPG buses are on the same cycle and every service costs them $200.

Maintenance Supervisor Jackson says that the diesel buses are additionally problematic due to their Diesel Exhaust Fluid (DEF) system. He points out that the DEF filters are not designed well for the start and stop duty cycle of a school bus. In order for a DEF system to work properly, the vehicle has to get up to speed and generate sufficient heat to get the regeneration system going so that the filter can work properly. That means the bus has to run at least 45 miles per hour to get the regeneration to clean the system. If they can't get up to speed due to frequent stops, it may result in having to clean the DEF filter. That cost is $500. If they are unable to clean the filter, a replacement costs $1,600. Modern heavy-duty diesel engines typically have 20 more parts than LPG engines. LPG eliminates all of the frustration and costs created by DEF systems.

Todd Mouw is President of Roush CleanTech, the Ford QVM that converts the Ford 6.1L V8 engine from gasoline to LPG. He says, "Today's diesel buses are cleaner than in years past, but only through complexity, like expensive equipment and high-maintenance systems, which aren't required on propane buses".

LPG fueling infrastructure is scalable and relatively inexpensive. The district started with an 18,000-gallon tank. Later, two 2,000 gallons tanks were added for additional storage capacity and to act as a backup fuel system. They have two dispensers and use a Petrovend electronic card reader system that ties into their fleet management and fuel management computer system. When the buses are fueled, the operator enters the odometer readings at the LPG dispenser and that data is used to feed the preventative maintenance schedule.

The drivers of the diesel buses fuel the vehicles they drive, but the district employs six LPG fuellers. The LPG fuellers fill the buses two times per day. They are trained by the LPG distribution company and licensed by the State of Texas for the safe dispensing of fuel.

The Director of Transportation, Ann Hatton, formerly served in transportation related roles in neighboring school districts that were diesel-only. When she first arrived at Leander ISD, she said, "I was skeptical about propane prior to coming here, but after driving one I saw they had the power. After driving the propane buses, I can tell they are more powerful than a diesel. They are so quiet, too. We get cost savings and we have power hauling 60 to 70 kids up and down hills. It proves itself".

Mr. Jackson added, "If I could put my whole fleet on propane, I would do it".

Chapter **Four**

Australian Fleet Case Study

Package delivery company United Parcel Service (UPS) is focused not just on customer satisfaction and enhancing shareholder value, but they have a corporate strategy to substantially reduce emissions. Worldwide, UPS operates nearly 114,000 vehicles, of which about 8,100 operate on alternative fuels. Each day the UPS alternative fuel fleet travels nearly 1,609,344 km (1,000,000 miles). Since 2000 they have driven more than 1,609,344,000 "clean" kilometers, or about a billion miles.

UPS deploys more than 1,150 Autogas delivery trucks in the United States (California, Colorado, Georgia, Louisiana, Minnesota, North Carolina, Oklahoma, Puerto Rico and Texas) and more than 1,110 in Canada and Mexico; UPS operates 55 fueling stations. Currently, no UPS Autogas vehicles are deployed in Australia.

In 1998, the Australian Government established ambient air quality standards. The National Environment Protection Measure for Ambient Air Quality (the Air NEPM) set national standards for the six key air pollutants to which most Australians are exposed: carbon monoxide, ozone, sulfur dioxide, nitrogen dioxide, lead, and particles. Under the Air NEPM, all Australians have the same level of air quality protection"[15.]

Australia follows European Union (EU) regulations, including exhaust emissions standards. Currently, Australia enforces Euro V heavy-duty diesel engine emissions standards. The EU is currently using the Euro VI standard. There is no established timeline for Australia to adopt Euro VI.[16]

UPS has established corporate goals that align with many government policies related to combating climate change and improving air quality and public health. They include:

- Reduce absolute Greenhouse Gas emissions in their ground operations 12% by 2025.
- Also, by 2025, have 40% of ground fuel be low carbon and alternative fuel types.
- 25% of annual purchases will be for alternative fuel and advanced technology vehicles.[17]

So how could UPS, and other delivery companies, field Autogas delivery trucks effectively? One potential solution is using advance low-emission Autogas engines in delivery truck chassis such as the Chevrolet Express 3500/4500 Cutaway. One engine option is the liquid LPG injection (LPI) 6.0L V-8 LC8 is a dedicated LPG version of the L96 engine. The 6.0L engine is a powerful, spark-ignited engine that is factory converted from gasoline to dedicated Autogas. It delivers similar performance to gasoline engines with superior emissions reductions.

