The Global LPG Partnership

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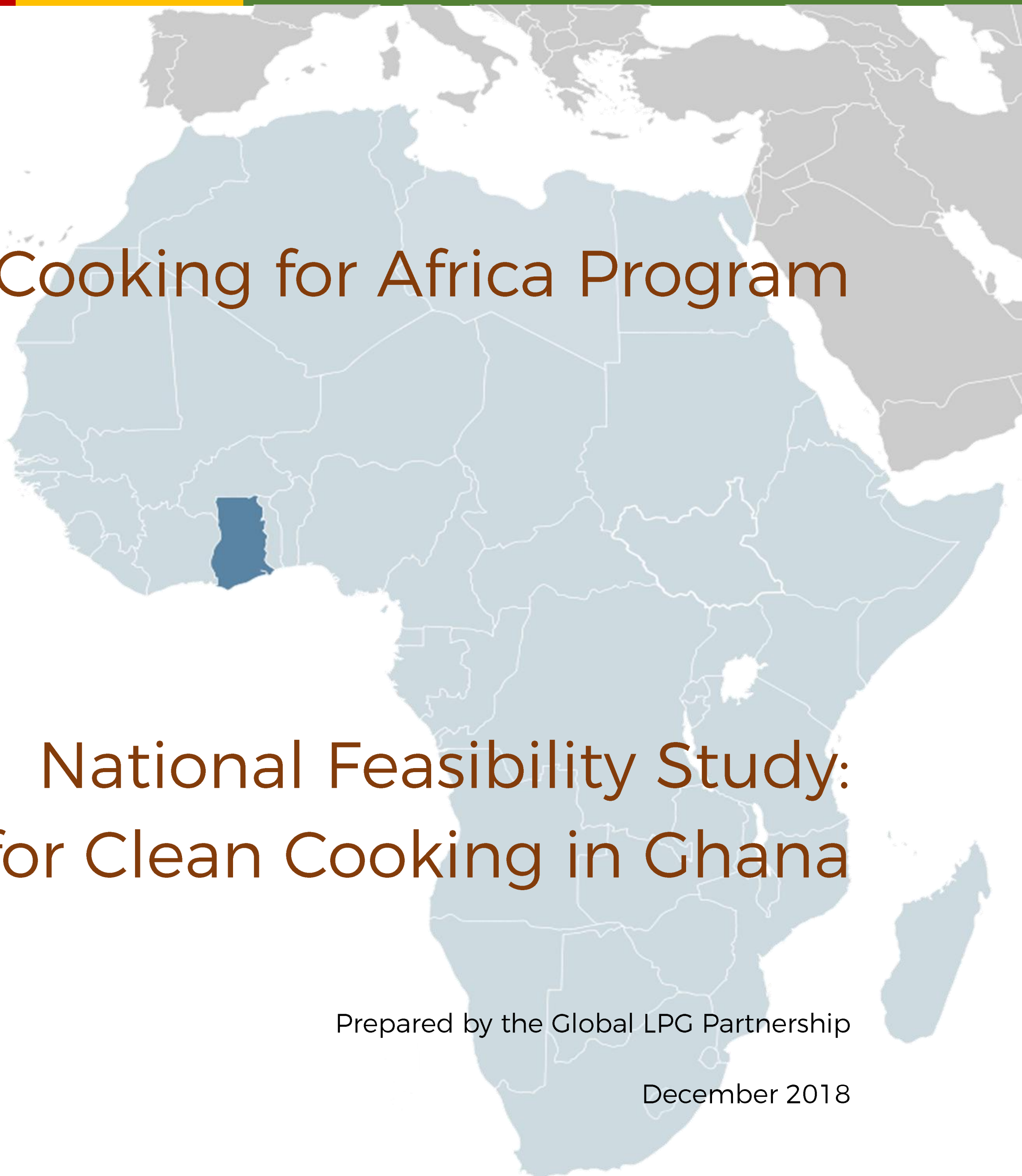

Clean Cooking for Africa Program

National Feasibility Study: LPG for Clean Cooking in Ghana

Prepared by the Global LPG Partnership

December 2018

Household cooking smoke in Ghana:
Before and after switching from biomass to LPG

Photo credit: XpressGas Ghana

Citation

GLPGP (2018). National Feasibility Assessment: LPG for Clean Cooking in Ghana. New York: The Global LPG Partnership.

Contents

List of Tables

List of Figures

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Glossary and Abbreviations

BC	Black Carbon
BCRM	Branded Cylinder Recirculation Model Best-practice model for the structuring and regulation of LPG markets for growth, safety and bankability[1]
BoG	Bank of Ghana
BOST	Bulk Oil Storage and Transport Company
BP	LPG Bottling Plant (also referred to as LBP)
CCA	Clean Cooking Alliance (formerly, the Global Alliance for Clean Cookstoves)
CCCM	Consumer-Controlled Cylinder Model
CDM	Clean Development Mechanism
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CRM	Cylinder Recirculation Model Term of national policy used in Ghana to refer to Ghana's instance of the BCRM
DALYs	Disability-Adjusted Life Years
DHS	Demographic and Health Survey
DFI	Development Finance Institution
EU-ITF	European Union Infrastructure Trust Fund Primary source of financial cooperation funds supporting the Clean Cooking for Africa Program
FNGOs	Financial Non-Governmental Organizations
fNRB	Fraction of Non-renewable Biomass
GACC	See CCA
GBD	Global Burden of Disease
GCMC	Ghana Cylinder Manufacturing Company
GGC	Ghana Gas Company
GHACCO	Ghana Alliance for Clean Cookstoves
GHC	Ghana Cedis
GHG	Greenhouse Gases
GIPC	Ghana Investment Promotion Centre
GLSS [6–7]	Ghana Living Standard Survey 6 or 7
GOIL	Ghana Oil Company

[1] See www.wlpga.org/wp-content/uploads/2015/09/wlpga-guidelines-for-the-development-of-sustainable-lp-gas-markets.pdf

GLPGP	The Global LPG Partnership The Project Execution Agency for the Clean Cooking for Africa Program
GS	Gold Standard
GWP	Global Warming Potential
HAP	Household Air Pollution
HH	Households
IAQG	Indoor Air Quality Guidelines (defined by the World Health Organization)
IFI	International Financial Institution
Institutional capital	Pension funds, sovereign wealth funds, foundations, large family offices, DFIs, IFIs, MDBs, banks and proprietary capital
ISLE	Indicators of Sustainable LPG Expansion
KfW	KfW Development Bank Administrator of the EU-ITF financial cooperation funds supporting the Clean Cooking for Africa Program
kge or kgeq	Kilogram-equivalent A measure used in expressing weighted-average cylinder sizes
KT	Kilotonnes
LMICs	Low and Middle Income Countries
LBDC	LPG Bulk Distribution Company (also referred to as BDC)
LMC or LPGMC	LPG Marketing Company
LPG	Liquefied Petroleum Gas LPG is comprised of propane (C_3H_8), butane (C_4H_{10}), or a blend of both. LPG combusts to give heat with near-zero emissions. LPG is a gas when unpressurized and becomes a liquid under modest pressure across a wide range of temperatures. LPG is created as a by-product of oil and gas production and oil refining
LPGBC	LPG Bottling Company A new category of supply chain participant for 2019 under BCRM, owning/operating a regional bottling (cylinder filling) plant
LPGMC	See LMC
M&E	Monitoring and Evaluation
MDB	Multilateral Development Bank
MICS	Multiple Indicator Cluster Surveys
MFI	Microfinance Institution
MJd	Megajoules Delivered to a cooking pot
MoE	Ministry of Energy and Petroleum
MoH	Ministry of Health
MT	Metric tonnes

NAMA	Nationally Appropriate Mitigation Action Climate change mitigation measures proposed by developing country governments to reduce emissions below 2020 business-as-usual levels and to contribute to domestic sustainable development, as called for in the Bali Action Plan of the UN Climate Change Conference of the Parties
NG	Natural Gas Natural gas is comprised primarily of methane (CH_4) and may contain fractional quantities of other gases such as LPG
NGLs	Natural Gas Liquids Components of natural gas other than methane, which may be separated and handled distinctly from natural gas. LPG is a type of NGL
NIHR	National Institute of Health Research
N_2O	Nitrous Oxide
NPA	National Petroleum Authority Ghana Government agency responsible for implementing Ghana's LPG policy and regulating the LPG sector
OC	Organic Carbon
OMC	Oil Marketing Company
PDC	Private and Development Capital
$PM_{2.5}$	Particulate Matter of a diameter of up to 2.5 micrometres
PRG	Partial Risk Guarantee
Quasi-equity	Convertible debt, convertible securities, revenue shares, warrants
SDG	United Nations Sustainable Development Goals See www.un.org/sustainabledevelopment/sustainable-development-goals
SEforAll	Sustainable Energy for All UN-affiliated organization responsible to assist countries in achieving Sustainable Development Goal 7 (universal access to clean, modern energy)
SSA	Sub-Saharan Africa
TNMOC	Total Non-Methane Organic Compounds
UN	United Nations
Unit margin	The profit to a seller from the sale price of (revenue from) one unit of a product less the variable costs associated with that product
USD	United States Dollars
WHO	World Health Organization
WLPGA	The World LPG Association The international trade association for the LPG industry

Cooking smoke-free on a basic LPG burner and cylinder

Photo credit: GLPGP

I. Introduction

LPG and the vast, deadly, environmentally destructive "clean cooking problem"

2.8 billion people across the developing world have no access to clean, modern energy for their main energy-consuming task: cooking. They rely instead on solid fuels like wood and charcoal, or on kerosene. Their reliance on solid fuels causes millions of premature deaths each year, causes large-scale loss of health, significantly harms forests, retards economic development and contributes to climate change. In this report, this reliance, together with its severe, negative consequences, are called the Clean Cooking Problem.

Addressing this 2.8-billion-person challenge became one of the pillars of United Nations Sustainable Development Goal 7 (SDG7). It is also a stated policy priority of the governments of over 20 low- and middle-income countries (LMICs), together representing one quarter of the world's population.

