



# Global LPG Power Generation

## Market Development & Recommendations for Future Growth



## 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 organisation. 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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Delta-ee are experts in heat and distributed energy. Our commercial insight and market expertise helps utilities, product manufacturers and policy makers navigate the transformation to a more distributed, customer centric and service-orientated energy future. We provide research services and bespoke consulting on a wide range of decentralised energy topics such as Micro-CHP, Heat Pumps, Energy Storage, Connected Homes, Demand Response and Customer Data Analytics.

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## Chapter One

# Introduction

Following the successful delivery of the report “Power Generation from LPG - The Global Status of LPG-based Power Generation in Commercial, Industrial, and Power Sectors” by Delta-ee in 2016, the WLPGA wanted to build on this study to:

- Further explore the global market outlook associated with the growth of the LPG Power Generation sector within a band of systems from 250 MWe as an upper threshold to 5 MWe as a lower threshold of analysis
- Identify the market characteristics which are likely to be present in the markets which are most promising for LPG Power Generation (e.g. lack of natural gas infrastructure, high electricity prices, etc.)
- Highlight 6-8 specific countries which are likely to be some of the most promising for LPG Power Generation globally, together with an analysis of the market characteristics which make these countries promising
- Provide clear guidance and recommendations to global LPG stakeholders (e.g. governments, associations, suppliers, manufacturers, etc.) on steps that can be taken to maximise the opportunities to grow the LPG Power Generation sector globally.

This report, completed by Delta-ee in Spring 2017, summarises the results from this follow-on research, and consists of three parts:

1. **Market Outlook:** An Executive Summary style overview of the global potential for LPG within the power generation sector
2. **Key Countries & Market Characteristics:** An in-depth review of eight global markets that are considered to have the greatest potential for LPG Power Generation
3. **Recommendations:** A list of recommendations, targeted at stakeholders, to help grow the use of LPG within the global Power Generation sector

## Chapter Two

# Executive Summary

### Key Markets

The following eight countries were identified during the research for this Study as markets of high opportunity for LPG Power Generation:

1. **Angola:** With limited natural gas infrastructure in most areas of the country, the use of LPG as a ‘bridging’ fuel presents a strong opportunity in the short term
2. **Argentina:** Opportunity driven by critical need for more electricity generating capacity and constrained natural gas supplies during times of peak demand
3. **Cayman Islands:** With LPG infrastructure and storage already in place, LPG is well-placed to displace much of the power generation capacity which is currently met by diesel
4. **Greece:** Likely one of the strongest opportunities for LPG Power Generation in Europe, driven by lack of natural gas infrastructure throughout many of the country’s islands, and an ambition to move away from diesel
5. **India:** With wide-spread LPG infrastructure already in place, India represents a strong opportunity for LPG Power Generation, especially in regions of no natural gas grid and expensive diesel
6. **Indonesia:** One of the strongest potential markets for LPG Power Generation
7. **Morocco:** A more limited opportunity for LPG Power Generation. There may be some opportunity to use LPG as a ‘bridging’ solution in some areas until natural gas infrastructure is developed, but the high butane content of domestic LPG supplies is likely problematic
8. **Philippines:** With limited natural gas infrastructure in most areas of the country, the use of LPG as a ‘bridging’ fuel presents a strong opportunity in the next 10 to 20 years

## Summary of Recommendations

The following recommendations, targeted at LPG industry stakeholders, have been compiled with the ultimate intention of improving the future prospects of using LPG as a fuel for power generation. Each of the recommendations is elaborated in more detail in the 'Recommendations' section towards the end of the report.

- 1. Better positioning of LPG to policymakers and energy users**
- 2. Better positioning for development finance for energy projects in emerging markets**
- 3. Develop and encourage new business models for LPG – new solutions and services**
- 4. Indexation of LPG with other fuels**
- 5. A comparison of emissions profiles of pollutants between LPG and other fuels**
- 6. Better understanding of the costs of local LPG infrastructure development**
- 7. Exploring the opportunity of converting diesel engines for LPG use**

## Chapter Three

# Market Outlook

### Market Outlook for LPG Power Generation – An Overview

There is growing evidence to suggest that LPG will have an important role to play within the global Power Generation sector in the next 10 to 20+ years. As the trend towards renewables continues throughout many parts of the world, and with coal increasingly seen as a power generation source of the past rather than the future, the role of gaseous fuels as a lower carbon, flexible way to generate electricity has never been more important.

The International Energy Agency (IEA) anticipates a 50% growth in the demand for natural gas in the period 2016 to 2040 – with much of this growth associated with electricity generation, and a continuation of the trend away from using coal-fired power plants.

Where pipeline infrastructure exists in close proximity to the demand, natural gas is clearly the gaseous fuel of choice. However, many countries do not have an established network of natural gas pipelines. In countries where these do exist, infrastructure is often reserved for areas of high population density and/or centres of industrial activity, leaving more remote areas with little or no access to natural gas. In such cases, there is a clear opportunity for LPG to provide a solution for power generation – especially when new power plants are necessary to meet increasing electricity demand.

Over time, we expect natural gas grid infrastructure to expand in many regions throughout the world. However, in some countries, power shortages are becoming critical issues today and governments cannot afford to wait for five to ten years before natural gas pipelines are in place to fuel new-build power plants. Therefore, in a bid to provide security of electricity supplies, governments are increasingly considering the potential for using LPG as a ‘bridging’ fuel. In these cases, power plants fuelled by LPG are built – often with short one to two year lead times - but with a longer-term plan to convert to natural gas once the pipeline infrastructure is in place.

Once such example is the Bridge Power Plant, which is currently under construction in Ghana. This facility, which will ultimately have an electricity generating capacity of 400 MWe, is the largest power plant of its kind to be fuelled by LPG. The plant will use gas turbine generator sets with steam turbines in a CCGT (Combined Cycle Gas Turbine) configuration. Once completed, it will represent over 15% of the country’s power generation capacity. In the short term, the plant will be run on LPG. However, the plant is ‘fuel-flexible’ with the intention to replace LPG with natural gas once the pipeline infrastructure is complete. There is also the option to fuel the plant with diesel should there be any disruption to supplies of either LPG or natural gas. This flagship project illustrates the potential for using LPG as a flexible, low-emission alternative to other fuel types within power generation facilities. Other, similar projects are expected to follow in the coming years as the potential for LPG becomes more understood.

In the future, there is also likely to be an emerging opportunity associated with the use of LPG Power Generation in combination with renewables such as solar PV (photovoltaics) and wind power. These ‘hybrid’ (or microgrid) projects are likely to be particularly well-suited to remote, or island, locations which currently rely on expensive diesel to meet their power needs. While this is not a topic explored within this study, it will likely be a focus area for future projects carried out by the WLPGA.

## Market Characteristics Supporting LPG Power Generation

The table below summarises some of the key market characteristics which can support the use of LPG as a fuel within the power generation sector. These characteristics were also used to determine the key countries to focus on in the later section of the report.

Market Characteristic	Reason why LPG Power Generation is well placed to benefit
<b>Limited natural gas grid</b>	The most attractive regions for LPG Power Generation tend to be those with no (or limited) access to natural gas. Therefore, countries without widespread natural gas pipeline infrastructure often represent the markets with the greatest potential for LPG Power Generation. Emerging markets, and countries that are made up of many islands, often represent good opportunities because of a lack of gas pipelines.
<b>High / increasing electricity prices</b>	High electricity prices can improve the economic proposition for using LPG as a fuel for power generation. As electricity prices rise (which is expected in most parts of the world), the case for LPG power generation will likely improve still further. Markets with ageing electricity grid infrastructure or high targets for renewable energy penetration often have inflated electricity prices.
<b>Diesel costs expensive relative to LPG</b>	In off-gas grid areas, diesel is often the primary fuel for power generation. With LPG often significantly cheaper than diesel, there is a strong opportunity for using LPG as an alternative fuel source in these areas.
<b>Unreliable electricity grid</b>	This issue is typically more prevalent in developing countries, yet even in North America power outages are an increasing occurrence due to extreme weather events, for example. The use of onsite power generation, fuelled by LPG, can be one way to mitigate the risks associated with an unreliable electricity grid (especially where natural gas cannot be relied upon).
<b>Expected growth in power demand</b>	Economic growth, along with accompanying structural changes, strongly influences world electricity consumption. As countries develop and living standards improve, electricity demand tends to grow rapidly. Power plants fuelled by natural gas are often the preferred choice, but where the pipelines are not yet in place, LPG is well placed to act as a ‘bridging’ solution until the necessary infrastructure is in place.
<b>Focus on emissions reduction</b>	There is ever growing political and public pressure to reduce global carbon emissions from the energy sector. In addition to greenhouse gas (GHG) emissions, targets are gradually being considered for criteria pollutants such as NO <sub>x</sub> , SO <sub>x</sub> , particulate matter, etc. Power generation fuelled by LPG tends to have similar or lower emissions profiles when compared with natural gas, LNG, heavy fuel oil and diesel.
<b>Government incentives for oil-to-gas or coal-to-gas switching</b>	Involves a variety of measures from mandated initiatives to voluntary schemes. For example, some countries have introduced an emissions trading scheme, which is designed to encourage coal-to-gas switching over the long term as the price of carbon increases. Some governments may reduce subsidies for diesel to encourage switching to gas, including LPG.

## Main Players: Power Generation Market – Sub-200 MWe

While there is no upper size limit when it comes to the use of LPG for power generation, the accepted wisdom is that LPG is a fuel best suited to power generation applications in the size range below 100-200 MWe, with only limited opportunities in larger size bands due to the more compelling economic proposition provided by LNG at these larger sizes.

Therefore, in this section we summarise the global manufacturers who are most active in the power generation sector in the sub-200 MWe size range. It should be noted that while we are concentrating on players with product sizes below 200 MWe, these units tend to have the ability to be installed in a modular arrangement, such that multiple units can be installed in parallel to create much larger power generation facilities, often well in excess of 200 MWe.

Gas-fired power generation units (including those fuelled by LPG) can broadly be categorised into two types: gas engines and gas turbines. The companies listed in the table below are global players who are likely the most active within the power generation sector with products in the sub-200 MWe size range. It should be noted that while most of the companies listed below have previously carried out projects which demonstrate the use of LPG as a fuel for power generation, not all these companies are currently marketing LPG-fuelled products.

Gas Engines		Gas Turbines	
	<b>GE:</b> A wide range of gas engine products, using two global brands: Jenbacher and Waukesha. Product portfolio includes units across the sub-250 kWe to 10 MWe size range.		<b>GE:</b> A wide range of gas turbine products, with power generation capacities ranging from 5 MWe to over 100 MWe.
	<b>Siemens:</b> Following the acquisition of Guascor engines in 2015, Siemens now offers gas engines in the size range from 300 kWe to 2 MWe.		<b>Siemens:</b> A wide range of gas turbine products, with power generation capacities ranging from 4 MWe to over 100 MWe.
	<b>Wärtsilä:</b> A manufacturer of larger gas engines in the 10 to 20 MWe size range, with a number of reference plants using LPG as a fuel.		<b>Kawasaki:</b> Offers gas turbines for power generation in the size range from 2 MWe to over 30 MWe.
	<b>Rolls-Royce Power Systems:</b> Through the MTU and Bergen brands, RRPS offers gas engines across the sub-250 kWe to 10 MWe size range.		<b>Mitsubishi Hitachi Power Systems:</b> Offers gas turbines for power generation in the size range from 28 MWe to over 100 MWe.
	<b>Caterpillar:</b> A wide range of gas engine products, using two global brands: CAT and MWM. Product portfolio includes units across the sub-250 kWe to 5 MWe size range		<b>Solar Turbines:</b> A Caterpillar company, manufacturing mid-size industrial gas turbines in the 1 to 22 MWe size range.
	<b>Cummins:</b> Offers gas engines for power generation from below 250 KWe to 2 MWe.		<b>Capstone:</b> A major supplier of propane fuelled turbine generators from 30KWe to 1 MWe.
	<b>MAN:</b> Offers gas engines for power generation in the 7 MWe to 21 MWe size range.		

Please note: The order in which companies have been listed in the table above is not indicative of market share.

## Challenges for LPG Power Generation to Overcome

Despite the many advantages of using LPG, there remains a number of challenges which need to be addressed if LPG is to be considered more than a niche fuel type within the power generations sector. A summary of these is discussed below.

### **1. Long-term LPG pricing**

Perhaps the single biggest challenge for the LPG sector to overcome is that associated with long-term future pricing. LPG prices tend to be quite volatile, with a significant element of 'seasonality' in year-round pricing associated with varying supply and demand profiles. Therefore, as discussed later in the report, an explicit recommendation of this study is to consider mechanisms which can be used in order to reduce the risk of future LPG price volatility, and thus improving the confidence of end-consumers of the fuel.

### **2. Advantages of LPG over other fuel types are not well understood**

In most cases, the advantages of using LPG over other fuel types for power generation are not well understood, including lower emission profiles (versus diesel, for example), lower full life-cycle costs (versus LNG, for example), and quicker lead-times (versus natural gas, for example). In order for LPG to become a more compelling choice for customers, the LPG sector should do more to communicate the advantages of the fuel to a wide range of industry stakeholders, including governments, utilities, distributors, etc.

