The Benefits of LPG as the Fuel for Decentralised Power Generation

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Abstract

While Western Europe and parts of North America concentrate on deep decarbonization and net zero carbon emissions from power generation by 2050 or earlier, much of the rest of the world faces a different problem: access to secure, affordable electricity.

In the modern world, electricity is essential for economic growth and for improving the quality of life. With limited or no grid infrastructures in many places – and over 1 billion people still without access to any electricity – islands, rural towns and cities and related industries have relied on their own decentralized power generation. Traditionally these power plants rely on diesel or heavy fuel oil, two of the most polluting fuels with high CO2 emissions and high levels of pollutant emissions, which contribute to the premature deaths of close to 4 million people per year globally due to poor air quality.

While renewables are being developed globally, these schemes on a small scale rarely solve two parts of the energy trilemma: they may be good for the environment, but the affordability is questionable due to the high initial investment costs, and they do not provide security of supply.

LPG-fuelled gas turbine-based decentralized power generation can address all these major issues. Not only is LPG a clean burning fuel with a low carbon footprint, but it is also competitively priced, readily available, easily transportable and simple to store. The advent of bioLPG will further enhance its credentials as a bridging fuel to natural gas and a zero-carbon future. Decentralized power generation using LPG can thus help achieve greater electrification globally, bringing affordable secure power and helping to improve the quality of life for tens of millions of people across the globe.

Nomenclature

CNG	Compressed Natural Gas
CCGT	Combined Cycle Gas Turbine
CO	Carbon Monoxide
CO2	Carbon Dioxide
DLE	Dry Low Emissions
GHG	Greenhouse Gas
GWP	Global Warming Potential
HFO	Heavy Fuel Oil
IARC	International Agency for Research on Cancer
LFO	Light Fuel Oil
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
NGL	Natural Gas Liquid
NOx	Oxides of nitrogen
OEM	Original Equipment Manufacturer
RICE	Reciprocating Internal Combustion Engine
SOX	Sulphur Oxide
UHC	Unburned Hydrocarbons
U.S. EPA	U.S. Environmental Protection Agency
WHO	World Health Organization

Introduction

Secure energy supplies, and especially electricity, are vital for modern society. Economic growth, improved health and quality of life are dependent on access to affordable supplies of electricity. This gives rise to the so-called Energy Trilemma – how to provide secure, affordable electricity but with minimal impact on the environment.

In developed countries, electricity has traditionally been provided by large centralized fossil-fueled power generation plants connected to an extensive power transmission and distribution system. While this model has generally provided low cost power, the impact on the environment of burning oil and coal has been significant. The drive for decarbonization in recent years in has encouraged the switch from coal to lower carbon fuels, predominantly natural gas. However, with growing political consensus over the need for even deeper decarbonization, there is increasing penetration of renewables onto the grid and proposals to use zero carbon fuels, such as hydrogen, to support a high level of renewable power generation.

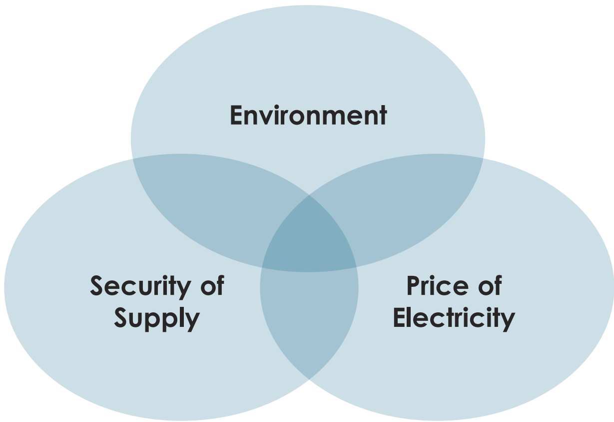

Figure 1. The Energy Trilemma – the need to balance environmental impact, security of supply and price of electricity

While deep decarbonization is the focus in Europe and North America, the rest of the world faces a different challenge: the need for access to sufficient and affordable electricity. The forecast growth in electricity consumption comes mainly from developing nations where globally an estimated 1.2 billion people do not have access to any electricity, while the industries needed to generate economic growth suffer from inadequate electricity supplies. In many such countries comprehensive transmission and distribution systems do not exist, and power generation capacity is insufficient to guarantee secure power supplies even at today's load consumption levels. The electricity infrastructure investment required to resolve these issues using the traditional centralized power generation models runs into trillions of US dollars.