The International Energy Agency, in its World Energy Outlook 2017, reported that if universal energy access for cooking is to be achieved by 2030, it will be achieved for 1.4 billion of these 2.8 billion persons through access to, and use of, LPG. That is, LPG would become the solution to the Clean Cooking Problem for, potentially, half the world, over at least the next 12 years.

What is LPG?

Briefly, LPG is a gas with very high energy content, similar to natural gas, that can be transported very efficiently in small, sturdy bottles, called cylinders, for combustion by consumers to create heat. LPG is often called "cooking gas" in developing countries, where cooking is its primary use. Chemically, LPG is comprised of the gases propane or butane, or a mix of the two. Approximately 2 billion people worldwide are LPG users today, according to the World LPG Association, an international trade body.

The Clean Cooking for Africa Program

Supported by a grant from the European Union Infrastructure Trust Fund and administered by German development bank KfW, the Global LPG Partnership undertook to address in detail the question of how feasible and scalable LPG could be as a clean cooking energy solution in three partnering African countries, and how such scale-up could be effectively carried out and financed across the full LPG value-chain.

These three countries are Ghana, Cameroon and Kenya.

Collectively, this multi-country effort is called the Clean Cooking for Africa Program. The program further contemplates, where properly justified, to direct appropriate resources for implementing national-scale LPG solutions.

The purpose of this report

This report, part of a series of five, examines the feasibility and potential role and scale of LPG as a major clean cooking energy solution for Ghana through 2030. It also estimates the range of beneficial social, environmental and economic impacts potentially realized from deploying an LPG solution at scale in Ghana through 2030.

The Government of Ghana has set a national policy goal of at least 50% of the population using LPG for cooking by 2030, up from 24.5% in 2017.

The Clean Cooking for Africa report series also seeks to contribute meaningfully to the global evidence base that informs energy-development debate and decision-making for addressing SDG7 and the Clean Cooking Problem, and to highlight areas for follow-on research to strengthen the evidence base yet more.

Reliable data about LPG sectors and consumers in the LMICs is not yet plentiful. However, enough data existed or were created through fieldwork to make a feasibility assessment possible in the three partner countries. The sources of data and of assumptions used are referenced throughout this report to allow interested readers to examine further and confirm for themselves the soundness of the report's findings and conclusions and the reasonableness of its recommendations.

Companion report

A companion report, the *Ghana LPG Investment Report*, examines in much greater depth the essential investment projects required for scale-up of the Ghana national LPG sector, the associated risks and rewards, and how their financing could be best achieved.

For whom this report is written

This report is intended to provide evidence, analysis, guidance and recommendations to five main categories of reader:

- Policymakers and governmental agencies;
- LPG industry participants, in particular those operating in Ghana;
- Public sector and private sector investors;
- Other stakeholders in the clean cooking and LPG sectors with respect to Ghana; and
- The global research community.

The report attempts to balance the needs and interests of all five audiences.

Beyond 2030

The Clean Cooking for Africa Program limits its time horizon to 2030, on the premise that the LPG solution is likely to be transitional. If the answer to the question of whether LPG is a viable, large-scale, rapidly deployable, and overall socio-economically beneficial and environmentally and climate-benign solution to the Clean Cooking Problem in many, or most, countries is yes through at least 2030, then LPG is at a minimum a bridge to a fully renewable, clean, modern and effective cooking-energy solution that may emerge in the future. With the entry into commercial markets of meaningful, competitively priced quantities of bio-LPG during 2018, the lifespan of investments in LPG-based solutions for clean cooking may well extend far beyond 2030.

Potential LPG Impacts in Ghana to 2030

People cooking cleanly — **10-14** million more

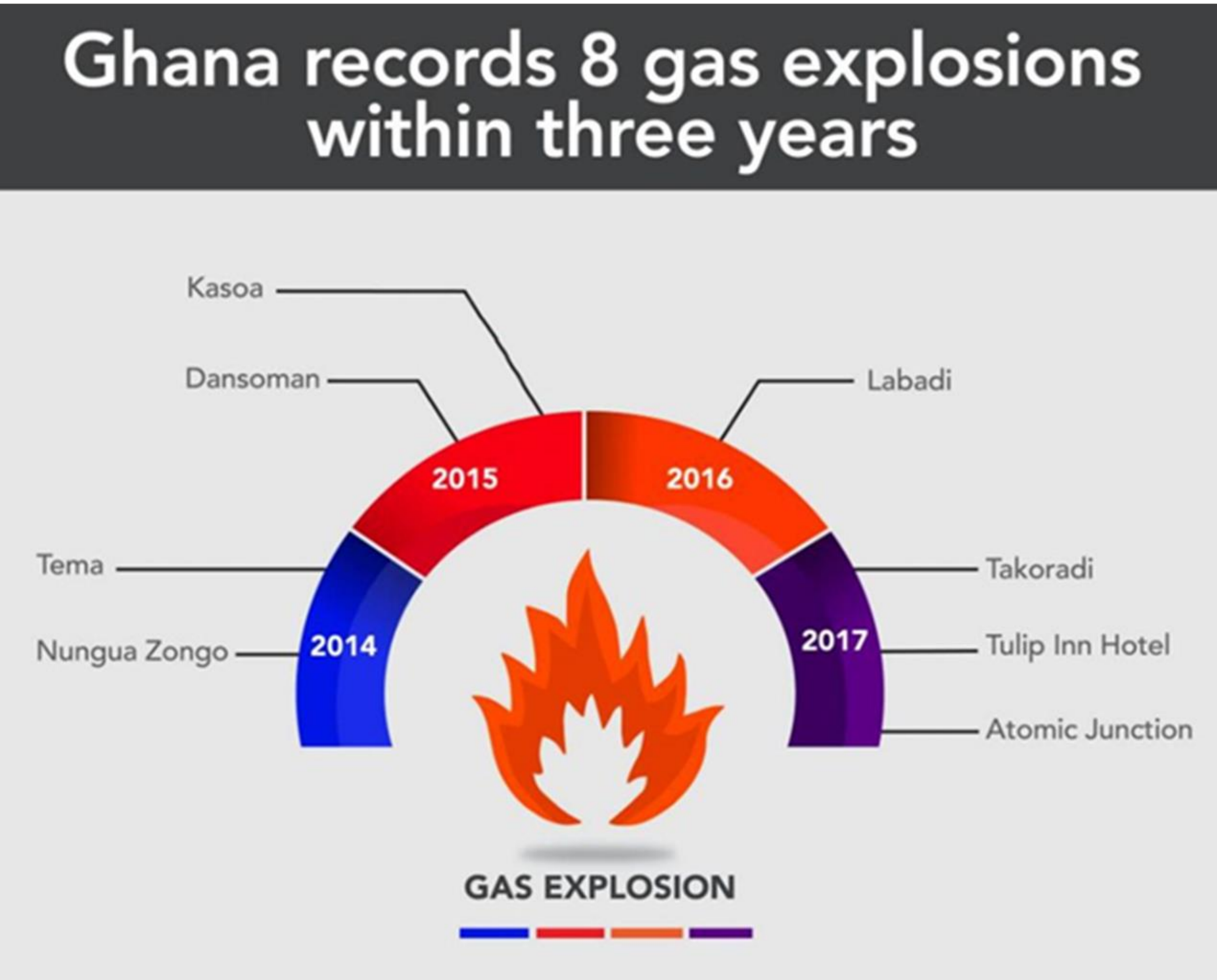
Lives saved — **12,000-19,000**

Trees saved — **130-220** million

CO_2 reduced — **7-9** million tonnes

New investment — € **335** million

Future safety incidents  **Zero**



Safety meter credit: CitiFM Ghana

II. Executive Summary

The Government of Ghana has set a policy goal of 50% of the population using LPG as their main cooking fuel, and for other uses, by 2030. The main reasons are to reduce pressure on Ghana's forests from use of unsustainably harvested wood fuels and production of charcoal for cooking; to make substantial progress toward Sustainable Development Goal 7 (universal access to clean, modern energy); and to improve the lives of Ghana's people and accelerate Ghana's development.

Today, approximately 24.5% of Ghana's population uses LPG as its main cooking fuel.

This report reviews Ghana's progress, issues, and planning toward its policy goal; assesses under what conditions and to what extent the policy goal is most likely to be achieved; and presents a roadmap for completing the enabling environment for, structuring the financing of, and specifying the implementation of the projects throughout and adjunct to the LPG value-chain necessary to reach the policy goal.

Demand

A key finding is that the LPG demand quantity in Ghana is supply-constrained. This is true of many Sub-Saharan African LPG markets which have not yet reached a mature and sustainable stage. This indicates that LPG adoption can be expanded significantly by increasing LPG availability to new consumers. A second key finding is that additional measures, such as improved affordability and consumer education, would have additive effects on both adoption and usage.

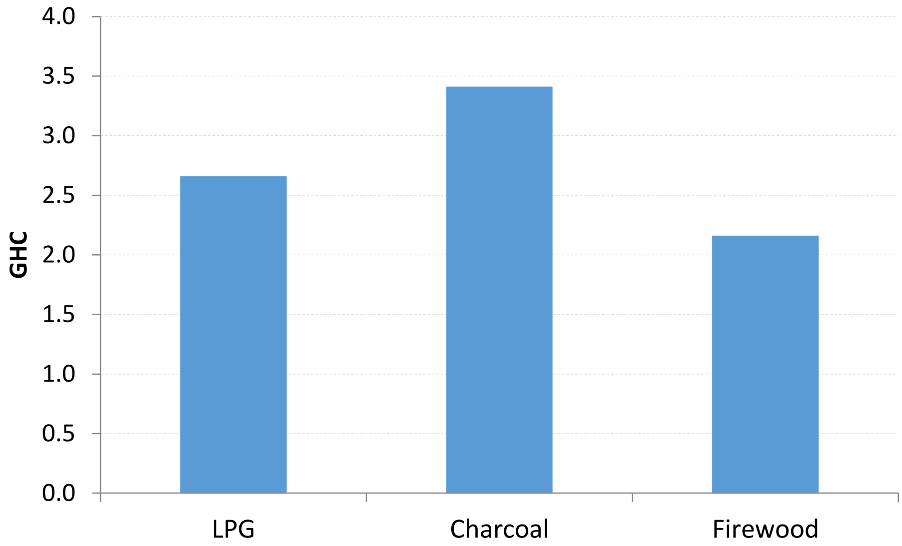
A detailed modelling of demand potential in Ghana indicates that the demand potential among candidate households could reach between 46-55% of all households by 2030, if supply were unconstrained and essential market reforms and investments made. These factors are discussed in more detail in Part VI of this report.

