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ECONOMIC CONSULTING ASSOCIATES

THE GLOBAL LPG PARTNERSHIP

European Union

Consulting services for elaboration of a feasibility study for LPG promotion in Ghana

Econometric analysis of potential LPG household cooking market in Ghana

8 February 2017

Economic Consulting Associates, The Global LPG Partnership

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Abbreviations and acronyms

BDC	Bulk Distribution Company
ECA	Economic Consulting Associates
EU-AITF	European Union African Infrastructure Trust Fund
GDP	Gross Domestic Product
GHS	Ghanaian cedi
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GJ	Gigajoule
GLPGP	The Global LPG Partnership
GLSS 6	Ghana Living Standards Survey 6
Gp	Ghanaian pesewas
kT	Kilotonne
LPG	Liquefied Petroleum Gas
MJ	Megajoule
NPA	National Petroleum Authority
RLPP	Rural LPG Promotion Program
SE4All	Sustainable Energy For All
UN	United Nations
USD	United States Dollars

Executive summary

Aim	This report addresses the demand potential for liquefied petroleum gas (LPG) to be scaled up as a clean household cooking fuel in Ghana, under the assumptions of high LPG and cylinders availability across the national territory and consumer-awarness being created.
Conducted a probit analysis of GLSS 6 data	Utilised the most recent Ghana Living Standard Survey's nationally representative dataset (GLSS 6) conducted in 2012-2013 to run a probit analysis of household energy use.
Potentially large increase in LPG market with a major improvement in availability	Under GLSS 6 demographic and socio-economic conditions (2012-2013), and an assumed major increase in LPG availability and distribution in the country, could see the LPG household cooking market grow from 120.8 kilotonnes (kT) in 2013 to between 333.6 and 402.1 kT by 2030, based on population increase and income trends.
Any potential market growth would largely come from urban regions	The main areas for LPG demand potential are no doubt from the urban and peri-urban regions (absent further government interventions in rural areas). Almost 65% of the estimated *absolute* increase in the LPG household cooking market would occur in urban and peri-urban areas. Rural regions would also see an increase in demand with higher availability and distribution, with demand volumes potentially tripling.
LPG demand is highly price-sensitive	Analysis of (limited) available 2013 LPG price data suggests that price-sensitivity would remain an important driver of demand. For urban households for whom LPG is widely available, usage is estimated to drop below 35% should prices rise above USD$0.75/kg (314 Gp/kg[1]). For rural households, this number would drop below 10%. However, income increases over time can help compensate for price increases, as would a more stable supply environment. Uncertainty regarding these factors makes reliable predictions difficult.
Interpret with caution given data limitations	Caution should be used in interpreting the results, given potential flaws in both the GLSS 6's household responses to LPG supply availability and price data.

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[1] Note all USD-GHS conversions are set at the 12 December 2016 rate of 4.18 GHS (418 Gp) per USD.

1 Estimating the potential LPG household cooking market size in Ghana

1.1 Introduction

LPG has become an integral component of the domestic energy mix in Ghana. According to GLSS6, LPG for household cooking (i.e., bottled gas) was used by 35.8% of the urban population and 5.5% of the rural population (with a national average of 22.3%) in 2013. Over 52.7% of households in Accra used LPG.[2]

Promotion of LPG as clean household cooking fuel is part of the Sustainable Energy for All (SE4All) governmental strategy. Ghana has adopted a goal of expanding LPG access to 50% of the country's population by 2020[3]. As reported in its 2012 SE4All Action Plan:

> "A *key policy shift to accelerate the rate of uptake of LPG for cooking would be a return to the 'LPG bottle recirculation'[4] model for the distribution of LPG where there would no longer be the need for the construction of LPG filling stations all over the country. Under the 'LPG bottle recirculation' model, consumers will not own their cylinders, but simply pay a deposit for the cylinders and exchange their empty cylinders for a cylinder filled with LPG on payment for the LPG."*

> *"The National Energy Policy strategies relevant to facilitating access to LPG are expanding supply infrastructure and increasing access by:*
> * *expanding storage capacity, and extending bulk distribution infrastructure to all parts of the country;*
> * *supporting expansion of the supply and reach of LPG to homes and small businesses; and*
> * *addressing institutional and market constraints that hamper increasing access" (p. 36)[2]*

Based on these ongoing national efforts, the Global LPG Partnership (GLPGP) has commissioned this report to estimate the potential demand for domestic LPG to help with further planning under the assumptions of optimal LPG supply and a more efficient and effective LPG distribution model.

In a poorly structured market with weak enforcement of market rules, demand is depressed by lack of access to safe cylinders and scarcity of retail points. Cylinder ownership influences how an LPG company (or marketer) maintains cylinders and whom to hold accountable if there is an accident. In the current LPG distribution system throughout most of Ghana, customers purchase LPG cylinders and become the owners of the cylinders, bringing them to filling stations to purchase fuel as needed. This can result in a decline in the safety profile of the existing cylinders in circulation over time. Under a "cylinder recirculation model", proposed in the 2012 SE4All Action Plan, the LPG companies own the

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[2] Ghana Living Standard Survey Round 6 (GLSS 6). Main report. See:
http://www.statsghana.gov.gh/docfiles/glss6/GLSS6_Main%20Report.pdf
[3] Ghana Energy Commission, 2012. Sustainable Energy for All Action Plan. See:
http://www.energycom.gov.gh/files/SE4ALL-GHANA%20ACTION%20PLAN.pdf
[4] Also commonly referred to as 'LPG cylinder recirculation'; LPG 'bottle' or 'cylinder' is used interchangeably.

cylinders and are responsible for maintenance and repair to ensure optimal performance over time.

1.1.1   Objectives

Conducting econometric analysis on the latest round of GLSS 6, we sought to:

❏   Estimate the future potential household cooking market for LPG in Ghana, by region and for urban and rural users, should fuel availability and distribution improve and be more reliable; and

❏   Derive a classic demand curve for LPG as the primary clean cooking fuel with given price data (as of 2013) under the "cylinder non-recirculation system"(i.e., cylinders owned by the customers), which currently characterises Ghana.

1.2   Estimating the potential LPG market size

1.2.1   Methods: probit model

The dataset used for this estimation was GLSS 6, a survey of 16,772 households across Ghana's ten regions, conducted in 2012-13. The survey allowed us to control for socioeconomic and demographic variables, such as age, income, education, etc., its geographic stratification allows for estimating the potential LPG market in all ten regions of Ghana, and it also allows for distinguishing rural and urban households.

The survey provides two key variables of interest. The first is the "main fuel used for cooking" and the second is "respondents' perception of the availability" of certain items, including gas[5].

For the first variable, possible answers included: wood, charcoal, gas (LPG), electricity, kerosene, crop residue, sawdust, animal waste, or other. We set up our probit model such that answering gas equalled 1 and any other fuel option was set equal to 0.

GLSS 6 unfortunately lacks additional questions on secondary fuel use for cooking. Households typically use different fuels at different times depending on the price and availability of fuels as well as types of foods to be cooked, so the survey answers are incomplete in understanding the drivers of LPG demand and estimating the potential household cooking market for LPG. However, the "main fuel" question necessarily serves as the main variable of interest in our probit analysis and the LPG demand projections.

The probit model then provides an estimate of the probability that a household uses LPG as its main cooking fuel. This focuses the identification of the probit model on the impact of increased LPG availability and accessibility on LPG usage. We then combine this probability estimate with household cooking energy needs in order to estimate the total potential

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[5] Note that the GLSS 6 questions do not differentiate between bottled gas (LPG) and natural gas. Given there was no usage of natural gas for domestic use in Ghana at the time of the survey, it is assumed that all the gas used and reported was LPG.

market size of LPG in Ghana under conditions of improved fuel availability and accessibility.

Our second main explanatory variable of interest is the household's perception of LPG availability. For GLSS 6, households indicated whether a collection of items, including energy products like gas (LPG), were "always available", "often available", "rarely available", "unavailable", or "not applicable". For our probit analysis of potential market share, we transformed the responses for gas into a dummy variable such that an answer of "always available" or "often available" was set to 1 and answers of "rarely available", "unavailable", or "not applicable" equalled 0 (see our discussion of the limitations of this response variable in Annex 1). Comparing these two groups allows us to estimate the increase in the probability of gas use due to improved access to gas.

The econometric strategy here is to identify the relationship between LPG availability and household LPG use. Should a significant relationship exist (as expected), we can then estimate the extent to which household LPG usage would increase, should the availability of gas improve. This could potentially be achieved through a campaign to improve LPG access, secure supply lines, and raise household awareness of the benefits of using LPG for daily cooking. The 0-1 dummy variable for LPG usage as the dependent variable focuses the analysis on how much LPG usage would increase, relative to other cooking fuels, given an increase in LPG supply availability and distribution.