Autogas vehicle technology is similar to a conventional gasoline delivery truck. A standard delivery truck is converted to use LPG as a fuel. As with gasoline, the LPG is in a liquid state when it is delivered to the fuel injectors via an electric fuel pump. And like its gasoline counterpart, the LPG vehicle's engine also uses a spark ignition. This makes operation of the LPG vehicle virtually identical to a standard gasoline model. According to General Motors, the engine's efficiency optimises emissions performance. The engine meets US Environmental Protection Agency standards that closely align with EU emission standards.

With over 500,000 Autogas vehicles registered in Australia, there is existing availability of fuel and fuel dispensers. Autogas has the highest energy content of any alternative fuel so there are few concerns about vehicle range. In fact, where UPS deploys Autogas vehicles they utilise them on their longer rural routes due to the exceptional range[18].

In addition to moving Australia to lower-carbon economy LPG, Autogas costs less than gasoline. In June of 2018 the average price for Autogas was $0.92/L and gasoline was $1.46/L[19]. Based on that pricing, a hypothetical delivery fleet of 111 vehicles that transitions 28 of those vehicles to Autogas may achieve cost savings similar to this:

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[15] Australian Government. Department of the Environment and Energy. Air Quality Standards. http://www.environment.gov.au/protection/air-quality/air-quality-standards. Accessed June 18, 2018.
[16] "LPG for Heavy Duty Engines, Buses, Trucks, Marine and Other Applications ". World LP Gas Association. Issue 2017. https://www.wlpga.org/wp-content/uploads/2017/11/LPG-for-Heavy-Duty-Engines-2017.pdf. Accessed June 18, 2018.
[17] UPS. "Environmental Responsibility".https://sustainability.ups.com/committed-to-more/fuels-and-fleets/. Accessed June 18, 2018.
[18] UPS. "Environmental Responsibility". https://sustainability.ups.com/committed-to-more/fuels-and-fleets/. Accessed June 20, 2018.

	LPG	Gasoline
Average km traveled:	42,351	42,351
Average km per liter:	2.368	2.976
Total annual fuel usage:	17,885 L	14,231 L
Total annual fuel cost:	$16.454.09	$20,777.23
Average PM cost:	$200.00	$400.00
PM interval:	16,093 km	9,565 km
Annual PM cost:	$526.32	$1,754.40
Annual fuel savings:	$4,323.14	
Annual PM savings:	$1,228.08	
Annual savings per truck:	$5,551.22	

Twenty eight Autogas vehicles would result in an annual savings in about $155,434.

In Australia there are over 739,000 registered commercial vehicles. If just 5%, or 36,955 vehicles, converted to Autogas the potential fuel and preventative maintenance savings would be $205,146,461.

Elgas Limited is a leading Australian LPG distribution company founded in 1984. Throughout six Australian states they service industrial, commercial, agricultural and residential clients for all of their LPG needs. As a major distribution company they have a large fleet of delivery vehicle and are always looking for options to meet their environmental commitments and to reduce fleet costs.

A significant portion of their fleet is dedicated to delivering LPG cylinders for industrial use primarily to fuel forklift trucks and similar material handling vehicles. Elgas has about 400 stake-bed trucks used for this purpose. Over the last few years they embarked on a programme to transition their cylinder delivery fleet to LPG. Australia has six states and each has its own climate and unique topography. In 2018 and 2019 they intend to field one Freightliner S2G in each state. After their trial period they plan to move forward transitioning their 400 cylinder trucks to dedicated LPG.

Some fleets in Australia have experimented with Compressed Natural Gas (CNG), but it has not been well received by fleets. The incremental cost of CNG vehicles acquisition is substantially higher than conventional fuels and there are very limited refueling options. Across Australia only there less than 10 CNG fuel stations while LPG has a robust nationwide refueling infrastructure.

Freightliner Custom Chassis Corporation is a subsidiary of Daimler Trucks North America. They manufacture class 5-8 trucks. Elgas is working with their local dealer to define their specifications and import the vehicles. The Freightliner S2G is an OEM produced, fully warranted, dedicated LPG vehicle. It will eventually replace the diesel fleet currently operated by ELGAS.

The S2G is a V8 “Big Block” 8-liter engine that delivers 339 horsepower (HP) at 4,100 rpm. At 3,100 rpm it can provide 495 lb./ft. of torque. The engine is factory-installed and is not a ship-through or aftermarket installation. Through rigorous testing and strict design criteria the Freightliner S2G is engineered to meet or exceed all applicable emission standards.