### **3. Customers cannot locate suitable LPG Power Generation systems**

Suppliers of power generation systems are often not equipped (or inclined) to cater for customers who are looking for assets fueled by LPG. As LPG Power Generation is still a niche application today, there is a perceived lack of opportunity associated with designing, manufacturing and marketing products fueled by LPG. As such, when potential customers enquire about acquiring such power generation equipment, they are often met with a negative response. This is particularly true when customers approach local distributors who, naturally, are primarily concerned with selling their established product lines, fueled by diesel or natural gas.

### **4. Local LPG infrastructure often under-developed**

While it is important to note that 133 countries in the world have infrastructure to import LPG only 33 countries have LNG importing facilities. However, in countries where LPG is seldom used today, the necessary local infrastructure needs to be developed before the fuel can be widely used for power generation. This will include building up a local network of LPG distributors and retailers in addition to the necessary receiving terminals, storage facilities, etc.

### **5. In markets where LPG primarily consists of butane, new infrastructure is required**

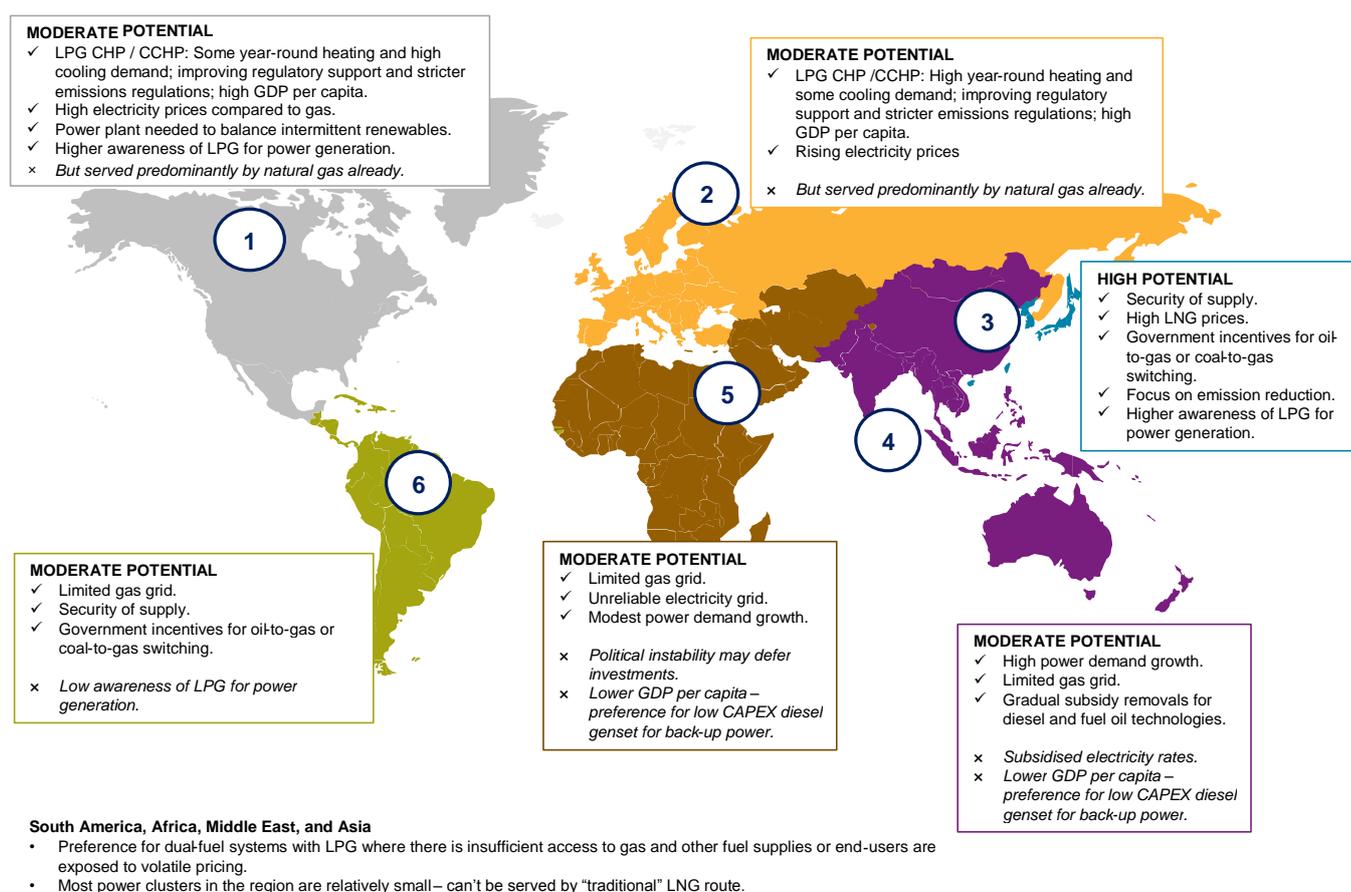
Some countries have an LPG supply which is primarily made up of butane rather than propane. While this fuel type is suitable for most heating and cooking applications, it can present significant challenges when the fuel is used for power generation, especially within reciprocating engines. Therefore, in these countries, it would almost certainly be necessary to develop new infrastructure which allows the import of LPG fuel which consists of more propane rather than butane.

## Chapter Four

### Key countries and market characteristics

During the previous study for WLPGA, six global regions were characterised by their potential for growth in LPG Power Generation. These regions are illustrated in the figure below. For this study, WLPGA wanted to identify six to eight countries from across these six regions for deeper analysis to understand the specific characteristics of countries that have a good outlook for LPG Power Generation.

#### Target regions for LPG-based power generation



A number of key criteria were discussed and refined between Delta-ee and WLPGA that would enable a short listing of countries that could be interesting for deep dive analysis. The criteria that were considered, which are based around factors that would likely result in a positive outlook for LPG Power Generation, are:

1. Penetration / extent of natural gas within the market
2. Share of electricity generation from oil / diesel
3. Reliability of and reach of electricity network
4. Energy prices
5. Regulatory framework (policies, incentives, environmental push)
6. Presence of existing LPG infrastructure, primarily for propane
7. Macro-economic factors (e.g. GDP, political stability, ease of doing business)
8. Rate of growth in electricity demand
9. Interest in the market from WLPGA members
10. Availability of majority propane mix

During the initial filtering process, high level information and data (where easily available) was gathered for 30 – 40 countries from across the six global regions illustrated above. This information was used to help inform the decision making around which countries to shortlist for further analysis, along with the views, opinions and interests of WLPGA members.

The eight countries that have been short listed for further analysis with a summary of the rationale for selection are:

Country	Rationale
<b>Angola</b>	<ul style="list-style-type: none"> <li>▶ Big need for electrification with almost half of power generation from oil / diesel</li> <li>▶ Provides coverage of countries in developing regions</li> </ul>
<b>Argentina</b>	<ul style="list-style-type: none"> <li>▶ Large population with one of the highest GDPs in South America</li> <li>▶ Modest oil / diesel use in power generation</li> </ul>
<b>Cayman Islands</b>	<ul style="list-style-type: none"> <li>▶ Small island country with power generation primarily from diesel</li> <li>▶ High GDP and electricity demand per capita</li> <li>▶ Currently reviewing its energy policy</li> </ul>
<b>Greece</b>	<ul style="list-style-type: none"> <li>▶ Island country with a significant amount of diesel generation</li> <li>▶ Provides European coverage in the study</li> </ul>
<b>India</b>	<ul style="list-style-type: none"> <li>▶ Huge population</li> <li>▶ Electrification still occurring with very weak grids in certain areas</li> </ul>
<b>Indonesia</b>	<ul style="list-style-type: none"> <li>▶ Huge population, lots of islands using diesel</li> <li>▶ Electrification still occurring with weak grid in certain areas</li> </ul>
<b>Morocco</b>	<ul style="list-style-type: none"> <li>▶ Modest sized African country with significant diesel use in power generation</li> <li>▶ Provides coverage of countries in developing regions</li> </ul>
<b>Philippines</b>	<ul style="list-style-type: none"> <li>▶ Large population, lots of islands using diesel</li> <li>▶ Electrification still occurring</li> </ul>

For each of these countries, a summary of the market characteristics and key headlines on the outlook for LPG power generation is provided in the following section.

#### 4.1 Angola – With limited natural gas infrastructure in most areas of the country, the use of LPG as a ‘bridging’ fuel presents a strong opportunity in the short term

Headlines on the outlook for LPG Power Generation in Angola:

- Ambitions centre around the expansion of hydro and LNG, but there may be room for LPG to compete against diesel generators in areas that continue to be off-grid.
- Although regulatory changes are creating a more stable business environment, Angola continues to have problems that may inhibit LPG investment.

Below, we discuss the key factors that influence the outlook for LPG Power Generation in Angola in more detail.

##### Energy prices – Steep diesel price increases may favour LPG in the short term, but the low price of LNG relative to LPG may be hard to compete against

Diesel, traditionally the dominant generation fuel in Angola, is becoming less economically attractive since fuel price subsidy reforms starting in 2014, prompting an almost four-fold increase in its price over 2015. The LPG price was also affected by the reforms, increasing by 22% over the same period. This is part of the government’s plan to progressively eliminate oil and gas price subsidies. The increase in price for diesel is prompting businesses and residents who rely on isolated generators for power to explore alternative solutions.

The LNG currently produced by the Angolan LNG terminal at Soyo in the very north of the country is the most economical alternative to diesel, prompting the government to focus its efforts on the conversion of 300 MW of existing diesel generation to LNG fuel based by 2025. Heavy fuel oil (HFO) is also a very cost competitive alternative to diesel as Angola produces a greater quantity than it consumes and can be used in around 400 MW of the diesel engines already installed. Relative to these alternatives, LPG is an expensive option for electricity generation in Angola. However, LPG will also be produced in Soyo’s terminal, and may therefore represent a significant cost reduction relative to diesel for the smaller stock of backup generation that the government foresees it will require out to 2025.

##### Electricity & natural gas grid infrastructure – Plans to rapidly expand the reach of the electricity grid to meet new demand and the replacement of diesel could provide opportunities for LPG if the focus shifts away from LNG and hydro

Angola’s electricity network is constituted of three main independent systems (north, central and south), with the north system, which supplies the capital city of Luanda, representing around 80% of the whole electric power production of the country (almost one-half of all power produced serves Luanda).

Angola currently has an unstable grid, damaged by years of war. It is subject to frequent blackouts and reaches 30% of the population (see Figure 2), and only 9% in rural areas. For these reasons, both residents and businesses rely heavily on diesel generators for power (approximately one-third of businesses in the capital Luanda and 90% of those outside the capital use private power generation via diesel generators). Angola has ~13 larger diesel power generation plants, with capacity totalling approximately 2,400 MW, almost all of which are owned by the government utility.

The Angolan government aims to reduce this reliance on diesel generators and meet rapidly growing demand for electricity (expected to increase by ~12.5% per year between 2017 and 2025) by approximately quadrupling 2014 installed capacity to total 9.9 GW by 2025, with a strong focus on hydropower and natural gas. The ambition is for hydropower to reach 6.5 GW of installed power (66% of the total). Current hydropower capacity is around 1.8 GW, rising by an additional 2,070 MW once the Lauca Dam is completed (expected 2018). LNG is expected to reach 1.9 GW (19% of the total) with the doubling of capacity at Soyo and the conversion to natural gas of several turbines and combined cycle plants in the provincial capitals (illustrated in Figure 2). Also, an additional 800 MW of wind and solar (~8%), and 700 MW of ‘other thermal-based’ generation (~7% of total generation) are planned.

Angola has enormous potential for domestic natural gas exploitation, with estimated reserves at the end of 2015 of 308 bcm, however huge scope remains to increase its gas infrastructure and networks. However, systemic issues such as the building of networks and processing facilities, developing effective markets and pricing, as well as defining ownership rights to natural gas resources must be addressed if natural gas is to become a significant source of power generation. As such so far local availability of gas for power generation has been very low. There have also been problems expanding generation from LNG due to the Soyo plant shutdown (so that design flaws could be fixed). In addition, since the ambition is for LNG to provide peak / back up generation for much of the time for hydro, it may not be deemed economical to convert all diesel plants.

