FACTS GLOBAL ENERGY

Long-Term Price and Dynamics for LPG Markets

March 2024

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Modern Energy Cooking Services (MECS) is a seven-year programme funded by UK aid (FCDO) which aims to accelerate the transition in cooking away from biomass to modern energy. By integrating modern energy cooking services into energy planning, MECS hopes to leverage investment in clean electricity access, both grid and off-grid, to address the clean cooking challenge. Modern energy cooking is tier 5 clean cooking, and therefore MECS also supports new innovations in other relevant cooking fuels such as biogas, LPG (bio) and ethanol, though the evidence points to the viability, cost effectiveness, and user satisfaction that energy efficient electric cooking devices provide. The intended outcome is a market-ready range of innovations (technology and business models) which lead to improved choices of affordable, reliable and sustainable modern energy cooking services for consumers. We seek to have the MECS principles adopted in the SDG 7 global tracking framework, including integrating access (7.1) , renewables (7.2) and energy efficiency (7.3) and promote an informed integrated approach.

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Acronyms

Kt	Kilotonnes
ktpa	Kilotonnes per annum
mmt	Million metric tonnes
mmtpa	Million metric tonnes per annum
y-o-y	Year-on-year
LPG	Liquified petroleum gas
NGL	Natural gas liquid
rescom	Residential and commercial
GPP	Gas processing plant
VLGC	Very large gas carrier
LGC	Large gas carrier
MGC	Medium gas carrier
SAF	Sustainable aviation fuel
MSW	Municipal solid waste
HVO	Hydrotreated vegetable oil

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Outlook

Propane and Butane: Demand Outlets, End-Uses, and Long-Term Market Implications

LPG consists of propane and butane. It is primarily used in the rescom sector as a household cooking or heating fuel, accounting for around half of the global LPG demand. Cylindered LPG is especially handy for countries without a complete gas distribution network and is thus widely used for cooking in countries like Indonesia, India, and China.

Beside rescom usage, LPG has also been increasingly used as a petrochemical feedstock for petrochemical units such as:

- Steam Cracker: Thermally cracks propane/LPG to produce mainly ethylene and propylene.
- Propane dehydrogenation (PDH) unit: A catalytic technology to convert propane into mainly propylene.
- Butane dehydrogenation (BDH) unit: A catalytic technology to convert n-butane to mainly butadiene.

Petrochemical demand made up around a quarter of global LPG global demand in 2023. Petrochemical products produced include ethylene, propylene, butadiene, and isobutene that are essential building blocks for a range of products like plastics, rubber, textiles and automotive. Butane, while more costly, can produce higher value co-products like pygas and crude C4s.

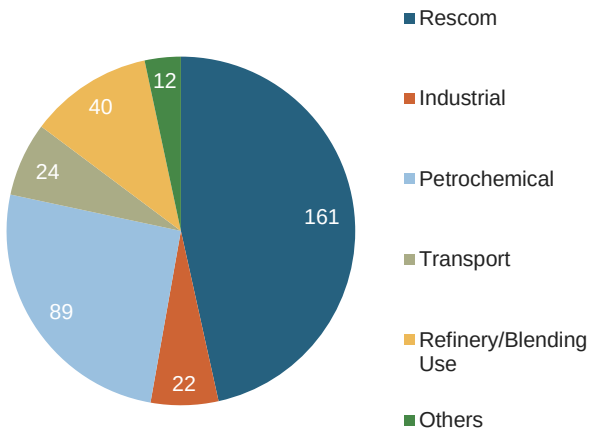
Furthermore, LPG is also used as autogas (Europe and North Asia), in the industrial sector as well as in other sectors such as city gas spiking, crop drying (North America) and gasoline blending.

Key Demand Drivers and Dynamics

The demand of LPG fluctuates seasonally depending on the countries' profile and needs. Typically, there would be higher rescom demand for LPG for heating during winter months. Guided by forward pricing and fundamentals, the US would have stock builds of propane inventories between spring and autumn to prepare for seasonal winter draw. In Japan, there is an increase in LPG demand for use in city gas spiking during winter. Seasonal trends are also evident in activities like gasoline blending and crop drying.

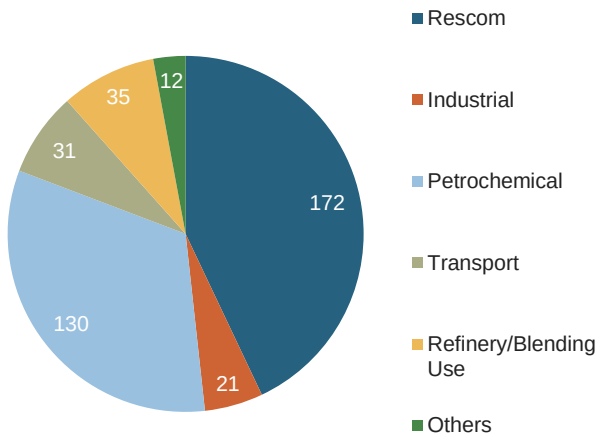
Going forward, we expect rapid petrochemical demand growth for LPG, which we forecast to rise from nearly 90 mmt (Fig. 1) in 2023 to 130 mmt in 2030 (Fig. 2). The greater global consumption of plastic would increase the need for LPG as a competitive feedstock. The demand of propane and butane as petrochemical feedstock depends on various factors, including the price spreads, cracker margins and product yield demand.

Fig. 1: Global LPG Sectoral Demand Breakdown 2023 (mmt)



Source: FGE

Fig. 2: Global LPG Sectoral Demand Breakdown 2030 (mmt)



Source: FGE

Petrochemical demand growth for LPG is spearheaded by China. This is in line with the country's goal for self-sufficiency (NDRC, 2016) in petrochemical derivatives by ramping up domestic petrochemical production capacity and supply, which in turn raises petrochemical demand for LPG. The wave of new PDH capacity coming online will lift the country's propane appetite.

Similarly, rescom demand is forecasted to increase from around 160 mmt in 2023 (Fig. 1) to 170 mmt in 2030 (Fig. 2). While growth in the usage of LPG in the rescom sector pales relative to the petrochemical sector, rescom would remain the biggest part of the pie in global LPG demand and is the key driver of growth in many Southeast Asian Countries. Most sub-urban or rural areas still need LPG for cooking and heating. Meanwhile, most countries in Southeast Asia lack actual or active plans from the government to replace LPG with alternative energy.

LPG Production Methods

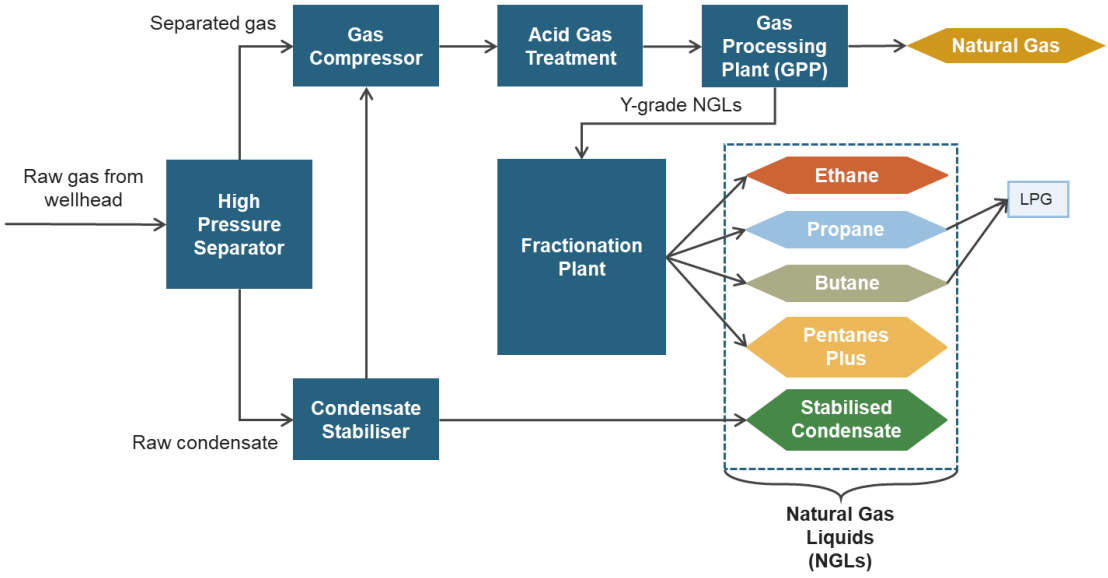
Global LPG production was over 350 mmtpa in 2023. There are two main LPG production pathways, either from natural gas processing or crude oil refineries, which makes up around 60% and 40% of LPG produced, respectively.

Gas Processing

A mixture of gases is extracted from gas reservoirs, the bulk of it being natural gas. NGLs, which contains LPG, make up a smaller fraction of around 10% of the total volume, though the exact percentage is highly dependent on the "wetness" of the gas reservoir. NGLs is separated out from natural gas at the GPP, then further fractionated through a fractionation plant to produce propane and butane.

Chart below shows the NGL fractionation process:

Fig. 3: NGLs Fractionation Process



Source: FGE

Refinery

LPG is a co-product of in oil refining, produced at different stages including the atmospheric distillation, reforming, and cracking steps. Refinery LPG yields are typically 1-4% of the crude oil processed, depending on the crude oil type, the degree of sophistication of the oil refinery and the relative market values of propane and butane compared to other oil products.

Key Supply Drivers and Dynamics

The principal driver of global LPG supply (especially propane) is the US. Following the shale revolution in the late 2000s, US seaborne LPG exports rose sharply from 25 mmt in 2016 to nearly 70 mmt in 2023.

We expect LPG exports from the West (mainly the US and also Latin America) to continue their upwards trajectory. Many US midstream companies are starting up gas processing plants in the Permian over the next few years, supporting the growth in Y-grade and LPG production. Besides, there are also higher investments to increase takeaway capacity from the Permian. With oil prices to remain high enough (WTI at US$70-80/bbl), this should incentivise oil producers to continue drilling.

We also expect growth in Middle Eastern LPG supply to be supported by upstream developments in the coming years. Several gas projects such as the Jafurah Basin development in Saudi Arabia, the North Field expansion in Qatar and the ramp up of the South Pars fields in Iran will sustain the region's LPG growth through the late 2020s and into the 2030s. The healthy pipeline of gas projects also eases the exposure of Middle Eastern LPG supplies to OPEC+ decisions on crude quota policies, with continued Middle Eastern supply growth in 2024 despite the extension of crude cuts being a case in point.

Market Structure

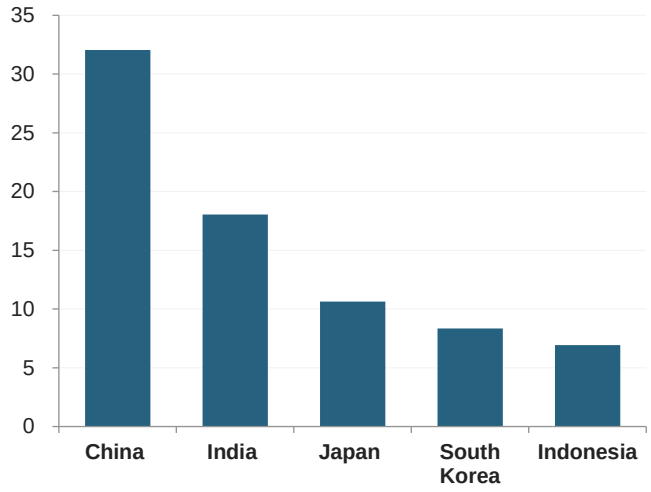
The global trade of LPG has grown in both magnitude and complexity since the US shale revolution in the 2010s. Currently, the global traded seaborne LPG market is around 130 mmtpa in 2023, up by 36 mmtpa since 2016. The outlook remains positive for the LPG trade, sustained by continued growth in upstream production and end-use demand.

In this section, we will give a brief overview of key importers, exports, and trade flows of the LPG market.

Key Importers

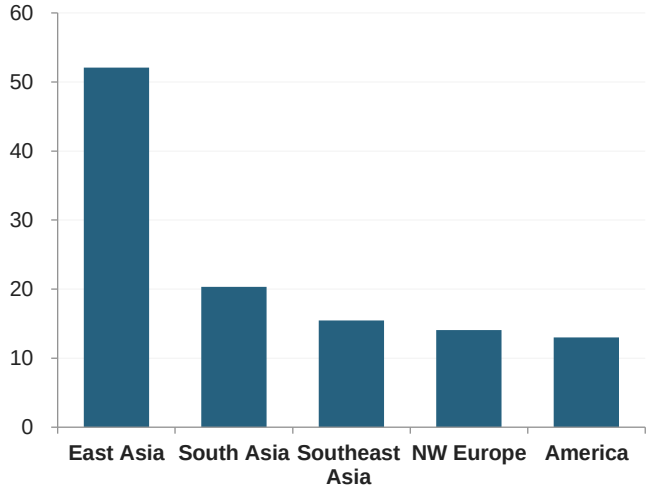
Asia remains the primary region for LPG imports, experiencing a growth from 55 mmt in 2016 to nearly 90 mmt in 2023. Figures 4 and 5 provide a breakdown of the leading importing countries and regions.

Fig. 4: Top 5 LPG Importing Countries in 2023, mmt



Source: FGE

Fig. 5: Top 5 LPG Importing Regions in 2023, mmt



Source: FGE

China is the largest LPG importer in the world, with imports satisfying about a third of China's LPG demand. Similar to demand, the country's import growth is largely driven by the petrochemical sector. There has thus been a rise in coastal petrochemical plants largely reliant on imported LPG, poised to sustain China's demand surge throughout the 2020s.