As with most modern LPG powered vehicles the S2G LPG engine is delivered with a Liquid Propane Injection (LPI) system. LPI systems have replaced older technology that used to deliver LPG vapor via a carburetor. The use of the advanced LPI system ensures that the LPG vehicles deliver approximately the same power, acceleration and cruising speed as conventional fuel vehicles. The S2G has a 16” x 97” fuel tank that holds 60 gallons and has an approximate range of 482 kilometers (300 miles).

The Australian trucking market is dominated by Japanese truck makers that are not currently producing LPG vehicles. Elgas seeks to import the US-manufactured Freightliner S2G to reduce fleet costs and to demonstrate to other fleets the viability of LPG Autogas for medium and heavy-duty engines in Australia.

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[19] Global Petrol Prices.com. “Australia LPG price”. https://www.globalpetrolprices.com/Australia/lpg_prices/. Accessed June 20, 2018.

Chapter Five

Road Map

Market Outlook for LPG in Heavy Duty Engines

This study is meant to give a snapshot into the market potential that exists for the use of Autogas in 100% LPG engines for heavy duty vehicles between of approximately 7 to 12 tonnes that operate in urban environments.

The three case studies are designed to highlight this potential by demonstrating that LPG is currently being used successfully in these types of vehicles in different markets. It is also meant to highlight that LPG as a fuel for heavy duty vehicles could have an important role to play in this segment of the transport fuel market in the coming years despite the development of electric vehicles and other competing technologies. This is especially true for markets which already have large LPG footprints and thus the required infrastructure for maintaining heavy duty engine vehicle fleets.

Market Trends: Characteristics of a Strong Market Opportunity for LPG use in Heavy Duty engines.

Many of the market trends that are necessary for the growth of the heavy-duty engine segment are also necessary for the growth of the use of Autogas more generally. These characteristics are covered extensively in numerous WLPGA documents on Autogas, including 2017's "Autogas Incentives Policies: A country-by-country analysis of why and how governments encourage Autogas and what works".

The following characteristics which are identified as creating strong potential for growth of vehicles powered by Heavy Duty Engines come from the 2017 WLPGA Study "LPG for Heavy Duty Engines: Buses, Trucks, Marine and other Applications"

Market Characteristics	Drivers accelerating LPG growth for heavy duty engines
New regulations	The stringent emissions standards for Heavy Duty Engines in force around the world can easily be met with adoption of modern LPG systems
Cost and Complexity of emission Compliance	Replacement of old buses trucks with new ones to comply with new regulations could increase the demand for HDV LPG fuelled.
Attractive LPG price	The decline in oil prices and the corresponding decline to LPG prices in 2015 and 2016 provides a window of opportunity for fleet operators.
Government incentives for switching to alternative fuels	Green grants and tax credits are in place in many countries.
Business and industrial growth	The growth in the global consumption of liquid fuels is driven by transport and industry, with transport accounting for almost two-thirds of the increase. The growth in transport demand reflects rapid increases in vehicle ownership in emerging economies, partially offset by sustained gains in vehicle efficiency, which slow the sector's growth post-2025. The other major source of demand growth for LPG is industrial use and new markets that create great potential to use LPG in different applications.
Adequate Availability of refuelling infrastructure	Extensive refuelling infrastructure network is in place thus supporting the development of fleets in trucks applications. Countries which are already consuming large volumes of LPG are likely to have the necessary infrastructure

	in place to facilitate the use of LPG within the Autogas and industrial sector.
Sufficient supply of affordable LPG over the forecast horizon	The global LPG fundamentals in 2017 are shaping up to be bullish. USA LPG output from NG processing plants more than doubled between 2010 and 2017 as a result of the shale boom. With domestic demand effectively static, the surplus is largely destined for overseas markets.
Increasing awareness of the advantages of new technologies	Customers are aware of the advantages of new technologies. The most important for higher market entry is the growth of confidence of LPG among all stakeholders and end users.

Barriers to Growth

The barriers to growth for the heavy-duty engine segment are similar to those faced by Autogas more generally. These include:

Limited OEM Engine and Vehicle Options

OEMs sometimes produce alternative fuel vehicles directly or by use of a qualified converter. In both cases the engineering costs associated with design, testing and environmental certification is substantial. Qualified converters typically have a low capitalisation than the main OEM and are more subject to cost factors such as engineering and regulatory expense. When OEMs make decisions about what type of vehicle to delivery they must consider market demand, design and production cost and government policy among other items. In addition to uncertainty related to market demand a significant factor is government policy. Subsidies and government mandates impact OEM decisions and directly affect production decisions. Engine design and testing generally have long design horizons. Regulatory uncertainty or changes in government policy may result in delays for market delivery or force costly design changes.