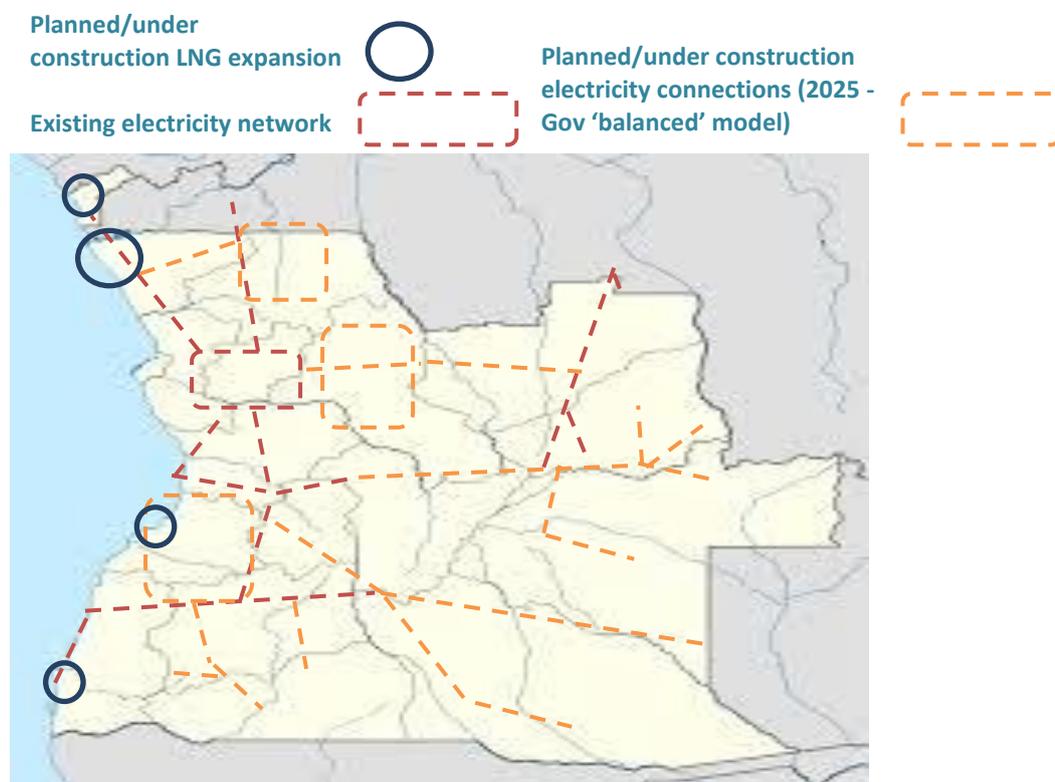
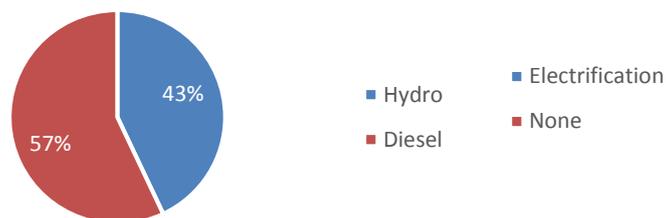


FIGURE 1: ILLUSTRATION OF EXISTING AND PLANNED ELECTRICITY INFRASTRUCTURE IN ANGOLA

The government preferred ‘balanced’ plan of grid infrastructure expansion (see Figure 1) aims to reach the goal of 60% electrification. With this target, it is expected that a total of 3.7 million consumers will be connected in 2025 (more than three times the present number). It plans to do this through a more than doubling of the length of transmission infrastructure to 2500 km, unifying 3 separate transmission systems, and rebuilding war-damaged networks. The electrification effort will focus on provincial capitals and their urban areas – covering 130 municipalities, whilst also extending the grid to outside large urban areas to allow for the electrification of the majority of municipal townships – a total of approximately 1.7 million people. However, the outlook still looks to a small increase in decentralised, isolated systems such as small hydropower, PV systems and diesel generators to supply electricity where these alternatives exist or when distances per consumption unit are too high. These isolated systems are expected to serve ~1% of the population. There may be a small opportunity here therefore for LPG to displace the diesel portion of this increase in decentralised, isolated generation to reduce fuel costs for these municipalities.

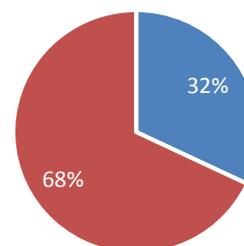
FIGURE 2: BREAKDOWN OF ELECTRICITY GENERATION MIX AND ELECTRIFICATION RATE IN ANGOLA

Electricity generated by fuel type (MW capacity)



Source: ENE 2014

32% of customers are connected to the grid



Source: World Bank 2016

**Policy & regulatory framework– Focus is on the development of its considerable hydro resources, however the continuing lack of grid coverage and the opening of the market to private players could give LPG an opportunity.**

The Ministry of Energy and Water (MINEA – who manage the electricity sector) has dedicated \$29 billion to construct large infrastructure projects to increase power generation and improve grid infrastructure. Much of this is directed towards hydro. Angola’s energy sector has traditionally been characterised by strong public activity, with state companies acting throughout the value chain, but this is gradually changing with private player participation in diesel generation and mini-hydro projects. That said, Angola remains a notoriously difficult country in which to do business – with the lowest ranking in the Ease of Doing Business Index in the SADC region. Poor quality supply and high T&D losses also inhibit cost recovery for generators. The government is aware of this, and has put in place a public private partnership law as well as changing its general electricity law in an effort to promote private sector involvement.

Policy	Summary	Impact on opportunity for LPG
Electricity Law amendment (June 2015)	The establishment a regulatory framework to encourage private investments in Angola, with support from the African Development Bank. This will allow negotiation of power purchase agreements (PPAs) with independent power production (IPPs) and the implementation of feed-in-tariff rates.	Positive – An established regulatory framework is critical to attracting private LPG investment
Increase in Angolan tariffs for electricity consumption	As of early 2016, the Angolan Regulatory Agency for Electricity (IRSE) had increased Angolan tariffs for electricity consumption to 7.05 Kz per kilowatt hour (kWh), up 60% for private consumers and 190 percent to 5.88 Kz per kWh for businesses.	Positive - With these higher electricity rates, the government aims to create a more sustainable business model for the electricity sector that will be more attractive to potential independent producers, including LPG.
“Aldeia Solar”	The National Strategy for New Renewable Energies foresees a target of 500 solar villages (settlements with >3000 inhabitants) by 2025. Particular focus on public buildings.	Negative/Negligible – More solar eats away at the potential market for electrification via LPG, however many of these communities may be too isolated to be considered target markets for LPG.

Current LPG activities & deployment

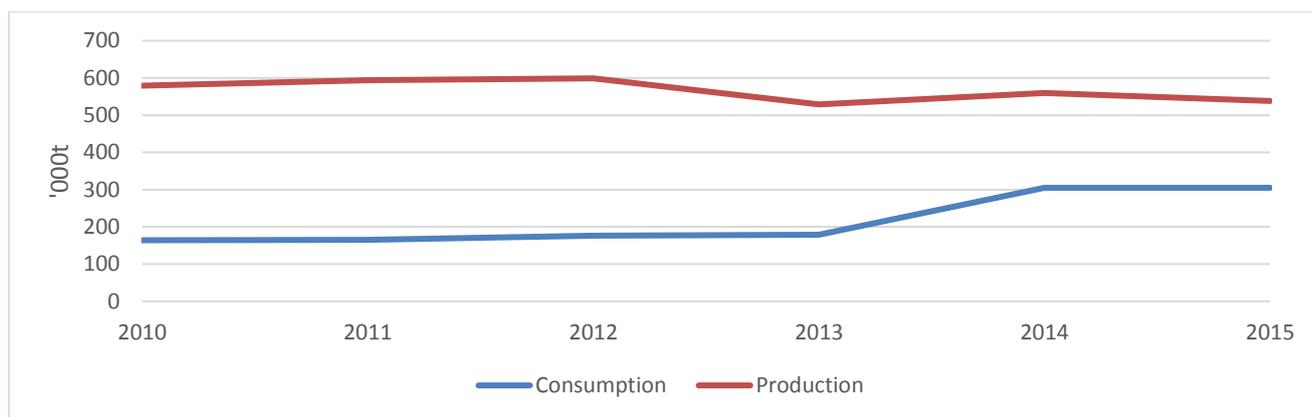


FIGURE 3: Angola production and consumption of LPG

As well as producing LNG from its offshore gas resources, Angola’s Soyo facility also produces propane and butane to supply both domestic and export markets. The facility has storage tanks capable of holding 88,000 m3 of propane and 59,000 m3 of butane, with a jetty dedicated to propane, butane and condensate loading and a second jetty for pressurised butane loading which serves the domestic market. As Figure 3 illustrates, total production exceeds domestic demand, and there could be scope therefore for Angola to utilise this excess for domestic power generation.

## 4.2 Argentina – Opportunity driven by critical need for more electricity generating capacity and constrained natural gas supplies during times of peak demand

Headlines on the outlook for LPG Power Generation in Argentina:

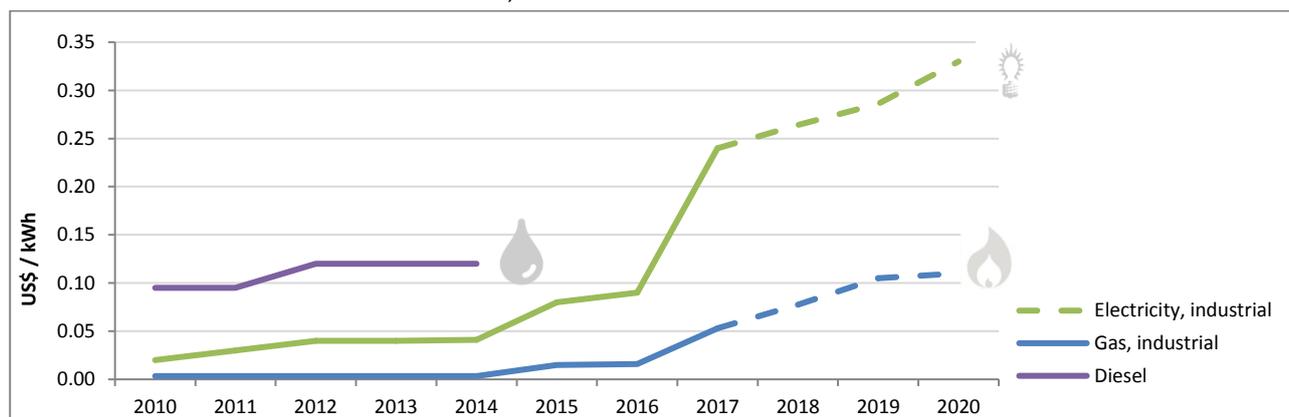
- Sharply increasing electricity, natural gas and diesel prices, along with the government’s stated aim of moving away from its main power generation fuel (natural gas), puts LPG in a good position as a strong alternative in the short term.
- The need to replace much of the existing capacity, could support LPG Power Generation deployment.

Below, we discuss the key factors that influence the outlook for LPG Power Generation in Argentina in more detail.

### Energy prices – Natural gas, oil, and electricity prices are high and set to continue to rise, providing an opportunity for power generation from increasingly cost-effective LPG

For 12 years, industrial and residential customers in Argentina paid extremely low, distorted prices for their energy. Tariffs for electricity were significantly subsidised by the government. However, in 2015, the new government announced that it would aggressively cull its large subsidies for energy (both electricity and natural gas) and reduce them to zero by 2019 in order to help the government close its yawning fiscal deficit. This has caused sharp increases in the price of energy; electricity prices increased by up to 300% in 2016, and natural gas prices were up by almost 400% (illustrated in Figure 4). Prices for both are expected to continue to rise sharply. This presents a strong opportunity for LPG power generation, as natural gas makes up the majority of the generation mix (used in 60% of power generation – see Figure 5). This opportunity is compounded by the fact that the government aims to reduce its dependence on natural gas to produce electricity.

FIGURE 4: HISTORIC & FORECAST ELECTRICITY, GAS AND DIESEL PRICES IN ARGENTINA.



SOURCE: CAMMESA, World Bank AND DELTA-EE ANALYSIS

### Electricity & natural gas grid infrastructure – The need to replace existing power generation capacity, with the aim of moving away from natural gas all play in LPG’s favour.

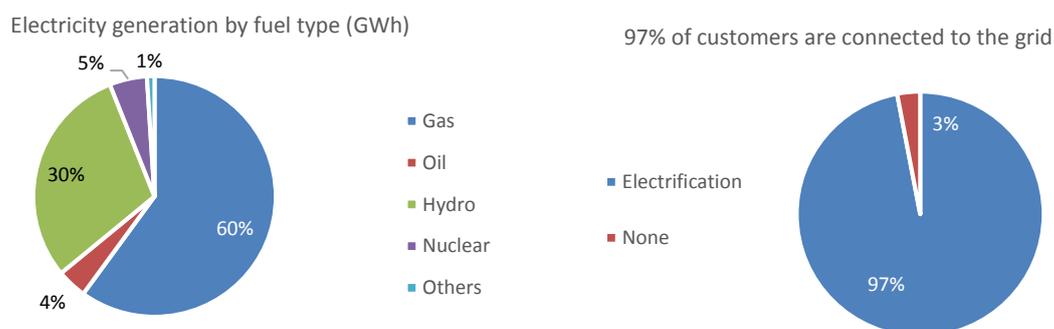
Key characteristics of Argentina’s power sector are increasing demand for electric power (at a rate of ~6% annually), coupled with aging, inefficient electricity generating capacity (70% of the country’s conventional installations have been described as ‘obsolete’), and high operational costs. Natural gas is the dominant fuel for generation and demand for it is growing (consumption has increased by ~18% since 2005). However, not being available for large parts of the year due to the fact that it is diverted to homes during the winter months, along with its general availability declining (domestic oil and gas production has dropped by 12% and 20% respectively compared to 2005 levels), means that the country has to import large quantities to meet its generation needs, and has had to plan blackout events for certain areas.

The Argentinian government is seeking to increase its domestic natural gas production by further exploiting its 802 trillion cubic feet of shale gas resources (the second-largest shale gas reserves and fourth largest shale oil reserves globally), with the aim of halting LNG imports by 2022.