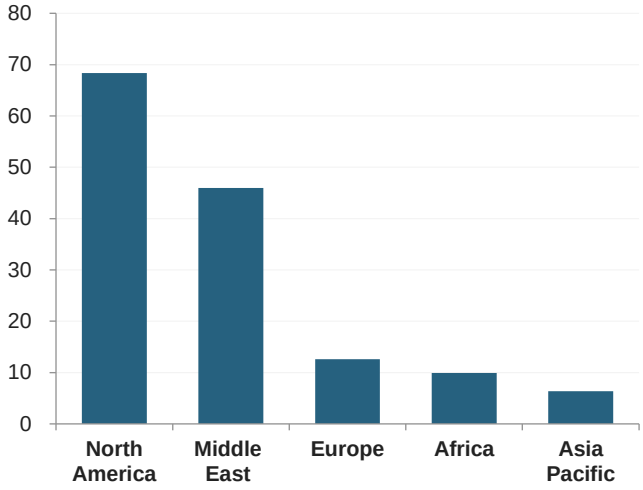
In India, LPG demand was largely fuelled by the rescom sector for cooking and heating, as many areas still lacked city gas pipeline connections. Approximately 57% of India's total LPG supply comes from imports. The consistent investments in India's LPG policies and infrastructure have significantly enhanced the availability of LPG for its population.

Europe is also a net importing region for LPG, amounting to around 25 mmt in 2023. Key importing countries by volume are Netherland, Belgium, and Turkey. The petrochemical sector represents the most significant end-use category in Northwest Europe, with LPG being utilised as a crucial feedstock for steam crackers.

Key Exporters

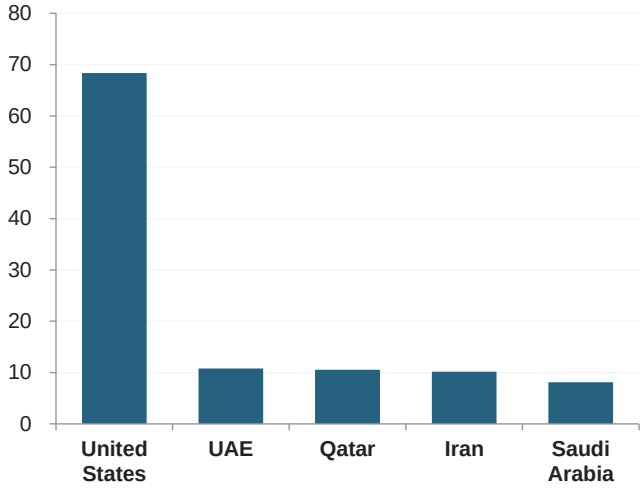
The primary regions for LPG exports are from North America (mainly the US) and the Middle East (Fig. 6). The two regions have overlapping markets (Asia) and prices that can mutually affect each other in global trade.

Fig. 6: Top 5 LPG Exporting Region in 2023, mmt



Source: FGE

Fig. 7: Top 5 LPG Exporting Countries in 2023, mmt



Source: FGE

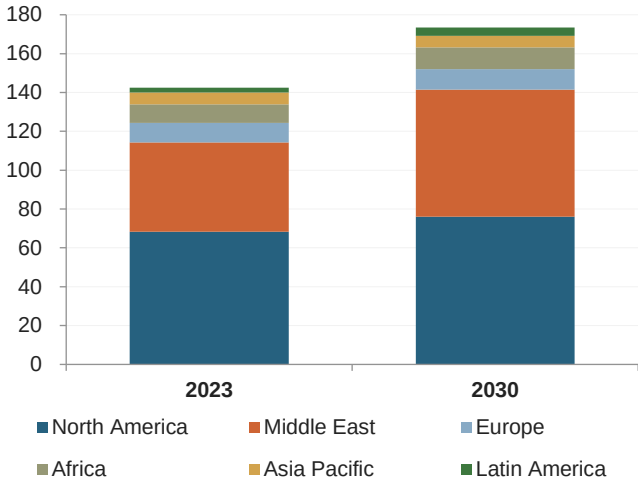
Among the Middle East countries, the key exporters are the UAE, Qatar, Iran, Saudi Arabia, and Kuwait, accounting for 98% of the region's LPG exports. The Oil and Gas Industries were predominantly managed by state-owned entity such as Saudi Aramco, ADNOC, QatarEnergy, and Kuwait Petroleum Corporation (KPC). Almost all LPG exports from the Middle East are directed towards Asia. However, in the last decade, the Middle East has met rising competition from the US in the Asia market.

Since the shale revolution, the US has transitioned from being a net LPG importer to the world's largest LPG exporter (Fig. 7). The annual exports from the US have more than tripled from 12 mmt in 2014 to nearly 70 mmt in 2023. The US increasingly expanded its market to the Asia, especially in countries like China, Japan, and Korea. Seaborne LPG exports from the US are predominantly concentrated along the Gulf Coast, utilising major ports like Houston, Freeport, Beaumont, and Corpus Christi.

Global Trade Flows

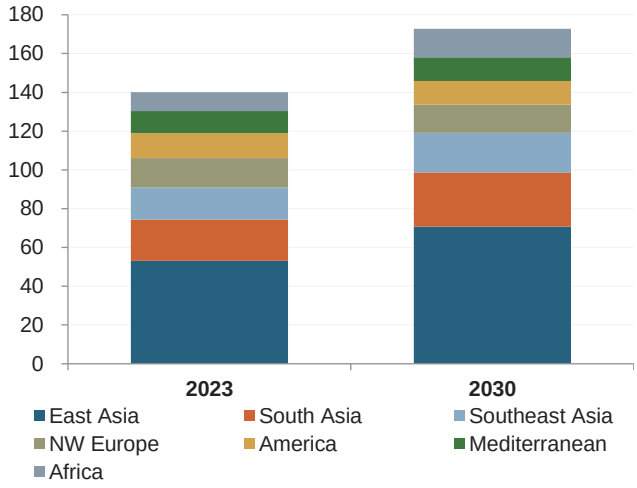
The East used to boast a larger seaborne trade market for LPG with increasing exports from the Middle East feeding the rising demand in Asia. However, since the shale revolution, the West (mainly the US) has increasingly expanded its market to the East, driven by the rising petrochemical sector and in some countries, the rescom sectors. The demand pull from Asia will likely remain firm in the coming years. Figures 8 and 9 show the LPG export and import growth by region, respectively.

Fig. 8: LPG Exports by Region (Forecast), mmt



Source: FGE

Fig. 9: LPG Imports by Region (Forecast), mmt



Source: FGE

In 2023, the Middle East exported 46 mmt of LPG where about all of them ended up in Asia. Middle East also accounted for nearly all of India's LPG imports of 18 mmt. Ultimately, beyond what Asia imports from the Middle East, the marginal demand of Asia is supplied mainly by the US and other sources in the West of Suez. In 2023, the US exported 68 mmt of LPG in which around 37 mmt went to Asia, 12 mmt to America, 11 mmt to Europe and 7 mmt to Africa. LPG exports from the West might fluctuate depending on the production situation of Middle East LPG and the congestion at the Panama Canal.

The bulk of the seaborne LPG trade is transported on refrigerated VLGCs (Very Large Gas Carriers) which can carry 44 – 46 kt of LPG per shipment. The bulk of VLGCs (and Medium Gas Carriers, or MGCs and Large Gas Carriers, or LGCs) trade primarily occurs across continents or larger distances. In contrast, regional LPG trade largely involve smaller, pressurised LPG vessels, with the largest carrying some 7 – 8 kt of LPG per shipment.

Pressurised LPG trade include revolves around the exports of pressurised cargoes from suppliers (typically refineries), and break-bulk or re-export activities. The latter refers to breaking up big, refrigerated LPG cargoes into small parcels at LPG import terminals or via ship-to-ship in hubs like the Nipah anchorage or the gulf of Thailand. Some South Korean and Japanese importers also re-export some LPG on pressurized vessels into China amid the saturated and slowing domestic demand. In general, pressurised trade occurs within some regions in Asia Pacific, Northwest Europe, and the Mediterranean.

Pressurised trade still plays an important role for countries with smaller terminals that lack the required receiving facilities and capacity for large vessels. For instance, Bangladesh mainly imports via pressurised cargoes, notably to Mongla port, as the country lacks a refrigerated terminal. Nonetheless, the freight costs for the pressurised trade typically exceed the refrigerated VLGCs trade due to the lack of economies of scale. Consequently, traders would strategically position their VLGC to optimise shipping distance and minimise incurred costs.

Case Studies

Introduction

Globally, the direction of LPG uptake varies across regions. Across the developed world, markets tend to be matured and gas grid penetration tends to displace some LPG use as well. A drive towards sustainability and zero carbon has also seen policies that are incentivising the use of circular LPG like bioLPG as a drop-in fuel in several countries (see *circular LPG* section).

Across the world of emerging economies, the approach towards LPG adoption has been rather mixed. Several countries such as India and Indonesia have propelled LPG usage in the past two decades through generous subsidies, oft at the expense of their governments. However, both countries became heavily reliant on LPG imports to meet the rise in domestic consumption.

India's growth in the long run will begin to slow (but not negative just yet!) with the rising penetration of piped natural gas (PNG) and national plans to embrace solar and electric cooking in the future. On the other hand, Indonesia aims to cut LPG import dependency in the long run through various initiatives with varying degrees of success (see *Indonesia case study* section).

Meanwhile, there are numerous emerging economies that are further behind on the curve of LPG adoption for rescom use. For purposes of cooking and heating, biomass has been a cheap and accessible option for large swathes of the population – especially in the rural regions. Like India and Indonesia, the growth of LPG adoption here will depend on government policy and attitude in pushing for the adoption of the fuel –be it through subsidies, market creation, infrastructure developments etc. Several countries across the sub-Saharan Africa region are certainly leading the charge in this direction and could see per capita consumption of LPG skyrocket (albeit from a low base) in the next decade or so.

Kenya: LPG growth potential this decade

The Kenyan LPG market is currently in state of flux as the government pursues subsidies, tax breaks and infrastructure investment to propel LPG penetration from 25% in 2023. Supply side initiatives include discouraging imports of kerosene and incentivising free market competition to distribute LPG from the port of Mombasa. Demand side policies further encourage LPG adoption, such as the re-introduction of the low-income subsidy scheme.

The principal driver behind the current policy action to increase LPG consumption is to reduce illegal logging and combustion of biomass (AECOM, 2022). Action to reduce imports of filled cylinders such as a stronger regulatory framework, excise duty on filled cylinders and the entrance of new distributors in the market, will help improve consumer and investor confidence in LPG. This will in turn reduce demand for biomass fuels and deforestation.

The shift to LPG is time critical as illegal logging for fuel has far-reaching downstream economic and social effects, from respiratory illnesses caused by particulate pollution to flash flooding and malaria. The localised effects of deforestation are very severe and the current administration, led by William Ruto, is pursuing a multiple pronged approach to the energy transition.

Rural consumers, where accessibility is the primary hurdle in increasing LPG consumption, will benefit from the continued expansion of motorcycle courier distribution. Meanwhile urban consumers that lack the liquidity to purchase an LPG cylinder are incentivised to use pay as you go cylinders, available at no initial cost.

Recent legislation and policy directions

The predecessor to current president William Ruto, Uhuru Kenyatta, primarily directed investment at large infrastructure projects such as the Mombasa-Nairobi standard gauge railway (Xinhua, 2017) and construction of port facilities at Kipevu and Lamu (Beja, 2023). Kenya's LPG demand saw rapid growth from 85 kt per year in 2016 to 372 ktpa in 2021 (Cowling, 2023). Demand stagnated to 332 kt in 2022 as a VAT of 16% levied on LPG in 2021 by Uhuru Kenyatta (UCL, 2022) increased the price of a 13 kg cylinder from KSH 2,000 (US$14) in 2020 to KSH 3,000 (US$21) in 2022 (Murungi, 2024).

During the COVID-19 pandemic, Kenyatta took US$3.2 billion of aid from the IMF (World Bank, 2020). Large infrastructure projects and solvency commitments to the IMF left Kenya's economy fiscally vulnerable and lacking a solid tax base. Inflation was at a five year high of 9.6% in October 2022 (Shibia, 2023). Reigning president Ruto hence sought to tackle inflation, while also eradicating hunger and developing the tax base by 2027 (Kenya Investment Authority, 2023). Ruto's flagship policies were thus regarded as the 'Bottom-up Economic transformation agenda' (Parliamentary Service Commission, 2023).

Small businesses have been identified as crucial to economic transformation and Ruto has allocated US$350 million of finance, delivered over the next four years, to grow small and medium sized enterprises, as they are seen as economically productive and crucial to alleviating poverty. Food security is seen as key to stimulating economic growth at grassroots level and KSH 3.5 billion (US$23 million) of finance has been set aside to fund agricultural equipment, fertilisers, and risk management products (Ayalew, Breisinger, Karugia, & Olwande, 2023).

With plans to increase LPG consumption per capita to 15 kg in 2030 from 6.3 kg in 2022 (World Bank, 2018a), Ruto gradually cut VAT on LPG to 8% at the end of 2022 and finally removed VAT on LPG completely in the May 2023 budget (Nyawira, 2023). Simultaneously VAT rates were increased to 16% on kerosene (Kemp, 2023). Subsidies introduced in July 2023 cut the price of a 6 kg cylinder from 2800 KSH (US$20) to 500 KSH (US$4) for low-income households which will expedite demand growth as LPG is currently by the most price-competitive fuel source (Okata, 2023).

Infrastructure developments at Mombasa port to drive higher throughput of LPG

Currently, LPG flows into the Port of Mombasa through two facilities. The oldest of the two is the Shimanzi Oil Terminal, which can accommodate only small gas carriers no larger than 7 kt. The other one, the Mombasa Oil Terminal, houses the principal LPG import facility. This is an offshore jetty that has been operated by African Gas and Oil Company Limited (AGOL) since 2013 (METI, 2019). The jetty is linked by a 4.2 km pipeline to 30 kt of pressurised storage bullet tanks.

Around 90% of LPG imported into the Mombasa port flows through the AGOL facility. There are also partial discharges from VLGCs and cargoes brought in by small gas carriers and handysize vessels. We understand that players such as Geogas have been offloading smaller parcels through vessels used as 'floating' storage in East Africa as well.