High cost of engine emission certification

Under current regulatory schemes in many countries it is more costly to obtain environmental certification of Autogas engines than traditional diesel and gasoline engines. Alternative fuel engines are typically subject to the same regulatory testing requirements as diesel or gasoline engines. Due to the higher volume sales of gasoline and diesel engines the cost per engine to meet the certification is lower for traditional fuels. The higher cost per unit is a barrier to growth and limits medium and heavy-duty LPG engines to select OEMs.

Lack of understanding of environmental and cost saving benefits of Autogas

LPG has been in use for over 100 years yet many fleet operators and government officials are not aware that LPG is a clean burning fuel that is low carbon and emits virtually no black carbon. The use of LPG improves air quality, reduces the emission of greenhouse gases and protects the environment. Sometimes environmental analysis that drive government policy focus on tailpipe emissions instead of the full fuel cycle often referred to the “well-to-wheel” analysis. More environmental benefits can be found at https://www.wlpga.org/about-lpg/why-use-lpg/clean/.

Ideally a fleet manager could go to a trusted website, enter some data and get an answer that shows they would potentially save money by switching to Autogas. There are many such resources available to get a high-level snapshot. One example for medium and heavy-duty engines is http://www.roushcleantech.com/saving-calculator/.

Lack of knowledge of refuelling options

If one needs diesel or gasoline for their fleet, everyone knows how to obtain that fuel, but that is not always the case with LPG. Fleets unfamiliar with Autogas are not aware of the multiple, cost effective refuelling options. These options include onsite fill via a delivery truck, proprietary refuelling at private fleet domiciles, public refuelling, and even if a vehicle runs out of fuel on the side of the road they can get emergency refuelling via delivery truck. Fuel stations often start out with small storage tanks to meet the fleet needs and are easily expandable to larger storage capacity. Fleets also may not understand financing options for financing fuel infrastructure such a lease, lease-to-own or purchase.

Concerns about safety

Do to a lack a familiarity with LPG some may think that it is a dangerous fuel. All liquid vehicles fuels are combustible. That is the very quality that generates the controlled power necessary to cycle the internal components of the engine. LPG has the narrowest flammability range of any alternative fuel. The fuel to oxygen mix required for combustion is:

Diesel :	06 to 5-5%
Gasoline:	1-7.6%
LPG:	2.2 – 9.6%

LPG vehicles have built in safety devices such as automatic shut-off valves. The steel fuel tanks on Autogas vehicles are 20 times more puncture resistant than gasoline tanks. LPG is non-toxic and it is not a groundwater contaminant. If LPG were to leak it vaporizes immediately and does not pool.

Government policies that are not fuel neutral

Some governments adopt policies that favour one fuel type over another. Such policies can impact manufacturer decisions on engine and vehicle production. The LPG industry favours polices that focus on the end benefits of using low-carbon fuels and allows flexibility for government and private fleets to adopt the best solution for their circumstances. These fuel neutral policies allow for greater efficiency in the marketplace and lead to greater innovation in vehicle production.

Governments that do not lead the market

Trying to steer fleets to low-carbon fuels is an objective of many governments. Governments sometimes fail to require their own fleets to transition from diesel and gasoline to more environmentally friendly options. Governments that want private industries to adopt such alternatives should lead by example and adopt policies that require their own fleet to transition to Autogas.

Incentives that are too short in duration

It is not uncommon for policies intended to incentivise fleets to move to Autogas to have short timeframes in which to take advantage of the incentive. Sometimes this is because governments plan their budgets on one or two-year cycles. Fleet vehicle acquisition budgets are frequently tight and the replacement programme may be established over the course of five to ten or more years. The addition of Autogas vehicles to a fleet is generally incremental and a portion of the fleet will be transitioned and over time that may lead to a substantial portion of the fleet being replaced. A typical vehicles acquisition cycle may exceed two years, so the longer an incentive programme is available the greater the chance a fleet will be able to take advantage of the opportunity.

Range anxiety

Vehicle users and fleet administrators measure vehicle range and performance versus traditional fuels such as diesel and gasoline. Fleet directors and drivers are concerned with the distance vehicles can travel on a single tank of fuel. This is referred to as range anxiety. LPG has the highest BTU content of any alternative vehicle fuels and as such, with proper fuel tank sizing, has ranges that are comparable to gasoline and diesel.