The corresponding growth in residential LPG consumption would be in the range of 2.5X to 3.3X of the 2017 level, rising from approximately 165 KT in 2017 to between 404 KT and 530 KT in 2030.

LPG penetration would grow most noticeably in Ghana's southern and central regions outside of the Greater Accra region. Growth in the three northern regions (Northern, Upper West and Upper East) would be proportionately less. This is caused in those three regions by (i) lower average household incomes; (ii) prevalence there of "free" wood fuel for the collecting; and (iii) less developed road infrastructure.

An examination of fuel costs and consumption data in representative locations throughout Ghana showed that LPG competes favorably on a cost-per-meal basis with charcoal, but not with purchased firewood:

Figure 1. Average household fuel cost per meal cooked with LPG, charcoal and firewood (in GHC)



However, LPG is chosen by consumers not only on the basis of cost, but also on the basis of preferences. Increase in preference for LPG, particularly among higher-income households, would lead to a greater and faster adoption and greater consumption in a reformed market with adequately expanded supply. This case is modeled in the upper end of the range presented above.

Part VI (LPG Demand Potential to 2030) of this report describes in detail the demand projections, modelling, and associated methodologies.

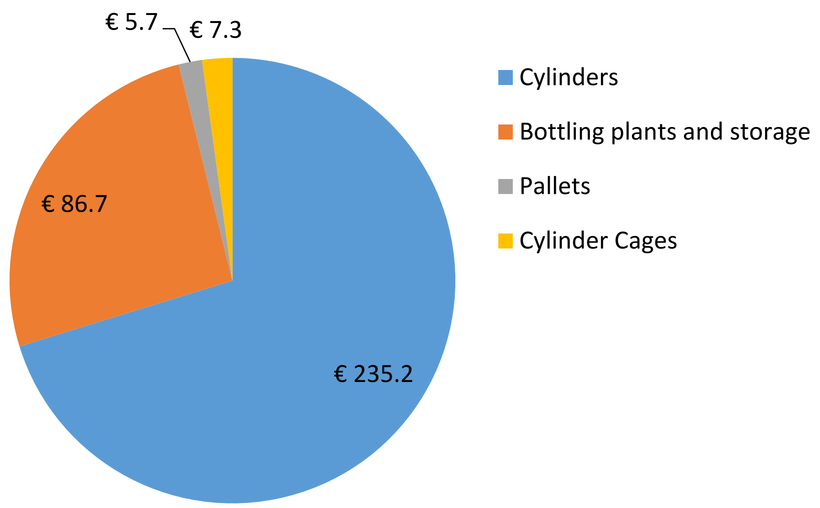
This Part also describes a microfinance pilot project that has been designed with relevant Ghanaian stakeholders as the operational and financial partners, intended to overcome the barrier of up-front cost for poorer households to acquire the LPG equipment needed to begin using LPG, and the results expected to be achieved based on relevant benchmarks.

Investments

The total investment required to expand the LPG supply chain to achieve the policy goal, and thereby to satisfy a level of demand within the aforesaid range, is estimated at € 335 million, excluding importation and production, allocated as follows:

Table 1. Capital investment requirements to 2030 for LPG sector scale-up

Category	Capital Requirement (mm Euro)
Cylinders	€ 235.2
Bottling plants and storage	€ 86.7
Pallets	€ 5.7
Cylinder Cages	€ 7.3
Total	**€ 334.9**



As is the case in all LPG markets worldwide, the key asset for LPG market expansion is the inventory of cylinders, without which there can be no growth in residential LPG users.

Such investment would be staged in annual increments over 12 years. When the key leading indicator of market saturation used by the LPG industry, the cylinder rotation rate, begins to trend downward, further investments made on a commercial basis would be slowed or stopped in order to meet the financial return requirements of investors. Any further expansion of the value chain would then depend on additive incentivizing measures put in place for industry and/or for consumers.

The scale of investment, calibrated to the governmental policy goal, lies between the lower bound and upper bound of projected demand, with the key difference between the lower bound (44% penetration) and upper bound (55%) being increased consumer preference for LPG. Therefore, to realize the adoption level of the policy goal (50%) that is above the lower bound projection, it may be necessary for preference-stimulating measures to be implemented, such as affordability measures and consumer educational measures.

Part VII (LPG Supply Chain Development and Planning) of this report discusses these investment projects and supply chain design in detail.

Policy and regulation

The Government of Ghana, following several years of consultations with stakeholders, local and international partners (including the Global LPG Partnership), and policymakers, regulators and LPG sector leaders of other developing countries, determined that the country's market model for LPG must be transitioned from the current Consumer-Controlled Cylinder Model (CCCM) to the Branded Cylinder Recirculation Model (BCRM), for two main reasons.

First, the CCCM model, which has been in effect in Ghana for much of the 21st Century, has contributed to an accelerating number of serious, often fatal, LPG safety accidents. The BCRM model, when well implemented and well enforced, has had a demonstrated superior record of public safety worldwide[2]. Second, the CCCM model results in an industry structure with high investment risk characteristics and negligible incentives for private sector-led market growth, contrasted with the BCRM model, which creates a lower risk profile for investment and effective incentives for private sector-led market growth.

As of this writing, the Government has not completed its planning process for the implementation of BCRM and the corresponding investments and transition steps applicable to the full supply chain.

Therefore, certain decisions about the ultimate structure of the market, its regulation, and its (regulated) economics and pricing are still pending. The Government expects to conclude its process in early 2019, and to begin implementation as soon as practicable thereafter.

Part V (LPG Enabling Environment) of this report discusses the nature and status of the policy and regulatory reforms currently underway or contemplated, the rationale for these reforms, and anticipated consequences for safety, supply availability, affordability, and bankability and growth financing for the LPG sector.

Impacts

A key motivation of the Ghana Government to promote national LPG adoption and use; of the Global LPG Partnership, the EU ITF and KfW to study, to assist, and potentially to direct resources to, Ghana's LPG transition and scale-up efforts; and of the global development community generally, is to translate wisely spent funds into demonstrated, significant social, environmental and economic impacts for the host country.

This report examines three scenarios of LPG market development through 2030 and estimates the expected impacts from these against a business-as-usual case in the following categories. The lower-bound and upper-bound of these scenarios are shown here, covering the period 2020[3]-2030:

Environmental:

- **Averted deforestation**: 11 – 21 million trees saved annually relative to base case projections in 2030 and 127 – 221 million trees saved between 2020 and 2030.
- **Carbon dioxide equivalent (CO_2eq) emissions[4] averted:** 0.50 – 0.76 million MT of CO_2eq emissions reduced annually in 2030 and 6.76 – 9.30 million MT of CO_2eq emissions averted cumulatively between 2020 and 2030.
- **Black Carbon equivalent (BCeq) emissions[5] averted:** 1.0 – 1.7 million MT of BCeq emissions averted annually in 2030 and 10.4 – 16.6 million MT of BCeq emissions averted cumulatively between 2020 and 2030.

2 WLPGA (2015). *Guidelines for Sustainable LPG Market Development*.

3 For purposes of this analysis, it is assumed that key governmental decisions, pending as of this writing, will be taken in early 2019, with implementation of BCRM and initial associated expansion investments occurring in time to take effect in 2020. The potential for an increase to end-user LPG prices and associated consequences are discussed in Chapters 10 and 12 and in Part X.

4 CO_2eq emissions include carbon dioxide equivalent emissions from carbon dioxide, methane, and nitrous oxide. These were calculated using IPCC conform standards.

- **The economic value of averted CO_2eq emissions in terms of carbon financing:** € 30 – 41 million cumulatively between 2020 and 2030, using the 2018 prevailing price of carbon.

Health:

- **Averted premature deaths:** between 11,965 and 19,415 deaths could be averted cumulatively between 2020 and 2030 due to increased LPG usage.
- **Avoided Disability Adjusted Life Years (DALYs):** 423,774 – 688,042 DALYs
- **Value of labor time gained:** € 198 million - € 321 million

Consumer economics:

- Average annual savings per household from switching to LPG from charcoal: GHC 48 (€ 8.6) urban; GHC 66 (€ 11.9) rural
- Average annual spending increase per household from switching to LPG from firewood: GHC 146 (€ 26.3) urban and GHC 220 (€ 39.6) rural

National economics:

- **Cumulative tax revenue (assuming no rate or law changes):** Increase of tax revenue of GHC 76 million (€ 13 million) and GHC 162 million (€ 29 million) from 2020-2030
- **Trade balance (assuming no rate or law changes and constant local LPG production):** Decrease of the trade surplus[6] by GHC 314 million (€ 56 million) and GHC 732 million (€ 132 million) as of 2030
- **Job creation:** 7,412 – 11,757 net new jobs in the LPG sector, but an unquantifiable reduction in the charcoal and woodfuel sectors

Part X (Environmental, Health, Social and Economic Impact Potential) of this report describes in detail the impact projections, modelling, and associated methodologies.

Financing

Two important considerations in the financial structuring and arranging for the required investments are

- The capacity of the LPG sector companies to absorb and deploy capital. This is especially relevant in countries, such as Ghana, where unit margins are fixed by governmental regulation. The aggregate free cashflows existing, or potentially existing, in each of the main supply chain nodes over time affect the capacity of companies at that node to absorb and deploy capital, and thus the rate at which growth can occur and be sustained.
- The financial return, risk characteristics, and counterparty risk related to the cylinder investments. Because cylinders are a mobile asset, financing sources may be less willing to provide financing for

5 BCeq emissions includes black carbon equivalent emissions from black carbon, organic carbon, carbon monoxide, and total non-methane organic compounds.