This refocus on domestic production of shale oil and gas should substantially increase the availability of propane on the domestic market, however according to experience in the USA and China for example, it may take 6-9 years for a shale area to reach the stage of full commercial development. In 2015, unconventional gas (including shale and ‘tight-sands’ gas) accounted for 15% of Argentina’s domestic gas production, and industry forecasts suggest that unconventional gas production will grow by 13% year-on-year to 2030 (with a total of 9,800 unconventional wells to be drilled in the period 2016 – 2030). However, with conventional gas production forecast to steadily decline over the same period (at around 4% annually), it is expected that Argentina will remain a net importer of gas through to 2030 at the earliest (unconventional gas production is expected to overtake conventional gas production in 2025). Therefore, to 2022, we expect gas shortages to remain an issue – but becoming less critical during the next five or so years, providing a short-term opportunity for LPG to make up for the shortfall.

To meet rising power demand, it is estimated that domestic power generation will need to increase by 900 MWe/yr up to 2025, with the government’s aim for renewables to represent ~48% of this growth (10 GW). However, the government also aims to increase installed capacity of conventional technologies (investing ~\$6bn), by adding 8 GWe of dispatchable energy by 2025 replace old LNG assets and add back-up power generation assets. Annual tenders for this capacity will amount to around 800 MWe. There should be room for LPG Power Generation to claim a portion of this opportunity. During winter months, industrial facilities usually use diesel to meet their power needs, while diverting natural gas to residential consumers for space heating. LPG could provide a more economic, cleaner option here too.

FIGURE 5: BREAKDOWN OF ELECTRICITY GENERATION MIX AND ELECTRIFICATION RATE IN ARGENTINA TODAY



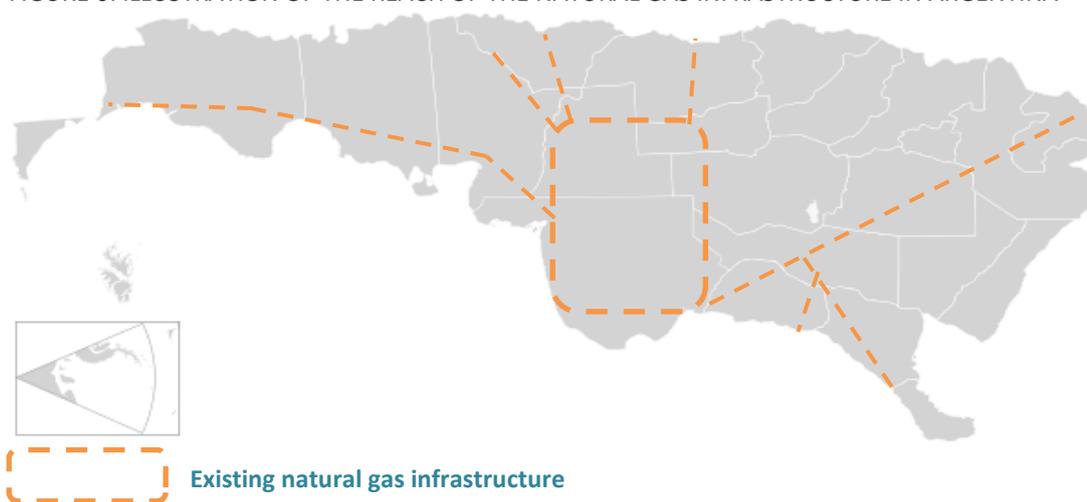
SOURCE: IEA, 2017

SOURCE: World Bank, 2017

The Ministry of Energy aims to improve existing grid infrastructure and build new transmission lines in order to supply the population and ~150,000 industrial and commercial users with reliable power and eliminate significant transmission bottlenecks in the national grid. To help with this, the government plans to increase the supply of electric power from neighbouring countries (for example a 1 GWe HV line from Bolivia).

Argentina possesses a comprehensive natural gas pipeline infrastructure (see Figure 6) and a highly developed and mature internal market. However domestic LNG supply (which reached 1.3 trillion cubic feet in 2015), is insufficient to meet the country’s needs.

FIGURE 6: ILLUSTRATION OF THE REACH OF THE NATURAL GAS INFRASTRUCTURE IN ARGENTINA



SOURCE: DELTA-EE

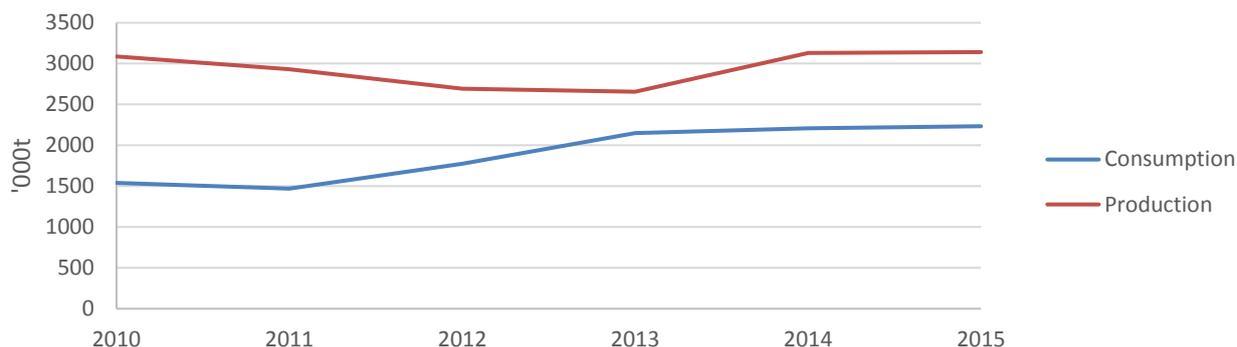
**Policy & regulatory framework– LPG may be able to beat stiff competition to profit from new capacity tenders**

Along with the other challenges outlined above, Argentina has previously suffered from a set of regulations that have complicated investments in power generation and distribution. Now, the government is seeking to remedy the situation by introducing more market-friendly policies. This has yielded cautious optimism among investors in the country’s energy projects. However, further clarity is needed within the regulatory framework to provide LPG investments with long-term confidence.

Policy	Summary	Impact on opportunity for LPG
Compensation scheme for generation companies and increased tariffs to help the sector reduce its deficit	This scheme replaces the previous arrangement, which saw power generation companies being saddled with volatile cash from government owned utilities, which is dependent on subsidy pay outs by the government.	Positive: Higher spark spreads and more solid financial ground on which to base investments.
1 GWe tender for thermal energy projects, more tenders predicted in the future	30+ bids, 2,871 MWe awarded, 6,611 MWe offered (6.6x oversubscription)	Positive/negative: Lots of new opportunities to win projects, but clearly high competition for projects.
Establishment of a government trust fund of \$4 bn in grants, along with tax breaks, for renewable power plant developers	The government has awarded contracts to produce 1,281 MWe of clean energy through 30 different wind and solar power projects, helping the country meet its goal of raising clean energy output to 8% by the end of 2017 and 20% by 2025.	Negative: Will drive competition to LPG Power Generation via incentivising renewable power generation.
Renewable energy purchase obligation large commercial / industrial energy buyers	Binding renewable energy targets in the form of purchase obligation on energy buyers with an annual demand of more than 300 kWh. This requires these buyers to source at least 8% of their energy from renewable sources by the end of 2017, with the target rising by 4% every two years to reach 20% by 2025.	Negative: LPG not likely to be included in these purchase obligations – will reduce the amount of power generated from LPG that can be sold to these customers.

**Current LPG activities & deployment – Fewer players, involved in large scale infrastructure projects.**

FIGURE 7: LPG PRODUCTION AND CONSUMPTION IN ARGENTINA



Several global engine manufacturers are active in Argentina (illustrated below), many of which have projects in remote regions where pipeline access is currently difficult. Power shortages have resulted in a number of fast-tracked power plant orders, with companies like Wärtsilä benefiting from this. There is a big demand for dual fuel engines - Wärtsilä received 384 MWe of orders (consisting of five projects) for their dual fuel engines in 2016, three of which (totalling 192 MWe) will be installed in the central region of Santa Fe. As a result of the country’s new government’s openness to foreign capital, GE will invest \$10bn over the next decade to develop power plants, while Siemens will help create investment and provide financing for \$5.6bn in infrastructure projects, including gas-fired power plants.

### 4.3 Cayman Islands – With LPG infrastructure and storage already in place, LPG is well-placed to displace much of the power generation capacity which is currently met by diesel

Headlines on the outlook for LPG Power Generation in the Cayman Islands:

- There could be a good opportunity for LPG to replace much of the island’s diesel generation in the short term, if it can prove itself economically against LNG.
- The lack of action on renewables and interest in transitional fuels could work in LPG’s favour.
- There is already extensive LPG import and storage infrastructure in the country.

Below, we discuss the key factors that influence the outlook for LPG Power Generation in the Cayman Islands in more detail.

#### Energy prices – Reliance on diesel results in a volatile fuel price that LPG could take advantage of

Electricity for all power requirements in Cayman is provided by Caribbean Utilities Co.Ltd. (CUC), which operates under a licence from the Cayman Islands Government. Diesel, imported from refineries in the Caribbean and Gulf of Mexico, is relied upon heavily for generation, which makes the price of electricity higher than the global average. Reliance of CUC’s power generation on diesel fuel means that it is heavily subject to the volatility of the global oil market, with prices for diesel often changing quickly. The price for LPG on the island is already much lower than diesel and could decrease further due to relative newcomer Clean Gas Ltd breaking the almost 50 year-long monopoly by Home Gas on propane supplies on the islands.

#### Electricity & natural gas grid infrastructure – Strong push for LNG, but LPG could win the economic argument

The CUC’s power system comprises of 20 generating units (17 diesel generators, two gas turbines and one steam turbine) with a combined capacity of ~161 MW. In addition, the company has 4 x 1.5 MWe mobile generator units. Diesel fuel is transferred by pipeline from suppliers’ tanker terminals to CUC’s central power plant and storage facility on the outskirts of the capital, George Town (in the west of Grand Cayman).

Power supply lags demand. To correct for this, and to meet new demand, the CUC expects to need ~60 MWe of additional power capacity within the next 30 years. The CUC has indicated it aims to move away from diesel generation to cut the country’s carbon emissions (58% of which come from its diesel generators), seemingly towards (at least in the short term) LNG; the utility is working hard to establish a large LNG storage facility on Grand Cayman. However, several things may hinder this. One is the lack of space for a large LNG facility. A second is that, since the CUC can shift the cost of infrastructure upgrades onto end-user bills, converting existing infrastructure to LNG as well as building large new storage facilities is likely to hit consumer bills hard. Since there already exists LPG storage infrastructure (see section below), it is likely that converting to propane may be more affordable and quicker.

FIGURE 8: BREAKDOWN OF ELECTRICITY GENERATION MIX AND ELECTRIFICATION RATE IN THE CAYMAN ISLANDS TODAY



SOURCE: IEA, 2017

SOURCE: World Bank, 2017

**Policy & regulatory framework– Renewable aspirations but lack of concrete action may signal opportunity for LPG**

The government’s long-term goal is to accelerate the penetration of renewables in the generation mix from 0.9% currently to 70% by 2037, most of which will come from utility-scale solar PV (62%). Over the same period, it forecasts that ~11 MWe of additional ‘reliable transitional’ capacity will also be needed to maintain a reliable reserve margin.

Whilst this is the stated aim, progress towards this has so far been slow. The only large scale renewable development so far is a 5 MWe solar farm on the east of the island, due to be completed late 2017, which has been plagued with setbacks and rocketing costs. Analyses have cast doubt on the viability of the overall renewables goal due to the availability of acreage for renewable generation development. Some of this pessimism has perhaps filtered through to government – which in 2012 tried to finalise a more conservative renewable penetration target of 13.5% by 2030, and failed. The unwillingness of the Cayman government to show with action that they are fully committed to solar may provide an opportunity for LPG to convince the CUC that it is (at least in the short term) a better alternative to meet the gas in electricity generation capacity.

Policy	Summary	Impact on opportunity for LPG
CUC’s ‘CORE’ Renewable energy support program for residential and businesses generating energy from renewable sources (primarily solar).	FiT given to CORE generator (~\$0.30/kWh). Program has a limit of 6 MWe which was hit in March 2017, leading the utility to stop new connections to the national grid. It is likely this cap will be increased by 1-2 MWe in summer 2017.	Negative/positive: Rapid uptake of the scheme shows interest on the side of customers. However the scheme is still relatively very small (6 MWe of the CUC’s total 161 MWe) and there is currently very little large scale commercial interest, leaving a lot of scope for LPG to replace diesel generation.
Fuel Sector strategy – promote the introduction of alternative transitional fuels where it is proven to be economically advantageous	Where it is determined to be prudent and achieves the objective of balancing consumers’ interests, the use of transitional fuels such as liquefied natural gas (LNG) or compressed natural gas (CNG) will be considered for power generation over the period to 2037.	Negative/positive: Shows that natural gas may be considered first; however the focus on ‘best economic option’ and ‘balancing consumer interests’ falls in LPG’s favour.
An agreement with the government allows the utility to add infrastructure upgrade costs onto customer bills.	Infrastructure upgrades as well as cost of repairs is added to customer bills as a surcharge fee.	Positive: If the cost of converting to LPG can be shown to be cheaper than LNG then LPG will seem like a far more attractive option to customers.

**Current LPG activities & deployment – Lots of existing LPG availability and storage facilities**

There are two propane suppliers in Cayman; the incumbent, Home Gas, and the younger Clean Gas Ltd. Propane gas is supplied via the US, to the extensive existing storage operations of both companies on Grand Cayman, plus satellite branches on Cayman Brac. Whilst currently most of this propane gas is used for cooking in homes and for other gas-operated appliances like water heaters and clothes dryers, the companies have capacity to feed storage for the CUC for power generation.