The demographic and socio-economic variables included in GLSS 6 allow us to control for household size, the sex of the head of the household, the age of the head of the household, and gross household income. Such controls are included to reduce the possibility of spurious correlations in order to identify better the relationship between perceived gas availability and gas being a household's main cooking fuel. These controls are also used in our estimate of the price effect in Section 2.3.

The probit equation is:

$$\Pr(Y = 1|X) = \Phi(\beta_1 A + X'\beta)$$

where Y indicates whether a household uses LPG as its main cooking fuel or not, Φ is the cumulative distribution function of the standard normal distribution, A is our key explanatory variable: a dummy variable of whether the household considers gas to be "always/often available" or not, X is a vector of our demographic and socioeconomic controls, and the β parameters are estimated via maximum likelihood.

1.2.2   Estimating household LPG consumption in 2013

Our probit model gives an estimate of the probability that a household will choose LPG as its main cooking fuel, but this must also be combined with *how much* LPG a household would consume in order to derive the whole household market's potential size.

We first estimate the size of the LPG household cooking market for each region of Ghana divided in 2013 between rural and urban consumers. GLSS 6 provides an estimate of the number of households in each region (6,601,484), split between urban (3,513,132) and rural (3,088,352) households. We then combine national estimates of households' LPG use with GLSS 6's percentage of households using LPG and average size of LPG-using households.

The national estimates of households' LPG use were obtained by using two sources, as no single source is fully reliable. This is because LPG household usage is usually measured in terms of numbers of cylinder sales and the equivalent amount of tonnes is then extrapolated. However, in Ghana, cylinders are often refilled at filling or petrol stations, making it more difficult to estimate the amount of LPG used for the household cooking sector only. The sources used include the United Nation (UN) Energy Statistics Database, which estimates a 144.3 kT average of total household LPG use for 2012 and 2013[6], and the World LP Gas Association annual statistics, which estimates an average of 122.0 kT of domestic LPG consumption for the same years.[7]

The average of these two estimates (133.1 kT) was then combined with GLSS 6's percentage of households using LPG (22.3%)[8] and GLSS 6's mean household average size for the country (4) to derive LPG use per LPG user. The resulting estimate, *22.6 kg per LPG user per year*,[9] was then applied to the number of LPG users in each region to extrapolate the 2013 LPG household cooking market size by region.

Furthermore, as an alternative measure, using figures drawn from a study of household cooking activities in another lower-income country as no other Ghana-specific figures were identified at the time of the search,[10] we also report the results assuming 27.3 kg of LPG per LPG user per year.[11] This number serves as an upper bound. We report this figure as well in order to provide a conservative range of potential LPG use in household cooking. We use both numbers (22.6 and 27.3 kg of LPG per LPG-user per year) for our projections of total LPG household cooking market size to provide lower and upper bounds, depending on the extent LPG is used more or less exclusively for all cooking needs (see results in Section 2).

1.2.3 Estimating the potential LPG household cooking market size across the national territory

Our estimate of the **potential** household cooking market for LPG is calculated by multiplying the predicted percentage of households who would use LPG (should availability increase to 100%), by the amount of LPG a household consumes and each region's (projected) population. We concentrate on the potential increase in market size that

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[6] Average taken of 2012 (130.2 kT) and 2013 (158.4 kT), given GLSS 6 was conducted between October 2012 and October 2013. Source: UN Statistics Division Energy Statistics Database, 2015. Available at: http://knoema.com/UNSDESD2015/un-statistics-division-energy-statistics-database-2015?location=1000850-ghana

[7] Average taken between 2012 (156 kT) and 2013 (88 kT). Reports (for members only) available at: http://www.wlpga.org/publication/statistical-review-of-global-lp-gas-2012/ and http://www.wlpga.org/publication/statistical-review-of-global-lp-gas-2013/

[8] The percentages of LPG-users by region from GLSS 6 were cross-checked with Ghana's 2010 Population & Housing Census and were found to be generally consistent.

[9] Total household LPG consumption (133.15 kT) / [total number of households (6,601,484) X percentage of households using LPG (22.3%) X average household size (4)] X 1,000,000 = 22.6 kg

[10] Singh and Gundimeda, 2014. 'Life Cycle Energy Analysis (LCEA) of Cooking Fuel Sources Used in India Households', Energy and Environmental Engineering 2(1): 20-30, 2014.

[11] The average daily heat energy requirement per household for cooking activities has been estimated at 2150 kcal in India (equivalent to 9 MJ), based on Singh & Gundimeda, 2014. This corresponds to 620 MJ per capita per year (based on an average household size of 5.3 according to 2011 Census data). Assuming a typical LPG stove efficiency rate of 50% (efficiency typically ranges between 45%-60%), and considering that LPG contains 45.5 MJ/kg of energy, the total minimum annual requirement for cooking is approximately 27.3 kg of LPG per LPG household member.

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would result from an improvement in supply such that 100% of households consider LPG to be "always" or "often" available.

The probit analysis allows for estimating the probability of a household using LPG as its main cooking fuel at various levels of regressors, i.e., for different quintiles of income, age, etc. This allows for estimating what percentage of a region's population would use LPG as its primary cooking fuel if availability was "set" to 100%, as well as forecasting LPG usage as income (and population) rises in Section 2.2.

We report two different potential market sizes: LPG-using households consuming 22.6 kg and 27.3 kg of LPG per person per year as the lower and an upper bounds, respectively. The former can be considered a low case where LPG supply availability improves but households continue to fuel stack due to household cooking preferences, an only partially successful awareness campaign, other fuel prices lowering or LPG prices rising, or a mixture of different reasons. The high adoption case, 27.3 kg of LPG per person per year, would be due to households limiting their fuel stacking due to LPG being more available, reliable and accessible, as well as the ability to afford LPG for daily cooking needs.

In Annex 1, we discuss the difficulty of discerning what the GLSS 6 response "not applicable" means for households perceiving gas supply availability. Such an answer may indicate a household has no access to gas, has never used gas (because the gas is not available), or is unaware of using gas as a cooking fuel in the first place. We believe our full-sample model, which does not drop respondents who answered "not applicable" from the sample and thus estimates the effect of supply availability increasing from "rarely available", "unavailable", or "not applicable" (0 for our 0-1 dummy variable) to "often" or "always" available (1 for our 0-1 dummy variable), is a sensible approach given households unaware of gas or not interested in gas might likely reconsider should gas become widely available and easily accessible to them. A major improvement in supply would also presumably be accompanied by an LPG awareness and safe-use campaign, or other efforts, as those recently promoted by the Government through the Rural LPG Promotion Program (RLPP) distributing LPG equipment free of charge in the northern regions of the country[12].

The predicted number of households using LPG as their primary fuel is based on the probit analysis. In this case, the availability of LPG is set at "always"/"often" available (i.e., demand is not constrained by fuel supply). Fuel supply may be constrained by price regulation that creates supply chain margins (inclusive of transport costs) inadequate to incentivize supply chain participants to expand to serve all available demand. Other non-price constraints may also contribute to conditions of under-supply. A relaxation of supply constraints would likely be accompanied by a supplier expansion and by upward movement (if permitted) in LPG prices (subject to the uncertainties of international fuel price trends), particularly for rural areas. Such an increase in the LPG price could offset to some extent the benefit of increased supply availability. However, for the analysis of the potential LPG household cooking market in this report, we have simplified the prediction and assumed that price is unchanged. We analyse the potential price effect in Section 3, but the utilised price data has important limitations as further discussed in Annex 1.

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[12] https://www.modernghana.com/news/534312/1/govt-launches-lpg-cook-stove-program.html

2   Results

2.1   LPG household cooking market: current size (2013) and potential increase

Our main results for 2013, the final year in which GLSS 6 data were collected, are presented in the percentage of households using LPG in each of Ghana's 10 regions in Figure 1, splitting each region between rural and urban households. The chart is ordered from left to right by largest percentage-point increase, with Volta Urban being first at 20 percentage points. Percentage-wise, some rural areas, like in Volta and Brong Ahafo, could see 400-500% increases in LPG-using households, but this is from a much lower baseline and at lower overall volumes.