6 Ghana ended a decade of a trade deficits in 2017, positing a US $1.5 billion trade surplus. Source: Statista (2018).

their acquisition and, when doing so, may seek higher rates of return and/or greater security (when debt instruments are used) in order to offset the risk. The Branded Cylinder Recirculation Model mitigates some of these risks. Additionally, lower levels of transparency and of demonstrable balance sheet strength characteristic of the players at some nodes of the supply chain increases counterparty risk.

Any financial structuring solution must take these factors into account.

The Ghana financial sector does not have the capacity (particularly when limited by its sector allocation rules) to finance the entirety of Ghana's LPG value chain expansion using entirely domestic resources. Therefore, outside capital must be attracted. The Government, under IMF limitations, is also limited in its ability to contribute fiscally to LPG sector development.

The recommended financing approach reflects 75% debt and 25% equity financing for cylinders and debt for the bottling plants, pallets and cages, with the debt calculated at an 8.9% interest rate and the equity at a minimum 20% internal rate of return (IRR) in order to be attractive to both domestic and international capital sources. These financial cost estimates should be seen as indicative, and not final rates and maturities, at this point in the national planning process. They are intended to show the magnitude of the effects of the cost of financing on repayment of borrowed/invested funds.

A key role in creating capital affordability and mitigating risk can be played by concessional capital, such as from the global development system.

Part IX (Financing) of this report describes the investment projects from a financing and investing perspective and discusses the financing issues, main risks and mitigations, and the most viable financial structuring alternatives for the investments, including the role for blended capital and the potential role for carbon finance.

Monitoring and evaluation

Part XI (Monitoring and Evaluation) of this report defines a set of indicators, called the ISLE indicators, for tracking progress in Ghana's LPG development and the social, environmental and economic impacts thereof. This Part also provides current values for the indicators, where values were obtainable.

Recommendations

This report concludes with summary recommendations for further efforts (and corresponding resources) to assist Ghana in the conclusion of its LPG planning, implementation and financing processes, and for research efforts to strengthen the evidence base regarding the proper role and potential of LPG as a clean cooking solution.

Conclusion

Ghana's policy goal of achieving LPG use as a primary cooking fuel for 50% of its population by 2030, and delivering meaningful social, environmental and development benefits to the country and its people, can be achieved if (i) key reforms to the LPG market structure and regulation are well concluded and effectively implemented and enforced, (ii) essential investments are adequately defined with capable and bankable counterparties and financing structures. Well-considered use of blended capital (private capital at market rates plus concessional capital) will be important to Ghana's overall success.

III. LPG and the Clean Cooking Problem

1. The Clean Cooking Problem

The global community has recognized the central role of access to clean, modern energy for development with the adoption of the 2030 Agenda for Sustainable Development by the United Nations in 2015.

With the second decade of the 21st Century nearly over, more than 3 billion people still suffer the harmful and often fatal effects of cooking with solid fuels and kerosene. Household air pollution (HAP) caused by burning these fuels far exceeds the safe levels defined in the World Health Organization (WHO) Indoor Air Quality Guidelines (IAQG). According to WHO[7], nearly 4 million people die prematurely each year from these effects of HAP, and many more suffer from chronically worsened health. Recent evidence on the relationships between HAP exposure and health risk indicates that levels of household particulate matter must be reduced nearly to WHO guidelines levels if a large portion of this health burden is to be averted.

A major portion of the woodfuels and charcoal consumed for cooking purposes come from unsustainably harvested biomass. This adds to already significant pressure on forest cover, in the form of increased deforestation and forest degradation. Loss and degradation of forest cover may, in turn, weaken agricultural productivity in adjacent land areas.

The pollutants from cooking with solid fuels also contribute to shorter-term climate warming through black carbon and methane.

Obtaining and cooking with solid fuels is also more time consuming than obtaining and cooking with fuels such as LPG, which are commercially obtainable (or are delivered to the home), provide “instant-on, instant-off” heat energy for cooking, and require de minimis maintenance and cleaning of cooking appliances and cooking areas.

In Sub-Saharan Africa (SSA), four of five people use wood fuel or charcoal as their main source of cooking energy. In view of the rapid population growth in Africa (projected to more than double to 2.5 billion by 2050)[8], the total number of solid fuel users will increase, together with all the associated negative health, environmental and development consequences, unless urgent and effective action is taken.

In this context, a growing number of governments of countries in Sub-Saharan Africa and other regions have set ambitious policy goals and plans for scaling up the use of liquefied petroleum gas (LPG) as a cooking fuel. Their reasons include meeting the Sustainable Energy For All (SEforAll) goals and Sustainable Development Goal (SDG) 7 of universal access to modern energy; improvements in public health from reduction of the health burden from HAP caused by cooking with biomass and kerosene; improvements in quality of life for their people; economic development; and forest protection.

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[7] WHO (2016). Burning Opportunity: Clean Household Energy for Health, Sustainable Development, and Wellbeing of Women and Children Report. Geneva: World Health Organization.

[8] United Nations, Department of Economic and Social Affairs, Population Division (2015). World Population Prospects: 2015 Revision, Key Findings and Advance Tables. Working Paper No. ESA/P/WP.241.

All of these goals are applicable to Ghana. Indeed, Ghana was the first country in the world to create and governmentally approve a Sustainable Energy for All Action Plan (in 2011), which included major focus on developing the Ghana LPG sector rapidly and sustainably.

2. Clean Cooking for Africa Program Overview

Government ministries and agencies in Ghana and a number of other countries have sought advice on the development of policies and investments required for enabling the expansion of effective, safe, and sustainable markets for LPG cooking fuel.

For three in Sub-Saharan Africa, namely Ghana, Kenya and Cameroon, this support is being delivered through the Clean Cooking for Africa Program of KfW, funded through the European Union–Infrastructure Trust Fund and implemented by the Global LPG Partnership.

Countries seeking to achieve major transitions in household energy must respond to the needs, resources and circumstances of their populations, which will vary markedly across urban and rural settings, by socio-economic status, and over time. A variety of fuels and technologies may be required, with roles for both modern fuels such as LPG and electricity, as well as improved biomass cooking technologies.

In recent years, LPG has been selected by a growing number of low and middle income country (LMIC) governments to be the primary cooking fuel for expanded access to clean and modern energy for their populations.

Ghana is among the leaders in Sub-Saharan Africa in national planning for, and in taking comprehensive action to implement, a national transition to clean and modern energy for cooking for its people.

The **Clean Cooking for Africa Program** assists selected African partner countries in planning, financing and executing national-scale transitions from the use of solid fuels and kerosene for cooking to clean, safe, modern cooking using LPG. This assistance includes:

- National planning processes, conducted in partnership with the partner-country governments and relevant stakeholders, to create or enhance the enabling environment for successful, sustainable LPG scale-up, and to plan and financially structure the required corresponding investments in LPG infrastructure and distribution systems; and
- Relevant studies to define and justify the proper role and scale for LPG as a national clean cooking solution, whose findings may guide the planning of LPG transition.

This report reflects the results, through the date of its writing, of such planning and studies in Ghana.

3. The Role of LPG

What is LPG?

According to the World LPG Association, LPG stands for "Liquefied Petroleum Gas", whose acronym is widely used to describe two prominent members of a family of light hydrocarbons called "Natural Gas Liquids" (NGLs): propane (C_3H_8) and butane (C_4H_{10}), either individually or in a blend. While "liquefied gas" may seem a self-contradiction, liquidity is the unique character of LPG that makes it a widely-used fuel. At normal temperatures and pressure, LPG is gaseous. It changes to a liquid when subjected to modest pressure or cooling. In liquid form, the tank pressure is about twice the pressure in a normal truck tire. This makes LPG very safe when properly handled. LPG is a by-product of two large energy industries: the processing of natural gas liquids and the refining of crude oil.

Thus, LPG is a supply-driven commodity. It must always be disposed of by its producers. Globally, the market is cleared of surpluses by the petrochemical and plastics sector, which can use LPG as a feedstock. Currently, a global surplus of LPG supply over demand is expected to persist to at least 2030[9].

In 2018, the first commercial quantities of bio-LPG were introduced into the global market at prices competitive to NGL-sourced or refinery-sourced LPG.

LPG has a number of qualities which make it an effective, large-scale off-grid gas energy solution in complement to the other large-scale clean energies, electricity and natural gas. This is summarized in the following table:

Figure 2. Key characteristics of LPG, natural gas and electricity solutions[10]

Household Energy Source	Key Characteristics	Primary Uses in Developing Stage Energy Market	Primary Uses in Mature Energy Market
LPG	• Low capital intensity • Infrastructure quick to deploy • Affordable, especially in urban/peri-urban areas • Portable • Salable in small units • Safe (with proper systems and handling) • High heat delivery	• Cooking/heating	• Non-urban cooking/heating • Industrial • Occasionally, transport

9 See the Annexes, Chapter 33 (Note Regarding Long-Term LPG Pricing and Availability) for a discussion of LPG pricing and availability beyond 2030.

10 GLPGP: World Gas Conference (2015)

Household Energy Source	Key Characteristics	Primary Uses in Developing Stage Energy Market	Primary Uses in Mature Energy Market
Grid Electricity	• High capital intensity • Time-consuming to deploy • Occasionally affordable • Safe (with proper systems) • Low-to-medium heat delivery	• Urban lighting, cell phones, electrical appliances including cooking, mechanical work	• Lighting, cell phones, electrical appliances including cooking/heating, mechanical work
Off-grid Electricity: Minigrids	• High capital intensity per kw • Usually more costly than grid-based • Potentially rapid deployment	• Small business use, cell phones, household lighting and low-power (non-cooking) electrical appliances	• Small business use, cell phones, households electrical appliances, sometimes including cooking (with larger-scale systems)
Off-grid Electricity: Solar PV	• Rapid deployment • Low to medium capital intensity per kw • Pay-as-you-go can be an option	• Cell phones, household lighting and low-power (non-cooking) electrical appliances and productivity devices (e.g., sewing machines)	• Cell phones, household lighting and low-power (non-cooking) electrical appliances and productivity devices (e.g., sewing machines)
Natural Gas	• Very high capital intensity • Time-consuming to deploy • Very affordable • Primarily grid-based • Safe (with proper systems and handling) • High heat delivery	• Power generation	• Urban household cooking/heating • Power generation • Industrial and transport

LPG is an essential solution to achieve WHO emissions guidelines and to reduce pressure on forests

To achieve WHO guideline levels of particulate matter requires community-wide use of clean fuels. In the transition towards universal use of clean fuels, countries will evaluate and execute on strategies that address the energy needs of their varied populations over time, involving a portfolio of energy carriers and technologies to meet cooking and other household needs.