Current diesel-based generation is supplied mainly by the engine developers MAN and BWSC. The two companies have been strategic partners with the CUC since 1998 and have designed and installed multiple diesel generating units on a turn-key basis (seven MAN engines provide nearly 90 MWe of the country’s power).

#### 4.4 Greece – Likely one of the strongest opportunities for LPG Power Generation in Europe, driven by lack of natural gas infrastructure throughout many of the country’s islands, and an ambition to move away from diesel

Headlines on the outlook for LPG Power Generation in Greece:

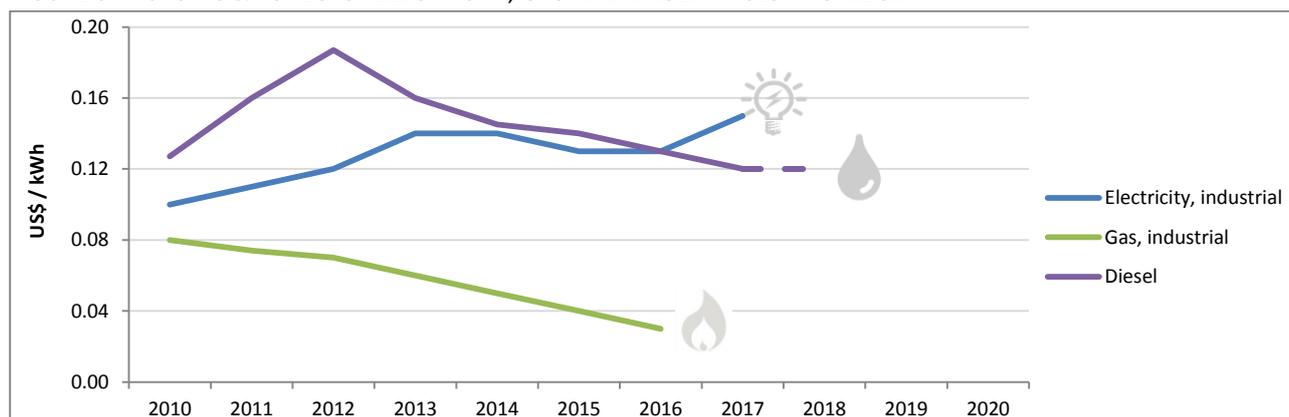
- Low and decreasing natural gas prices, along with plans to expand the reach of the natural gas infrastructure means LPG may find it difficult to compete as an electricity generation alternative.
- LPG may find opportunities, however, on many of the as yet non-interconnected Greek islands which currently use expensive diesel generators.
- There may also be potential to replace oil back-up generation and meeting the shortfall in domestic production during periods of high electricity demand.

Below, we discuss the key factors that influence the outlook for LPG Power Generation in Greece in more detail.

##### Energy prices – High diesel prices with weakening policy support presents a good opportunity for LPG

With natural gas becoming a larger part of the electricity generation mix in Greece and its price decreasing over recent years as a result of the drop in oil price (as illustrated in Figure 9), it will become more difficult for LPG to compete as an alternative electricity generation fuel. However, the use of oil stocks held by industry continues to be central to Greece’s emergency response policy. There may be an opportunity for LPG to replace much of this back-up generation by proving it can be a more economic, cleaner alternative.

FIGURE 9: HISTORIC & FORECAST ELECTRICITY, GAS AND DIESEL PRICES IN GREECE.



SOURCE: IEA, Eurostat, World Bank, IMF, DEPA AND DELTA-EE ANALYSIS

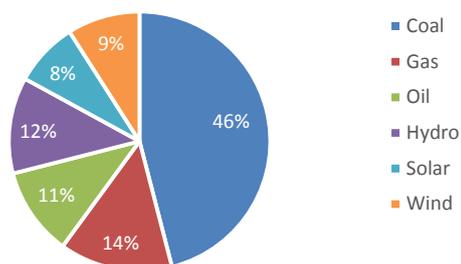
##### Electricity & natural gas grid infrastructure – Short / medium term opportunity to provide power to off-grid islands, but likely to be displaced by renewable sources in the longer term.

Among the 83 inhabited Greek islands, only 28 are interconnected to the main national power grid. These islands obtain their electricity primarily from diesel generators, which are subsidised to lower tariffs in these areas (720 million euros was spent by the government in 2016). Total production from these generators was 3,604 GWh in 2016. Current plans to connect the majority of these islands to the mainland by 2030 (see Figure 11) are likely overly optimistic, given the current economic situation. This therefore presents a sizeable opportunity for LPG to displace more expensive, carbon intensive options before more significant renewables penetration.

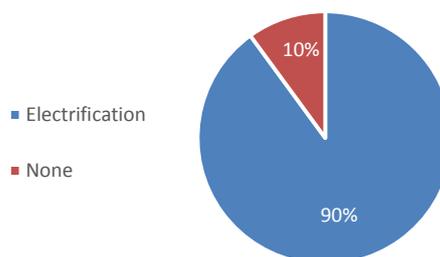
In the country generally, natural gas is increasingly playing a larger role in meeting the country’s electricity needs. However, it has to be imported at significant cost from Russia, Turkey and Algeria. Greece is looking to sign new contracts for gas supplies as well as develop the transmission system (by updating the existing LNG terminal, building a new pipeline and an underground gas storage facility). However, Greece struggled to meet its growing gas demand during winter 2016. LPG could provide part of the solution in the short term if Greece faces similar gas shortages in the near future. Gas power producers are also required to hold back-up reserves (at least five days’ worth) of alternative fuel – LPG could provide this alternative, at least in part.

FIGURE 10: BREAKDOWN OF ELECTRICITY GENERATION MIX AND ELECTRIFICATION RATE IN GREECE TODAY

Electricity generated by fuel type (GWh)



90% of customers are connected to the grid



SOURCE: IEA, 2017

SOURCE: World Bank, 2017

FIGURE 11: ILLUSTRATION OF THE REACH OF THE NATURAL GAS INFRASTRUCTURE AND PLANNED ELECTRICITY CONNECTIONS IN GREECE



SOURCE: DELTA-EE

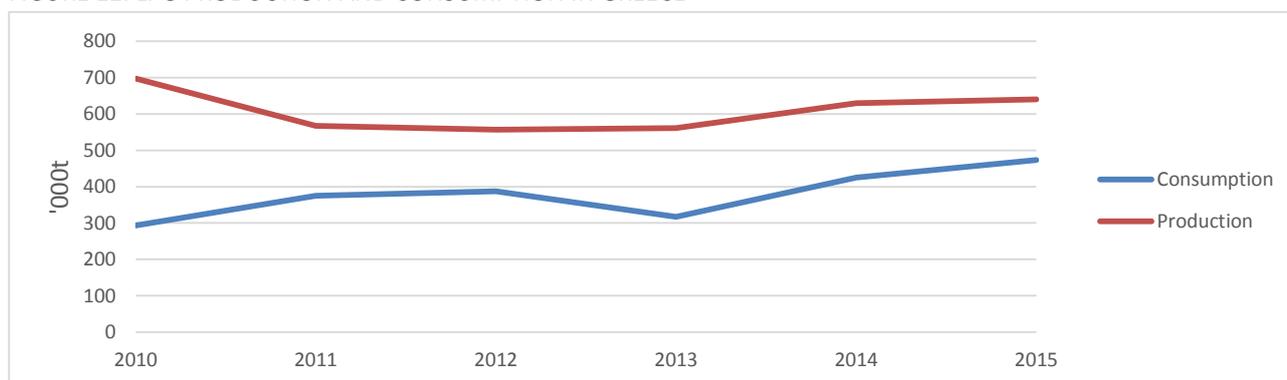
**Policy & regulatory framework – Support mainly for renewable generation**

The Greek energy market is undergoing structural changes to meet the challenges of the implementation of the EU target electricity model – part of the ‘ENTSO-E’ effort to integrate European electricity markets. This involves the creation of a more liberalised market in the wholesale, retail and generation sectors in electricity and gas, privatisation of state assets, as well as the support of new renewables.

Policy	Summary	Impact on opportunity for LPG
Promotion of electricity from renewable sources – aiming to install 2.5 GWe of new renewable capacity by 2020.	From 2017 electricity from renewable sources and combined heat and power (CHP) fed into the transmission system in Greece is promoted through a feed-in premium (FiP) granted by participation in “technology specific” tenders.	Negative: FiPs have reduced the cost of RES electricity production (162 €/MWh in 2016 compare to 200 €/MWh in 2014). This will make it more difficult for LPG generators to compete unless they also take advantage of support for high-efficiency CHP.
Tax relief and subsidies for CHP, hydro and RES	Support for CHP plants, hydro-power plants, and self-production using other RES in the form of subsidies and tax relief.	Negative/positive: Support is targeted at renewables - but may be support for LPG if used within CHP projects.

**Current LPG activities & deployment – Lots of players active with growth in LPG use and infrastructure planned**

FIGURE 12: LPG PRODUCTION AND CONSUMPTION IN GREECE



Greece has major LPG import/export terminals in Aspropyrgos and Elefsis, both of which are close to Athens.

Many of the global engine manufacturers are active in Greece, a good number of which already have installations on the islands. Wärtsilä, Mitsubishi, MAN, B&W have provided engines to Greek islands in the past, which run mainly on heavy fuel oil. Deutz and CAT have supplied natural gas engines.

## 4.5 India – With wide-spread LPG infrastructure already in place, India represents a strong opportunity for LPG Power Generation, especially in regions of no natural gas grid and expensive diesel

Headlines on the outlook for LPG Power Generation in India:

- Good opportunity in the short to medium term for LPG to displace diesel generation, either where there is no electricity grid access or where the grid is unreliable
- Opportunity to utilise pre-existing LPG storage and distribution infrastructure from government schemes to promote LPG as a clean cooking fuel.
- Long-term potential may be limited as grid extension and reinforcement will remove need for supplementary generation and electricity fuel mix will be dominated by cheap coal and increasingly low-cost renewables, especially onshore wind and solar PV.

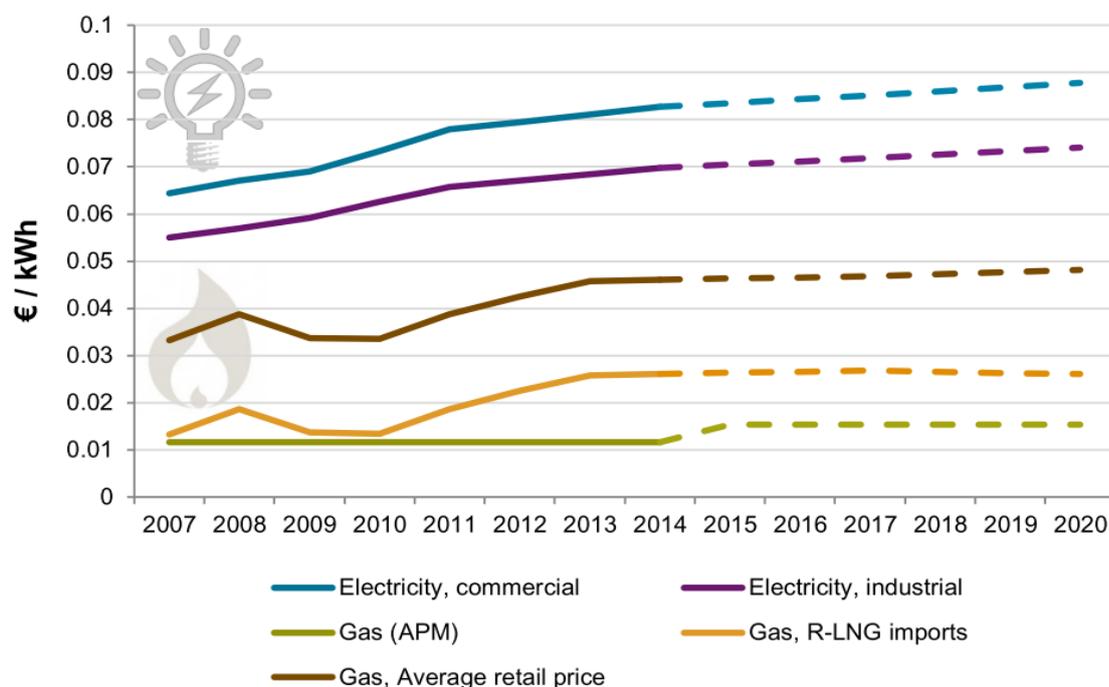
Below, we discuss the key factors that influence the outlook for LPG Power Generation in India in more detail.

### Energy prices – Electricity

Energy prices are greatly regulated in India and electricity prices are heavily subsidised: electricity prices for industrial and commercial users are double the rate charged to agriculture and domestic users, though there is considerable variation between States. On average, electricity prices are twice those of natural gas (see Figure 13).

Diesel is considerably more expensive, at roughly €0.2/kWh, and is predominantly used in areas without access to the electric grid or where the grid is unreliable. In the short to medium term there is an opportunity for LPG, which is considerably cheaper, to replace diesel in this fuel mix whilst the grid is extended and reinforced.