Uncertainly about fuel price stability and fuel supply

Every fleet and vehicle owner is concerned about the total cost of ownership and fuel costs are a major factor in this equation. LPG is affordable and abundant. It is not unusual for LPG fleets to see substantial cost savings over gasoline or diesel. Many LPG suppliers have pricing strategies to keep Autogas competitive so their customers may reap the benefits for their fleet.

Waiting for the next best transportation option

LPG Autogas is right here, right now. In a world of rapidly evolving technology sometimes decision makers can suffer from analysis paralysis. Deciding on the best solution for a fleet can be daunting and most organizations want the perceived “best solution”. Perception that future vehicles solutions are on the immediate horizon can actually slow decision-making. Autogas is a market-ready solution with a proven record of environmental benefits.

Concerns about vehicles repair service

Some fleet directors are concerned that service technicians are inexperienced in servicing LPG vehicles and may not have the tools required to maintain and repair LPG vehicles. OEMs that produce LPG engines and vehicles have training programmes and service support programmes for customers and vehicle dealers to support these vehicles.

Vehicle warranty concerns

Prior to the era of OEM produced engines and vehicles the Autogas market was dominated by after-market conversions. OEMs generally denied warranty service on vehicles with these after-market conversions. Today’s OEM products are fully warranted.

Chapter Six

Recommendations

Adopt a government fleet policy that requires government fleets to acquire LPG vehicles and fueling system so that government can take a leadership role in protecting the environment and reducing operating costs.

When adopting policies about natural gas vehicle incentives, define LPG appropriately as a "natural gas liquid" as it is in the same family as natural gas, compressed natural gas, and liquefied natural gas.

Reduce the regulatory burden as it relates to development, engineering and environmental testing by Original Engine Manufacturers (OEMs) so that they are incentivized to produce LPG engines instead of diesel engines.

Adopt tax incentive programmes to encourage the purchase of LPG vehicles. Set a minimum length of the incentive at ten years. The buying cycle for vehicles by fleets can be between one to three years due to scheduled vehicle replacement cycles. If an incentive was available for just one or two years the fleet may not be able to execute any significant vehicle purchase in such a short timeframe. The longer incentive period allows for a phased approach to growing the number of vehicles in the LPG fleet.

Adopt policies that waive toll road/bridge fees for LPG vehicles. Allow LPG trucks to travel in high occupancy vehicle (HOV) lanes even if only one person is in the vehicle. Allow LPG vehicles access to areas where at certain times passenger vehicle traffic may be restricted due to environmental concerns.

When establishing emission standards, consider the "well-to-wheel analysis" where emissions are not just measured at the tailpipe. LPG is among the cleanest fuels on a well-to-wheel basis and governmental policies should take a holistic approach on emissions and not narrowly focus on one source.

Exempt Autogas on-road and off-road vehicle fuel from all fuel taxes.

Adopt policies that allow entities subject to environmental fines to pay the fine to an NGO or third-party administrator that uses those funds as grants to offset the acquisition costs of LPG vehicles and LPG fuel infrastructure instead of depositing the fine money in the government's general revenue fund.

Create a fee on diesel vehicles and other high-emission vehicle registrations. The proceeds from the fee should be used to offset the cost of LPG vehicle and infrastructure acquisition.

Exempt LPG vehicle and infrastructure acquisition costs from all taxes.

Adopt tax accounting rules that allow for 100% depreciation in the year of purchase for capital investments of LPG vehicles and infrastructure.

Glossary

CM	CARBON MONOXIDE
CNG	COMPRESSED NATURAL GAS
DEF	DIESEL EXHAUST FLUID
EPA	UNITED STATE ENVIRONMENTAL PROTECTION AGENCY
EU	EUROPEAN UNION
HC	HYDROCARBON
HOV	HIGH OCCUPANCY VEHICLE
ISD	INDEPENDENT SCHOOL DISTRICT
LP	LIQUIFIED PETROLEUM GAS
LPG	LIQUIFIED PETROLEUM GAS
LPI	LIQUID PROPANE INJECTION
NEPM	NATIONAL ENVIRONMENTAL PROTECTION MEASURE (AUSTRALIA)
NGO	NON-GOVERNMENTAL ORGANIZATION
NOx	NITROGEN OXIDE
OBD	ON BOARD DIAGNOSTICS
OEM	ORIGINAL EQUIPMENT MANUFACTURER
PM	PARTICULATE MATTER
RPM	ROTATIONS PER MINUTE
UPS	UNITED PARCAL SERVICE
USD	UNITED STATES DOLLAR
WLPGA	WORLD LPG ASSOCIATION

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