Figure 1 Current and potential % of households using LPG, by region for 2013, ordered by percentage-point increase
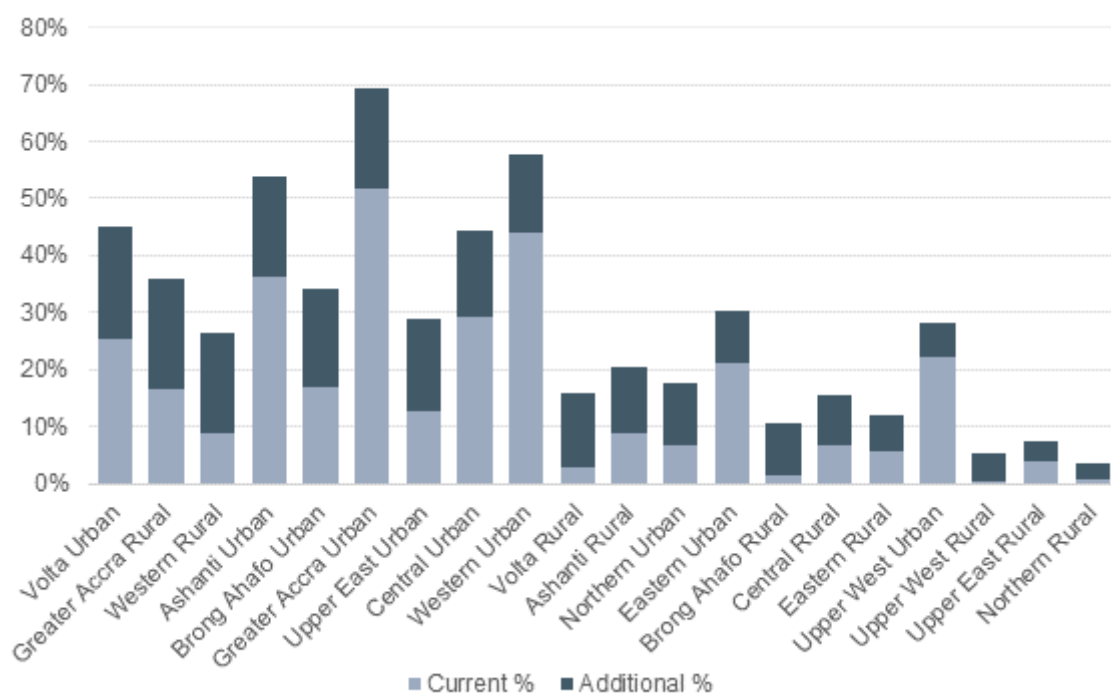
Note: Compares current percentage of LPG-use by households to probit estimate of LPG-use at gas being "always" or "often" available 100% of the time. Probit estimation controls for age of household head, sex of household head, size of the household, and total household income. Evaluated at the region-specific average values of the control variables.

Large potential gains can be seen for the Volta Urban region in particular, as well as the rural areas of the Greater Accra and Western regions and most urban areas. There are significant potential gains for rural regions as well, although the absolute numbers are more subdued due to rural users being less willing LPG users in the first place. Rural regions could see a relatively large increase in LPG use, but urban users would remain the most enthusiastic adopters of LPG in place of purchased traditional fuels.

Table 1 reports the current and potential LPG percentage and volume results for each region.

| Table 1 Summary of current and potential LPG markets by region for 2013				
Region	**Current LPG use**	**Potential LPG use**	**Current LPG market size (kT)**	**Potential LPG market size (kT)**
Greater Accra (*Urban*)	51.9%	69.3%	45.82	67.46 ± 6.28
Greater Accra (*Rural*)	16.5%	35.8%	1.52	3.64 ± 0.34
Ashanti (*Urban*)	36.4%	53.9%	25.71	41.98 ± 3.91
Ashanti (*Rural*)	8.7%	20.5%	3.99	10.38 ± 0.97
Western (*Urban*)	43.9%	57.7%	10.23	14.83 ± 1.38
Western (*Rural*)	8.9%	26.5%	2.82	9.24 ± 0.86
Central (*Urban*)	29.2%	44.4%	7.18	12.03 ± 1.12
Central (*Rural*)	6.8%	15.6%	1.87	4.74 ± 0.44
Eastern (*Urban*)	21.0%	30.3%	5.66	9.00 ± 0.84
Eastern (*Rural*)	5.8%	12.1%	2.03	4.68 ± 0.44
Brong Ahafo (*Urban*)	16.9%	34.3%	4.47	9.99 ± 0.93
Brong Ahafo (*Rural*)	1.6%	10.5%	0.53	3.81 ± 0.36
Volta (*Urban*)	25.5%	45.2%	4.41	8.62 ± 0.80
Volta (*Rural*)	2.9%	15.8%	0.99	5.93 ± 0.55
Northern (*Urban*)	6.6%	17.7%	1.2	3.54 ± 0.33
Northern (*Rural*)	0.7%	3.5%	0.29	1.61 ± 0.15
Upper East (*Urban*)	12.7%	28.9%	0.64	1.62 ± 0.15
Upper East (*Rural*)	3.9%	7.6%	0.74	1.60 ± 0.15
Upper West (*Urban*)	22.3%	28.1%	0.63	0.87 ± 0.08
Upper West (*Rural*)	0.4%	5.4%	0.06	0.86 ± 0.08
TOTAL			**120.78**[13]	**216.43 ± 20.14**

Source: ECA analysis and GLSS 6.

Considering that the total Ghanaian population in 2013 was about 25.9 million according to World Bank data, the LPG per capita consumption for cooking is estimated to be **4.7 kg/capita in 2013**.

Figure 2 illustrates both the current (2013) and potential LPG market sizes from Table 1 with a map of Ghana's regions. Figure 2 shows how the majority of the Ghanaian LPG household cooking market would develop in the Southern regions, which would also be the main source of *absolute* growth in the market. The rural market can achieve a high growth *rate*, but

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[13] Note this slightly differs from our averaged estimate of 133.1 kT due to having to construct estimates of the number of urban and rural households in each region with both GLSS 6 and the 2010 Census, which was used to calculate the percentage of urban households in each region as it is not directly reported in GLSS 6.

it will remain relatively smaller unless specific targeted action is taken (e.g. making LPG cylinders much more available and increasing LPG retail density in the Northern regions). Declared LPG demand often reflects the attractiveness of the offer to the consumer and consumer knowledge, although it is nonetheless clear that LPG would compete with freely-gathered biomass.

Figure 2 Illustration of Ghana's current (left, 2013) and potential (right) market size, by region (kT)
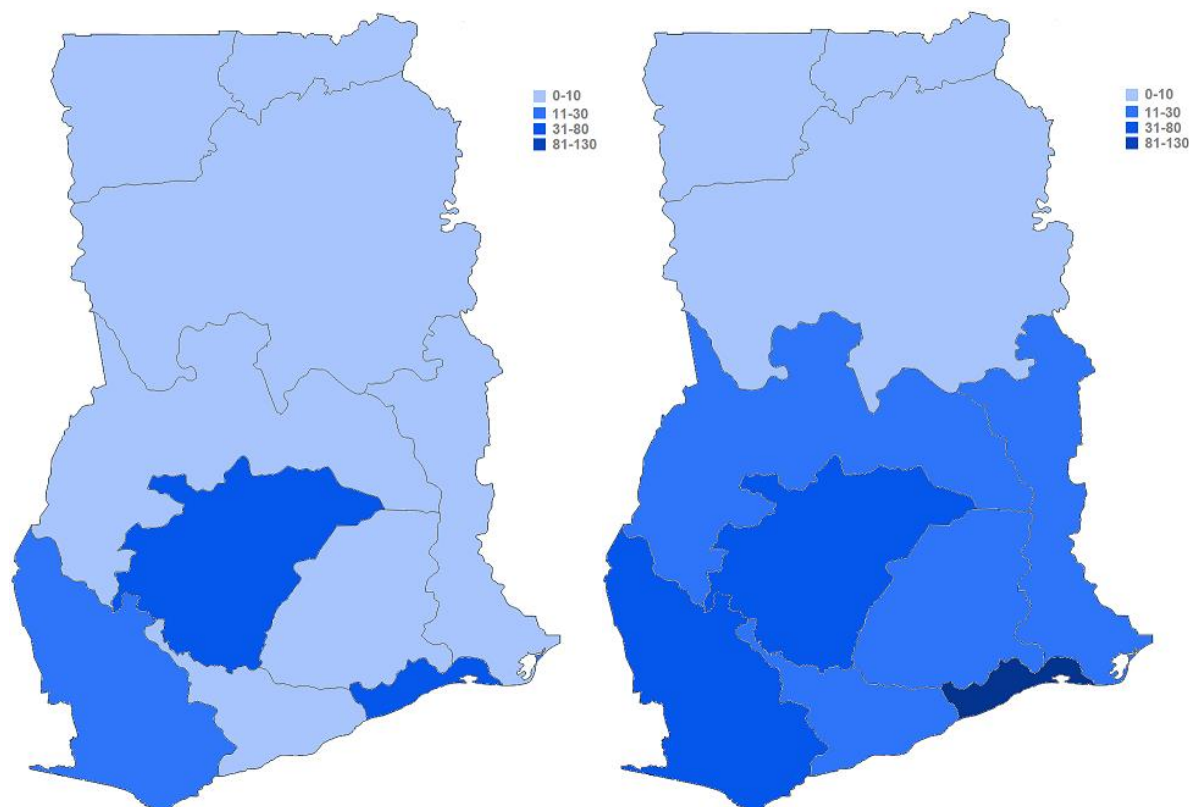
Note: This map assumes the upper bound of LPG consumption for the potential market (on the right).