FIGURE 13: HISTORIC & FORECAST ELECTRICITY AND GAS PRICES IN INDIA



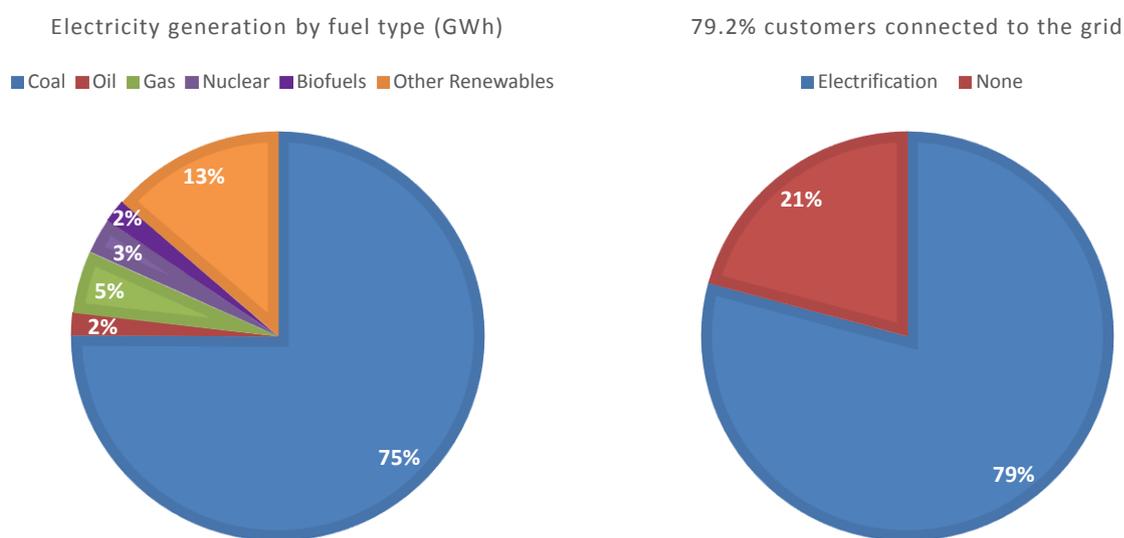
SOURCE: IEA, Eurostat, World Bank, IMF AND DELTA-EE ANALYSIS

**Electricity & natural gas grid infrastructure – Opportunity for LPG to displace diesel generation as supplement to expanding and unreliable electric grid**

79% of India’s population has access to electricity (see Figure 14) and the government is working towards achieving universal access as a matter of priority. The population without access is concentrated in a relatively small number of states, notably Uttar Pradesh and Bihar. India faces chronic power shortages with frequent electricity grid failure as continued economic expansion coupled with greater access to electricity, urbanisation, and population growth places the grid under excessive pressure.

Back-up diesel generators are prevalent (over 90 GWe installed generating capacity), used especially by industrial and commercial customers and India’s growing middle class. This poses an opportunity for LPG as a cheaper alternative and much of the necessary distribution and storage infrastructure already exists due to previous government policies encouraging LPG as a clean cooking fuel.

FIGURE 14: BREAKDOWN OF ELECTRICITY GENERATION MIX AND ELECTRIFICATION RATE TODAY



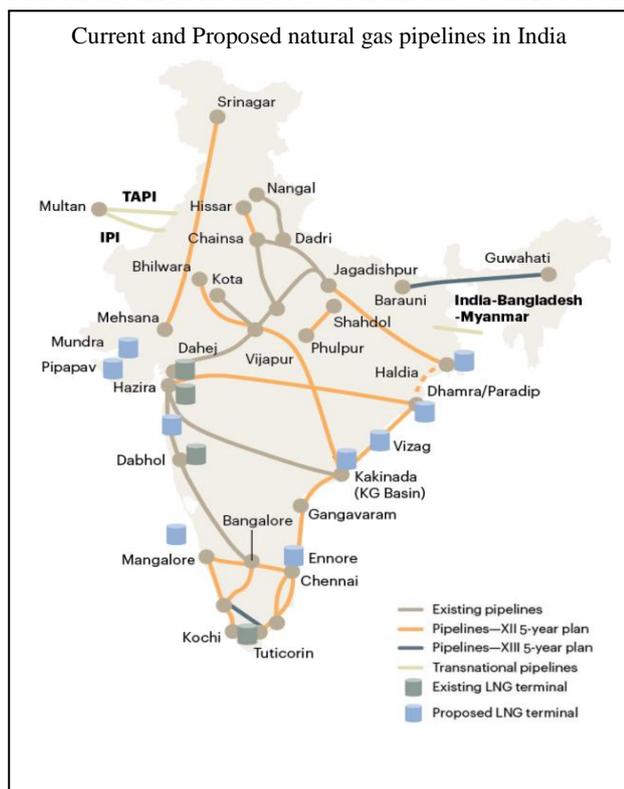
SOURCE: IEA, 2017

SOURCE: World Bank, 2017

Access to natural gas varies considerably across India (see Figure 15), with a few states such as Gujarat, Maharashtra, and Uttar Pradesh consuming more than 65% of the available gas, while other states have no access mainly due to a lack of pipeline infrastructure. India’s natural gas market has a supply deficit primarily resulting from low domestic production and inadequate transmission and distribution infrastructure, which has resulted in increased dependence on imported LNG.

There is a moderate opportunity for LPG Power Generation, though this is limited by a government focus on increased wind and solar PV deployment to meet rising energy demands instead of natural gas, whose share in the generation mix is not forecast to rise significantly.

FIGURE 15: ILLUSTRATION OF THE REACH OF THE NATURAL GAS INFRASTRUCTURE IN INDIA



**Policy & regulatory framework – Policy focus is on electricity grid expansion coupled with increasing share of renewable generation; potential for LPG to benefit from favourable LPG policies in other sectors.**

India has pledged to cut the emissions intensity of its economy by 33-35% by 2030 against a 2005 baseline. To achieve this, it aims to source 40% of electricity from renewable and low-carbon sources, especially onshore wind and solar PV. While this limits the potential for LPG power generation in the long-term, in the short and medium term there is a strong potential for LPG generators to be used in lieu of the electricity grid, which requires significant reinforcement to be suitable for decentralised generation e.g. solar PV and onshore wind.

Policy	Summary	Impact on opportunity for LPG
<b>Pradhan Mantri Ujjwala Yojana (PMUY)</b>	Heavily subsidised domestic LPG connections to encourage clean cooking	Positive: broadens market and ensures necessary infrastructure for widespread delivery.
<b>Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY)</b>	Rural electrification programme to provide electricity to villages of 100+ inhabitants and free electricity to those below the poverty line.	Positive: potential for LPG generators in places without electricity and to provide back-up power in event of grid failure.

**Current LPG activities & deployment – Dominant LPG use is in domestic sector as an alternative clean-cooking fuel**

India has become the second-largest domestic LPG consumer in the world due to the Narendra Modi government’s rapid rollout of clean fuel plan for poor households and fuel subsidy reforms. This has resulted in the domestic distribution sector having the highest consumption of LPG (88%).

India produces about half of LPG for domestic consumption and has almost 18,000 LPG distributors and 182 million state- and company-wise customers. State-owned oil marketing companies (PSU OMCs) have a total of 188 LPG bottling plants all over India, and a total of 677 Auto LPG Dispensing Stations for catering to LPG demand in the automotive sector.

## 4.6 Indonesia – One of the strongest potential markets for LPG Power Generation

Headlines on the outlook for LPG Power Generation in Indonesia:

- High diesel prices, reduction in subsidies for diesel and an 11% share of electricity generation coming from oil/diesel presents a good opportunity for LPG Power Generation to displace this.
- Growing electricity demand and plans to incentivise and accelerate deployment of generation capacity could support LPG Power Generation deployment in the near term.
- Expansion of the natural gas grid will make it tough for LPG Power Generation in the long term.

Below, we discuss the key factors that influence the outlook for LPG Power Generation in Indonesia in more detail.

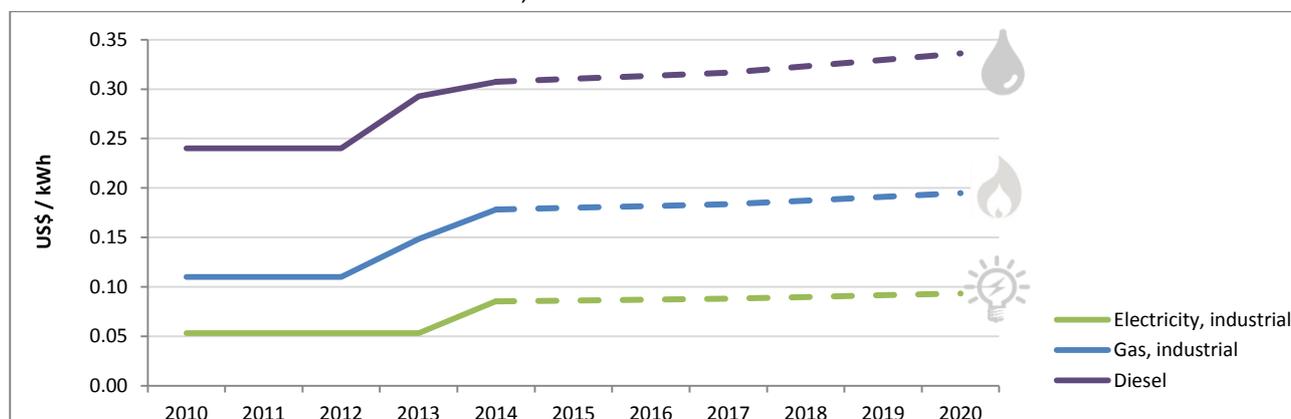
### Energy prices – High diesel prices with weakening policy support for diesel presents a good opportunity for LPG

A high share of coal in the power generation mix (over 50%) results in low electricity prices of ~US\$0.09/kWh (illustrated in Figure 16) in Indonesia currently. Competing with this will be difficult for LPG today, but where power generation is fuelled by diesel (expensive and currently used in ~5,000 gensets across the country) and heavy fuel oil (commonly used at industrial sites), LPG presents a more economically attractive option.

Ambitions to expand the natural gas network in Indonesia will likely increase the share of natural gas used for power generation in the longer term, reducing the opportunity for LPG. Yet, natural gas is currently priced at ~US\$0.18/kWh for industrial consumers (double that of electricity), which could provide an opportunity for LPG Power Generation.

Global oil prices are gradually re-bounding, and if they rise significantly, the government will have to choose between the unpopularity of local electricity price hikes, or the budgetary risk of re-introducing energy subsidies. We anticipate a middle-ground, whereby electricity prices will likely increase (1 – 2%/yr), modest price rises in the period to 2020.

FIGURE 16: HISTORIC & FORECAST ELECTRICITY, GAS AND DIESEL PRICES IN INDONESIA.



SOURCE: PLN, PGN AND DELTA-EE ANALYSIS

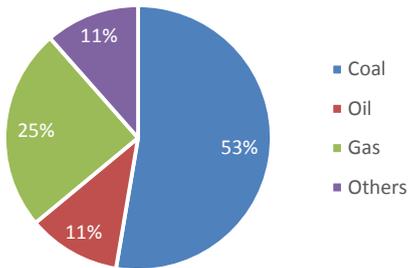
### Electricity & natural gas grid infrastructure – A short term opportunity to support electrification and meeting a growing electricity demand, but likely to be displaced by natural gas / renewable sources in the medium term.

With around 11% of electricity generation from oil (illustrated in Figure 17 below), there is a good opportunity for LPG to displace, or compete with, these generation plants with less carbon intensive options. A strong drive from Government to extend the natural gas grid could result in this window of opportunity being limited, but natural gas will likely be targeted at displacing coal fired generation first – which accounts for over 50% of electricity generation.

A growing economy and growing energy demands put further stress on an already weak electricity grid which currently covers ~80% of the country (illustrated in Figure 17). The Indonesian archipelago currently suffers from lengthy blackouts – spurring the need for distributed power. The Government of Indonesia (GoI) estimates that electricity demand will likely rise by 5-8% p.a. to 2020, resulting in additional power generation (potentially in remote areas) and extension of the electricity grid will be required.

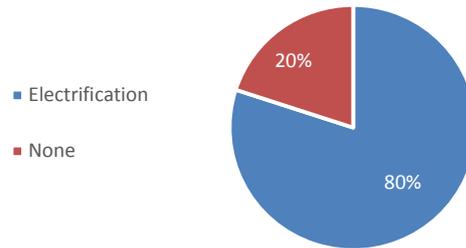
FIGURE 17: BREAKDOWN OF ELECTRICITY GENERATION MIX AND ELECTRIFICATION RATE IN INDONESIA TODAY

Electricity generation by fuel type (GWh)



SOURCE: IEA, 2017

80% of customers are connected to the grid



SOURCE: World Bank, 2017

Currently, there are Government plans to improve the natural gas grid and increase gas supplies, as illustrated in Figure 18 below, with 50% of all gas produced to be used locally. The main gas demand centres – Sumatra and Java – are experiencing gas supply deficits, which could take over ten years to rectify.

FIGURE 18: ILLUSTRATION OF THE REACH OF THE NATURAL GAS INFRASTRUCTURE IN INDONESIA



SOURCE: DELTA-EE

**Policy & regulatory framework – Could encourage increased generation capacity and make LPG more economic**

The GoI policy focus is on energy supply security, which involves incentivising power plant construction (but no policy focused on LPG) and the use of local resources. Combined with the likely reduction in subsidies for diesel, this could make LPG Power Generation an attractive option.