In its *Special Report: Health and Climate Change*[11], WHO states: “It is not necessarily straightforward to choose the optimal household energy, and it may sometimes involve trade-offs. For example, while [LPG] is a fossil fuel, it emits almost no particulate air pollution and emits less climate pollutants than many other household energy sources. There may therefore be rapid health gains and sustainability if it replaces more polluting fuels and technologies, as opposed to crowding out investment in renewable energy.” It is

[11] WHO (2018). www.who.int/iris/handle/10665/276405

therefore important for Ghana, and other LMICs, to define an optimal portfolio of energy carriers and technologies for the household sector, which portfolio will require adjustment over time as relative technological capabilities, scalability, and costs evolve.

Over the next one to two decades in Sub-Saharan Africa, this energy and technology mix is expected to include LPG and, where feasible, reliable electricity capable of delivering the wattage necessary to cook and to boil water. For those unable to transition quickly to clean liquid or gaseous fuels or to adequate electricity supply, improved (e.g., rocket-type) and advanced (e.g., fan-assisted, pellet fueled) biomass stoves are expected to have a transitional role, even though in daily use they do not deliver the emissions levels called for by the WHO guidelines.

Among existing liquid and gaseous fuel options, LPG can make an important contribution. It has the potential to deliver substantial benefits for health, climate, the environment, and development. As with biomass fuels and stoves, building the enabling environment and developing an effective and cost-efficient market and value-chain are required for success with LPG. Correct and safe handling and use of LPG is also a key requirement.

A number of national governments, including India, Ghana, Kenya, and Cameroon, have made it a priority to serve a majority of their populations with LPG for reasons including (i) addressing energy-related air pollution, (ii) forest preservation and (iii) economic development.

LPG is benign for the climate

At a global level, however, the fact that LPG is created as a by-product of the production and refining of fossil fuels requires evaluation of its environmental impacts.

Issues around the overall affordability and accessibility for poorer and more rural populations also need to be addressed.

The findings described in this report indicate that the use of LPG instead of traditional biomass fuels and kerosene in Ghana would contribute little or no net climate warming effect and would protect forest resources. Lifecycle assessments (performed by others) have found that LPG as a cooking fuel performs similarly to advanced biomass stoves for net CO_2 emissions in settings where biomass fuel harvesting is partially renewable, and better than these technologies for black carbon and other short-lived pollutants.

This is because (i) LPG has a lower Carbon-to-Hydrogen ratio (C:H of about 1 to 3) than any other hydrocarbon fuel except for natural gas (e.g., coal has a C:H ratio of about 2 to 1); (ii) LPG combusts very efficiently compared with other fuels, thereby keeping emissions lower; (iii) LPG has high completeness of combustion, which results in black carbon and other climate-active pollutant emissions being much lower than from biomass-burning stoves and open fires; (iv) LPG stove emissions performance generally remains the same over time and is relatively independent of user-operating factors; and (v) LPG fuel supply places no burden on forest resources.

Affordability of LPG

Where all or most cooking fuel is purchased, which occurs mainly in urban and peri-urban settings, LPG is price competitive with kerosene, wood fuel, biomass pellets and charcoal on a cost-per-meal or cost-per-month basis.

These alternative fuels to LPG are typically bought in small daily quantities. While overall costs of LPG may be similar or superior over time, the transaction size for refilling an LPG cylinder may be a barrier for some low-income households. A number of options are available to address LPG refill transaction size. One that is well-established is use of smaller (e.g., 3 kg) cylinders. Newer initiatives involving pay-as-you-go LPG use and microfinance of, and/or mobile payment for, LPG refills are in early commercial operation in some SSA countries. Some households may also need financial assistance or tools to cover the initial acquisition cost of an LPG stove, cylinder and associated equipment, because traditional stoves are in general less costly than the equipment required for cooking with LPG. (See Chapter 18 (Consumer Empowerment) beginning on page 188 for more information.)

For poorer and more rural populations currently gathering all or most of their fuel, the initial and ongoing costs for LPG refills can be barriers. Targeted subsidies or other forms of financial support, which preferentially assist poorer households, have a role in facilitating acquisition and use of LPG for such consumers. This type of targeted financial assistance is already a key component of policy on LPG access in several countries with large scale LPG use, such as India, Brazil and Peru.

Creating a universal LPG refill price through regulatory measures (that is, a price that, through transportation cross-subsidy, is the same for all consumers no matter where they are located in the country) also benefits rural consumers, who tend to be both poorer and more remote from LPG refilling facilities.

Proven technical and operational feasibility of LPG in LMICs

LPG is a well-established technology for cooking. The World LPG Association estimates that 2 billion people use LPG for cooking, heating, and other uses. LPG has already become a large-scale solution for clean cooking in a numerous low and middle income countries[12].

Challenges for scaling up LPG on a national basis are addressable through effective policy, regulation and enforcement of regulation, ensuring adequate supply, developing robust distribution networks (limited by where the road network makes distribution viable), and, optionally, developing and implementing sustainable fiscal policy to support more equitable access.

User benefits of LPG

For the user, the speed and controllability of LPG cooking, combined with the convenience of storage, result in substantial convenience and time savings. This has particular implications for women, children, and others currently engaged in collecting and cooking with biomass fuel and cleaning their cooking appliances and cooking areas after use. The added convenience and time savings offer the potential for making more of employment and education opportunities.

LPG may also be viewed culturally as an aspirational fuel that some households would use, if available, based on their association of LPG with modernity—the “modern” of SDG7—even when cost savings from

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12 A non-exhaustive list of examples of LMICs which have achieved safe and sustained use of LPG for cooking by no less than 50% to upwards of 90% of their populations for cooking (and other uses) include Bolivia, Brazil, India, Indonesia, Malaysia, Morocco, Thailand and Vietnam. SSA countries which are approaching this range of LPG use include Cote d’Ivoire, Gabon and Senegal.

LPG use do not arise for them. While it is not possible to quantify this factor from available data, and it is excluded from this report's analytics, desire for LPG as an aspirational energy choice frequently arises anecdotally in interviews with Ghanaian consumers, policymakers, industry veterans and other stakeholders. (Many of which policymakers, industry veterans and other stakeholders being LPG consumers as well.)

IV. A Brief History of LPG in Ghana

During the 1970s, LPG was produced at Ghana's oil refinery as a by-product of oil refining. This LPG was disposed of by flaring it into the atmosphere.

In the 1980s, the refinery allowed the first Ghanaian entrepreneurs to obtain LPG for free to sell onward to consumers. The LPG at this time was comprised of a mix of 70% propane and 30% butane.

In the 1990s, national demand at that time was in the range of 6,000-7,000 tonnes per annum. LPG was primarily used in Greater Accra. Only 0.8% of the urban population located outside of Greater Accra used LPG, according to Ministry of Energy (MoE) statistics. LPG use in rural Ghana was, to the extent measured, zero.

The market model established by the Government during this period was a variant of the Branded Cylinder Recirculation Model (BCRM). International oil majors such as Mobil, Texaco, Shell participated in the Ghana LPG market.

The Government took several actions beginning in 1989 to promote LPG adoption and use, noting that several other West African countries were progressing faster than Ghana in developing their LPG sectors. These actions included the following:

- LPG prices and margins were regulated by the Government
- A new tax was applied to petrol (gasoline) and used to subsidize the cost of LPG fuel and to fund LPG awareness programs
- A residential door-to-door delivery option for LPG cylinders was defined and priced
- Cylinders were provided to households at discount, with partial cost make-up through the refill price
- Government institutions were encouraged to switch their kitchens to LPG
- The national oil refinery was expanded
- Financial assistance was offered to food sellers to switch to LPG from other fuels

The results from these actions, and from the organic development of the sector, were positive:

- The known count of cylinders in circulation increased from approximately 80,000 in 1989 to approximately 600,000 as of 1997
- LPG consumption grew from 6,000-7,000 tonnes per annum to approximately 32,000 in 1996
- According to a governmental survey conducted in 2000, 20% of the Greater Accra population used LPG to some extent; 5% of other urban consumers used LPG; and 0.5% of the rural population used LPG

However, arbitrage between the after-tax price of petrol vs. LPG, in favor of LPG, led to of widespread, informal, unregulated switching of vehicles from petrol to LPG, and the corresponding development of a private-sector-built network of small local filling stations for LPG vehicles. As an adjunct line of business, the operators of these filling stations (called "microstations" in industry terminology, using a filling process referred to as "decanting") also took to using their automotive LPG filling pumps for filling the residential LPG cylinders that were used by the general population for cooking.

The Government introduced a scheme for unbranded, generic cylinders around 2002.

This, plus a decline in government enforcement of the main pillars of the BCRM, led to the following changes in the market:

- The LPG marketers (brand-owners) lost control over their cylinder assets to the consumers
- The Consumer-Controlled Cylinder Model (CCCM) took hold, de *facto*; all cylinders of all brands, or of no brand, were accepted by the microstation operators for roadside refilling
- No party in the LPG market assumed ongoing responsibility for the safety (inspection and maintenance) of the cylinders, because the link between cylinder income, cylinder brand, and cylinder refilling had been broken
- The major international players withdrew from the market due to loss of control of their cylinder assets (without losing liability for safety incidents involving their brand of cylinder) and an inability to compete effectively with the microstations, whose cost structures did not include rigorous cylinder inspection and maintenance

The Government then began licensing the microstation operators. The operators, in turn, formed a trade association. (Today, there are two complementary microstation trade associations, distinguished in part by the number of microstations owned by the members.)