One potential solution to this issue is to expand capacity and access to power by using a decentralized power generation model based on a combination of fossil fuels and renewables. While renewable power generation growth is required to limit Greenhouse Gas (GHG) emission growth in the developing world, fossil fuel combustion will still provide the bulk of electricity supplies for years to come, but by decentralizing power generation, these fossil fuel power plants can be operated more efficiently and flexibly and be better integrated with intermittent renewable sources.

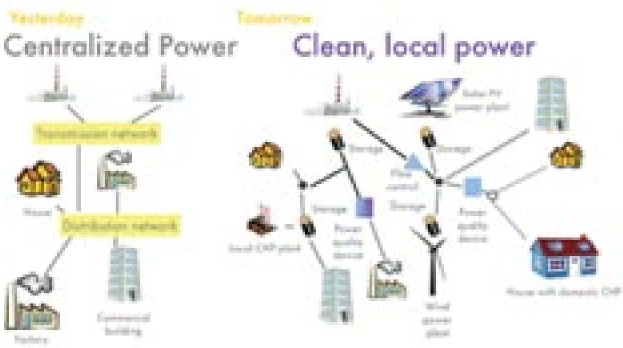

Figure 2: Comparison of centralized and decentralized power systems (Institute for Local Self-Reliance, 2011)

From a GHG perspective, natural gas is usually the favoured fossil fuel. In developed nations there is often a widespread natural gas pipeline network, allowing easy access to this clean fuel. However, in developing nations or more remote regions, there is no access, or very limited access, to natural gas. Decentralized plant have tended to rely on fuels oils, such as diesel or Heavy Fuel Oil (HFO), as a fuel because of their availability and transportability. While this helps ensure security of energy supplies, using fuel oils has a very negative impact on the environment and frequently leads to high electricity prices for people who can least afford to pay for electricity. The challenge is therefore to find a suitable fossil fuel that combines the availability and ease of transportation/storage of fuel oils, with the low environmental impact and affordability of natural gas. Liquefied Petroleum Gas (LPG) is well placed to meet this challenge.

What is LPG?

LPG is a subset of Natural Gas Liquids (NGLs) and comes from two key sources: natural gas production and oil refining.

Produced natural gas consists of many compounds. While predominantly methane, produced natural gas often contains inert gases such as nitrogen and carbon dioxide, or heavier hydrocarbon species such as ethane, propane and butane. Pipeline operators have strict specifications on the composition of natural gas that is transported through the pipeline network, so the produced gas must be treated in order to provide the 'pipeline quality' gas. The heavier hydrocarbons are mostly removed, and NGLs created as a by-product at the gas processing plant. Propane and butanes are a sub-set of NGLs commonly referred to as LPG.

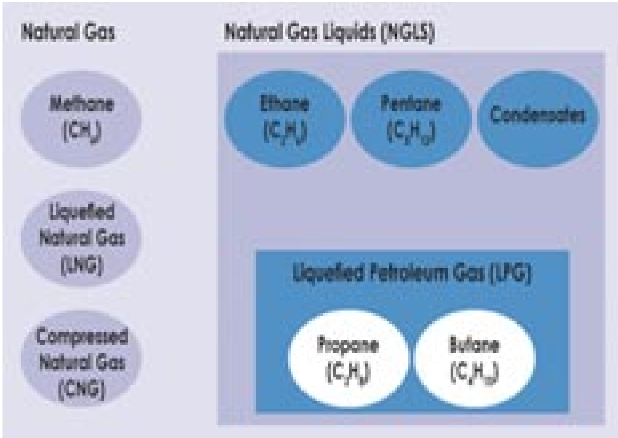

Figure 3: Typical high-level hydrocarbon composition of produced natural gas

LPG specifications and compositions vary greatly around the World. In some countries, LPG comprises pure propane, in others it is pure butane. Mostly though it is a mixture of propane and butanes and classified according to the respective propane content. Table 1 (page 16) gives the composition for the various LPG grades found throughout Europe.