Two LPG storage and handling facilities are currently under construction – the privately-financed Taifa Gas facility and the state-managed Kenya Pipeline Company (KPC) facility. Both facilities will receive LPG through a common import delivery line from the offshore jetty operated by AGOL to the new Kipevu Jetty. They will each install 30 kt of pressurised storage, cylinder filling facilities, and pressurised truck loading bays (Owere, 2023). KPC also plans to build rail loading capacity to transport LPG to its 10 kt cylinder filling plant in Nairobi and an additional 25 kt of storage capacity at Mombasa (Herbling, 2018).

Six private companies also submitted their environmental and social impact assessments to the Kenyan government back in 2020, wishing to tap onto the LPG line at the new Kipevu Oil Terminal. Unfortunately, the nearly 60 kt of storage capacity they would add is unlikely to be approved, given Kenya's current LPG import capacity is already booked by KPC and Taifa Gas.

Nonetheless, the additions of KPC and Taifa Gas' LPG storage and handling facilities by late 2024 will pave the way for LPG distributors in Kenya to compete on price and reach through an open tender system. Increased competition and storage capacity will also ease price fluctuations for end-consumers in the event of a supply shortfall. We thus expect Kenya's LPG imports to reach 40-50 kt/month by 2025 from the current 15 kt/month.

Consumer and investor confidence dependent on strong regulatory framework

Previously, the lack of an efficient LPG cylinder exchange system also hindered demand growth. Regulations outlined in 2009 allowed consumers to return their empty cylinders to any LPG distributor that belonged to the LPG cylinder exchange pool (PIEA, 2019). The LPG distributor would then have to return cylinders that do not belong to them to a central depot, where the rightful brand owner would collect and refill them. However, due to the lack of a monitoring system, many took the opportunity to illegally refill, modify, and rebrand the LPG cylinders. This contributed to the rise in LPG-related accidents in the past decade, undermining the reputation of the fuel as a safer alternative to biomass and kerosene.

In June 2019, the Kenyan government introduced new regulations to crack down on these illegal activities, improve safety and transparency in LPG distribution, and ultimately encourage investments into Kenya's LPG market (PIEA, 2019). The old LPG cylinder exchange pool was disbanded in favour of a mutual exchange system that requires approval from the country's Energy and Petroleum Regulatory Authority (EPRA). This makes it illegal for an LPG distributor to refill cylinders of another brand without written consent from the original brand owner or approval from the authorities. Those found breaching the law would face a hefty fine of KSH 10 million (~US$69,000) and/or a five-year jail term.

On top of making brand owners responsible for the refilling and maintenance of their own cylinders, tracking devices such as QR codes must be installed on cylinders to monitor their movement across the distribution and supply network (Clean Cooking Alliance, 2020). All LPG cylinders must also have a unified valve as prescribed by the Kenyan Standard (FAO, 2009), which will allow end-consumers to easily switch to other brands. The EPRA has also stepped-up routine inspections in recent years to ensure compliance to these rules.

Upstream industry remains a pipe dream

The recent departure of TotalEnergies and Africa Oil Corp from Blocks 10BB, 13T and 10 BA has cast doubt on the extraction potential of Kenya's South Lokichar assets (Esau, 2023). Tullow Oil stands as the only stakeholder in the Turkana oil field, rendering recovery of the 500 mmb of oil unlikely. We therefore believe no refinery supplies of LPG will materialise in the foreseeable future. Ultimately, the growth of LPG consumption in Kenya will have to be fuelled entirely by trade.

Downstream effects of deforestation threaten livelihoods and food security

Illegal logging threatens the forest ecosystem and Kenya currently loses about 12,000 of its 4.6 million hectares of forest cover each year (Rioba, 2022). Recognising the importance of forests, president Ruto has allocated US$87 million per annum to forest conservation, aiming to increase forest cover from 7% to 10% by 2030 (Rioba, 2022). The secondary consequences of deforestation reduce crop yields and food security, threatening the 5.4 million people in Kenya who currently experience food insecurity.

Tree-felling for fuel is a barrier to economic development as Kenya's tropical climate causes rain to fall in heavy downpours, requiring large areas of forested land for drainage to avoid flash floods. Flooding displaced 36,432 people in the spring of 2023 in Kenya, destroying houses and businesses and increasing disease prevalence (IFRC, 2023). Current wood harvests of 25-33 mmtpa need to be controlled as the consequences of deforestation are severe and localised, the need to increase LPG adoption across rural Kenya is time critical.

Agriculture accounts for 33% of Kenya's annual GDP and flash flooding threatens the productivity of agricultural land as soil erosion washes away fertile topsoil (USAID, 2023). Farmers affected must use artificial fertilisers and pesticides to break even and feed their communities. As the government is currently pursuing fertiliser subsidies, stopping deforestation will improve the livelihoods of the 21.2 million Kenyans employed in the agricultural sector.

It will also prevent other agricultural ramifications. This includes the risk of eutrophication and the destruction of aquatic life when mud and artificial fertilisers to run into rivers, potentially impacting freshwater fish stocks and food security. Deforestation also disrupts the cycle of moisture and water around the trees via evapotranspiration. This dries the air and reduces rainfall over a much larger area than the felled forest, resulting in droughts and disrupted agriculture during the dry seasons.

President Ruto aims to incentivise farmers to use forests in a sustainable way. The Plantation and Livelihood Improvement scheme allows farmers to lease a parcel of forest for crops and grazing for KSH 500 (~US$4) a year (Rioba, 2022). Farmers are encouraged to take an active role in forestry management, planting new fast-growing trees and protecting mature trees.

International tourism receipts provided 10% of Kenya's annual GDP before the COVID-19 pandemic, as tourists seek pristine environments and abundant wildlife (Ministry of Tourism and Wildlife, 2022). Tree-felling in large volumes is incompatible with Kenya's lucrative tourism sector as tree felling leads to loss of topsoil and habitat destruction. Heavy downpours in the wet

season coupled with poor drainage creates standing water where malarial mosquitos thrive. The government is keen to eliminate tree felling as increased malaria prevalence too threatens international tourism and domestic economic activity.

That said, President Ruto in July 2023 controversially lifted a six-year ban on logging in a bid to create jobs and reinvigorate the local timber industry (Africanews, 2023). The lifting of this ban, while seemingly political, involves gazette forest plantations that have been deemed “over-mature”. While this may cloud the potential for LPG to displace biomass, the controlled nature of policy surrounding this is still encouraging. The biggest criticism of this however will be the enforcements in place to ensure sustainable forest management in the long run.

Particulate pollution and the health burden of biomass combustion

Particulate production from biomass combustion is estimated to be seven times greater than combustion of LPG. The Kenyan ministry of health estimates that 21,500 people die each year because of household air pollution (Shilenje, Maloba, & Ongoma, 2022). Lower respiratory tract infections such as pneumonia and bronchitis are the most significant contributor to the death total (Shilenje, Maloba, & Ongoma, 2022). The burden of disease is greatest among the young, with pneumonia accounting for 45% of cases of infant mortality across sub-Saharan Africa (World Health Organisation).

Lower respiratory infections are the second most common cause of death in Kenya and the burden of disease is highest in rural areas, given 54% of urban households use LPG as their primary cooking fuel compared to only 18% of rural households (Lee, Shirley, Otieno, & Nyambura, 2021). In light of the threat posed to citizens by particulate pollution and also the push towards clean energy adoption, President Ruto directed public institutions to switch to LPG for use as cooking fuel by 2025 back in February 2023 (Mueni, 2023).

Subsidies and couriers to decrease price and increase accessibility of LPG in rural areas

Previously the factors limiting the rollout of LPG as the primary cooking fuel beyond 18% of rural households were price and accessibility. Recent policy direction seeks to address the disparity in accessibility between rural areas and urban areas in LPG adoption. The creation of the mutual exchange system saw supermarkets and local kiosks began to stock LPG, supplanting existing distribution infrastructure at petrol stations and fuel distributors. Previously accessibility was limited to those without transport; the average distance between an LPG fuel source and a household is 5.3km.

Interestingly, a key driver of a preference of LPG over kerosene has been the lower frequency of LPG refills. Kerosene refills tend to require daily or weekly commutes with LPG refills having a considerably lower frequency of travel for purchase of refills.

The Energy and Petroleum regulation Authority licenced 227 storage and wholesale firms as of 2021, many of these firms have begun to provide motorcycle delivery of LPG. The Motorcycle Assemblers Association of Kenya estimates there are 500,000 professional couriers, providing affordable and convenient delivery to rural consumers. Couriers will become an increasing important component of the value chain as Kenyans transition to LPG.

Back in 2016, the government worked with the National Oil Corporation of Kenya (NOCK) to roll out an LPG enhancement programme known as the “Mwananchi Gas Project” to expand clean fuels usage to low-income households (Odhiambo, 2023). It was to be executed in two phases. The first phase includes the distribution of filled 6 kg LPG cylinders under the brand of ‘Gas Yetu’ fitting with a grill and burner in Nairobi at a subsidised price. Meanwhile, the second phase entails the distribution of these filled 6 kg LPG cylinder alongside a smart metering device, horse pipe, and two low burner tabletop cookers.

These 6 kg ‘Gas Yetu’ branded LPG cylinders, including the gas, burner, and stove, were distributed to low-income households at a discounted price of KSH 2,100 (US$19), KSH 3,000 (US$30) cheaper relative to the market prices. Subsequent refills from ‘Gas Yetu’ retailers can be purchased at KSH 840 (US$8) per cylinder (Rotich, 2022).

Unfortunately, this gas project lacked proper implementation strategy and supportive policies to see an effective take-up rate. The project was also suspended in 2019 upon the discovery of defective LPG cylinders supplied by fraudulent contractors (Odhiambo, 2023). 40% of the LPG cylinders (67,251 cylinders) supplied to NOCK were deemed substandard, with concerning

defects such as faulty valves (Africa Oil+Gas Report, 2020). Consequently, a total of 109,649 LPG cylinders, 329,422 burners, and 329,260 grills remained undistributed (Africa Oil+Gas Report, 2020).

As Kenya LPG consumption were up for headwinds given the soaring prices of LPG cylinders, the Kenyan government have since implemented the LPG subsidy scheme, starting from July 2022 (IEA, 2022b). This scheme aims to distribute 60,000 LPG cylinders, and 470,000 over the next three years from then (Kivuva, 2023). Under this scheme, the lower-income households could purchase the 6 kg LPG cylinders accompanied with its burner and grill at the discounted price of KSH 2,000 (US$19).

Not just that, in March 2023, the President Ruto announced plans to further subsidise LPG cylinders, with the price of a 6 kg LPG cylinder potentially dropping to KSH 300 to 500 (Muthoni, 2023), amounting to about 80% price cut (see Recent legislation and policy directions section).

More recently, the EPRA have announced that the Kenyan government have allocated KSH 2.4 billion (US$ 16.48 million) for LPG cylinders subsidies, targeting about 4.5 million low-income households (Xinhua, 2024). This came after a drop in Kenya' LPG consumption to 6.8 kg per capita in 2023 as compared to 8 kg per capita in 2022.

Increased rollout of flexible payment to further increase LPG consumption in urban areas

In addition to subsidised cylinders and stoves, pay as you go schemes allow payment for gas in units as small as KSH 50 (US$0.35). Energy firm, Pay-Go distributes cylinders with smart meters at no initial cost, customers can more effectively cashflow if the initial cost of purchasing a cylinder remains prohibitive. Empty cylinders can be replaced by Pay-Go couriers using their mobile phone app.

The Pay-Go scheme aims to increase uptake among time-pressured urban residents with mobile phone access and low liquidity. A client survey found that use of the Pay-Go scheme saved an average of 3.5 hours a week compared to traditional methods of fuel procurement.

Conclusion

The Kenyan administration is keenly aware of the far-reaching economic and social impacts of reliance on biomass. Supply developments, principally the expansion of distribution and bottling facilities pave the road for demand increases expected in the coming years. Targeted policies such as subsidies, couriers, pay as you go systems and regulation of the cylinder exchange will increase the prevalence of LPG across all income groups.

The story of LPG in Kenya is also the story of deforestation. Policies to increase the prevalence of LPG aim to address the demand for felled wood. The government is concurrently addressing the supply of felled wood through sustainable forestry management schemes, subsiding farmers to symbiotically grow crops and graze cattle in the forest, while planting new trees and deterring loggers from felling protected trees.

Evidently, as Kenya government continues to roll out subsidies to keep LPG cylinders affordable for the lower-income households, Kenya's future for increased LPG-fuelled cooking is poised for greater growth. The Kenya National Clean Cooking Strategy (KNCCS) continues to place emphasis on developing strategies to ensure accessibility to clean cooking sources to be widely available by 2028 (MECS, 2023). Furthermore, KNCCS is also in line with National Determined Contributions intents to keep carbon emissions below 2.8 kt equivalent in 2030. Hence, this certainly means that though LPG would be in Kenya's energy picture, using electricity for cooking would be a topic worth looking at in the longer term as well. That said, with electricity pricing much higher relative to LPG cooking alongside the cost of electric stoves, LPG cooking would remain as the more viable option in clean cooking.