Figure 3 gives a further sense of the comparative scales of the potential household LPG markets in Ghana's rural and urban regions in 2013. While rural users could see their consumption more than triple from 14.8 kT to 50.8 kT, that is spread over 10 regions. Current and potential rural LPG use is much smaller in aggregate in comparison to the LPG consumption of urban regions, with urban users in Accra potentially seeing their consumption grow from 45.8 kT to 73.7 kT, while the rest of urban Ghana could see their consumption almost double from 60.1 kT to 112.0 kT. Ghana as a whole could see its domestic LPG market grow from 120.8 kT (4.7 kg/capita) to 236.6 kT (9.1 kg/capita). While rural regions could see a ~343% increase in the size of their LPG markets, 69% of the nationwide increase in LPG sales would be in urban markets.

Figure 3 Current and potential size of LPG market (kT) for 2013
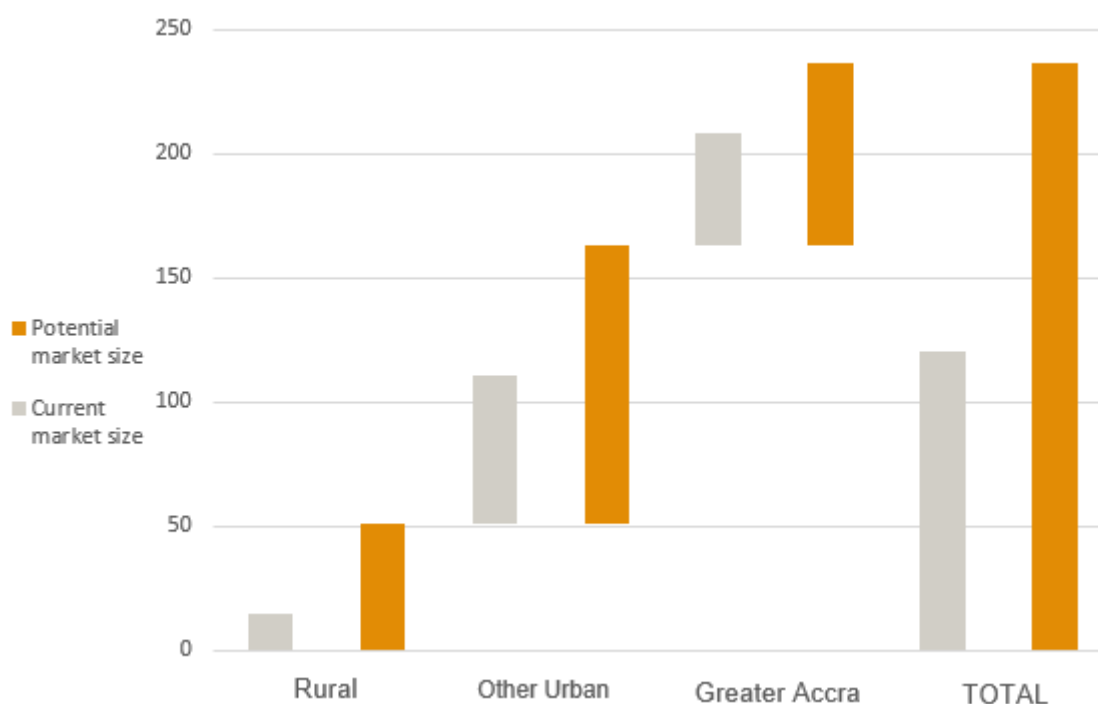
Note: Estimates the current size of the Ghanaian LPG market by multiplying the GLSS 6 estimate of current LPG use by the UN estimate of LPG use per household. We then estimate the potential market for LPG via a probit model of LPG use, estimated at gas being "always" or "often" available for 100% of respondents. The probit estimate controls for age of household head, sex of household head, the size of the household, and total household income.

2.2 Forecast of future potential LPG household cooking market size: 2020, 2025, and 2030

The above estimates only take into account the demographic and socio-economic situation based on GLSS 6 data collected in 2013. We are also interested in what the Ghanaian LPG household cooking market potential may look like 5, 10, and 15 years from now.

We now re-run the numbers under the simple assumptions that Ghana's rural and urban populations will follow an average of their growth rates for 2011-2014,[14] and income per household grows at 5% per annum[15]. For 2020, 2025, and 2030 this corresponds to urban population figures of 16.1M, 19.3M, and 23.1M, and rural population figures of 13.6M, 14.3M, and 15.0M.

For simplicity, we assume that our other demographic controls (age and sex of household head, and average household size) will remain unchanged over this period. The results for

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[14] 1.03% and 3.7% per annum, respectively. Source: World Bank Data. Available at: http://databank.worldbank.org/data/reports.aspx?source=2&series=SP.POP.GROW&country=GHA

[15] Ghana's GDP has grown at an average rate of 6.1% for 2012-2015 (World Bank data: http://data.worldbank.org/indicator/NY.GDP.MKTP.KD.ZG?locations=GH), but this growth was on a downward trend from 9.3% in 2012 to 4% for 2014 and 2015.

the forecasted population and income values for 2020, 2025, and 2030 are presented in Figure 4.

The presented numbers in this section are the *potential* LPG household cooking market size in Ghana with full availability of, and reliable access to, LPG throughout the country. This is not the same as actual LPG demand development extrapolated from current market and supply conditions. Growth of LPG demand would in all likelihood not follow a linear growth pattern and would depend on various factors including LPG availability, increase in total number of safe cylinders in circulation, density of retail outlets (i.e., last mile LPG distribution), capacity of the national filling system, LPG price, consumer awareness of LPG usage benefits, as well as policy and regulatory changes.

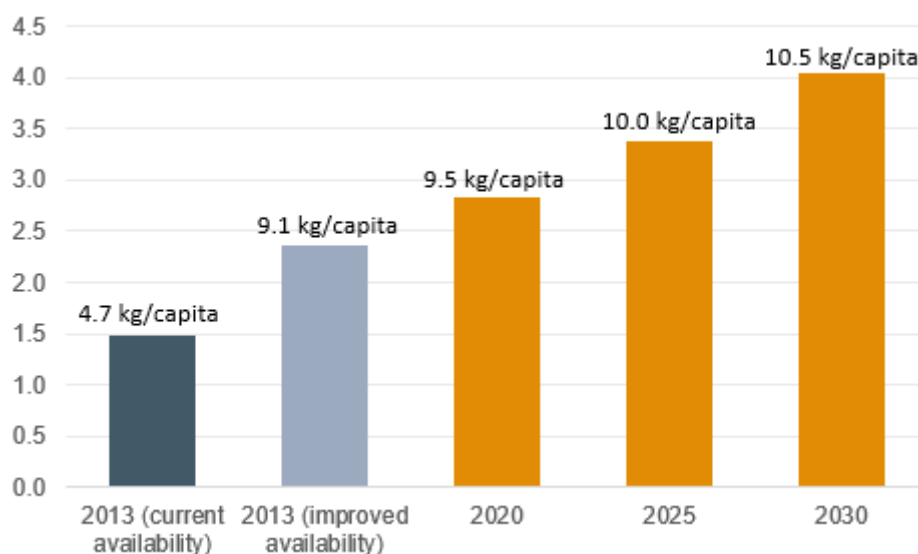**Figure 4 Forecast of potential (not actual uptake) LPG household cooking market size (kT)**
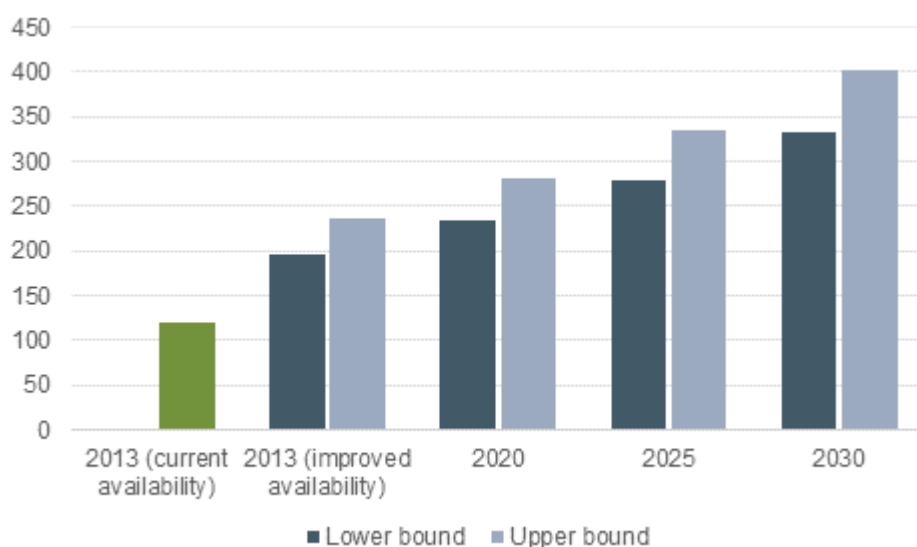
Note: Results of probit model. Applies 5% per annum growth rate to income, 1.03% growth rate to rural populations, and 3.7% growth rate to urban populations.