Historically LPGs came predominantly from oil refining, but recent increases in natural gas production, and

Designation	Propane	Butane	Propylene	
HD5	Min 90%	Max 5%	Max 5%	May also include C1, C2 etc in max 5% Butane content
HD10	Min 90%	Max 5%	Max 10%	May also include C1, C2 etc in max 5% Butane content
Grade A	60 to 100%	0 to 40%		
Grade B	40 to 60%	40 to 60%		
Grade C	30 to 40%	60 to 70%		
Grade D	10 to 30%	70 to 90%		

Table 1: Definition of European LPG Grades

especially shale gas in the USA, have changed this scenario so that today and in the future the bulk of LPG will come from natural gas production.

The Greenhouse Gas advantages of LPG over Fuel Oils

CO_2 emissions from power generation are dependent on two factors: the carbon content of the fuel and the efficiency of the power plant.

Combustion of hydrocarbons creates, amongst other things, carbon dioxide (CO_2). As CO_2 is a greenhouse gas, there is a growing global consensus that CO_2 emissions must be reduced to prevent catastrophic climate change. For hydrocarbons there is a simple relationship for every fuel type between CO_2 emissions and the number of carbon atoms per molecule: the higher the number of carbon atoms per molecule, the higher the CO_2 emissions per unit of energy consumed. Diesel, LFO and HFO are composed of a variety of complex chain and ring hydrocarbons with large numbers of carbon atoms, typically between 10 and 19 per molecule for diesel. With more carbon atoms per molecule, combustion of fuel oils produces more CO_2 per unit of energy than natural gas and LPG. In addition, the production of fuel oils is more energy intensive than the production of natural gas and LPG, so when considering the complete cycle, or 'wellhead to electrons', additional CO_2 emissions are incurred. The comparison of CO_2 emissions for the combustion of various fuels is shown in Figure 4.

Figure 4 illustrates the potential CO_2 reduction from using a LPG rather than a fuel oil for a power plant of the same effciency, although the CO_2 emissions are greater than using natural gas. It should be recognized though that CO_2 is not the only GHG: methane, the major constituent of natural gas is a very potent GHG, with a Global Warming Potential (GWP) of 28 (CO_2 = 1) compared to LPG's GWP of 4.53. Fugitive methane emissions from production, transportation or incomplete combustion can therefore significantly reduce the GHG benefits of natural gas, which could actually make LPG the best fossil fuel from a GHG perspective.

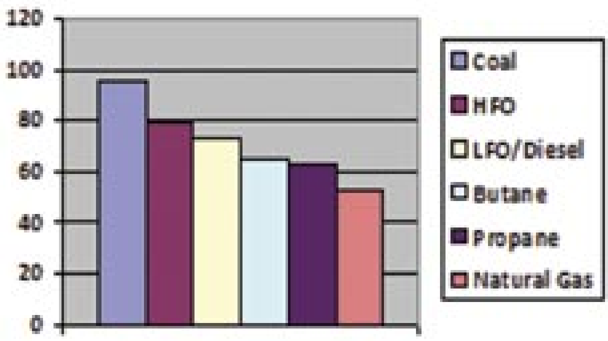

Figure 4: Comparison of CO_2 emissions in kg CO_2 per million BTU for fuel combustion (source US EIA)

The CO_2 emissions from power generation depend also on the overall electrical efficiency of the power plant – when using the same fuel, the higher the efficiency the lower the CO_2 emissions, but it's also possible to reduce CO_2 emissions in a less efficient power plant by using a lower carbon fuel. For example, a typical 30MW power plant with a 45% net efficiency operating on HFO would emit 17.9 tonnes/hour of CO_2, the same amount as a 30MW LPG power plant of just 36% efficiency, so any LPG power plant with a net efficiency above 36% would show a CO_2 benefit over the typical HFO plant.