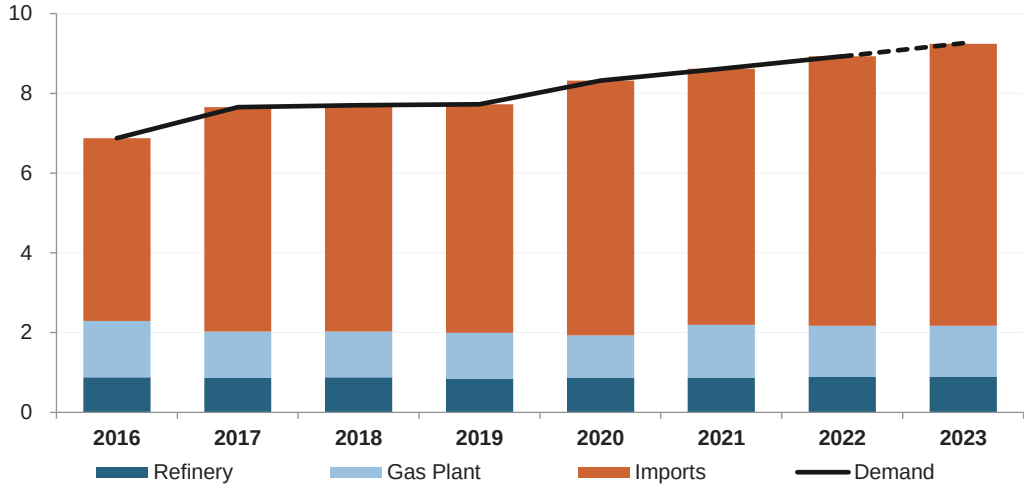
Given the Kenyan government's focus on maintaining the affordability and accessibility of LPG cylinders, this situation easily parallels India's approach - Pradhan Mantri Ujjwala Yojana (PMUY) programme in 2016 coupled with India's extensive infrastructure developments.

Indonesia: A successful LPG growth story from the 2010s

Strong growth in demand spurs increased reliance on imports

Indonesia's LPG demand has grown over the years, reaching its highest at 9.2 mmt in 2023. This was 1.6 mmt higher than in 2017, when the kerosene-to-LPG conversion program was first declared a success (Hakam, Nugraha, Wicaksono, Rahadi, & Kanugrahan, 2022). Demand growth between 2017 to 2023 has averaged 5% y-o-y, despite being impeded by COVID-19 restrictions in the country. Further LPG demand growth may start to slow down to a more organic 3% y-o-y growth however, given that the LPG market is relatively saturated with the current annual LPG consumption sitting above 30 kg/capita.

Fig. 10: Indonesia LPG Supply and Demand, mmt



Source: Statistics Indonesia, FGE

Meanwhile, Indonesia's domestic supplies from their refineries and gas plants were not able to keep up with the growth in demand. Overall domestic LPG supplies rose by only around 160 kt between 2017 to 2023 to reach 2.2 mmt (Statistics Indonesia, 2023).

The country has thus become increasingly reliant on LPG imports to make up for the deficit between domestic demand and supply. LPG imports grew by 1.5 mmt between 2017 to 2023 to reach nearly 7.0 mmt (Statistics Indonesia, 2023). The share of Indonesia's total LPG demand met by imports has also steadily grown from around 60% before 2017, to more than 75% by 2023. The country has been the fifth largest Asian LPG importer (behind China, India, Japan, and South Korea) since the 2010s, and still is even through 2023.

The success of Indonesia's kerosene-to-LPG conversion programme

Indonesia's LPG consumption took off when the government implemented the kerosene-to-LPG conversion program in 2007. The program was primarily motivated by the rising cost of kerosene subsidies (Hakam, Nugraha, Wicaksono, Rahadi, & Kanugrahan, 2022), as well as to promote the use of cleaner cooking fuels (Kuehl, Maulidia, Bajaj, & Boelts, 2021). To protect consumers from any financial shocks, the government kickstarted the project by providing free LPG starter packages including a filled 3 kg LPG cylinder, a stove, and other auxiliary units like a connecting rubber hose and a regulator (Thoday, Benjamin, Gan, & Puzzolo, 2018).

The program was rolled out in phases, starting with main urban areas between 2007 to 2010, including the big islands of Sumatra, Java, Kalimantan, and Sulawesi, as well as the densely populated islands of west Indonesia. It was expanded to the rest of the country between 2012 to 2015, before being declared a success in 2017 when 59 million out of the 68 million households converted to LPG cooking. LPG demand growth was the strongest in Java, Indonesia's most populous island, with West Java accounting for 20% of the national quota for subsidised LPG.

LPG subsidies and the exploitation in the distribution of it

To target lower income consumers, subsidised LPG was rolled out alongside the conversion program and continued till today. It is sold as small 3 kg LPG cylinders, also referred to as melon gas due to its small, green, nearly spherical appearance.

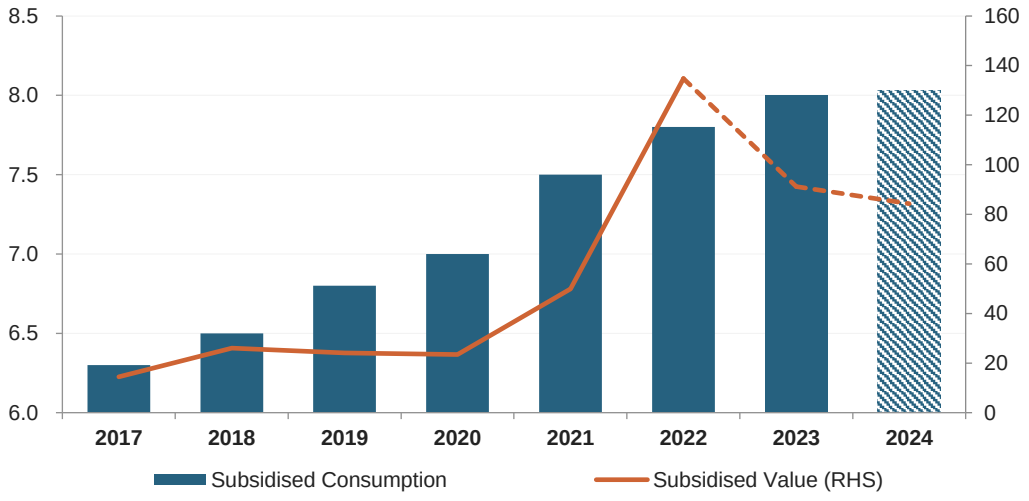
Subsidised 3 kg cylinder prices have remained the same since 2008 at 4,250 IDR/kg (0.28 US$/kg), though the price of it at a regional delivery point basis can be higher based on the Highest Retail Price (HET) set by the provincial governments (Thoday, Benjamin, Gan, & Puzzolo, 2018). In contrast, the larger, unsubsidised 5.5 kg and 12 kg cylinders are constantly adjusted to reflect international market prices. The 12 kg cylinders were going at around 17,000 IDR/kg (1.11 US$/kg) in July 2023, four times higher than unsubsidised cylinders (Pers, 2023).

Ideally, subsidised LPG cylinders should be reserved for the lower-income bracket, while those above the bracket should purchase the unsubsidised variants instead. Unfortunately, the absence of any real measure to control the purchase and distribution of subsidised LPG, paired with the widening difference between subsidised and unsubsidised prices, has attracted exploitation from those outside the lower income bracket.

Some retailers were known to illegally refill the unsubsidised cylinders with the subsidised 3 kg cylinders to lift business profits (Rochman, Kasim, & Atmoko, 2023). Around 75% of non-subsidised customers were also freely purchasing the subsidised 3 kg LPG cylinders. Ironically, just 30% of LPG subsidies go towards low-income households due to the lack of LPG accessibility in rural areas and the low consumption from low-income households. As of 2023, subsidised LPG made up more than 90% of Indonesia's total LPG demand.

Indonesia's LPG subsidies has thus remained a costly affair due to the unchecked subsidy exploitation. The country's budget allocations for LPG subsidies tends to trend with international prices such as the Saudi Aramco CP given their heavy reliance on LPG imports from the international market to meet its growing domestic demand. A higher CP would thus translate to higher import prices, and hence increased subsidy spending on LPG. The pain of Indonesia's LPG subsidy was intensified in 2022 when international LPG prices averaged at a five-year record high, resulting in the country's LPG subsidy spending surging 145% higher y-o-y.

Fig. 11: Indonesia LPG Subsidised Consumption and Value, mmt and Trillion Rupiah (RHS)

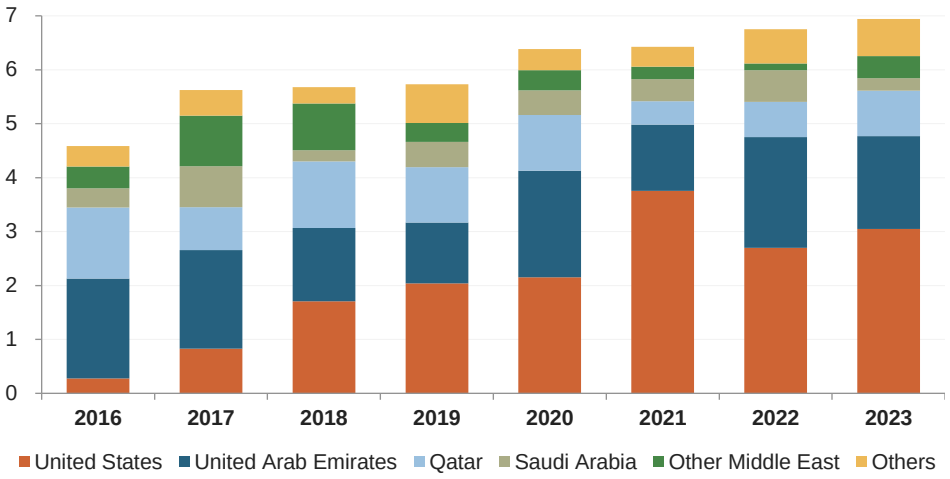


Source: Ministry of Finance of the Republic of Indonesia

Diversification of import supplies

Indonesia's increasing reliance on LPG imports pushed the country's state-owned importer Pertamina to improve LPG import supply diversification and secure more competitively priced LPG imports (Reuters, 2017). Indonesia's imports have thus expanded from being mainly supplied from the Middle East pre-2017 to include more LPG supplies from the United States.

Fig. 12: Indonesia LPG Imports by Origin, mmt



Source: Statistics Indonesia, FGE

By 2023, almost half of Indonesia's imports is supplied by the Middle East, notably UAE, Qatar, and Saudi Arabia, while 40% of it is was supplied by the United States. The bulk of Indonesia's imports are supplied via term contracts with both countries.

Pertamina also showed a growing ambition in their LPG trading plans. Their Singapore office was opened in 2019 to leverage and improve the profitability on its vast LPG import program. Pertamina International Marketing and Distribution (PIMD) sought to expand their regional LPG trading activity by venturing into the bunkering market and developing a resale market of distributing smaller pressurised cargoes into the region.

Pertamina's term supply contract is not for everyone, however. Given the complexities of redistributing LPG throughout Indonesia's many islands, Pertamina's contract imposes tight discharge windows with severe penalties. For these reasons, the Indonesian trade is limited to traders who have large trading systems and access to evenly split cargoes.

Cutting LPG subsidies, one way or another

The raison d'etre for Indonesia's LPG subsidies is eroded by its mounting financial cost given the country's growing reliance on LPG imports (MECS, 2021). The country is already exploring ways to reduce the cost of LPG subsidies by any means necessary, and LPG seems to be in precarious position of déjà vu just as kerosene had in 2007.

LPG alternatives placed on a pedestal, with straws as its foundation

The most notable measure is Indonesia's hunt for LPG alternatives for cooking to reduce the country's increasingly costly reliance on the fuel (ESDM, 2020a). Top candidates include shifting towards dimethyl ether (DME) or electric powered stoves.

Unlike the kerosene-to-LPG conversion program, the switch from LPG to these alternatives appears less straightforward. In a September 2022 conference, the Minister of State-Owned Enterprise (SOE) Erick Thohir said that LPG usage will not be eliminated immediately as many low-income households are still dependent on the fuel. Instead, the country will aim for a balance between LPG, DME, and electric stoves. But even striking such a balance will be fraught with challenges.

Planned adoption of DME

DME shares similar properties to LPG, thus making it a potential substitute over LPG for use in gas stoves (Anggarani, Ruliantoa, & Wibowoa, 2014). Pertamina has successfully trialled DME usage for cooking as both a standalone product and blended mix with LPG. They did a technical study on the performances for different blends of DME in LPG, as shown below:

Mix	Fuel Consumption	Cooking Speed	User Friendly	Flame Quality	Cleanliness
LPG	Worst	Good	Good	Good	Medium
20% DME	Medium	Medium	Medium	Worst	Worst
50% DME	Best	Best	Best	Best	Best
DME	Good	Worst	Good	Medium	Good

Source: Pertamina

An even mixture of LPG and DME thus appears the most ideal for cooking according to Pertamina's study (Pertamina, 2013). A higher blend of DME would reduce LPG usage, yet too high a composition of DME would slow cooking times due to the 40% lower calorific value of DME compared to LPG (Murti, Priyanto, Masfuri, & Adelia, 2021).

Unfortunately, DME may not play well with existing infrastructure and equipment. DME's high permeability makes it easily absorbed by rubber and plastics (Saputra, Sari, Maspanger, & Bismo, 2021). Using DME could thus potentially compromise the integrity of auxiliary units like rubber hoses and o-rings, as well as plastic regulators, thus warranting a replacement. While DME can be used in existing metal stoves as it will not cause corrosion, it has less combustion efficiency than LPG thus resulting in more waste gas being released (Harsono, 2020).

Speaking to Pertamina, they shared that a 20% blend of DME into LPG would maximise retail economics as most existing LPG infrastructure can still be used to support that blend (Harsono, 2020). We also understand that neither the government nor Pertamina are keen to foot the bill for new stoves supporting DME usage, which could thus keep a lid on the composition of DME blended into LPG.

DME project halted by major partner Air Products' departure

Despite these technical limitations, Indonesia has long been and is still interested in shifting towards DME to reduce and replace LPG for cooking. Not only would it reduce the country's cooking reliance on LPG, but it also allows the country to tap into its own domestic coal supplies required for DME production via gasification.

This pushed Indonesia's state-owned PT Bukit Asam (PTBA), Pertamina and Air Products to form a joint venture in 2020 (PTBA, 2020). PTBA would supply the coal required for gasification, Pertamina would market the DME, while Air Products would operate the gasification plant (Peh, 2022).