The market grew slowly and steadily on this basis. Adoption reached an estimated 18% of the population by 2010. Additional LPG importation and bulk storage infrastructure was developed, growing to 12,400 KT in 2014.

The LPG fuel subsidy (which was not a targeted subsidy) was largely phased out starting from 2013, due to its increasing drain on the Government's fiscal account.

Through 2017, the number of microstations increased to approximately 650. These had entirely driven out the pre-2002 market model. Consumers came to believe they were the *de facto* owners of the branded cylinders they had obtained on deposit in the past. The safety profile of the national cylinder inventory began to decline.

As residential demand grew, because prices were effectively fixed by regulation, shortages developed, exacerbated by the allocation of what LPG could be produced and imported to the fast-growing transport sector. Consumer queuing times to have a cooking cylinder sometimes would run to days.

Along with growing consumption and decaying cylinder and valve quality came increasing safety incidents.

The LPG sector also began to slow down its geographic expansion. According to the Ministry of Energy, a cyclical barrier had arisen, endemic to countries practicing CCRM instead of BCRM. The consumer would not invest in a cylinder and other equipment to become an LPG user without first knowing that an LPG filling station would open nearby, would have a reliable supply of LPG, and would remain in business for the long term. LPG filling station entrepreneurs would not open a microstation in a new area without first knowing that the area had a critical mass of demand for cylinder refills, as evidenced by the consumers having acquired cylinders.

In 2012, the Government completed and adopted a Sustainable Energy for All Action Plan which called, in principle, for a return to BCRM in order to accelerate investment in LPG and improve the safety of the national LPG system, and the development of an LPG investment program[13].

Under the Energy Sector Strategy and Development Plan of 2010, the Government set forth several measures for LPG sector development, including the following:

Table 2. Energy sector strategy and development plan (2010) LPG measures and status

Measure	Status in 2018
Establish a natural gas processing plan to produce LPG from the Jubilee Oil and Gas field	Accomplished and in operation
Recapitalize the Ghana Cylinder Manufacturing Company (GCMC)	Accomplished in part
Construct LPG storage and supply infrastructure in all regions	In planning stage
Increasing the margin for LPG marketers and distributors in a sustainable and predictable manner	In planning stage

These measures were carried forward into the Sustainable Energy for All Action Plan.

In 2013 the Ministry of Energy (MoE) and Global LPG Partnership formed a multistakeholder LPG Working Group, co-chaired by MoE, to review the state of the LPG sector and the potential for its transformation. This group was later subsumed into the National Implementation Task Force for LPG (NITF), led by the MoE. This body produced a draft national LPG policy that was submitted to the Cabinet for approval in early 2015.

Also in 2013, the Government instituted a Rural LPG Program (RLP) which sought to channel savings from the phase-out of LPG subsidies into providing free and discounted LPG equipment to rural Ghanaians who might otherwise not adopt or use LPG. While it is beyond the scope of this report to evaluate that program, it should be noted that the program distributed approximately 150,000 LPG cylinders and stoves, had an approximately 8% refill rate among the beneficiaries 18 months post-distribution, and is under review by the Government regarding potential redesign and relaunch[14].

The draft national LPG policy remained unapproved by the Cabinet until October 2017.

While the reason for the delayed action has not been officially disclosed, knowledgeable industry sources cite political resistance from microstation operators who feared disruption to their business operations and possible reduction or loss of livelihood (and increased risk to their banking collateral) from the transition to BCRM called for in the policy draft.

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[13] Ghana Energy Commission (2012): Ghana Sustainable Energy for All Action Plan; energycom.gov.gh/files/SE4ALL-GHANA%20ACTION%20PLAN.pdf

[14] See Energy for Sustainable Development: Ghana's rural liquefied petroleum gas program scale up: A case study. Volume 46, October 2018, Pages 94-102. A copy may be downloaded at Science Direct; www.sciencedirect.com/science/article/pii/S097308261830262X

On 7 October 2017, a large, fatal explosion occurred at a filling station at Atomic Junction in Accra. Seven were killed, 132 injured. On 12 October 2017 the President of Ghana held an emergency Cabinet meeting to discuss the explosion and steps to be taken in consequence of it. Quoting from the Presidency's press release, "…the President of the Republic, on the advice of Cabinet, directed that henceforth the Cylinder Recirculation Model …be implemented. This model means that LPG Bottling Plants will be sited away from congested commercial and population centers and will procure, brand, maintain and fill empty cylinders to be distributed to consumers and households through retail outlets. Low risk stations will be designated for the supply of gas to vehicles. This whole exercise must be completed within one year." The release concludes with the statement, "The safety of citizens is the paramount objective of Government, and the President will take all necessary steps to ensure that citizens are safe."

Follow-up actions included the designation of the National Petroleum Authority (NPA) to oversee the detailed planning and implementation of the policy and facilitate the mobilization of required outside capital, and the formation of a new multistakeholder task force to deliberate about, and provide decision-making input on, the relevant planning details.

In 2018 the NPA executed a Memorandum of Understanding with the Global LPG Partnership to partner on the foregoing work.

As of this writing, the NPA and task force have not yet fully concluded their efforts. NPA has conveyed a revised timeline that targets Q1 2019 to complete its planning and begin key aspects of implementation.

This is the backdrop against which this report's assessments have been prepared, and from which this report looks forward.

Aftermath of LPG filling station explosion in Atomic Junction, Accra, October 2017

Photo credit: Ghana Daily Nation

V. LPG Enabling Environment

The Government of Ghana determined to create an enabling environment for significantly improved safety, bankability, growth and oversight of its LPG sector. This involves transitioning rapidly and effectively from a national LPG system based on the Consumer-Controlled Cylinder Model (CCCM) that has taken root during the last 15-20 years, to the Branded Cylinder Recirculation Model (BCRM). In Ghana, "BCRM", which is an international term of art in the LPG industry, is typically shortened to "CRM". BCRM and CRM are used interchangeably in this document.

How the transition to BCRM will affect the design of the supply chain is set forth in Part VII (LPG Supply Chain Development and Planning).

4. Models of National LPG Systems

Globally there are two main models for organizing residential LPG markets: the Consumer-Controlled Cylinder Model (CCCM) and the Branded Cylinder Recirculation Model (BCRM).

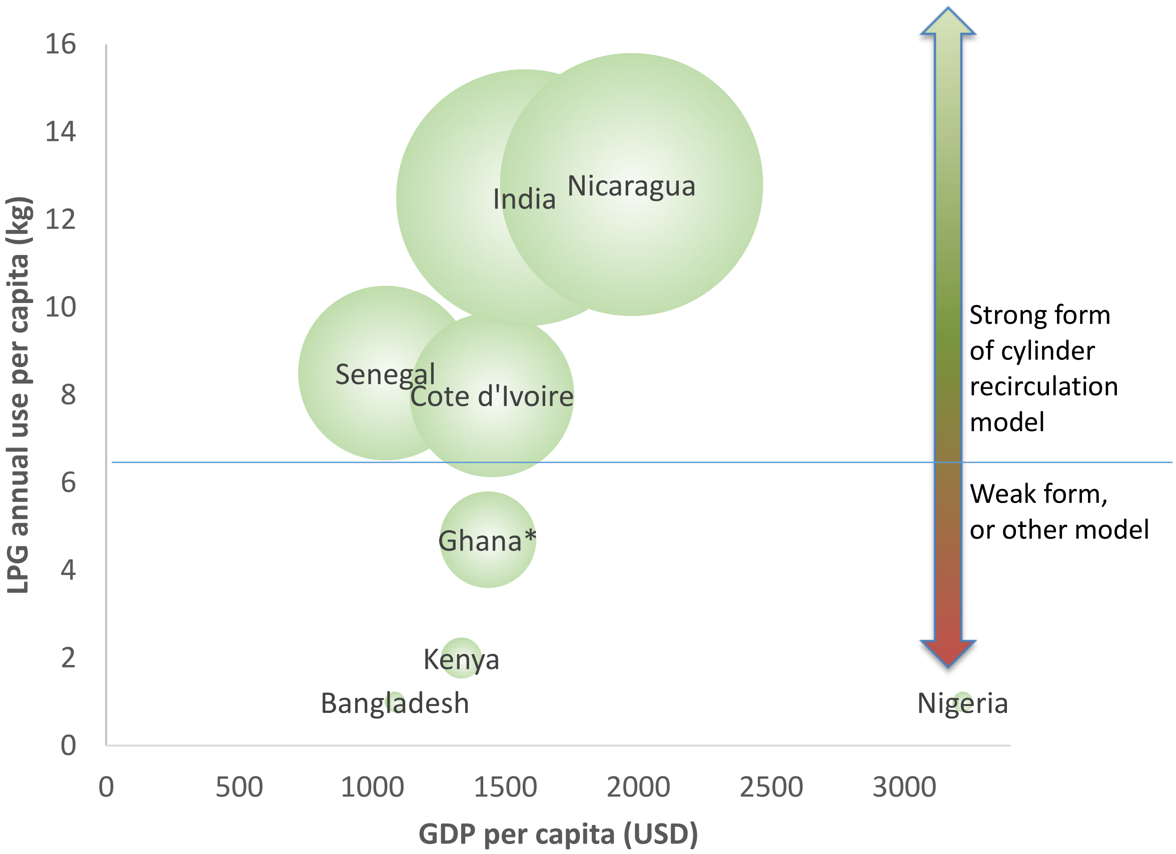
CCCM is used together with BCRM in the United States and Canada. CCRM is also used for a small portion of the LPG market of Germany. It has been tried, or has been devolved into, in some developing countries. Aspects of CCRM invaded the BRCM model in Brazil in the 1970s and resulted in a major increase in accidents and fatalities that shook public confidence in LPG and risked market implosion, until BCRM was properly reconstituted and enforced through concerted joint government-industry action. CCRM has been attempted in Haiti without success. It is the dominant model in Nigeria, which has suffered decades of boom-bust investment cycles in LPG with negligible growth in LPG use per capita, despite being a major LPG producing country and one of Africa's wealthier countries.