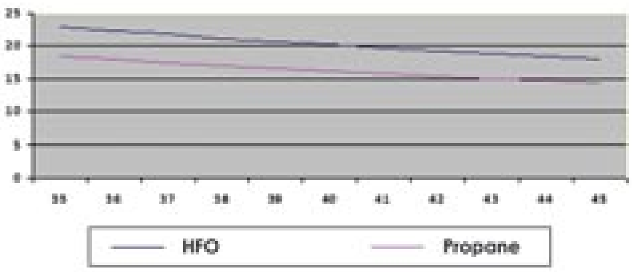

Figure 5: CO_2 emissions in tonnes/hour for a 30MW power plant based on fuel type and efficiency

The Local Environmental Benefits of LPG over Fuel Oils

Although widely used as primary and back-up fuels, diesel, HFO and LFO are 'dirty' fuels from a combustion perspective, with high environmental and human health impacts compared to the combustion of natural gas, propane or LPG.

In addition to CO_2, combustion of fossil fuels produces emissions such as CO, NOx, particulate matter (PM) and unburned hydrocarbons (UHC). The levels of emissions of these pollutants depends on the technology used – boiler, reciprocating engine (also known as reciprocating internal combustion engine, RICE) or gas turbine – and the precise combustion technology, such as Dry Low Emissions (DLE) or Lean Burn.

Emissions of NOX from the combustion of fuels in gas turbines are generally subject to stringent legislative limits. Over the past twentyfive years, much research and development has been done on DLE combustion systems to enable minimum NOX production without the need for water or steam injection, or post-combustion scrubbing systems. While initial work focused on 'pipeline quality' natural gas fuels, in recent years the capability of DLE combustion systems has been extended to include liquid fuels such as diesel, and 'non-standard' fuels such as high inert content gases as well as gases with relatively high concentrations of ethane, propane, butanes and pentanes. More recent work has expanded DLE fuel capabilities to encompass 100% propane and even propane/butane blends, enabling LPG to be considered as a suitable fuel for DLE combustion systems. Fuel oils other than diesel and kerosene are too viscous for correct atomization and are generally unsuitable for use in DLE combustion systems, so only conventional diffusion flame combustion systems can be employed and additional systems must be installed to reduce NOX emissions.

If the fuel contains sulphur, then conversion of this sulphur to oxides of sulphur (SOx) is virtually 100%. SOx is a precursor to acid rain which is highly damaging to the environment, so while propane has extremely low sulphur contents (if any), diesel and other fuel oils have relatively high sulphur contents, which when burned emit significant volumes of SOx into the atmosphere. If a reciprocating engine is used for power generation, then SOx emissions can occur even if there is no sulphur in the fuel: the lubricating oils used in reciprocating engines often contain Sulphur compounds, and some of the lubricating oil in the cylinders is burnt during the fuel combustion process.

The data in Figure 4 assumes 100% combustion of the fuel. In reality, there is always a small amount of unburned fuel in the exhaust gases in a power plant, the amount of which depends on the generation technology chosen. Gas turbines have very efficient combustion systems with very low levels of unburned fuels in the exhaust gases, whereas most RICE technologies have comparatively high levels. As methane is a greenhouse gas, with 28 times the Global Warming Potential (GWP) of CO2 over a 100 year period, methane slip (unburned fuel) from a natural gas-fuelled RICE has a significant impact on CO2 equivalent emissions (CO2EQ): methane slip of around 5.5g/kWh of power generated virtually eliminates the difference in CO2EQ emissions between burning natural gas and burning diesel. Unlike methane which is chemically stable in the atmosphere and has a life of around 12 ½ years, propane and butane have low GWPs of around 4 times compared to CO2. Propane and butane are chemically unstable in the atmosphere and quickly removed by natural oxidation in the presence of sunlight, or knocked down by precipitation, before they can become well-mixed in the atmosphere and have a significant impact on the global climate.

Incomplete combustion of diesel and fuel oils leads not only to CO emissions, but also high levels of particulate emissions (PM). These particulates can be of various sizes from ultrafine particles of less than 0.1 microns in diameter to coarse particles up to 10 microns in diameter. These particulates are made up of a number of different chemical elements, including elemental carbon, sulfates, nitrates and metals. These fine particles can be inhaled creating respiratory problems and in the most extreme cases, early death. In addition, some of the compounds found in exhaust gases on burning diesel and fuel oils have been shown to be carcinogenic, and various bodies such as the World Health Organisation (WHO), the International Agency for Research on Cancer (IARC) and the U.S. Environmental Protection Agency (U.S. EPA) have classified diesel engine exhausts as being 'carcinogenic to humans (group 1)' or a toxic air contaminant. For an LPG-fuelled gas turbine, PM emissions are negligible in comparison, and contain far fewer harmful compounds.