The goal was to establish a coal gasification plant with a DME production capacity of 1.4 mmtpa (or an equivalent 6.5 mmtpa of coal as 1 ton of DME requires 4.6 tons of coal) with an operational period of 20 to 30 years (ESDM, 2020a). Construction would take around 3-4 years, with the DME plant originally slated to start commercial operations in 2024/2025 (PTBA, 2020). However, delays were inherent when the groundbreaking ceremony of the project at Tanjung Enim was only conducted in January 2022 by President Joko Widodo (ESDM, 2022).

Unfortunately, the joint venture fell apart with Air Products' withdrawal from the project in March 2023 (McDonald & Cheng, 2023). The DME project is currently in limbo, and may even have to restart from scratch. Indonesia is still actively looking for a new international partner in their DME project, claiming that they have received interest from several Chinese companies, such as Chinese construction and petrochemical player Sedin Engineering (Muliawati, 2023).

Poor economics to remain a thorn in DME adoption

Regardless of who the new partner might be, the same issue of poor economics (which prompted Air Products' withdrawal) will likely be the biggest hurdle in DME adoption. Poor DME economics stemmed from Indonesia's Ministry of Energy and Mineral Resources (MEMR) fixing the price of DME at US$378/t, while assuming that coal will be priced at US$20/t (IESR, 2022).

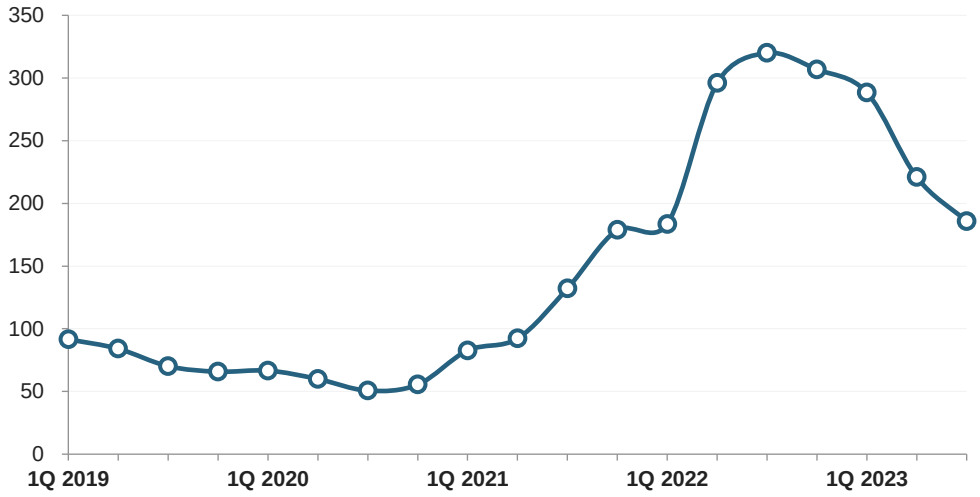
However, that is far from realistic as coal production costs averaged above US$30-40/t based on PTBA's annual report (IESR, 2022). Independent research firms like the Institute of Energy Economics and Financial Analysis (IEEFA) and Institute of

Essential Services Reform (IESR) have concluded that the current DME model does not make economic sense and have provided an estimate of how much DME should be sold for to incentivise operators to take part in the project.

- **IEEFA** estimates that DME would have to be priced at US$601/t to provide a 15% return for operators, or about US$520/ton to break even (Peh, 2022). This is assuming a coal price of US$48/t, a production cost of US$300/t (comparable to a Chinese coal to DME plant in Shanxi).
- **IESR** estimates that DME should be priced at US$725/t, or US$720/t for a 20% blend of DME in LPG (IESR, 2022).

Opportunity costs may also disincentivised coal supplier PTBA from selling coal to the DME project at production prices when they could sell it elsewhere at a better price. According to the MEMR, Indonesia's Reference Coal Price averaged US$270/t in 2022, peaking at a record US$330/t in October 2022 (PTBA, 2022).

Fig. 13: Indonesia Coal Prices, US$/t



Source: ESDM

As such, Indonesia's current DME model is less than appetising for its partners. This is further exacerbated by the additional costs stemming from carbon taxes on the coal derivative, the construction of DME blending facilities and the potential replacements of any incompatible pre-existing LPG facilities and equipment. Some industry experts estimate that the DME project would cause an annual loss of US$400 million, far exceeding the cost of importing LPG.

Poor economics will thus remain a thorn in DME adoption. Softening LPG prices on the back of rising international supplies may further question the need for DME, which now appears relatively pricier. To cushion the losses on DME, it is possible that the fixed DME price could be raised, as the current fixed price of US$378/t is still lower than the average Saudi Propane CP of nearly US$740/t in 2022.

That said, given the recommended breakeven range of US$600-700/t for DME prices, production costs may have to be reduced significantly for it to make economic sense. Softer regulations on carbon emission taxes, alongside hefty incentives would also be necessary to revive the project. DME adoption is certainly a tall (and expensive) order from the get-go.

Planned conversion to electric stoves postponed indefinitely

The proposed electric stove conversion program was another alternative that has taken the spotlight as a potential substitute to LPG stoves. Like the DME project, switching to electricity is appealing as it would tap into Indonesia's abundant coal reserves and sponge their electricity surplus (Karyza, 2023). According to state-owned electricity monopoly Perusahaan Listrik Negara (PLN), the largest electricity surplus hit 25 TWh in the Java-Bali system, followed by 8 TWh in the Sumatra system. It makes

sense to push for electric stove usage when a million households using electric stoves translate to around 1 TWh of electricity demand (Simanjuntak & Hasjanah, 2023).

To spearhead the electric stove conversion program, the Minister of SOE pledged to spend nearly 5 trillion Rupiah, or around US$330 million, per annum to provide free electric stoves to millions of households currently relying on subsidised LPG. SOE and PLN will work together to install electric stoves in houses built by state-owned companies. They aimed to expand the number of electric stove users to 15.3 million by 2025 (Karyza, 2023).

Indonesia's electricity subsidy scheme was also thought to be able to make electricity usage for cooking more appealing for poorer households. Poorer households tend to have a lower electricity connection capacity, thus qualifying them for electricity subsidies reserved for households with a connection capacity equivalent or under 900 VA (ESDM, 2020b).

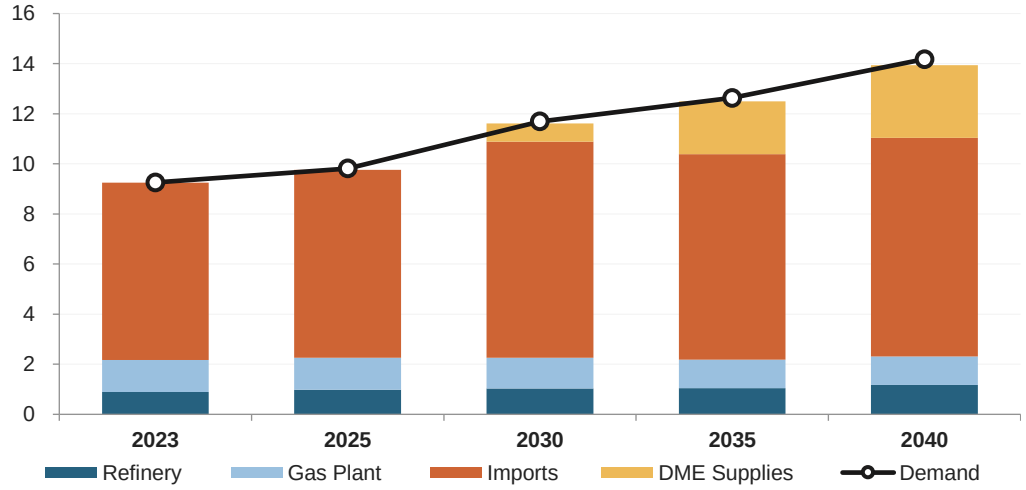
However, the electric stove conversion program was postponed indefinitely in 2022 after just 2,000 of the planned 300,000 electric stoves were distributed to Denpasar and Solo in a trial (Karyza, 2023). Indonesia's National Energy Council criticised the program as a "hasty step" that failed to consider the needs of the users. The initiative was revived through the planned distribution of 500,000 free rice cookers in 4Q 2023, though they fell short of the target and only distributed 342,000 units as of January 2024 (Muliawati, 2024).

Notable setbacks include the continued access to cheaper, subsidised LPG impeding the transition to costlier electric cooking methods (MECS, 2021). Wealthy households have little reason to switch to electric stoves, while poorer households with an electrical connection capacity under 900 VA may qualify for subsidies but face less-than-desirable electric cooking conditions. External studies have also shown that more than 90% of the population is limited to a power capacity of under 1,300 VA, making it inconvenient for induction stoves (HSI Foundation, 2021). Commercial users like street food vendors are also unable to use electric stoves due to its lack of mobility unlike LPG stoves.

LPG likely to be the mainstay fuel in Indonesia this decade

As such, while Indonesia's long-term aim to shift away from LPG may cast uncertainty on the country's LPG demand, we do not expect a significant impact during the 2020s. Both key LPG alternatives are fraught with challenges that will be difficult to resolve by this decade, thus impeding their adoption and substitution over LPG.

Fig. 14: Indonesia LPG Supply and Demand (Forecast), mmt



Source: FGE

Indonesia's LPG demand should thus grow modestly at around 3% y-o-y in the mid-term assuming it will not be significantly replaced by its alternatives. The country will continue to rely on LPG imports to meet its demand given that there is only one firm refinery CDU expansion planned in 2024, roughly translating to an additional 170 ktpa of LPG supply (Reuters, 2024).

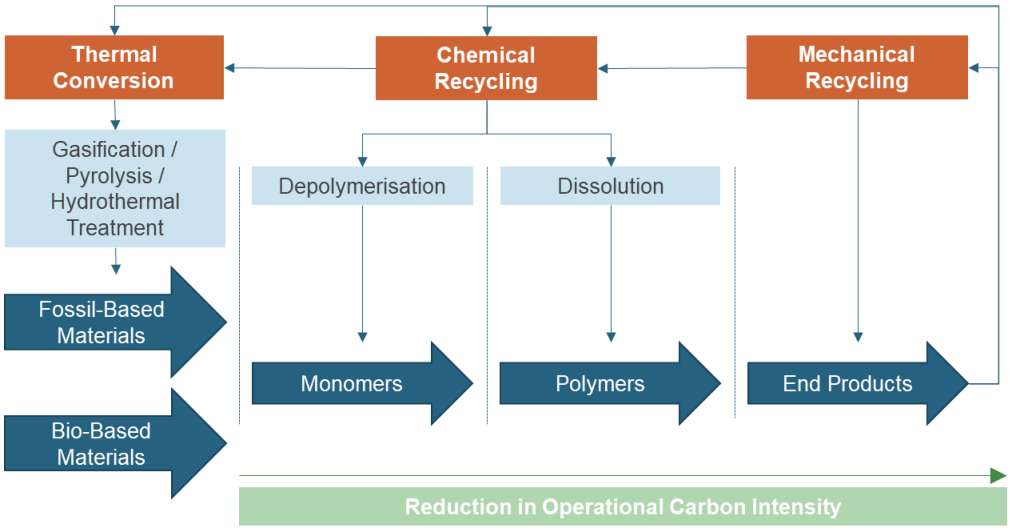
Long-Term Drivers

Outlook on Circular LPG and Its Implications

LPG is generally known as a low-carbon transition fuel with a wide range of uses from residential heating to petrochemical feedstock. Its carbon content can range between 3.0 to 3.6 kg CO_2/kg depending on the composition of propane and butane, offering 15% lower greenhouse than fuel oil for heating. However, with a multitude of companies focusing on decarbonising their operations, there are increasing investments into the renewable space. The expanding set of industries affected by the emergence of carbon markets has placed the spotlight on circular LPG.

Circular LPG can reduce associated carbon emissions by as much as 100% compared to conventional LPG, depending on the feedstock. Circular LPG is also chemically identical to conventional LPG, meaning that both fuels have the exact same functionality. It is thus also seen as a 'drop-in fuel', meaning it can be easily blended with or replace conventional LPG, while also being able to use existing LPG infrastructure without any additional investments. As circular LPG is costlier than conventional LPG, the flexibility in the ratio of blending the former into the latter is appreciated in making the increased cost more palatable by reducing the ratio of blended circular LPG.

Fig. 15: Overview of Circularity in LPG, Feedstocks and Petrochemicals

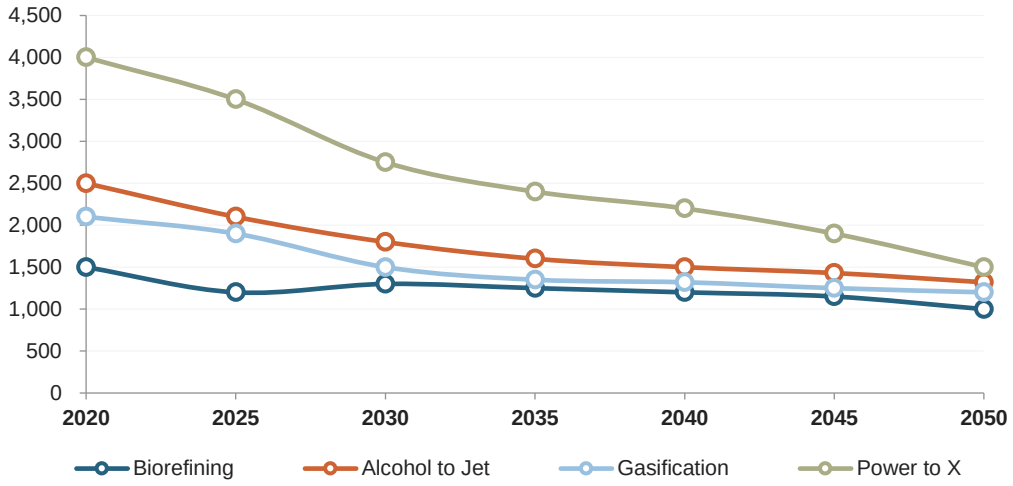


Source: FGE

BioLPG (a subset of circular LPG produced from biogenic materials) has steadily grown over the years, with around 480 kt of bioLPG was produced in 2021, triple the output seen in 2018. The bulk of bioLPG is produced as a byproduct of biorefining (hydrotreatment), of which around 80% of the produced bioLPG is biopropane.