Using the 2011-14 Ghana population and GDP growth trends, after the initial jump in LPG usage due to the assumed increase in LPG availability, the probit analysis roughly suggests that the potential LPG household cooking market size can grow by ~**20% every 5 years**.

After the growth induced by improving LPG availability from 120.8 kT to between 196.3-236.6 kT (depending on how extensively and exclusively LPG is used, see Table 1), the LPG potential household cooking market size would rise to between 234.1-282.1 kT in 2020, 278.4-335.6 kT in 2025, and 333.6-402.1 kT by 2030. Figure 4 presents the *potential LPG household cooking market* rather than actual uptake, which would likely follow an 'S-curve' pattern as uptake grows exponentially initially before plateauing.

Figure 5 presents the projected growth in the number of households using LPG. The assumed increase in LPG fuel and cylinder availability and retail point density would increase the number of LPG-using households from 1.49 million (measured) to 2.36 (potential) in 2013 as the base year for the projection. Afterwards, based on the income and population growth assumptions (population projected to 38.18M in 2030), the number of households using LPG would rise to 2.82 million in 2020, 3.37 million in 2025, and 4.05 million by 2030.

Figure 5 Forecast of LPG-using households (millions) and LPG use per capita

Note: Results of probit model. Applies 5% per annum growth rate to income, 1.03% growth rate to rural populations, and 3.7% growth rate to urban populations. We assume the number of persons per household stays constant at 2013 levels. LPG use per capita is reported above each bar.

3   Estimating the impact of price on LPG demand

The above analyses ignore the potential demand-dampening effect of LPG fuel price increases. LPG prices have gradually risen in Ghana as the market has become more liberalised, and as the falling Ghana cedi has made LPG imports in dollars more costly (despite a concurrent sharp fall in global LPG dollar prices in 2015-2016) (see Figure 8 below).[16]

To estimate the price effect on LPG demand, we again turn to a probit model. In this case, we include the surveyed price of gas as a regressor, with the dependent variable again being the household use of gas as its main cooking fuel (0 = not using gas, 1 = using gas).

We use the GLSS 6 surveyors' reported LPG market prices (see Annex 2 for a discussion of the serious drawbacks of this price data). After data cleaning,[17] we were left with only 223 observed LPG prices which, when applied to every household within each market's respective Enumeration Area, give 3,103 household-price observations.[18]

We run this analysis for urban and rural households, both for when LPG supply is perceived to be "unavailable" or "rarely" available and when supply is considered "often" or "always" available, and compare the resulting curves for each group of perceived availability. The

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[16] This trend is ultimately dependent on LPG import prices.
[17] Extreme data outliers and cases where the size of the LPG cylinder being priced was not made clear were removed.
[18] LPG prices were collected by GLSS 6's enumerators from the local market rather than from individual households.

demand curves for urban households are presented in Figure 6 and the demand curves for rural households in Figure 7.

In attempting to estimate the impact of price on demand there is normally a problem that the supply and demand equations are simultaneous and price is therefore endogenous rather than exogenous. However, before price deregulation took place in Ghana (most subsidies were phased out by end-2013), the LPG price was regulated at a uniform level across the country, which likely contributed to supply constraints. This means that the *true LPG demand curve is unobserved* and instead the data indicates supply plus a supply constraint. In this case price is exogenous. Although the LPG price was nationally uniform, the GLSS6 survey was undertaken over a 12-month period during which time there was a significant increase in LPG prices. This allows the analysis to identify price impacts on demand, albeit not for the same households.

Figure 6 Probability of LPG use by price – urban households
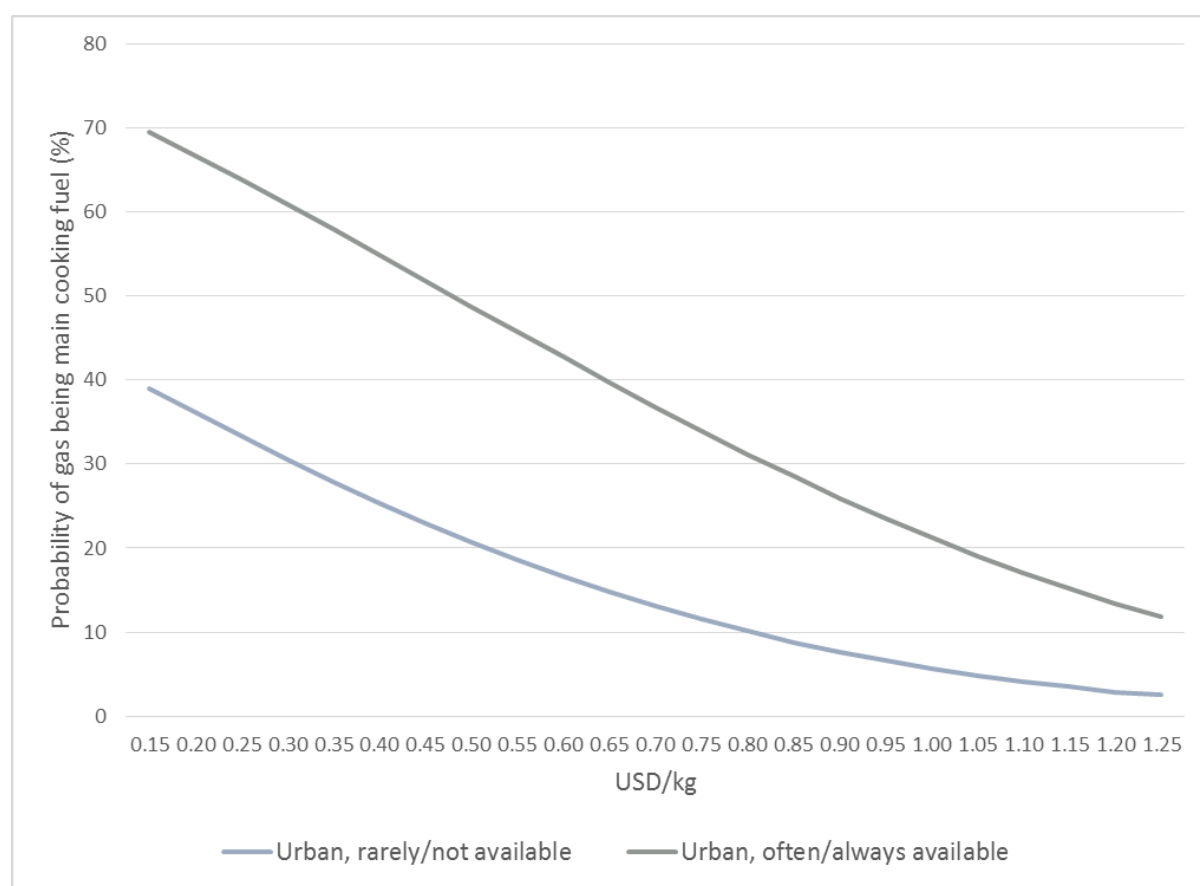
Note: Probit estimation controls for age of household head, sex of household head, and total household income. Curves represent the probit model's estimate of the probability of a household using gas as its main cooking fuel at different price levels. The "rarely//not available" curve sets gas availability equal to "rarely" or "unavailable", while the "often/always available" curve sets gas availability equal to "often" or "always" available.