Policy	Summary	Impact on opportunity for LPG
Direct Power Purchase Agreements (for power plant projects >10 MWe)	Incentivise power plant constructions in order to meet the 35 GWe additional electrical capacity goal by 2020, via enabling the State electricity firm (PLN) to directly purchase electricity produced by other players without the approval from the Energy and Mineral Resources minister.	Positive: Removing the need for ministerial approval should shorten the negotiation process between Independent Power Producers (IPPs) and PLN.
Reduction in diesel subsidies	The GoI has systematically reduced subsidies for diesel generation since 2012 and will continue to do so.	Positive: More opportunities to replace diesel gensets in remote areas (estimated installed base: ~5,000 - most of which are in the 250 kWe to 2 MWe size range).
FiT for renewable energy sources, plus tax incentives for bioenergy power plants	FiT scheme where the PLN is obliged to buy electricity generated from <10 MWe bio-energy power plants, aiming to promote renewables contribution in Indonesia's energy mix and make use of Indonesia's abundant bio-resources.	Negative: Will drive competition to LPG Power Generation via incentivising renewable power generation.

**Current LPG activities & deployment – Lots of players active with growth in LPG use and infrastructure planned**

Indonesia is the 4th biggest LPG importer in Asia (after China, Japan and India). In 2016, 6.67 million metric tons were used in the country, with the majority (~70%) imported. Annual LPG use is projected to increase by 5.7% per year up to 2019 – for use in power generation, cooking and other applications.

The state-owned oil and gas firm, Pertamina, plans to build new - and upgrade existing - LPG storage terminals to better manage growing imports over the next five years. This includes building two inland LPG storage terminals in East and West Java, upgrading the storage capacity of a terminal near Jakarta, and utilising terminals to help distribute LPG to the outer islands.

Several global engine manufacturers are active in Indonesia (illustrated below). Many of these have LPG offerings in their global portfolios, including Wärtsilä and GE. Wärtsilä also have multiple LPG plants in Indonesia, including the 190 MWe PLN Arun plant in Aceh and the 160 MWe Pltmg Bangkanai plant in Lahai district.

#### 4.7 Morocco – A more limited opportunity for LPG Power Generation. There may be some opportunity to use LPG as a ‘bridging’ solution in some areas until natural gas infrastructure is developed, but the high butane content of domestic LPG supplies is likely problematic

Headlines on the outlook for LPG Power Generation in Morocco:

- A high contribution to electricity generation from coal, with a focus on new-build renewable generation, may limit the opportunity for LPG
- LNG is currently favoured as the transitional fuel. Existing and future LNG infrastructure plans emphasise this.

Below, we discuss the key factors that influence the outlook for LPG Power Generation in Morocco in more detail.

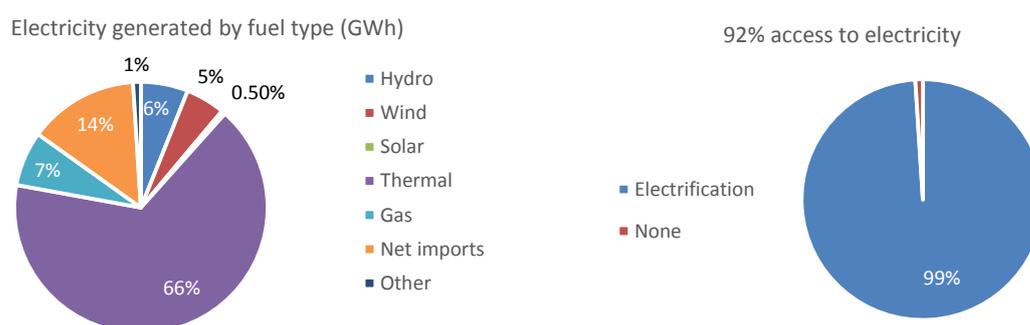
##### Energy prices – Fossil fuel subsidy slashes may impact coal but also LPG

Coal is the main electricity generation source in Morocco, offering the most stable prices and a relatively inexpensive price per kilowatt hour. In 2014, Morocco undertook significant steps in a gradual process of reforms to reduce subsidies for certain fossil fuels, including fuel oil for electricity generation. Diesel oil continues to receive a subsidy, along with butane – which could have a positive impact on LPG prices in the short term. However, in 2015, in its Intended Nationally Determined Contribution (INDC), Morocco announced further subsidy reforms for all fossil fuels. This will likely make coal less attractive as an electricity generation source, but may also reduce the economic advantage of propane gas / LPG.

##### Electricity & natural gas grid infrastructure – LPG may find it difficult to compete with plans for increasing renewables and LNG generation

According to Moroccan government projections, electricity generation from all fuels – except oil products – will increase to meet the additional 16,590 MW estimated to be needed by 2030. Coal remains the main component of the electricity mix (illustrated in Figure 19), and will do so until at least 2020, before its share declines around 2030. Natural gas is also projected to play a major role, with Morocco planning the construction of a new LNG importing terminal, which will supply 2,400 MWe of new combined-cycle gas turbines (CCGT). Both of these forecast increases are to provide dispatchable power to balance the intermittency of renewables. There could therefore be room for LPG to replace coal and compete with LNG in the near term. The country is also turning its attention to domestic unconventional fossil fuel deposits and progressively exploring the extraction of oil shale both on- and off-shore as well as nuclear energy.

FIGURE 19: BREAKDOWN OF ELECTRICITY GENERATION MIX AND ELECTRIFICATION RATE IN MOROCCO



Source: IEA 2016

Source: ONEE 2016

Morocco relies on imports for almost 95% of its energy requirements, and is heavily reliant upon imported oil, natural gas and coal to generate electricity. The vast majority of its natural gas is imported from Algeria (a mere 7% sourced from domestic production), and large quantities of electricity are imported from Spain (~15%). This means that the electricity and gas grids (which span almost the entire country) are connected to other countries via extensive international links. Morocco is also actively examining the possibility of exporting electricity to Europe and the Middle East - becoming a pivotal player in the future realisation of plans for a more interconnected international electricity grid, due to its strategic location and increasingly liberalised electricity market.

Morocco has a strong strategic motivation to source more of its energy for electricity generation from indigenous sources for both energy security and financial reasons, which could play in LPG’s favour - especially if plans to exploit domestic shale gas are realised. However, several factors continue to make imported electricity an attractive option, such as the fact that Spanish electricity is currently priced very competitively.

**Policy & regulatory framework – A supportive policy framework is expected to grow solar and wind significantly to 2030; LPG will have to compete with LNG to be the fuel of choice for additional dispatchable generation.**

Morocco has taken a series of bold steps to diversify its generation mix in the electricity sector. The government now identifies within its legal framework the national priorities of generation from renewables and increasing energy efficiency. Morocco’s recent successes with renewable energy deployment, achieving some of the world’s lowest bid prices for wind and solar CSP (Concentrated Solar Power), reflect not only its excellent natural resources but also the fact that it has established an environment conducive to renewables deployment. It is within this context that LPG must compete.

The national utility Office National de Electricité et de l'Eau Potable (ONEE) has a dominant role in Morocco’s electricity market as it owns the power transmission grid and operates throughout the whole value chain (generation, transmission and distribution). IPPs (although generating 53% of total consumed electricity) still have to rely on ONEE’s cooperation as there is no regulating authority yet established in Morocco. This could change as the market becomes more liberalised, but in the short term, at least for LPG to make headway in the generation mix, it is vital that LPG generators can convince ONEE of the fuel’s advantages over LNG (which is currently ONEE’s preferred choice when it comes to new dispatchable generation).

Policy	Summary	Impact on opportunity for LPG
Morocco National Energy Strategy (NES)	The strategy includes targets of reaching 42% installed RE capacity by 2020 and 52% by 2030 (to be met mainly from wind and hydro). An additional 2,400 MW of LNG is planned between 2016 and 2030 (reaching 23% of total power capacity in 2030).	Negative: Indicates Morocco’s enthusiasm for shifting away from fossil fuels and focusing on natural gas.
The Moroccan Solar Plan (Noor)	Created in order to boost Morocco's solar development. Noor aims to reach 2,000 MWe installed solar power capacity (PV and CSP) by 2020 and roughly 4,800 MWe by 2030 (additional 4,560 MWe from 2016 to 2030). The ‘Shemsi’ program complements this plan by supporting the development of solar hot water.	Negative/positive: Indicative of the country’s ambitious solar plans. However, large-scale solar PV is at an immature stage of development in Morocco, with the first plants still to be commissioned. A number of plans to develop selected solar sites for utility-scale PV have been recently announced, with over 1 GWe in various stages of development.
The Moroccan Integrated Wind Program	Ambitious plans to achieve 2,000 MWe installed wind power capacity by 2020 and up to 5,000 MWe by 2030 (additional 4,200 MWe from 2016 to 2030).	Negative: Wind is an especially low-cost source of electricity in Morocco, and its growth as a power source may reduce the opportunities available for LPG.

**Current LPG activities & deployment** – Due to current high volumes of LPG imported, there already exists extensive import/storage infrastructure which would benefit future growth in LPG power generation

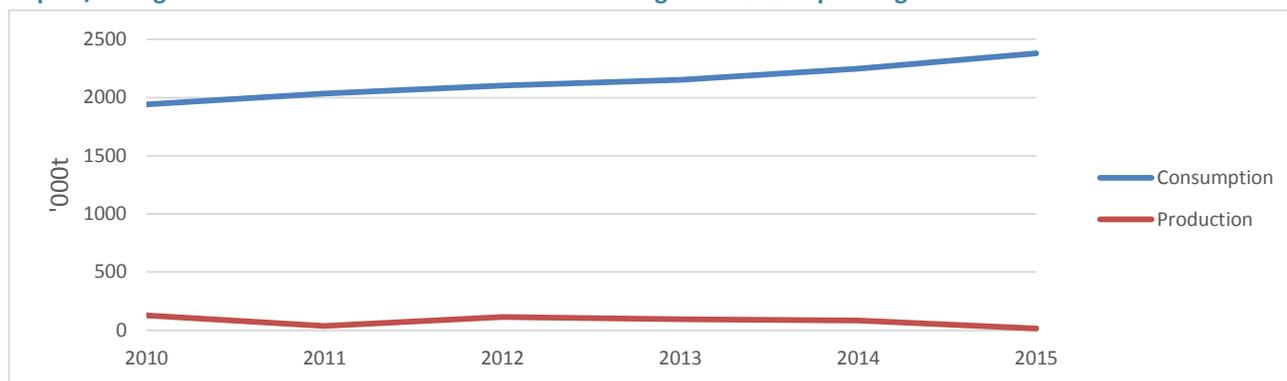


FIGURE 20: Morocco production and consumption of LPG

As shown in Figure 20, Morocco is a big consumer of LPG, but produces a relatively small volume domestically. Afriquia Gaz is the producer market leader. Consumption is predicted to grow by around 3.5% per year from 2015's 2.2 million tonnes to 2.8 million tonnes in 2020. The residential sector accounts for 86% of the total volume consumed, with LPG accounting for ~99%, 40% and 7% of all oil products used in the residential, commercial and industrial sectors, respectively. It is used in the residential and commercial sectors primarily for cooking and water heating. As these applications are gradually replaced with renewable heat (from e.g. solar) or electricity, this could free up storage/supply facilities of LPG to be directed instead towards power generation. However, post 2020 LPG will likely see increasing competition from LNG.

As part of the country's integrated energy strategy, Morocco aims to become a hub for the transit of gas from Africa to Europe. To support this, a large storage facility for hydrocarbons (diesel, LPG and gasoline, amongst others) is planned in Nador West Med Port (to be completed in 2020), adding to the capacity already available at Tanger-Med Port. This will enable higher quantities of LPG product to be refined and for domestic supply to be shored up.

#### 4.8 Philippines – With limited natural gas infrastructure in most areas of the country, the use of LPG as a ‘bridging’ fuel presents a strong opportunity in the next 10 to 20 years.

Headlines on the outlook for LPG Power Generation in the Philippines:

- Strong economic growth, limited natural gas infrastructure in most areas, high energy prices and issues with energy security present a strong opportunity for LPG Power Generation.
- Growing electricity demand will likely result in LPG Power Generation deployment in the short and medium terms.
- Availability of oil and gas reserves and development of natural gas infrastructure in the longer term could displace some LPG Power Generation, but the case for using LPG in the preceding years as a ‘bridging’ solution is strong.

Below, we discuss the key factors that influence the outlook for LPG Power Generation in the Philippines in more detail.

##### Energy prices – High electricity prices and issues with energy security present a good opportunity for LPG

Owing to its geography and 7,100 islands, the Philippines has strong issues in keeping its energy prices low. These have been increasing at a near constant rate for more than ten years after the removal of the Oil Price Stabilisation Fund and privatisation of the electricity sector in 2001, with the consequent reduction of subsidies. Electricity in off-grid areas is even more expensive. Furthermore, energy security has been a major issue recently with several blackouts throughout 2015 and 2016 caused by technical difficulties and natural disasters.