It helps that biorefining is the most commercialised production pathway of advanced biofuels today. This is attributed to the relatively low plant construction cost, with capex ranging between US$1,000-1,500/t (see following figure) for greenfield development facilities. Brownfield expansions (i.e. conversions of old oil refineries) can reduce capex by as much as 50% as most of the equipment present at a traditional refinery can also be used in biorefining.

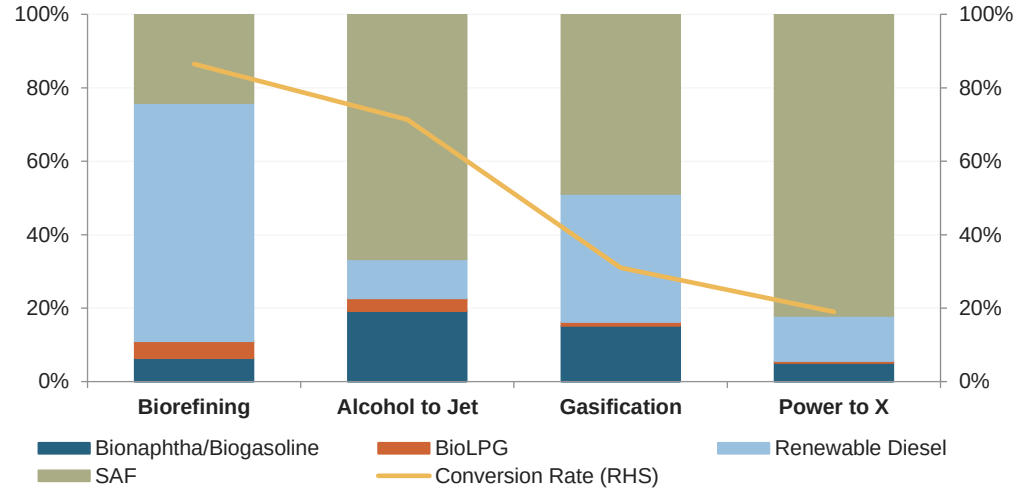
Fig. 16: Production Costs of Advanced Green Pathways, US$/t



Source: FGE

However, biorefining yields of bioLPG as a byproduct are low (see following figure on yields) compared to more valuable biofuels such as SAF and biodiesel. It thus bodes well for the future of circular LPG with more green production pathways emerging, with those closer to commercialisation including alcohol to jet, gasification and power to X.

Fig. 17: Average Yields in Different Green Pathways, %



Source: FGE

Not only do these alternative pathways tend to have relatively higher yields of circular LPG, but they also help diversify the risk of supply chain shortages crippling any one pathway. Even biorefining, which largely uses vegetable oils as a feedstock, is susceptible to the risk of a poor oilseed harvest season limiting the supplies required by a biorefinery to produce biofuels, as well as the ongoing “food-versus-fuel” debates.

Nonetheless, bioLPG is still fast gaining traction even in developing markets such as Africa. According to the IEA’s estimates, over 80% of the total population in Africa still rely on the usage of traditional solid fuels—mainly firewood and charcoal—for cooking. Moreover, 93% of waste is dumped in simple landfills in most of African countries. The harm of smoke and pollution from ‘dirty’ cooking fuels, paired with the urgent needs to manage the landfill sites, reveal the strong potential for increased waste to bioLPG conversion in Africa.

Waste to bioLPG pathways include the agro-processing of residues, filed residues, and biogenic MSW. The use of biogenic MSW also holds appeal for its negligible cost and availability (IEA, 2017). The UNEP projects 224 mmtpa of MSW produced by Africa by 2025 before doubling by 2050 (UNEP, 2018).

According to the IEA's estimates, nearly 70% of the total population in Africa still rely on the usage of traditional solid fuels—mainly firewood and charcoal—for cooking (IEA, 2022a). Moreover, 93% of waste is dumped in simple landfills in most of African countries (World Bank, 2018b). The harm of smoke and pollution from 'dirty' cooking fuels, paired with the urgent needs to manage the landfills sites, reveal the strong potential for increased waste to bioLPG conversion in Africa.

Biowaste as feedstocks, including agro-processing of residues, filled residues, and biogenic MSW, can be either directly used in the Integrated Hydropyrolysis and Hydroconversion (IH2) process or to converted into biogas through anaerobic digestion and catalytic upgrading to produce bioLPG (Chen, et al., 2021).

Policy and other considerations

The limited availability of bioLPG means that only certain sectors use it for very specific purposes, mainly driven by differences in regional policy. Some examples are as follows:

- The UK also proposed a Green Gas Support Scheme, which will replace the Renewable Heat Initiative that has been closed to new applicants since 31 March 2022. This would incentivise the blending of 3-5% bioLPG into biomethane for biomethane to meet UK gas standards. Generally, natural gas pipelines have up to 2% conventional LPG content, but as biogas has a lower calorific value, higher bioLPG blends may be permitted.
- Sweden provides a tax incentive for the use of bioLPG in both heating and transport. In the transportation space, bioLPG is exempt from a 2579 SEK/1000 m3 carbon tax, while in the heating space, industrial users of bioLPG are 100% exempt from carbon taxes as well as being exempt for 70% of energy taxes until the end of 2030.
- In the US, a combination of the federal Renewable Fuel Standard (RFS) and Low Carbon Fuel Standard (LCFS) program (available in some states) has greatly incentivised the use of bioLPG as a drop-in fuel. The LCFS can be stacked over the RFS – which ultimately means that developments of biofuel infrastructure and trade will greatly favour certain states.
- In Africa, there are increasing investments from Europe to push for waste management projects and the production of bioLPG from it. Kenya will be the pioneer to lead the bioLPG development. The Energy Act (2019) outlines their intention to facilitate the development of bioenergy and to make waste-to-energy projects economically feasible (Kenya Power, 2019). The government and Eni have also proposed to kick start Africa's first biorefinery with the conversion of the Mombasa refinery.

Broadly, we see bioLPG for use as a heating or cooking fuel, as an additive within transportation fuels or even as a petrochemical feedstock. Policy incentives have broadly favoured the former two end-uses while there lacks a concerted policy driven incentive specifically toward the use of green or renewable feedstock within the petrochemical space.

Interestingly, as bioLPG tends to be propane heavy, its use (as a standalone fuel at least) will be more suited to countries with temperate, seasonal, or colder climates. Across the warmer climates of South Asia, Southeast Asia and West Africa, retail LPG usage tends to be butane heavy.

Outlook for bioLPG consumption

It is pretty clear that we should see growth in bioLPG usage as it aligns with global net-zero commitments. However, meaningful adoption of it remains challenging outside of Europe and North America, given the lack of firm policy incentives involved elsewhere. For example, the bulk of biofuel products produced at Neste's recently expanded Singapore biorefinery is exported to the West Coast of the United States rather than consumed regionally.

Furthermore, bioLPG's profile as a byproduct (especially in the biorefining process) means that most production processes will likely be focused more on higher value products (such as HVO and SAF) over bioLPG. Riding on the coat tails of continued

growth in biorefining capacity and the push towards the commercialisation of other pathways could see bioLPG supply increasing to nearly 1.5 mmtpa in the next 10 years (a tripling from 2021 levels). That said, it is but a drop in the ocean compared conventional LPG supply exceeding well beyond 100 mmtpa, thus diminishing bioLPG's ability to swing the conventional LPG market and its prices.

Fossil Fuel Subsidies: Boon or bane for governments?

Governmental support to increase LPG adoption within a population has been well documented. Policies supporting LPG usage have already spurred LPG consumption in developing economies like India and Indonesia, thus improving accessibility to clean cooking in the residential sector.

However, the use of subsidies can also be a double-edged sword for governments. Attempting to remove subsidy support once a substantial percentage of the population has been using LPG can be tricky business for governments. Politically, raising prices of a necessity good is often viewed as an unpopular decision which may result in significant push backs from citizens.

Often, maintaining a status quo is preferred to avoid unpopular sentiments to grow. However, with substantial amounts of government budget channelled to fossil fuel subsidies, these very monies could instead be invested into infrastructure developments or education to improve the country's future growth potential.

Sometimes, the fiscal burden to support a subsidy scheme may see governments pre-maturely roll back its fiscal support before the population transits fully into LPG usage. This leads to stagnation in LPG growth, or in the worst case the population falls back to biomass for cooking, reversing earlier attempts to increase the accessibility to clean cooking.

Challenges to completely remove fossil fuel subsidies

Generally, governments understand the need to eventually remove fossil fuel subsidy support as the opportunity cost for not doing so is substantial. In 2023, Nigeria made headlines for removing over 40 years of fuel subsidies for gasoline. The immediate aftermath of this has resulted in petrol prices skyrocketing nearly three times, and demand has faltered consequentially. It may be too early to tell what the political consequence this may bring on the Nigerian government, or whether other forms of support may materialise in future to cushion the fallout of this subsidy removal.

Beyond the headline grabbing events in Nigeria, other governments have also attempted to remove fossil fuel subsidy support. In the context of LPG, India is one good example where the government had removed direct LPG subsidy for everyone three years ago. Back in June 2020, due to the collapse in LPG international prices, the Indian government was able to remove LPG subsidies without affecting the retail price of LPG. The timing of this removal came with minimal political cost to the government, and monies freed up were channelled to COVID-19 related supports.

However, the complete removal of LPG subsidies did not stick forever. Eventually in 2022, the Indian government reinstated some forms of LPG subsidy support, but now this is only restricted to Pradhan Mantri Ujjwala Yoana (PMUY) beneficiaries. The subsidy exclusion for nearly two-thirds of the population is welcomed. However, it was also a missed opportunity for the Indian government to completely remove LPG support.

Intriguingly, in early 2023, the Indian government had initially planned to completely remove LPG subsidies for PMUY beneficiaries for the new fiscal year of 2023-2024. However, the government ultimately backpaddled its plans and continues to extend subsidy support for PMUY beneficiaries. This episode highlights how sticky subsidies can be, and the complete removal of such support requires strong political determination.

India is not the only example where the government had found it challenging to move away from subsidies. Indonesia is another prime example, where subsidies to LPG remains despite the vast majority of the population are already using LPG for cooking. The gradual removal of subsidy support should be encouraged. However, in practice, this may not happen due to the high political costs that come with it.

Should governments avoid subsidies completely?

However, some countries in Asia have also demonstrated that LPG penetration rates can grow even without subsidy support. Vietnam and the Philippines are good examples where the price of retail LPG is not subsidised by the government. These two countries still enjoy healthy growth in LPG demand domestically, albeit these countries' growth rates will be sensitive to price movements in the international LPG market.

When the international LPG prices were very high in 2022, Vietnam registered negative growth in LPG demand as high domestic retail prices resulted in some form of demand destruction. However, this proved to be temporary as international LPG prices fell in 2023. Retail price in Vietnam fell in tandem and demand has since recovered. Such demand and supply response are to be expected given that these are normal dynamics expected of a free market.

Granted, employing such a "sans-subsidy" policy would mean a slower-than-normal uptake rate of LPG for clean cooking. However, as the country develops and the general populace's standard of living improves gradually, there will be a natural desire by the population to move towards cleaner forms of cooking. This natural process of continued economic and societal development will see an organic shift away from biomass to LPG use for cooking, without getting the government tangled with subsidy support and having to face the difficulty of removing them in future.

Long-term considerations

It could be argued that we are starting to see a shift in attitudes by governments when it comes to fossil fuel subsidies in general, given recent examples like India and Nigeria (for gasoline) trying to phase out subsidies in their countries.

Oil product subsidies, for example, may yield less-than-ideal benefits as it may result in the country being too reliant on them to keep fuel costs low. As we have seen, subsidies to gasoline also consume a huge part of any government's budget, and the self-enforcing nature of these policies means that governments also find it hard to break away from the vicious cycle.

On the other hand, LPG subsidies may provide near-term positive externalities (such as overall less emission and health benefits) which justify its initial use to boost adoption. Over the longer term, strong political will, and an exit strategy to slowly phase out these subsidies are needed to ensure a sustainable approach towards the usage of government budgets. While such a plan may sound straight forward to execute, unfortunately in practice, the outcome is perhaps less than ideal.

Long-Term Price Forecast

LPG, like other NGLs, lie between liquid oil products and natural gas. As such, the prices of NGLs are theoretically influenced by both gas and crude oil dynamics. In trading, however, LPG has tended to follow with the movements in oil markets more than that of natural gas. As such, much of the long-term forecast of LPG prices discussed in this section will depend more on how crude oil markets are priced in the future.

The international trade and pricing of LPG have become more intertwined over the years, and a strong relationship exists across key pricing regions such as the US, Europe, Asia, and the Middle East.

Since the shale revolution of the 2010s, the US has become the key marginal supplier of LPG and is expected to remain so into the future. Asia, being the biggest demand centre with continued growth in demand expected in future, will remain the marginal demand outlet for LPG cargoes.

The pricing of LPG is hence determined by how lengthy or tight the LPG market will be, based on our long-term forecast of demand and supply into 2040. The price of LPG is also influenced by transportation costs to move bulk cargoes across key regions (for example from the US to Asia, or Middle East to Asia). Henceforth, the average freight rate of Very Large Gas Carriers (VLGCs) are also important determinants of LPG pricing into Asia.