Figure 7 Probability of LPG use by price – rural households
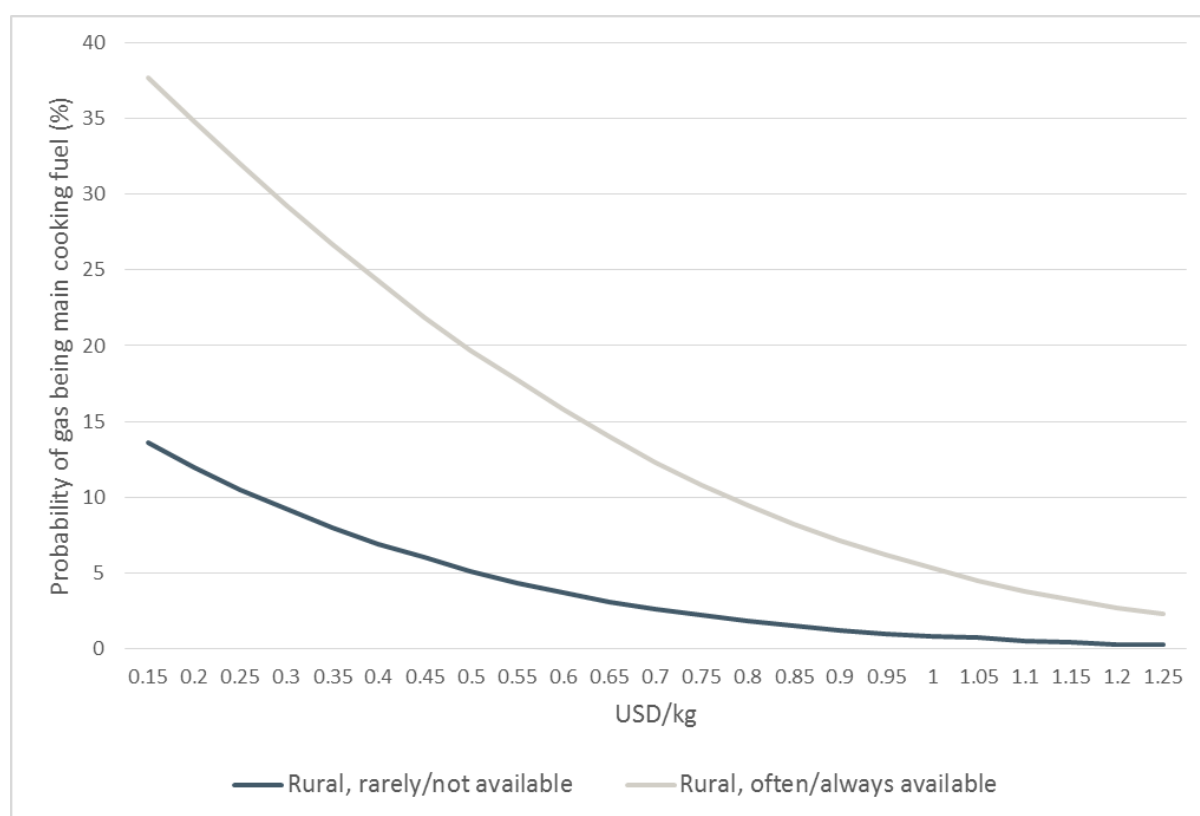
Note: Probit estimation controls for age of household head, sex of household head, and total household income. Curves represent the probit model's estimate of the probability of a household using gas as its main cooking fuel at different price levels. The "rarely/not available" curve sets gas availability equal to ''rarely' or "not available", while the "often/always" available' curve sets gas availability equal to "often' or "always" available.

In Figure 7 we see a strongly non-linear demand elasticity for rural users with broadly available LPG. Their probability of LPG use rapidly drops from above 30% for prices below ~USD$0.30/kg (125 Gp/kg) to less than 10% if the price rises above ~USD$0.75/kg (314 Gp/kg). The decline is less steep for LPG supply-constrained rural households, but demand is never high to begin with, only being above 10% if the price is less than ~USD$0.30/kg (125 Gp/kg) and dropping below 5% for prices above USD$0.50/kg (209 Gp/kg). However, in areas of the country experiencing rapid price increases for woodfuels due to forest depletion and degradation, LPG price sensitivity may be lower.

Urban users (Figure 6) are less sensitive to price, but even urban users who are not supply constrained see their LPG usage probability drop below 35% should prices rise above USD$0.75/kg (314 Gp/kg). However, these negative price effects will presumably be somewhat offset in the future as Ghanaian incomes rise. Furthermore, given the concerns we express about the price data in Annex 2, we caution against interpreting too much into the presented elasticity estimates.

4 Implications for the Ghanaian LPG household cooking market moving forward

4.1 Supply

Ghana has been afflicted by LPG shortages in 2016, as per numerous news reports[19]. The latest 2016 figures for total LPG consumption (which includes LPG for vehicles or "autogas" along with household cooking consumption) from the National Petroleum Authority (NPA) give consumption of 191.6 kT for January-September 2016. This is only ~5% lower than the respective figure for 2015[20]. Given wide reports of shortages throughout 2016, this may reflect that shortages have not been equally felt across the country or that existing supply infrastructure is being strained by rapidly growing demand. News reports on the shortages are generally unclear on the underlying causes.

It is anticipated that significant domestic production of LPG as a natural gas co-product by the Ghana Gas Company can alleviate domestic LPG supply shortages, until such time as its LPG production capacity is exceeded by the growth of consumption, requiring renewed expansion of LPG imports. LPG bulk distribution is conducted by bulk distribution companies (BDCs). As per the NPA's January-October 2016 statistics, Ghana's distribution is dominated by three companies: Fuel Trade Limited (41.8%), Eco Petroleum Limited/SAGE (29.7%), and Tema Oil Refinery (23.2%), covering almost 95% of distribution.

As per this report's analysis, the recent shortages could be interpreted as switching from LPG being "always available" to "rarely/never available". Supposing LPG costs USD$0.7/kg (293 Gp/kg), Figure 6 and Figure 7 imply that this would cause household take-up of LPG as the main cooking fuel to drop by 64% and 79% for urban and rural households, respectively. Intermittent shortages are different from long-term supply inadequacies, but this simple analysis serves to illustrate the importance of secure and reliable LPG supply.

4.2 Price

Prices have gradually risen in Ghana since 2010 (Figure 8) as the sector has been deregulated, subsidies have been pared back, and the cedi has devalued against the dollar (affecting LPG import costs, which are dollar-denominated). The NPA no longer sets regulated prices since the downstream sector has been deregulated, instead providing "indicative" prices for bulk distribution companies to base their prices on.

Reported LPG prices have ranged widely since deregulation. Prices for 2016 have reportedly varied from 305.22 Gp/kg (~USD$0.73/kg) to 472 Gp/kg (~USD$1.13/kg), averaging 387.4 Gp/kg (~USD$0.93/kg)[21].

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[19] See for example this news report on a shortage in Accra: http://www.ghanacrusader.com/gas-shortage-hits-accra/

[20] Consumption statistics downloaded from http://www.npa.gov.gh/downloads/general

[21] As per local sources.

Figure 8 LPG ex-pump price[22] in Gp, National Petroleum Authority (NPA)
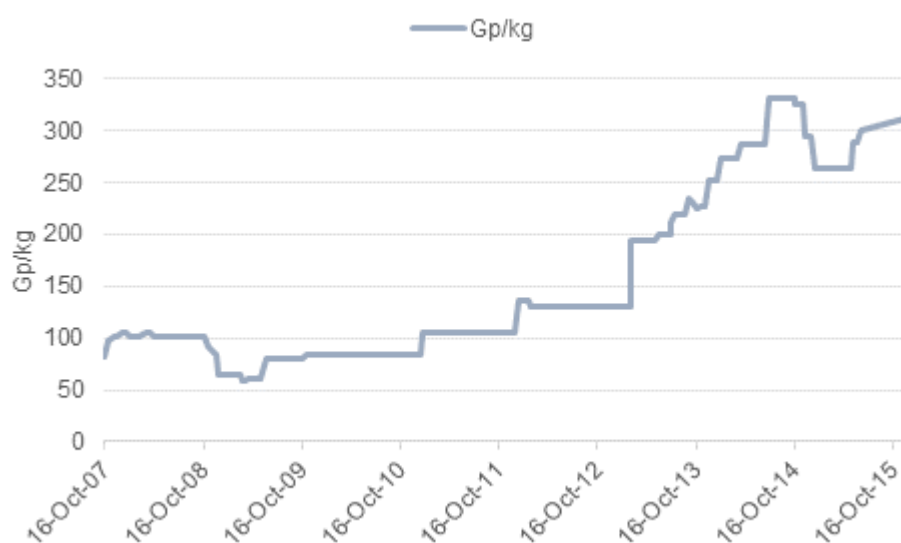
Source: NPA, 'Historical Trend of Petroleum Prices from 1989 to 16th Nov 2016', available at:
http://www.npa.gov.gh/downloads/general.
Note: The price between June 2015 and January 2016 has been extrapolated as the NPA phased out reporting regulated prices by June 2015. The downstream sector has since been deregulated, with the NPA now only providing an indicative price. The price for January 2016 comes from an interim NPA report as part of a parliamentary inquiry.