Overall the pollutant emissions reduction by switching from HFO-fuelled RICE to LPG-fuelled gas turbines is significant. As shown in Figure 6 below, the LPG gas turbine option shows significantly lower emissions, even when post-combustion emissions abatement systems are added to the RICE solution - for NOx reduction alone, over 90% reduction is achieved compared to an unabated RICE solution: for a 30MW power plant, this is equivalent to over 5000 tonnes per year of NOx emission reduction.

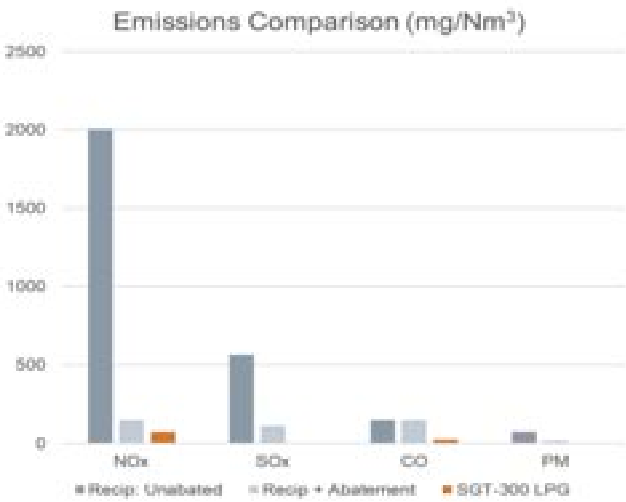

Figure 6: Pollutant emissions comparison for 9MW and 18MW HFO-fuelled RICE and a 7.5MW LPG-fuelled DLE Gas Turbine

The Storage and Transportation benefit of LPG over Fuel Oils

As well as combustion, storage and transportation can have potential environmental impacts, especially due to the potential of spillage. While both LPG and fuel oils are flammable and appropriate measures must be taken to detect and contain a leak, a fuel oil spillage could release hydrocarbons into surface water and groundwater, causing critical damage to wildlife.

Unlike LPG, diesel has a shelf life: while at ambient temperatures below 20°C the shelf life is 12 months or more, if the ambient temperature increases to 30°C the shelf life drops to between 6 and 12 months. This is compounded by the fact that as diesel ages, sediments develop at the bottom of the storage container. Water in fuel creates issues such as a decrease in heat transfer rate, loss in efficiency and wear of cylinder liner surface etc. while additionally any water present in the fuel will promote the growth of bacterial matter and funguses. To keep diesel fuel in a suitable condition for trouble-free operation of both reciprocating engines and gas turbines, additional features are required in the storage and fuel forwarding systems, such as floating suction pumps, centrifuges and fuel additives. There are often also two seperate 'day tanks', one running, one standby, to allow for settling of the fuel, to prevent particulate matter being sent to the power generation equipment. These add to both the capital cost and operation and maintenance costs. Storage issues are particularly relevant where diesel is a back-up fuel and used infrequently – a proportion of issues surrounding failure of emergency and standby generator sets to operate are related to fuel quality and not the equipment itself.

HFO has similar storage issues as diesel, but in addition must be heated to maintain it as a liquid. HFO, also known as residual fuel, is based on the high viscosity tar-like mass which remains after distiallation and cracking of crude oil to produce lighter hydrocarbon products. If the temperature drops below 50°C, the HFO starts to solidify. Storage of large quantities of HFO leads to formation of a sludge which can create a thick layer on the bottom surface of the tanks. This sludge also sticks to the heat transfer surfaces. If the heating system of the tanks fails, it becomes difficult to pump the heavy fuel oil from the bunker tank to the settling tank due to the high viscosity of the oil.

Storage of LPG is much simpler, as the fuel is contaminant free. LPG when stored under a slight pressure (approximately 130 psi at a temperature of 20°C for propane) becomes a liquid, which reduces the required storage volume by a factor of 270 compared to gaseous storage. Being pressurized has an inherent danger should the container be pierced, and would result in a gas leak, and since LPG has a higher density than air, the LPG would sink to the ground. Propane and butane are asphyxiants, displacing oxygen in the air, so care needs to be taken to ensure adequate ventilation. LPG, unlike diesel, does not have a shelf life and can last indefinitely, making it ideal as a back-up fuel.