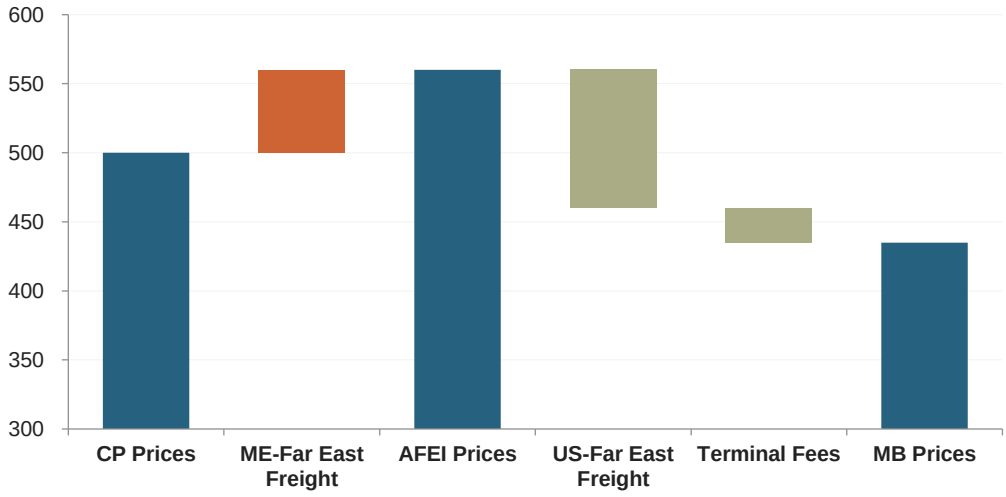
International LPG Price Markers

There are three main pricing points for international LPG prices:

- In the Middle East and in large parts of Asia, wholesale LPG are traded around the Saudi's Contract Price (CP).
- In the US, LPG prices are traded on the Mont Belvieu (MB) complex.
- In Far East Asia, prices are traded on the Argus Far East Index (AFEI).

In theory, Far East Asia AFEI LPG prices (on a delivered basis) should be in equilibrium to netback prices to both the Middle East and the US (see figure below). This is because Asia is the key LPG demand centre receiving supplies from both the Middle East and US. The pricing relationship below forms the basis of our price calculations used in this report.

Fig. 18: LPG Prices and Linkage with Key Benchmarks, US$/t



Source: FGE

Do note that for FOB US Gulf Coast (USGC) prices, a small terminal fee must be included which factors in the transportation cost of moving cargoes inland from storages at Mont Belvieu to the terminal which is subsequently shipped on VLGCs.

LPG Price Forecast Methodology

Given that LPG is mainly a supply-driven product, LPG tends to be priced at discounts to clear in a push market. There are times when a demand pull can emerge from Asia, though less common. When the LPG market is lengthy, LPG prices will be priced at steep discounts to crude to incentivise marginal demand to return into the market. The converse is true as well, when the LPG market is very tight, LPG will be priced upwards to disincentivise demand to rebalance the market.

In the US, MB LPG flat prices are often referenced as a percentage of crude. Historically, this ranged between 40% to 60% of WTI. In lengthy markets, US MB LPG will be priced under 40% of WTI, and in tight markets it will be priced above 60% of WTI.

Based on our long-term demand and supply view of global LPG markets, we make a call on the price of LPG in the US, often as a percentage basis to WTI. We have a long-term price forecast for the shipping market as well, analysing the tonnage supply and demand growth of VLGCs in the long term. This would inform the freight component in the equation, which will allow us to derive Asia's AFEI and the Middle East's CP prices eventually.

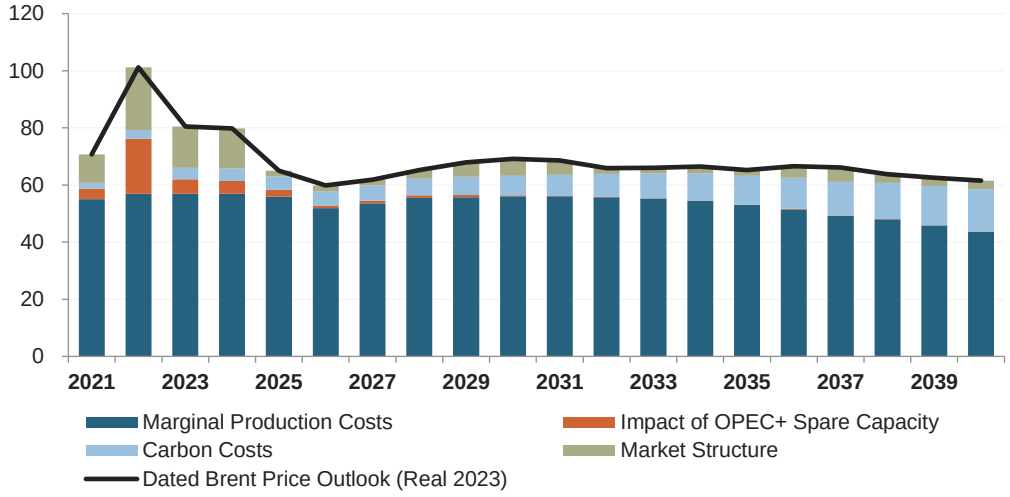
Brent Outlook

Crude prices have been on a rollercoaster ride over the past three years. In 2020, crude prices suffered one of the biggest collapses in recent memory following the onset of the COVID-19 pandemic. In 2022, the unexpected breakout of the Russian-Ukraine war saw crude price briefly spiking above US$130/bbl, albeit prices have since declined from its peak on fears of a weakening global economy and record Strategic Petroleum Reserve (SPR) releases.

In the near term, prices are likely to remain supported in 2024 as the supply and demand balance continues to look tight. This will necessitate OPEC+ to increase production to help rebalance the market. However, with OPEC+ already enforcing some form of crude output restriction till end-2024, we believe that the oil market will remain structurally tight. The tight market will lead to either falling crude stocks globally, or lower OPEC+ spare capacity, or both, which will help support crude prices in the range of $80-85/bbl.

Looking ahead, oil markets are on the cusp of what could be a 10-year period of low oil prices in real terms. From 2025, growth in non-OPEC supply will outstrip demand growth, and prices will come under downwards pressure. In dollar real terms, prices can fall towards $60/bbl by 2026, and then sit in a range of around $60-70/bbl (in line with marginal production costs) thereafter.

Fig. 19: Brent Outlook (Real 2023), US$/bbl



Source: FGE

Note: Inflation rate assumed to be 3% for 2024-2025, and 2% for the latter years

The gradual levelling off of crude oil demand, coupled with growing spare capacity by core OPEC members will ultimately put downwards pressure on oil prices. In our crude demand forecast, we see “peak oil” happening sometime in the early 2030s, with crude demand falling by around 10 mmb/d from its peak to 100 mmb/d by 2050. Furthermore, key members of OPEC like Saudi Arabia are also increasing their crude production capacity from the current 12 mmb/d to 13 mmb/d by 2027 for example. The increased production spare capacity from the oil producing group will weigh on longer-dated crude prices.

LPG Price Outlook

The past two years have been a rollercoaster ride for LPG prices as well. In 2021, due to declines in LPG supply globally from restricted associated gas production, coupled with strong petrochemical demand internationally, the LPG market was incredibly tight. This resulted in the US LPG to WTI crude price ratio to average around 65% in 2021.

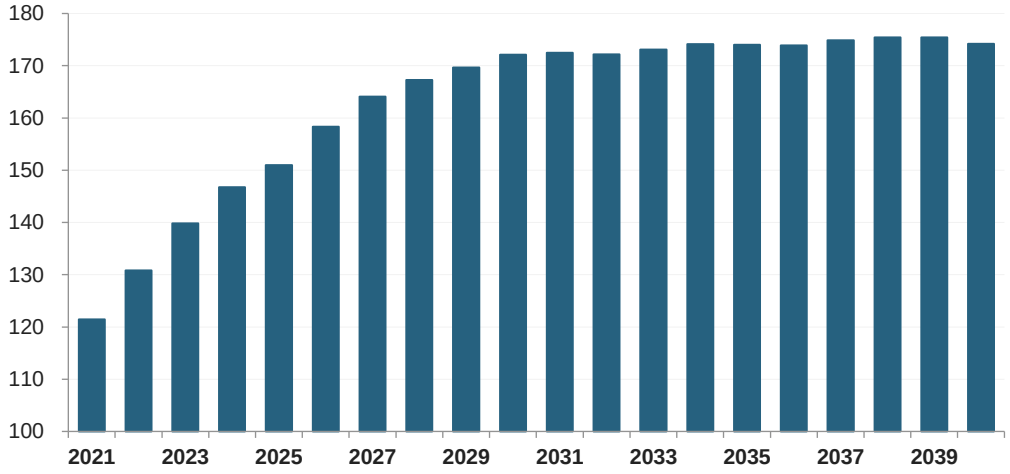
In 2022, the unexpected war between Russia and Ukraine resulted in a spike in crude prices, which in turn led to a surge in upstream investments in the US. Increased drilling for both tight oil and tight gas in 2022 led to a strong supply response, which in turn pressured LPG prices as the market became increasingly lengthy. The strong growth in US NGLs production rolled over into 2023, and the LPG market remains lengthy at the time of writing.

As all boom cycles eventually peter out, the same could be expected for this current growth cycle too. In 2024, we are expecting growth in US LPG to slow down to around 5% y-o-y, down from the 8% in 2023. US tight oil growth will eventually slow to around 1-3% growth for the remainder of the decade, before plateauing in the 2030s.

Relative to 2023, our view is that the LPG market will be fractionally tighter in 2024 albeit remain lengthy on the back of still-healthy production growth globally. Apart from the US, there will also be slight increases in LPG production from the Middle East with a couple of refineries and gas plant projects starting up or in the process of ramping up through 2024.

In the latter half of the decade, there are a few notable gas projects from the Middle East which will help keep LPG production growth healthy. Qatar’s North Field Expansion, for example, will yield close to 6 mmtpa of LPG supply once fully ramped up. Saudi Arabia’s Jafurah Basin project is another notable example which will yield around 4 mmtpa of LPG once fully operational as well. Growth in the Middle East will be more than able to satisfy demand growth in Asia, keeping the market well balanced throughout this decade.

Fig. 20: Total Traded Seaborne Volume of LPG, mmtpa



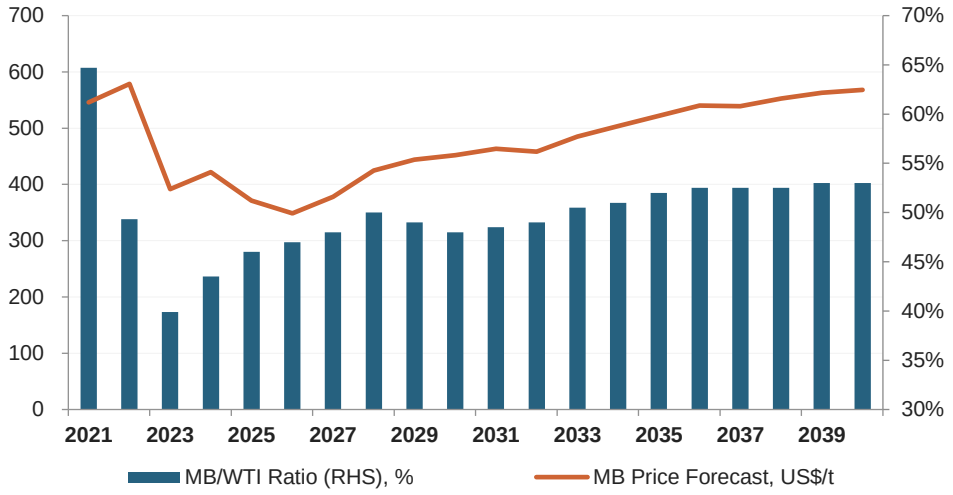
Source: FGE

The market dynamics of LPG will shift slightly as we enter the 2030s. On US production, we are expecting some declines to tight oil growth which will also see declines to LPG production from the US. US exports are expected to plateau as a result, which will see international trade of LPG start to flatline (see preceding figure).

Demand for LPG will also see slight declines in developed regions such as Europe and Northeast Asia. Consumers' shifting attitudes away from LPG, either into using more gas, electricity, or other carbon-lite alternatives, will result in declines to LPG demand. However, strong growth from countries in South Asia, Southeast Asia and Africa will negate these declines in demand expected. The net effect of both shifts to demand (from the developing and developed regions), and a slowdown in supply growth from the US and the Middle East, will see a gradual tightening of the LPG market as we head into the late 2030s.

This henceforth informs our view of a gradual increase in LPG prices. Our base case assumes a largely business-as-usual LPG market per the aforementioned fundamentals, with some small degree of trade war and resulting disruptions. It also assumes no significant shake ups to LPG supply and demand it is hard to say at the time of writing.

Fig. 21: US LPG (MB) and MB/WTI Price Forecast (Nominal), US$/t



Source: FGE

We thus see US MB LPG prices trending up on a relative basis to WTI towards 2040. The above figure's price forecast represents the traded wholesale LPG price of the US market, and the corresponding landed wholesale price into a destination country (in Asia for example) will be the additional freight costs to ship the product from US to the end destination.

LPG demand centres such as Asia will thus still feel fluctuations in US MB LPG prices, with higher US MB LPG prices translating to higher delivered prices into Asia and other demand centres as the cost is passed down the supply chain. Domestic pricing mechanisms in many unsubsidised, import-reliant LPG markets is calculated based on international LPG prices after all.

For example, wholesale LPG prices in Japan, one of Asia's most established LPG markets, is calculated 70-75% based on the Middle East LPG CP price, and the remainder based on US MB LPG price. The change in Japan's pricing formula, which used to be 100% based on CP before 2017, also reflect the US' growing importance as a key LPG supplier.

From the landed wholesale LPG price in the destination country, additional costs such as bottling, distribution and storage costs, traders and retail margins are factored in before the final price of retail LPG is determined.