Table 2 reports the implied take-up of LPG by household type across this range of prices, as well as NPA's last reported price in January 2016 of 314 Gp/kg (~USD$0.75/kg).

Table 2 Implied household take-up at 2016 LPG prices

	LPG price, Gp/kg (USD$/kg)			
Household type	**305 (0.73)**	**314 (0.75)**	**389 (0.93)**	**472 (1.13)**
Urban – LPG "often/always available"	35%	34%	25%	14%
Urban – LPG "rarely/not available"	13%	12%	7%	4%
Rural – LPG "often/always available"	12%	11%	7%	3%
Rural – LPG "rarely/not available"	3%	2%	1%	0%

Source: ECA analysis. Note these indicative numbers are based on 2013 Ghanaian demographics as per the GLSS6 data.

While rural households with limited LPG access have uniformly low take-up at these prices, we see a fairly large shift among urban households with good LPG access, ranging from 14%

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[22] Ex-pump price = commodity cost of gas + insurance + freight + off-loading cost + in-plant losses + rack loading cost + operating margins + taxes/levies.

to 35%. The range for urban households with limited LPG access is 4% to 14%, while for rural households with good LPG access is 3% to 12%.

It is difficult to apply these implied figures to the 2016 situation given we are not only seeing price changes but also intermittent LPG shortages. Further caution should also be taken given the limitations of the price data, as outlined in Annex 2. However, these numbers do illustrate how BDCs will need to take into account household sensitivity to both prices and the security of LPG supply when setting downstream prices.

5   Conclusion

This study was commissioned by GLPGP with funding from the European Union African Infrastructure Trust Fund (EU-AITF) to estimate how much household cooking demand for LPG as the primary clean cooking fuel can be unlocked under optimal conditions, such as a major increase in LPG reliable supply, distribution and safe cylinder availability.

Using GLSS 6, our analysis finds that the LPG market could increase from 120.8 kT in 2013 to 333.6-402.1 kT by 2030, given a continuation of 2011-2014 growth trends in population and GDP growth (barring any potential price effects given international LPG import prices, foreign exchange rates, and the deregulation of fuel prices). This would translate into an increase of LPG usage from 4.7 kg/capita/year in 2013 to 10.5 kg/cap/year in 2030. This increase would cover ~4 million Ghanaian households, approximately 40% of all households. However, such growth would require major improvements to the existing LPG supply chain, including storage capacity, filling, distribution and retailing, and the number of safe cylinders in circulation. In addition, a Government-led awareness-raising campaign to improve Ghanaian knowledge and education of LPG as a clean cooking fuel, could further contribute to increasing demand, provided adequate market rules are properly enforced, access to LPG is made reliable with good distribution, and pricing policy is set to foster adoption.

This analysis also shows that significant increases in the national LPG price may have a substantial negative impact on LPG demand and consumption (although the utilised data should be treated with caution and is insufficient for measuring a "true" demand curve). Price increases can be due to an increase in retail prices and/or higher international LPG prices. The retail prices (and other economically-equivalent terms offered to consumers) can vary geographically and over time because of variances in delivery cost and because of the ebb and flow of the permitted exercise of market power (pricing power) by the distribution and retail network. A regulated retail price system could help reduce the negative effect on demand of price volatility introduced by the distribution network. A temporary regulated price system may be considered in Ghana to stabilise retail pricing in order to create wider consumer adoption of LPG during the early stages of market expansion, and corresponding economic robustness in the distribution network, thereby promoting the switching to LPG across larger portions of the Ghanaian population currently relying exclusively on biomass fuels or kerosene for cooking. These considerations highlight the need to combine supply chain improvements with regulatory support in order to fully promote adoption of clean and safe LPG for cooking in Ghana.

ANNEXES

# ANNEX 1: Potential limitations of supply perceptibility data

There are limitations to relying on a household's perception of LPG availability. The response is necessarily limited by the respondent's exact memory of availability and there is uncertainty regarding what they personally perceive to be "always", "often", "rarely", or "unavailable". For our probit analysis, we try to sidestep this issue by combining the "always" and "often" answers to create a broader "good availability'" variable. The material difference between "always" and "often" available may actually be nil.

The data will also be biased by each respondent's personal perception. A household may regularly be able to use LPG, but users may have complaints about the service of their local gas vendor/filling station that go beyond the basic question of whether gas is available. One household may be too poor to afford and use LPG regularly, yet may perceive it to be often available. Gas may be "sufficiently" available for a household that consistently uses it as their main cooking fuel, but whether a household considers "sufficiently" available satisfactory is subject to their unknown preferences.

A household that fuel stacks between LPG and another fuel may be happy with its current mix of fuel use and may feel its LPG supply is adequate for its needs and therefore report "good availability". However, there may not be enough LPG available to fulfil 100% of the household's cooking needs. If a household were to cease fuel stacking if LPG availability were to increase, their original availability should have been deemed inadequate.

Of greater concern than the uncertainty of perception is the large number of respondents, 56%, who answered "not applicable" when asked about their perception of the availability of gas. 2.4% of respondents who answered "not applicable" also said that gas was their main cooking fuel, again highlighting the uncertainty of the perception answers. Answering "not applicable" could indicate either that they have never used LPG as a cooking fuel even if it were available, that they are unaware of using LPG as a cooking fuel and/or that LPG has never been an available option for them to even consider, or even that the respondent did not fully understand the question. Figure 9 displays summary statistic evidence that the latter two cases are more likely, as 69% of rural households, for whom it is more conceivable that they are unaware of gas or have never had it available to them, answered "not applicable" compared to 39% of urban households.

We do not consider this to be a critical issue for our probit estimate of the potential change in market share should gas become 100% available to Ghanaians. A household answering "not applicable" because they have no interest in using gas may change their mind if gas were to become widely available. Households unaware of gas or having never had it available and thus answered 'not applicable' would certainly give some consideration to using gas if it were to become widely available, particularly if an increase in supply coincided with an awareness campaign.

Figure 9 Perception of gas (LPG) availability, rural vs. urban households
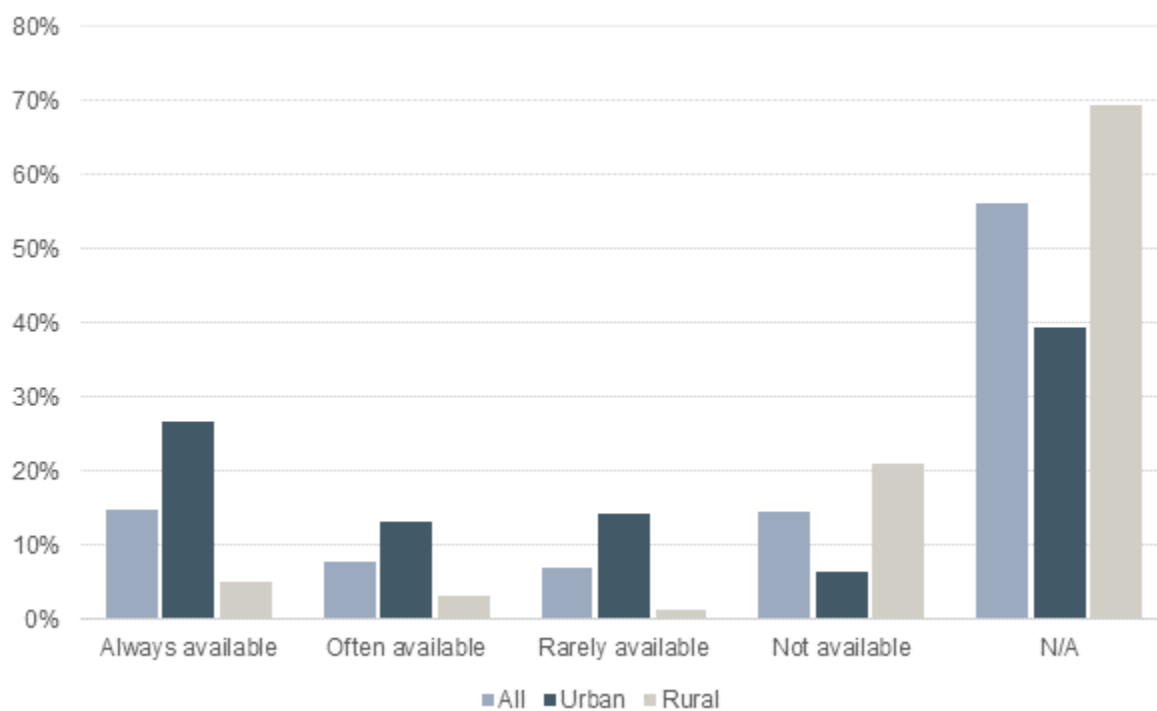
Source: GLSS 6.