LPG also has benefits over LNG when storage is considered: LPG can be stored in pre-fabricated bullet tanks, enabling cost-effective and rapid construction and installation. LNG requires purpose-built insulated concrete tanks, which can take 18 months to two years to construct. Overall, the cost of an LPG un-loading and storage facility is estimated to be between ⅓ and ½ that of a similarly sized LNG facility.

The Impact of LPG on Gas Turbine Performance and Operation

Operating a gas turbine on LPG instead of diesel offers a number of performance, environmental and operational benefits, such as improved start reliability, lower combustion emissions, and improved power output and efficiency.

When determining the suitability of a fuel for use in a gas turbine, a number of factors must be reviewed. These are more fully described in papers such as reference 2 on page 23, but the key criteria are Wobbe Index and Dew Point. These determine the quantity of fuel and the supply temperature of the fuel. When considering fuels with high concentrations of higher hydrocarbons such as propane, butane, pentane etc., auto-ignition and flashback must also be considered. Finally, of course, contaminants in the fuel such as sulphur compounds, alkali metals and heavy metals must be considered as these have an impact on gas turbine hot section component life.

LPG can be – and has been – used as a gas turbine fuel. Most of the operational experience gained on this fuel has been based on using LPG as a liquid fuel. Gas Turbine Original Equipment Manufacturers (OEMs) have in the past tended to use high pressure liquid fuel systems for LPG fuels to ensure the fuel stays liquid until the injector tip where it is atomized and sprayed into the combustor. These liquid fuel systems tend to be suitable only for diffusion flame combustors, so water injection is required for emissions control.

Figure 7: 7MW class gas turbine in Japan operating on vaporized LPG

Recent developments on Dry Low Emission (DLE) combustors have enabled gaseous fuel operation to become possible. This eliminates the need for a liquid fuel system on the gas turbine, as the same fuel system can be used for both natural gas and LPG. Thus, a gas turbine can be supplied to site and operated on LPG until natural gas becomes available, with no gas turbine core engine or package modifications required, after which the LPG becomes the back-up fuel. In some instances, it is still possible to have diesel as an additional back-up fuel. Using DLE combustors reduces the level of NOx emissions to levels similar to that achievable on natural gas, but this is dependent on the LPG blend, as butane-rich blends will tend to higher NOx levels, but still lower than the NOx produced on diesel operation. Currently there are still some limitations on the butane content of LPGs that can be accepted in DLE combustors on some gas turbine models, but additional development work could expand the range of LPGs that can be accepted. As shown in Figure 8 above right, the Siemens SGT-300 is now available for operation on any LPG blend from 100% propane to 100% butane in a DLE combustor, and it is possible that other models will also be able to operate on higher butane contents in DLE combustors in the near future.

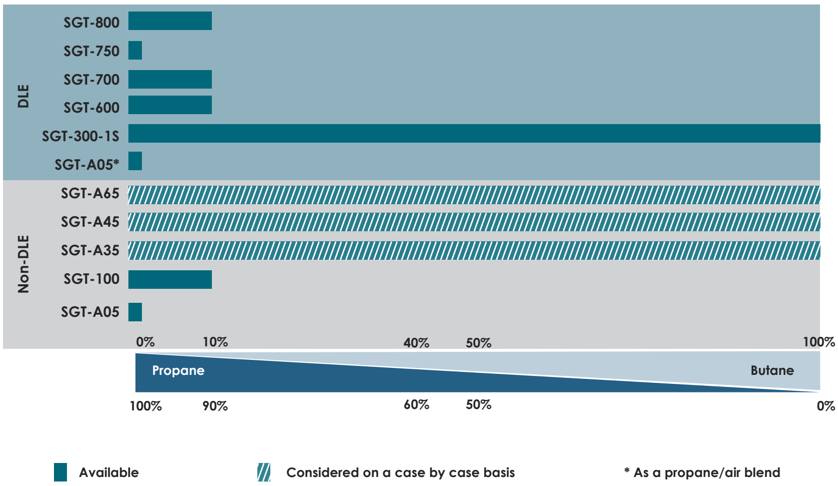

Figure 8: LPG Blend capabilities on some Siemens Gas Turbine models (as of Sep-tember 2019)