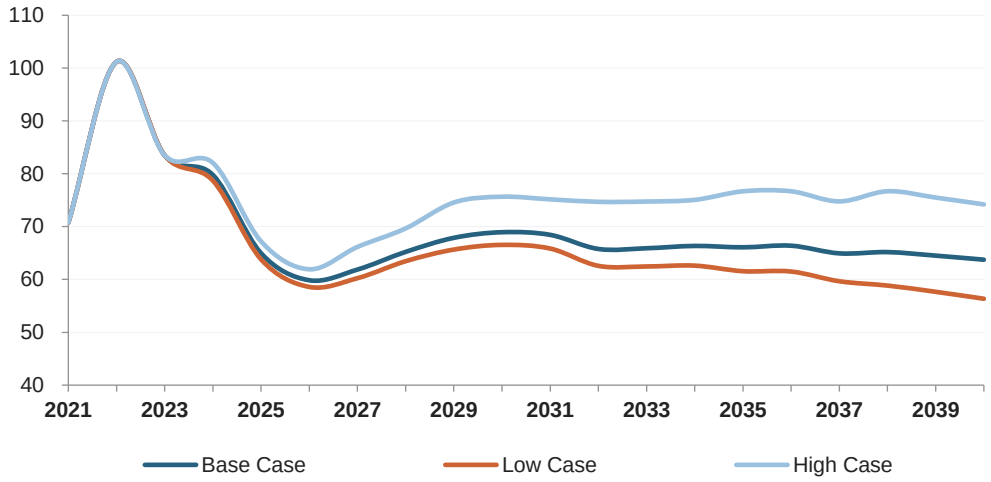
Sensitivity to Brent Price Forecast

We have assumed a “low” and “high” case for our Brent outlook which will impact long term LPG prices.

In the “low” Brent outlook case, we assume that the carbon cost factor to crude production will be lower than expected due to less-than-optimal implementation of carbon taxes over time. The effect of lower carbon costs to upstream production will mean that the marginal cost to supply crude will be lower, thereby informing a lower price to crude prices.

In the “high” Brent outlook case, we assume a higher marginal cost of production. Over time, as countries (and or companies) reduce their investments to upstream drilling activities, economies of scale and efficiency to production is expected to decline. Furthermore, the “high” case also considers higher-than-expected carbon costs should governments act more stringently against our base expectations. These factors, therefore, will raise the cost of production against our base estimates, which will form the upper basis of our Brent forecast.

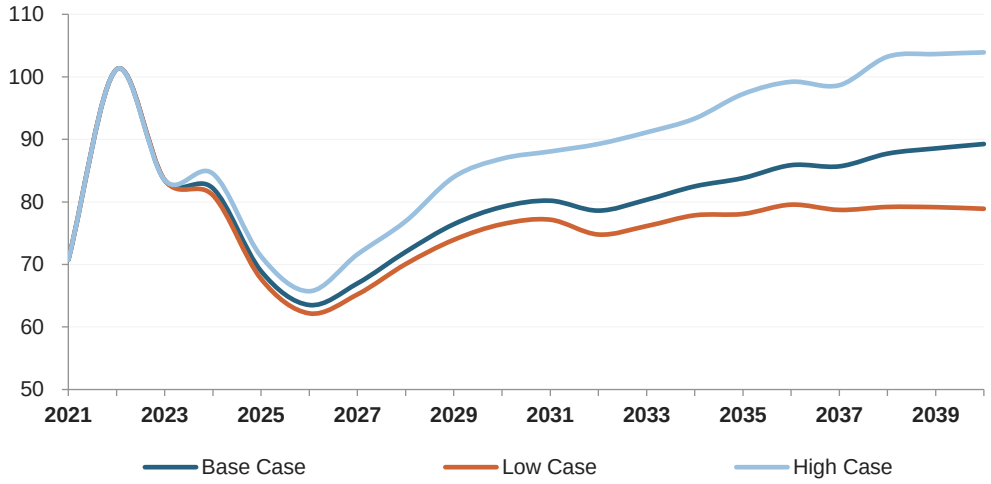
Fig. 22: Brent Forecast (Real 2023), US$/bbl



Source: FGE

Note: Inflation rates assumed to be 3% for 2024-2025, and 2% for the latter years

Fig. 23: Brent Forecast (Nominal), US$/bbl



Source: FGE

Risk Factors for LPG Price Forecasts

Apart from crude flat price sensitivities, there are other factors specific to the LPG market which may impact LPG prices in the future. In this section, we will discuss them in greater detail.

- Trade war between US and China.
- Heightened geopolitical risks resulting in an open conflict.
- Stronger-than-expected growth in LPG demand from the rescom sector.
- Quicker-than-expected declines to oil demand post-2020.
- The removal of fuel-based subsidies which may impact oil demand.

As always with price forecasts, we recognise that there might be unknown unknowns in the future which may see the market price moving beyond the forecasted bounds suggested in this report. Nonetheless, we attempt to factor in some of the known unknowns and forecast the probable impact some of these factors could have on the future price of LPG.

Trade war between the US and China

We live in an era of increased geopolitical risks. Talks about US-China strategic competition may ultimately manifest into another trade war, similar to what happened in 2018-2020.

The previous trade war between the US and China during 2018-2020 is one great example to show how LPG prices can be disrupted should such issues occur in future. Prior to the trade war in 2017, China imported around 20% of its LPG from the US. However, following the onset of the trade war, US-China flows of LPG declined significantly, with Middle East filling in the shorts. In 2019, at the peak of the US-China trade war, Middle East supplied about 70% of China's LPG imports while the US barely supplied any cargoes at all.

This shift was remarkable because it resulted in a dislocation in the LPG pricing benchmark. The Middle East LPG CP price was priced at steep premiums relative to the US LPG MB price since China had to preferentially procure its cargoes from the Middle East rather than the US. This price dislocation meant that other Asian importers, who previously procured cargoes from the Middle East, had to purchase from the US instead. The reshuffling of global LPG trade flow and greater trade inefficiencies meant that shipping costs went up too, which exerted an upwards influence on the Asian LPG AFEI price benchmark.

After Phase 1 of the US-China trade deal was signed in January 2020, the LPG market slowly begun to normalise. US-China flows gradually picked up while Middle East-China flows declined.

It is difficult to rule out the possibility of another trade war materialising in the future, given that the US-China relationship have deteriorated as both countries engage in a strategic competition for global influence. Although recent developments by both Beijing and Washington appear to show some willingness by both sides to improve relations going forward, any unexpected trade wars which impacts the LPG market will undoubtedly mirror the past events of 2018-2020.

The US-China relationship is also notable because both sides depend on each other for the LPG trade. The US as the major growth engine of LPG in the 2020s, will need an outlet for its LPG product. China, on the other hand, has plentiful investments in petrochemical units this decade which consumes a lot of LPG. Henceforth, disruptions to US-China trade relationship will have a big impact to global LPG markets and prices.

Heightened geopolitical risks resulting in an open conflict

Any deterioration in relations between countries which results in an open conflict will have a big influence on oil prices. Possible open conflicts could be between China and Taiwan for example, or further escalation in the ongoing Russia-Ukraine war which involves NATO's participation.

In these “possible” conflicts, crude price could move both ways:

- Downwards, if there is severe economic contraction globally. For example, China-Taiwan conflict results in a global recession because of how interconnected the world’s second largest economy is.
- Upwards, if the economic fallout is not too severe and the open conflict impacts the supply of crude. For example, conflict in the Middle East impacting crude production and crude loading for international markets.

Strong movements in crude prices will hence impact our base-case assumption to our Brent price outlook, which will in turn affect our LPG price forecasts.

Stronger-than-expected growth in the rescom sector

Globally, the rescom sector is expected to grow by around 10-12 mmtpa between 2023 to 2040. While there are still pockets of growth in key regions, many countries in the developed world will see a fall off in rescom usage of LPG over the next two decades. The overall increase in rescom demand between 2023 and 2040 is, on a relative scale, much smaller than the projected growth of LPG from the petrochemical sector.

However, any shifts in the trajectory of how LPG demand will materialise in both developed and developing countries away from our base case will impact the total rescom demand growth factor by 2040. For example, the inability to switch away from LPG for winter heating due to slower-than-expected shifts in consumers behaviours may slow down the rate of decline of LPG demand in developed nations.

On the other hand, stronger-than-expected growth in developing economies may see stronger demand growth profile for LPG, especially if countries introduce more supportive LPG-friendly policies to boost consumption in the country. The overall impact may see higher than expected rescom demand growth, which could tighten the overall availability of LPG in the long term.

This could have an upwards pressure on prices, especially in the 2030s, as LPG production growth starts to plateau off. The higher price could result in a slight reshuffling of demand, with more LPG going into the rescom sector at the expense of the petrochemical sector.

Quicker-than-expected declines in oil production globally

LPG, a byproduct of crude production, is strongly influenced by the output of crude oil across key producing regions. In our current forecast, we see crude oil demand (and production) peaking at around 110 mmb/d in the early 2030s, before declining to 100 mmb/d by 2050. This would inform the “base” level of LPG production from the US and the Middle East.

However, in our “accelerated transition” case, we see a steeper fall in total oil demand compared to our base case, with total demand falling to around the high 80 mmb/d by 2050. This accelerated case will see a quicker phase out of oil from power generation, and full compliance with IMO 2050 by fuel switch away from oil in the marine sector. The potential downside risk to oil production by around 15-20 mmb/d in 2050 (at the worst case) could result in around 15-20 mmtpa of lower associated LPG production consequentially.

The impact of how this may influence LPG price is twofold. Firstly, due to a quicker fall in oil demand, we may see downside risks to crude prices which ultimately feeds into softer pricing for LPG. However, assuming that LPG demand does not get impacted too greatly under the “accelerated transition” case (it is reasonable to expect that gasoline and diesel demand could decline more sharply than LPG), this would tighten LPG market in the late 2030s and into the 2040s due to the lower available supplies in the market.

This will result in an upward pressure on LPG prices on a relative pricing to crude. Ultimately, whether this translates to a higher or lower flat price for the LPG will depend on the relative push-pull factors. If the declines to crude oil prices is the more dominant factor for example, we will see LPG flat price likely to price on the lower end of the forecasts too (and vice versa).

Possible removal of fuel-based subsidies impacting oil demand

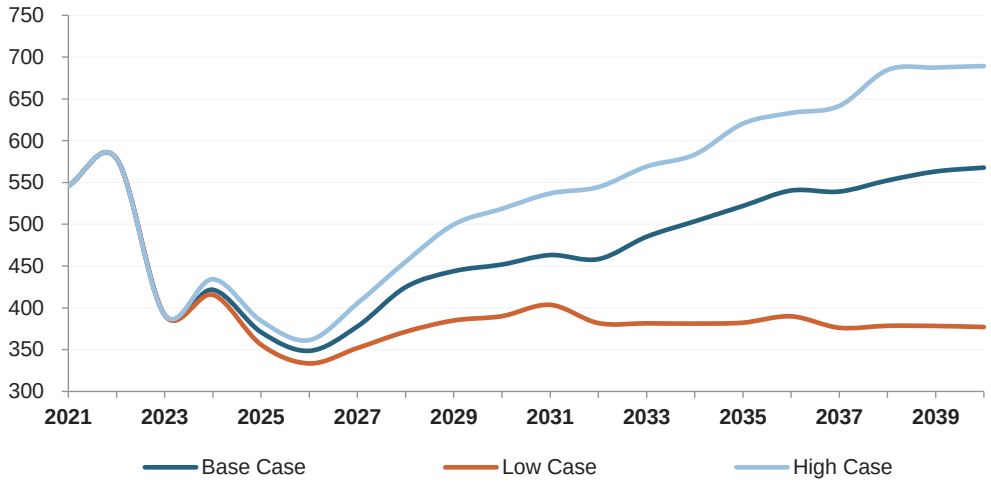
It is also important to recognise that in many parts of the world, there still exists varying degrees of fuel-based subsidies which arguably contributes to higher levels of demand than what it would otherwise be. There is also a growing determination by governments to phase out use of fossil fuel subsidies, following the landmark agreement achieved at the COP26 climate summit.

A scenario with an extensive removal of fossil fuel subsidies could lead to a stronger-than-expected fall in oil demand. Similar to the discussion in the preceding section, stronger declines to oil demand may lead to weaker oil prices which in turn will result in weaker LPG prices as well. Moreover, a removal of subsidies impacting LPG is likely to also lead to softer demand for LPG, which will translate to a lower LPG price on a relative basis to crude.

Sensitivity Analysis for LPG Price Forecast

Taking into account the ranges of Brent crude outlook, coupled with positive and negative variances to the MB/WTI ratio based on how lengthy or tight the market could be given the above-mentioned factors (primarily driven by expectations of lower-than-expected LPG production forecast and stronger-than-expected rescom demand growth), below details our price forecast of the MB price marker.

Fig. 24: US LPG (MB) Price Forecast Sensitivity Analysis (Nominal), US$/t



Source: FGE

Our base case sees the US MB LPG price climbing from US$391/t in 2023 to average US$422/t in 2024 due to tighter supply fundamentals. Healthy supply growth, especially in the Middle East, will lengthen international supply fundamentals and indirectly soften the US MB LPG price in the next few years, bringing it to trough at US$349/t in 2026. The US MB LPG will then gradually climb with the decline in US LPG production, reaching US$451/t in 2030, US$522/t in 2035, US$568/t in 2040.

While it is difficult to accurately predict long-term prices, our low and high cases below try to capture the upside and downside risks to longer dated LPG prices from our base case. The low case represents a possible decline in oil prices and LPG prices due to the removal of fuel subsidies and or an accelerated transition towards net-zero from the 2030s. We see the US MB LPG falling lower than the base case by 4%, 14%, 27% and 34% for 2025, 2030, 2035 and 2040, respectively.

The high case would represent upside risks to LPG prices from supply-related disruptions, or possible and persistent trade wars that may precipitate in the future. We see the US MB LPG climbing higher than the base case by 4%, 15%, 19% and 21% for 2025, 2030, 2035 and 2040, respectively.

Nonetheless, we recognise that there might be black swan events that could occur over the next 15-20 years which were not accounted in the above analysis. This may result in a vastly different LPG price outlook than what has been suggested in this report.

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