ANNEX 2: Potential limitations of reported price data

GLSS 6 includes price data with its surveyors recording the price of gas at the markets associated with the Enumeration Areas. We use this price data to estimate the price effect on demand for gas. The dataset of recorded prices often does not specify the units. For example, many observations only say "1 bottle" to describe the volume of LPG being priced. Therefore, in cleaning the data, we dropped observations that were not explicit about the volume of LPG. Furthermore, to remove the price effect of economies of scale from larger or smaller cylinders, we removed the 2% of the remaining sample that were not prices for 14.5 kg cylinders (which are the most popular cylinders in the market). This left 223 observed gas prices which, when applied to the number of surveyed households in the respective Enumeration Areas, translated to 3,103 price-household observations: 1,848 for urban households, 1,255 for rural households.

To get an indication of the price effect on LPG use, we used the price data collected by the GLSS 6 surveyors from the local market (not from households). The surveyors aimed to collect up to three price observations from each market for a number of different goods, including gas. The markets are unique to each Enumeration Area, so we assigned the observed price in each market to every household within that market's Enumeration Area. Because prices are nationally uniform, and because almost all of the cylinders were the 14.5 kg size, price variations should only arise due to timing differences.

The GLSS 6 data was collected between October 2012 and October 2013. Over this timeframe, Ghana's regulated end-user LPG price rose from 129.9 Gp/kg to 224.9 Gp/kg.[23] However, there is no timestamp on when the market prices were recorded for GLSS 6. The GLSS 6 documentation does not detail whether the three recorded prices reflect the prices of three different vendors at the same market on the day the surveyors visited or whether they are prices taken on three different visits. However, given the largest variability between recorded prices from the same market is only 27%, and 85% of the markets display zero variance across the three recorded prices, the surveyors likely recorded prices over a certain period at one area/market and then moved on to another area/market.
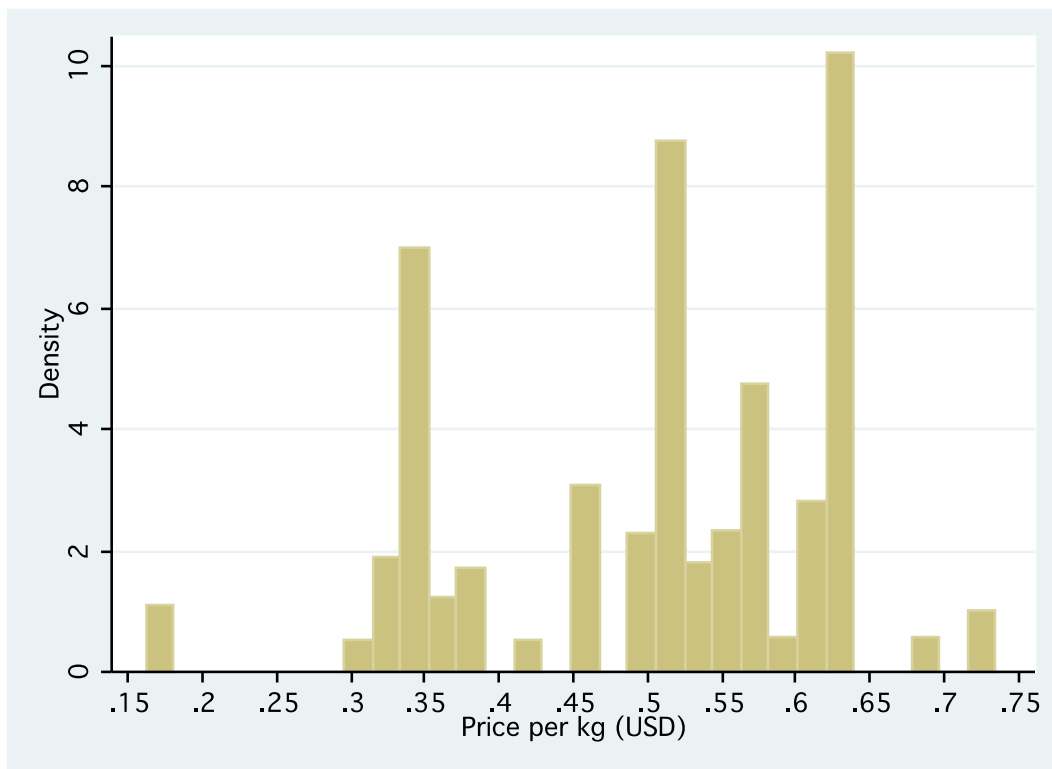
Unfortunately, a serious drawback to the price data is that the survey does not record the date each household was surveyed nor the time at which the market price data was collected. The reported choice of cooking fuel and the observed market price for LPG may not align, calling into question the usefulness of the price-fuel choice observations.

Nevertheless, our price effect estimates exploit the variation in prices observed in Figure 10 and Figure 11, whatever the actual reason for the price variation may be. We note the mean recorded LPG price for urban households was USD$0.475/kg (199 Gp/kg) with a standard error of 0.0026, and for rural households was USD$0.504/kg (211 Gp/kg), with a standard error of 0.0034. The average prices are thus broadly similar, though there is more variation among the rural data.

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[23] 'Historical Trend of Petroleum Products Prices – updated June 16, 2015', accessed at the National Petroleum Authority website.

Figure 10 LPG price histogram: urban households
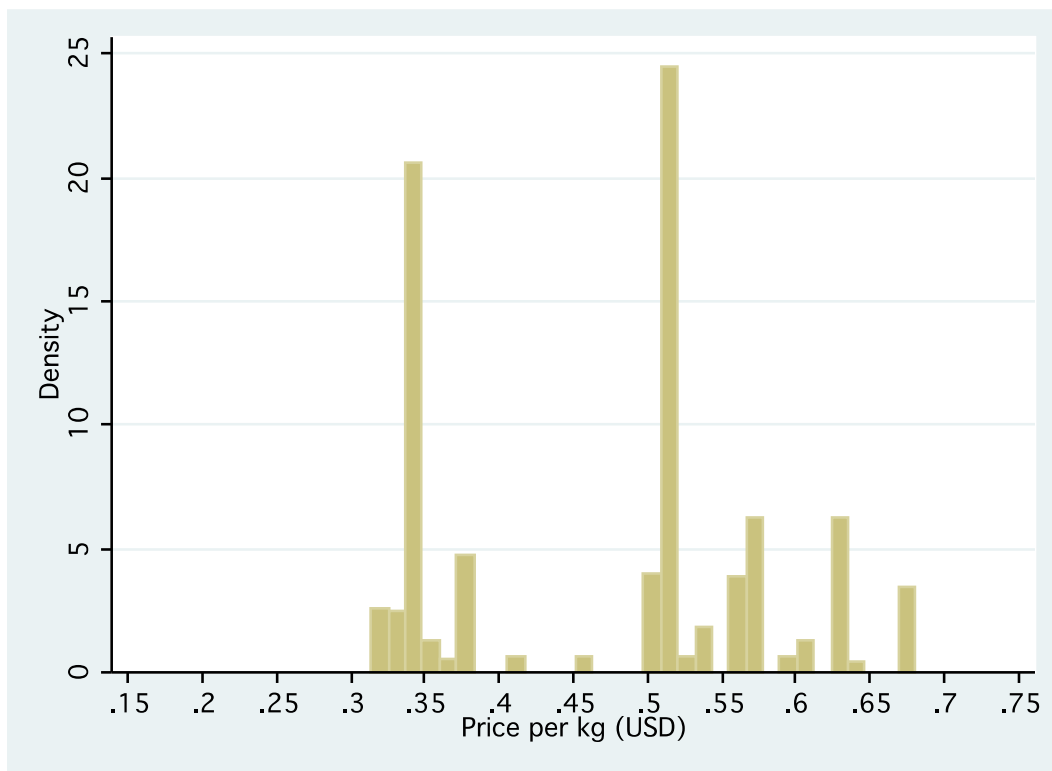
Source: GLSS 6, Stata histogram output.

Figure 11 LPG price histogram: rural households

Source: GLSS 6, Stata histogram output.