In all developing countries which have succeeded in achieving meaningful levels of residential LPG use per capita, BCRM has been the model.

BCRM can be implemented rigorously ("strong form") or loosely ("weak form").

The following figure (Figure 3) shows LPG development progress, measured in kilograms per capita of annual LPG use, plotted against GDP for a selection of developing countries, and categorizes these according to the strength of their BCRM model. (A method of scoring BCRM strength is presented later in this Part.)

Figure 3. Comparative LPG adoption and use vs GDP in selected countries, by market model



**Ghana value excludes vehicular use of LPG*

5. Conditions and Consequences of the CCCM LPG Market Model

In developing country contexts, this model has been shown to create a temporary surge in cylinder inventory and LPG consumption followed eventually by debilitating market dysfunction, the cessation of investment in new LPG cylinders, a rapid decline in cylinder safety, a corresponding rapid increase in fires and explosions, a surge in black market LPG activity, and eventual market stagnation or implosion. At the heart of CCCM is consumer ownership of, and control over, the LPG cylinder. This works well in America and Canada because:

- The consumer is very conscious of liability for cylinder safety, and will accept liability and the responsibility that goes with it;
- The consumer is well educated;
- The consumer has a vehicle and is easily able to transport his/her cylinder for periodic inspection and, when necessary, repair and recertification;
- The consumer is universally willing to pay to replace a damaged, unsafe cylinder that requires scrapping;
- The potential penalties (governmental, from civil lawsuit, and in terms of access to and of insurance) related to an LPG accident for which the consumer bears responsibility are very large, and are very likely to be experienced in practice;
- Corporations and SMEs in the U.S. and Canadian LPG sector are likewise very conscious of liability, and they are almost always unwilling to take non-compliant actions or to make non-compliant omissions in their activities, whether for the purpose of satisfying a consumer who does not want to pay to replace his/her unsafe cylinder, or for the purpose of avoiding business costs related to required safety practices;
- Corporations and SMEs are also conscious of, and comply with, generally strong and well-enforced consumer protection laws and competition laws that prohibit bad and unethical business practices;
- Corporations and SMEs are conscious of, and comply with, strict and well-enforced licensing requirements. One will almost never find an unlicensed or uncertified LPG business operating in the U.S. and Canada, or a licensed operator acting in intentional violation of its license terms.

Most developing countries do not have the above preconditions for success with CCCM.

The cost of regulation under CCCM model is high, because hundreds (as in Ghana) or thousands (in America) of points of LPG cylinder refilling and exchange must be monitored for compliance.

When tried for the first time in a market where cylinders were previously not consumer-owned and -controlled, CCCM has been shown to unlock pent-up demand for the first few years, but the seeds of the LPG market's stagnation or demise will have been planted.

The following are main reasons why CCCM has not worked over the long term in the other countries that have tried it:

- Consumers will shop around for a refill point that does not require the consumer to replace or repair an unsafe cylinder or valve at the consumer's cost; this "shopping around" favors black marketers, who as a group will disregard safety if it means getting paid to refill a given cylinder vs. not refilling one.

- Consumer control of cylinders makes it very easy for black market operators (who do not spend any resources on cylinder safety) to interpose themselves in the supply chain to take business away from legitimate market players. They do this by locating closer to the consumer than the nearest legitimate player, charging a lower price, and thus stealing profits from the legitimate player who used to serve that customer. This leads to the black marketeers driving out the good players, and unsafe cylinders driving out the good cylinders. This in turn leads to market stagnation, higher infrastructure investment risk, and increasing numbers of safety incidents—including fatalities.

- Without strong institutions to inspect and enforce pro-safety market rules, these factors eventually halt market growth.

- Businesses seeking LPG customers in a new geographic area require as a precondition a critical mass of initial customers to have cylinders to be refilled. Consumers in such an area who may wish to become LPG users require as a precondition to purchasing LPG equipment the presence of a reliable and trustworthy supplier who can refill their cylinders. Therefore, there is minimal incentive for either the supplier or the consumer to start the process of buying and selling.

6. Conditions and Consequences of the BCRM LPG Market Model

Everywhere else in the world, if implemented in a self-consistent, well-enforced, and adequately financed way, BCRM eventually leads to widespread adoption of LPG with an acceptable level of safety (acceptable to the consumers, industry and governments in question).

BCRM is endorsed and promulgated by the World LPG Association, the global LPG industry organization.

Examples of major successes in LPG market development using BCRM include: Brazil (starting in 1979 following a near-collapse of the LPG market due to enforcement failure that led to thousands of monthly LPG fires and explosions), Morocco, Vietnam, Malaysia, India, Japan, Turkey and Senegal.

BCRM comprises a number of key principles which are listed below.

- The LPG marketing company invests in, owns, inspects, maintains, and refills (away from populated areas) its own, branded cylinders and is responsible and liable for their safety. The marketer is also exclusively licensed by the government to market LPG. This linkage, between and among cylinder investment, cylinder refill income over the cylinder's life, liability for the cylinder's safety, licensing, and the brand, create the needed incentives for LPG marketing companies to invest to expand their cylinder inventories in order to create new customers and to spend to maintain safety throughout the value chain.

- The government must enforce the foregoing structure to ensure compliance by legitimate, licensed players and to create significant disincentive (through inspection, legal prosecution, significant penalties for conviction, and other means) for illegitimate players to coopt for their own ends the cylinders of legitimate players, thereby breaking the linkage.

- All cylinders in the market are branded cylinders.

- The consumer obtains his/her first cylinder from a marketer's distribution channel in exchange for a deposit, which is typically set below the cost of the cylinder with a maximum percentage specified by law or regulation. The cylinder remains the property of the marketer. When the consumer's LPG runs out or low, the consumer returns the empty cylinder to a refill point in the marketer's distribution network to exchange it for a full cylinder, at the prevailing price for a refill.

- Margins, if regulated, must be adequate to cover the costs of the operation of the supply chain across all its nodes, and to allow for adequate debt service, returns to equity investors, and investment in growth.

- Safety standards, in particular regarding the condition of cylinders and handling and transport of LPG, must be defined clearly and well enforced.

- Allowing cylinders to cross between marketers' branded distribution networks is discouraged, because it can lead to coopting and hoarding (taking off the market) of competitors' brands of cylinder.

BCRM is enhanced with certain optional characteristics, including:

- Industry consolidates, leading to fewer but more capable and bankable players which lead the sector's growth and help perpetuate essential BCRM practices. The presence of an effective LPG trade association is also useful for the latter purpose.
- Transportation cross-subsidy to cause prices paid by remote customers to equal prices paid by centrally located customers.
- Pro-poor mechanisms, which may include micropayment and pay-as-you-go schemes, targeted subsidies, and the like.
- Consolidation of regulatory authority regarding the LPG ecosystem into a small number of agencies, or one LPG superagency. This facilitates business formation and expansion and facilitates effective enforcement of BCRM and its elements.
- Sharing of major infrastructure for storage and filling. If done, this focuses competition on acquiring and servicing customers, instead of on acquiring LPG.

The NPA and LPG task force are determining, with advisory support from the Clean Cooking for Africa / GLPGP expert team, the details of the Ghanaian implementation of BCRM. Details about key impacts to the supply chain are discussed later in this report in Part VII (LPG Supply Chain Development and Planning).

7. Ghana Market Model Scorecard

There is no universally accepted way to score a country's LPG market model, as enforced. Thus, any scoring system will have a degree of arbitrariness. That said, the following is one way to score Ghana's current model, which is effectively CCCM, and the BCRM-based replacement model that has been in development by NPA and the Presidentially-mandated national LPG Task Force:

Table 3. LPG national market model and structure scorecard: Ghana to 2018

Core BCRM features	**Conforming**	**Intermediate**	**Non-conforming**	**Result**	**Score**
Marketer owns cylinder	H | Y	M	L | N	N	0
LPG license is for marketers only	Y		N	N	0
All cylinders are branded	Y		N	N	0
Exclusive distribution chain	Y	Hybrid	N	N	0
Recirculation of cylinder to closed facility with inspection	Y	Hybrid	N	N	0
Enforcement against cross-filling	H	M	L	L	0
Margins are adequate (and frequently refreshed, if regulated)	Y		N	Y	1
Safety standards and enforcement	H	M	L	L	0
Cylinder deposit scheme is defined and enforced	Y		N	N/A	1
Inter-marketer cylinder exchange mechanism	N	Strict	Loose	Loose	0
Marketer fragmentation	Score: (sum [top 4 market shares])			0.21	0
Valve differentiation	Y		N	Y	1
Subtotal					**3**
Supportive features					
Uniform pricing	Y		N	Y	1
Pro-poor support	Y	Untargeted	N	N	1
Common shared infrastructure (utility model)	Y	Selective	N	N	0
Fragmentation of authorizing/enforcing agencies	Score: (1 / number of agencies)			0.09	0
Subtotal					**2**
Total Score (Maximum Possible Score)					5 (16)
Score (scaled to 0-100)					**31**