Operating on LPG, a gas turbine can produce more power in comparison to diesel at a better efficiency. This is because a gas turbine's maximum load is defined by the hot component temperatures allowable for the gas turbine to reach its designed time between overhauls. These component temperatures are a result of many factors, such as external gas temperature, coolant temperature, heat transfer coefficients and gas properties to name but a few. When burning propane, compared to diesel the resulting combustion gas contains more water and, because the heat capacity of water is significantly higher than the other gas constituents, it means the gas can contain more energy at the same temperature. Therefore, when operating on propane, the gas turbine can produce more power than on diesel or fuel oils. On natural gas the same effect means that the gas turbine can produce more power than when operating on propane (see figure 9). In reality, the heat transfer coefficients are also different which means the actual gas temperature varies with water content.

As well as improving the power output and efficiency of the gas turbine itself, propane has an additional benefit for combined cycle (CCGT) operation. With no sulphur content in the fuel, there is no risk of acid condensation in the exhaust gas stream. This means that more energy can be extracted from the exhaust gases of the gas turbine compared to on diesel or fuel oil operation, allowing increased power output and higher efficiency from the combined cycle power plant – the efficiency achievable on LPG is similar to natural gas while fuel oil operation reduces the achievable electrical efficiency considerably. The low particulate emissions on LPG operation also eliminate the need for soot blowers in Waste Heat Recover Units, reducing the cost and complexity of the equipment. These benefits of LPG also apply to cogeneration applications, allowing very high overall energy efficiencies to be achieved. An industrial power plant with either a power only or a heat and power need can therefore act as the anchor customer for the fuel supply, and form the heart of an energy efficient, environmentally friendly and decentralized power system.

The lack of contaminants such as sulfur, alkali metals and heavy metals in propane also helps ensure reliable gas turbine operation with minimal maintenance inspections.

Gas turbine operation on propane follows a maintenance regime virtually identical to natural gas operation, whereas long term operation on diesel fuel requires more frequent maintenance inspections and hot section component replacement.

From a packaging perspective, LPG operation requires few modifications. By using vaporized LPG, the same gas fuel system as designed for natural gas operation can be used with the only requirement being to check that all the components are rated for a potentially higher gas fuel supply temperature to ensure the vaporized LPG remains in the gaseous phase. Low level gas detection will be required though, as LPG, unlike natural gas, is heavier than air.

The Availability of LPG as a Fuel for Power Generation

Like fuel oils, LPG is a globally available fuel: more than 130 countries have an existing LPG infrastructure. While LPG consumption is dominated by the residential and chemical market sectors, increasing production and availability is causing LPG producers and traders to seek new markets, and with its environmental benefits over fuel oils, power generation is an attractive potential market.

Global LPG production (and consumption) has risen year on year. In 2018, global production reached 317 million tonnes, with supply once again out-stripping demand. Historically LPG production was dominated by refineries, where LPG is a by-product of crude oil refining, but the global growth in natural gas production, and especially North American shale gas production, now means that the majority of LPG comes as a by-product from natural gas production.

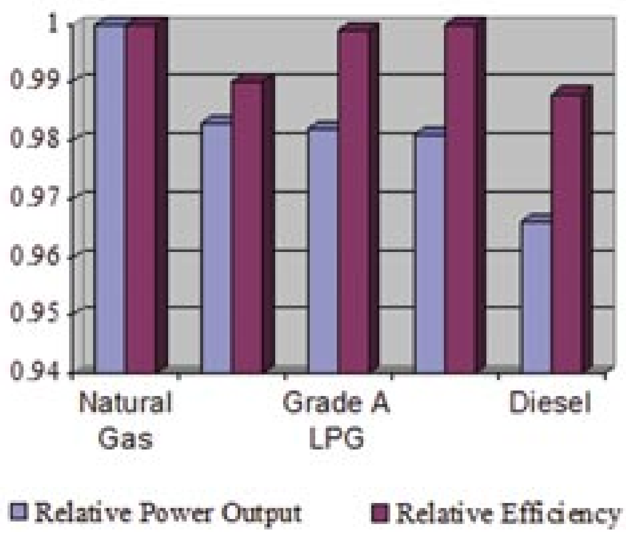

Figure 9: Relative power outputs and efficiencies for natural gas, different LPG blends and diesel fuel for an 8MW class gas turbine