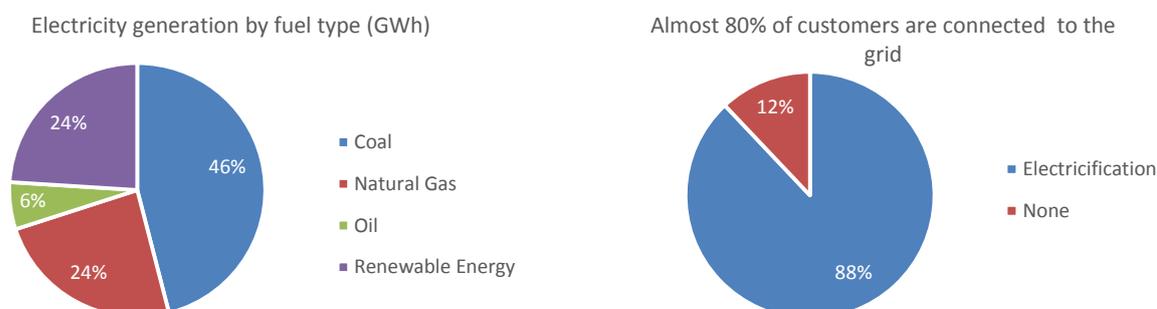
Please note: It has not been possible to collect reliable historic and current retail energy price data for natural gas and diesel in the Philippines. It should also be noted that there are large differences in energy prices across different regions of the country.

##### Electricity & natural gas grid infrastructure – Strong push for natural gas and renewables, but opportunity for LPG to displace diesel generation in remote locations

The Government committed to achieve a 90% household electrification rate by 2017, by expanding and improving the transmission and distribution network, interconnecting Visayas and Mindanao grids, increasing installed capacity and expanding the energy market from Luzon-Visayas to Mindanao.

Today, almost half of electricity generation is from coal today, which will be gradually displaced by a mixture of natural gas and renewables. Geothermal and hydro are responsible for over 20% of electricity generation. Diesel and oil currently account for 6% of power generation serving the most remote locations of the country.

FIGURE 21: BREAKDOWN OF ELECTRICITY GENERATION MIX AND ELECTRIFICATION RATE TODAY



SOURCE: IEA, 2017

SOURCE: World Bank, 2017

Existing natural gas infrastructure is largely limited to the North-west regions of the country, including the two most populous cities of Quezon and Manila.

FIGURE 22: ILLUSTRATION OF THE REACH OF THE NATURAL GAS INFRASTRUCTURE IN PHILIPPINES



**Policy & regulatory framework– LPG could solve the energy security issues in the short term before the ambitious infrastructural development program supporting natural gas and renewables is fully deployed .**

The Government has been actively encouraging private investments in the energy sector in the Philippines to help meet their ambitious infrastructure programme. From 2016 to 2030, 17,300 megawatts is needed to support the development plan of the Government, with additional power of 26,000 MW from 2030 to 2040 required. This totals 43,000 MW of new power generation capacity in the period 2016 to 2040.

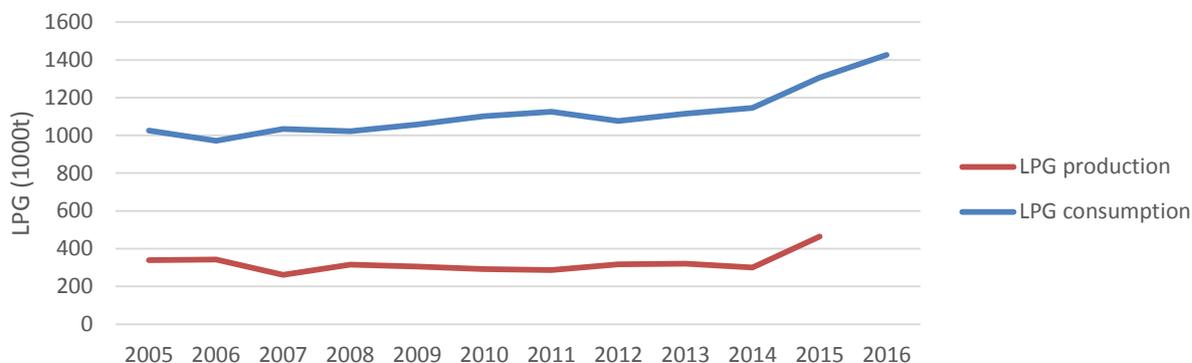
In 2012, it was estimated that the country’s required capacity to 2030 would be 13,166 MW of new capacities to meet domestic power requirement – energy demand and reserve margin. 1,766 MW will be provided by committed power projects, while the remaining 11,400 MW will be available for private sector investment. Of the 11,400 MW, 8,400 MW will be baseload plants, 2,100 MW mid-range plants, and 900 MW peaking plants.

Policy	Summary	Impact on opportunity for LPG
<b>Power Sector Development</b>	The development plans on power systems, transmission and distribution facilities and missionary electrification provide the platform to put in place long-term reliable power supply, improve the country’s transmission and distribution systems and attain nationwide electrification. Specifically, the Philippine Energy Plan (PEP) highlights the implementation of critical power infrastructures to address possible power outages. Based on the Plan, the government will concentrate its efforts on the completion of committed power projects, as well as attract local and foreign investors to venture into indicative and potential power projects to include electrification projects.	Positive: Energy security has been a major issue in recent years with the occurrence of several blackouts. Currently most of the low-cost electricity production is currently produced by kerosene and diesel. Owing to its cleaner properties, there is a clear opportunity to use LPG in the short-term to combat the issue of energy security.
<b>Master Plan for Natural Gas</b>	Expanding natural gas as a fuel for the future. Includes LNG Master Plan, Infrastructure Development Program, Market Development Program	Negative: Will provide extensive infrastructure and natural gas imports that will decrease the attractiveness of LPG in the longer term – but this will take many years to be implemented.

**Current LPG activities & deployment – Growth in demand coupled with increased activity and plans for expansion.**

Philippines’ LPG yearly demand in 2016 was of 1.43 million metric tons, with the majority (~68%) imported. Annual LPG demand has increased at over 10% per year since 2014. This trend is expected to carry on at a lower rate (between 4 and 12%) due to the growing economy (especially manufacturing and construction sectors) and issues with energy security despite the cost and transportation challenges of LPG.

FIGURE 23: LPG PRODUCTION AND CONSUMPTION IN THE PHILIPPINES



SOURCE: Statistical review of Global LPG 2016 and DOE data

There are two LPG refineries and 28 import facilities in the Philippines with a total capacity of respectively 400 kT/year and 73 kT. Plans are being made to improve the efficiency and safety of the refineries as well as expanding their output. More than 75% of the LPG is consumed on the island of Luzon followed by Visayas (13%) and Mindanao (9%). Domestic use of LPG is the most common in the Philippines with the industrial and commercial sectors respectively consuming 26% and 14% of the total LPG demand. LPG’s demand is currently being met mixture of oil refineries and other LPG players. The largest players are Petron (36.3%), Liquigaz (23.3%), Prycegaz (12.7%), Isla Gas (12.7%), South Pacific (6.6%), Petronas (4.8%) and JG Summit (3.1%).

## Chapter Five

# Recommendations

### 1. Better positioning of the fuel – to policymakers and energy users

LPG, as a fossil fuel, increasingly faces an image problem alongside other fossil fuels, and this will likely remain one of the biggest challenges facing the industry unless now tackled effectively. We believe that this is an important strategic challenge across all fossil fuel sectors, including the natural gas and LPG industries. Overall, based on Delta-ee's detailed tracking of policy trends and developments in Europe and elsewhere, this challenge is not being addressed effectively enough. Until this can be done, then it will be more difficult or impossible to secure some of the policy developments that could accelerate uptake of LPG in certain applications.

The challenge is especially the case in Europe, but is set to become an even stronger issue globally. We do not see these trends going into reverse over time. At a time when the long-term energy scenarios for decarbonisation developed by influential policymaking bodies, including the International Energy Agency, anticipate a phasing out of all fossil fuels in many regions, we believe that it continues to be vital that the LPG sector supports other gas industry initiatives to identify potential roles for LPG that are both consistent with decarbonisation scenarios (such scenarios do exist) and maintain a role for it.

This will likely be a complex and long-term challenge to tackle effectively, with multiple facets to it. **We therefore recommend that as part of this strategy, the industry should develop and communicate a detailed vision of the role of LPG in a decarbonising energy future.**

We see no inconsistency between a continuing / expanding role for LPG in the wider energy market, and the trajectory to the decarbonising of energy systems over time to 2050 and beyond – but it is clear that many influential policymakers, energy research agencies, think-tanks and NGOs do, and therefore oppose incentivisation of high efficiency and low carbon applications such as CHP. Given that the use of LPG / natural gas is needed until energy systems can be fully decarbonised, it makes sense to utilise these fuels as efficiently as possible through such applications.

Priority: *High*  
Time-frame: *Short, medium & long-terms*

### 2. Better positioning for development finance for energy projects in emerging markets

For decades, there has existed a wide range of bilateral and multilateral sources of development finance for energy projects, especially those that are low carbon alternatives to conventional systems, or ones which increase access to electricity. We believe that the LPG sector could be better positioned for accessing some of this finance, given that the 'fossil fuel' label is likely to increasingly count against it unless addressed in the same way as described in 1 above.

**We therefore recommend that the development and environmental benefits of LPG as a fuel be strongly developed and promoted to these institutions**, most notably the World Bank, International Finance Corporation, Inter-American Development Bank etc. Much of the same material developed to better position the fuel for policymakers would be highly relevant for the development finance community also.

Priority: *Medium/ high*  
Time-frame: *Short / medium-terms*

### 3. Develop and encourage new business models LPG – new solutions and services

**We recommend detailed analysis of the opportunities for LPG players to operate in new, higher margin parts of the energy value chain through the development of new services and solutions.**

Value chains are in growing states of flux in almost all parts of the energy market, including power and heat generation. This is in large part due to:

- The growing struggles of energy companies and utilities around the world, mainly falls in their margins, and thus their need to develop new business models, services and solutions for the existing and new customers.
- The linked issue of the rapid development of intermittent renewables in all parts of the globe, the consequent pressures being placed on energy networks to ensure balancing of supply and demand – and the opportunities this is now providing to create value from solutions that help provide these balances.

LPG fuel suppliers will often find themselves in parts of the value chain where the margins remain relatively modest, or will come under increasing pressure in the future. As margins shift across existing value chains, and as new value chains develop, we are confident that there will be opportunities for the sector to participate in and create innovative new business models in many different applications, including flexible utility power generation, CHP, heating & cooling (eg through gas heat pumps and trigeneration). This could be in the form of finance providers, project developers, ESCO services, O&M etc. There are numerous examples in related sectors where fuel suppliers have successfully developed such services. The LPG industry and stakeholders should also be more effective in promoting LPG for power generation as an energy solution and in promoting LPG power generation systems suppliers.

*Priority: Medium/ high*

*Time-frame Short & medium term*

### 4. Indexation of LPG with other fuels

**We recommend that the sector explores the extent to which price indexing and the wider use of long-term LPG contracts can be used to help mitigate the risk of wide LPG price fluctuations, and its associated unpredictability.** This would give existing and new customers greater confidence in future fuel prices of the fuel and therefore in the future commercial viability of their operations.

Generally speaking, the use of longer term contracts is more common in LNG markets than in LPG. LPG is therefore more greatly exposed to, for example, seasonal changes and short-term shifts in the supply-demand balance. Competing LNG and diesel prices tend to be more stable and thus customers of those fuels face lower energy price risk overall. In addition, while diesel prices are generally higher than those of LPG currently, the volatility can often mask this feature in the eyes of end users.

We therefore believe that the industry should work together to explore to what extent prices can be better indexed against other fuels. No doubt this is a long-term challenge that may be fraught with complexities, but if some progress can be made, LPG users would likely face lower risks.

*Priority: Medium / high*

*Time-frame Short-term*

## 5. A comparison of emissions profiles of pollutants between LPG and other fuels

Emissions constraints and regulations are growing fast at local, regional and national levels worldwide. Northern Europe and California might have been the hotbeds of implementation up to now, but this is now expanding to emerging markets, China being one of the most notable examples.

Given that the emissions profiles (NO<sub>x</sub>, SO<sub>x</sub>, CO, particulates etc) of LPG in the various different use cases will be superior to almost all fossil fuels except natural gas itself, **we recommend that the industry undertake some independent analysis of these emissions comparisons with other fuels**, in multiple use cases and based on different prime move technologies, in order to demonstrate this benefit of LPG.

Priority:            *Medium*  
Time-frame        *Short-term*

## 6. Better understanding of the costs of local LPG infrastructure development

In this report, we have identified and characterised some of the most likely attractive markets for LPG in the short / medium terms. In these and other markets, the establishment of local LPG network infrastructure, based perhaps on one or more major ‘anchor loads’, could well be a catalyst for future demand growth beyond what could normally be achieved.

We believe this opportunity should be studied and assessed more deeply and **therefore recommend that an analysis be done to explore the relative costs / benefits of developing LPG infrastructure as against LNG infrastructure** in the priority markets we have identified – which may be less suitable for LNG because of natural limits on demand growth in future years.

Priority:            *Medium*  
Time-frame        *Short-term*

## 7. Exploring the opportunity of converting diesel engines for LPG use

There are hundreds of GWe of installed diesel engines around the world, many of which are in backup applications and operate rarely, depending on the reliability of the grid or of whatever form of on-site generation is already installed. While it is unlikely that the continuous operation of these engines using lower price LPG would be a better commercial proposition than the incumbent form of supply in many cases, **we do recommend that this potential opportunity is explored more analytically than up to now, in large part due to the sheer volume of existing installed infrastructure that exists**. Successful low cost conversion of some of this installed base would clearly open up major new markets for the fuel.

Priority:            *Medium*  
Time-frame        *Short / medium-terms*



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