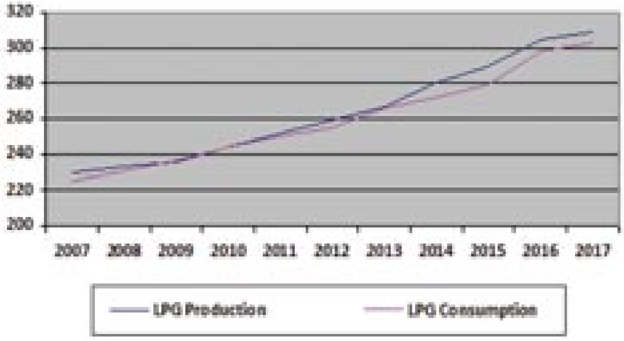

Figure 10: Global LPG Production and Consumption in Million tonnes/year (source: Argus Media)

The increase in LPG production, especially in North America, have changed international trade flows and pricing. The top 10 LPG Producers aand consumers in 2017 are shown in Table 2 below. The increase in production has also caused prices to fall: between 2012 and 2014 the Saudi Propane Index had a price range between US$800/tonne and US$900/tonne, but since 2015 the price range has been in the US$300/tonne to $500/tonne range.

As a globally traded commodity, LPG can be easily shipped to places where the infrastructure exists, or where a developer or LPG supplier is prepared to make the necessary investment to develop the infrastructure. The major LPG trade flows are shown in Figure 11, but smaller volumes can be readily shipped to smaller consuming countries or customers, such as Caribbean islands or West African nations. One advantage of LPG compared to LNG is the existing infrastructure: while LPG is already available in most countries in the world, there are few existing small and medium scale LNG terminals. There are already more than 1000 small and medium-sized LPG tankers in the global fleet, while conversely most LNG tankers in the global shipping fleet are classed as large or very large, with only around 40 small- and medium-sized tankers. LPG transport by road and rail is also very common, so wherever it is possible to deliver fuel oils, it is equally as possible to deliver LPG.

Conclusions

Replacing fuel oil-fired systems with LPG-fuelled alternatives would show an immediate reduction in carbon emissions from power generation and energy production.

LPG is an excellent potential fuel for power generation, offering many advantages over the fuel oils predominantly used today. With low CO2 and pollutant emissions, and only a minor impact on gas turbine performance compared to natural gas, it can help distributed power plants deliver clean, affordable power to consumers and industry with both local and global environmental benefits.

The low particulate emissions, and reduced potential for environmental damage in case of spillage, have a positive benefit environment, and a reduced impact on human health issues compared to the existing scenario, while LPG's competitive cost and the ability to be used as a fuel in high efficiency combined cycle or cogeneration plants can help bring secure electricity supplies to cities, towns and industries not within easy reach of an existing power or natural gas transmission system.

Its transportability make it a readily available fuel, negating the advantages that fuel oils have over natural gas. With the continued development and enhancement of supply infrastructures, LPG can become the main fuel for distributed power, or the bridging fuel for power generation until the availability of natural gas or renewable fuels, such as bio-LPG, and then take up a role as the ideal back-up fuel in case of primary fuel supply issues. ■

Rank	**LPG Producers** (Million tonnes/year)		**LPG Consumers** (Million tonnes/year)	
1	United States of America	67.33	China	53.25
2	China	36.71	United States of America	37.83
3	Saudi Arabia	30.39	India	23.76
4	Russia	16.66	Saudi Arabia	23.39
5	Canada	12.94	Japan	15.58
6	India	12.29	Russia	10.29
7	United Arab Emirates	10.55	South Korea	8.95
8	Qatar	9.96	Mexico	8.61
9	Iran	9.24	Canada	8.36
10	Algeria	8.92	Brazil	7.39

Table 2: Top 10 LPG Producers and Consumers (source: Argus Media)

Figure 11: Major LPG Trading routes (source: Argus Media)

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