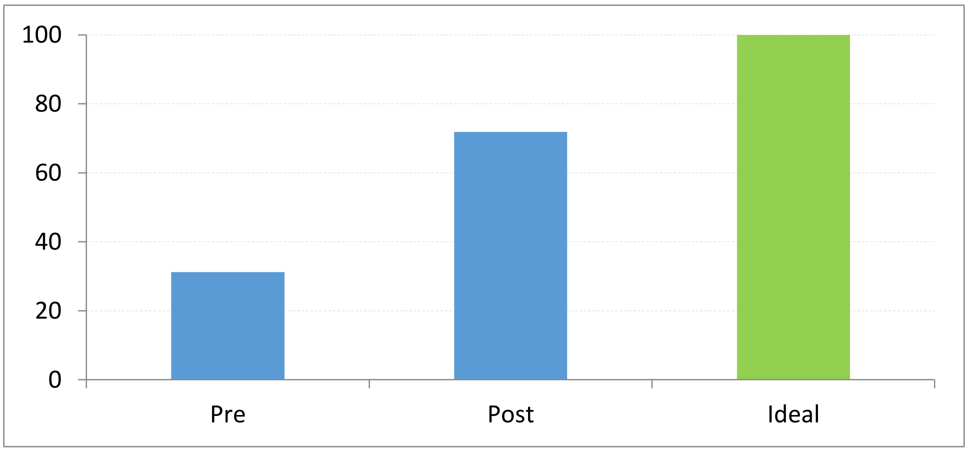
Based on the planning work completed to date, and what is known to be contemplated, the following is an approximate scoring of Ghana's BCRM strength post-BCRM:

Table 4. LPG national market model and structure scorecard: Ghana from 2019 onward

Core BCRM features	Conforming	Intermediate	Non-conforming	Result	Score
Marketer owns cylinder	H | Y	M	L | N	Y	1
LPG license is for marketers only	Y		N	N	0
All cylinders are branded	Y		N	Y	1
Exclusive distribution chain	Y	Hybrid	N	Unknown	0
Recirculation of cylinder to closed facility with inspection	Y	Hybrid	N	Y	1
Enforcement against cross-filling	H	M	L	H	1
Margins are adequate (and frequently refreshed, if regulated)	Y		N	Y	1
Safety standards and enforcement	H	M	L	H	1
Cylinder deposit scheme is defined and enforced	Y		N	Y	1
Inter-marketer cylinder exchange mechanism	N	Strict	Loose	N	1
Marketer fragmentation	Score: (sum [top 4 market shares])			0.21	0
Valve differentiation	Y		N	Y	1
Subtotal					**9**
Supportive features					
Uniform pricing	Y		N	Y	1
Pro-poor support	Y	Untargeted	N	N	1
Common shared infrastructure (utility model)	Y	Selective	N	Selective	0.5
Fragmentation of authorizing/enforcing agencies	Score: (1 / number of agencies)			0.09	0
Subtotal					**2.5**
Total Score (Maximum Possible Score)					11.5 (16)
Score (scaled to 0-100)					**72**

A graphical comparison of scores (Figure 4) shows the increase toward the idealized model, if Ghana's contemplated reforms are implemented comprehensively and self-consistently and are well-enforced.

Figure 4. Comparison of Ghana market model scorecard results from anticipated BCRM transition



8. Regulatory Agencies

The key governmental bodies overseeing the main aspects of the LPG sector are as follows:

Abbr.	Full Name	Role	Comments
NPA	National Petroleum Authority	The NPA was established in 2005 by NPA Act 691 which mandated it to regulate, oversee and monitor activities in the petroleum downstream industry and where applicable do so in pursuance of the prescribed petroleum pricing formula.	Past NPA policy of licensing as many players in the downstream petroleum sector to stimulate competition is controversial, as many of the licensees are inactive and are therefore potentially engaged in illegitimate activities. NPA has a large number of license categories which effectively prevent vertical integration; this increases sector fragmentation impacts efficiency.
GRA	Ghana Revenue Authority	The Ghana Revenue Authority is the Ghana administration charged with the task of assessing, collecting and accounting for tax revenue in Ghana. The core mandate of the Authority is to ensure maximum compliance with relevant laws in order to ensure a sustainable revenue stream for government as well as the controlled and safe flow of goods across the county's borders.	Underdeclaration of value of imported goods is a significant issue at Ghana Ports.
GPHA	Ghana Ports & Harbours Authority	The Ghana Ports and Harbours Authority is the national port authority of Ghana, responsible for the governance, maintenance and operation of the ports of Ghana, principally the Port of Sekondi-Takoradi, and Port of Tema, and the Fishing Harbour at Tema. GPHA main offices are in Sekondi-Takoradi, and Tema.	
GSA	Ghana Standards Board	The Ghana Standards Authority (GSA) formerly Ghana Standards Board (GSB) is a Government of Ghana agency responsible for the maintenance of acceptable standards for product and services and sound management practices in industries and public institutions in Ghana.	Has been ineffective in curbing importation of counterfeit goods such as second-hand cylinders.

Abbr.	Full Name	Role	Comments
DVLA	Driver Vehicle & Licensing Authority (DVLA)	The Driver and Vehicle Licensing Authority of Ghana is the government agency responsible for the licensing and evaluation of drivers and cars in Ghana.	
EPA	Ghana Environment Protection Agency	The Environmental Protection Agency, is an agency of Ministry of Environment, Science Technology and Innovation, established by EPA Act 490. It oversees the implementation of the National Environment Policy.	Underesourced
GNFRS	Ghana National Fire and Rescue Service	The Ghana National Fire and Rescue Service is an agency under the Ghanaian Ministry of the Interior, constituting Ghana's nationwide fire service. It was established as the Ghana National Fire Service by the GNFS Act of 1997 with a broad objective of prevention and management of undesired fires and other related matters.	
TCPD	Town and Country Planning Department	The Town and Country Planning Department was established in 1945 and charged with the responsibility of planning and management of growth and development of cities, towns and villages in the country. It is a service delivery Department under the Ministry of Environment, Science and Technology.	To date, the Ghanaian development control system has proven unsuccessful in delivering quality planning application approvals in a timely manner.

Ghana's pre-BCRM LPG sector has relatively high regulatory complexity, as shown in the following table:

Table 5. Pre-BCRM supply chain oversight matrix

Activity	Importation	Bulk Storage	Bulk Transport	Cylinder Filling	Cylinder Distribution	Cylinder Wholesale	Cylinder Retail	Storage Construction	Cylinder Manufacture	Cylinder Import
Sector Regulators										X
NPA	X	X	X	X				X	X	
Other Regulatory Agencies										
GRA	X	X								
GPHA		X		X				X		
GSB		X		X				X	X	
DVLA			X			No Licences Pre - CRM				
EPA		X		X				X		
GFS		X		X				X		
TCPD		X		X				X		
Licence Issued to:										
BDC	X	X								
OTC	X									
BRV Company			X							
LPG FILLING STATIONS				X						

Post-BCRM, based on the planning work completed to date, and what is known to be contemplated, the matrix will expand as shown in the next table:

Table 6. Post-BCRM supply chain oversight matrix

Activity	Importation	Bulk Storage	Bulk Transport	Bottling Plant	Cylinder Distribution	Cylinder Wholesale	Cylinder Retail	Storage Construction	Cylinder Manufacture	Cylinder Import
Sector Regulators										X
NPA	X	X	X	X	X	X	X	X	X	
Other Regulatory Agencies										
GRA	X	X								
GPHA		X						X		
GSB		X		X	X	X	X	X	X	X
DVLA			X							
EPA		X		X	X	X	X	X		
GFS		X		X	X	X	X	X		
TCPD		X		X				X		
Licence Issued to:										
BDC	X	X								
OTC	X									
BRV Company			X							
AUTOGAS STATIONS		X								
BOTTLING PLANTS		X		X						

An open question concerns the revenue models of the agencies (in particular, the NPA) under the restructured LPG sector. The NPA's revenue model has been primarily based on issuing and renewing licenses to a very large number of small LPG players. With restructuring of the industry around 8-10 major regional bottling facilities at the core (with one or more corporate owners potentially owning multiple facilities each), the original licensing revenue formulation has been recognized as requiring reevaluation.

Regulations, laws and standards governing the LPG sector are shown in Annex Chapter 32 (LPG-Related Laws and Regulations) on page 324.

9. Complementary Policy Initiatives

Taxes, duties and subsidies

During 2013, the Government of Ghana phased out subsidies on LPG fuel as part of a national program of liberalizing the petroleum sector. The Government also imposed registration fees applicable to LPG vehicles commensurate with those on petrol vehicles.

A consequence of these changes was a significant reduction in the rate of growth of the informal LPG-for-vehicles (in LPG industry terms, "Autogas") market. This market – and the network of LPG cylinder-filling stations to serve it – had grown rapidly on account of an arbitrage opportunity that had arisen between the operating costs of fueling vehicles with LPG (per the LPG pricing regime) and with petrol (per the petrol regime). At its peak, the Autogas segment represented over half of national LPG consumption.

The current LPG pricing regime (including taxation, levies, *etc*.) is shown in Chapter 10 (Pricing) beginning on page 53. LPG in Ghana is VAT-exempt but has hydrocarbon sector-specific taxes and levies applied equal to 20% of the current end-user price. To mitigate the potential risk to achieving the Government's 2030 policy goal from a potential end-user LPG price increase, associated with the transition of the supply chain to BCRM, that could cause a lower rate of growth in consumption, the Government could consider a temporary waiver of certain of the general hydrocarbon-specific taxes and levies with respect to LPG.

The growth rate of residential LPG penetration and consumption also slowed following the subsidy phase-out. This effect is discussed in more detail in Part VI (LPG Demand Potential to 2030) beginning on page 66.

The Government repurposed LPG fuel-subsidy savings to the provision of LPG cooking equipment cost-free to poorer, rural households through a Rural LPG Promotion Program (RLP).

In its general concept, the RLP was similar to the Indian Pradhan Mantri Ujjwala Yojana (PMUT) scheme, which directed subsidies on both LPG equipment and fuel to poor Indian households to empower them to access and use LPG, supported by a major expansion of LPG distribution, retail and logistics capacity. Since 2016, 58 million Indian households have gained access to LPG under the scheme[15]. Conversely, Ghana's program did not develop the level of LPG cylinder and fuel availability and retail density of the Indian program. According to a recent study of the Ghanaian program, the RLP did not drive significant rural uptake of LPG in part due to poor fuel and cylinder availability and long consumer travel distances to LPG refilling stations.[16] The details of this program have been under re-evaluation by the Government as of this writing.

Biomass cookstove policy development

The Government of Ghana has targeted policies to improve the wood-use efficiency of its charcoal supply chain and to support the uptake of improved biomass stoves for the portion of the population expected to

15 www.pmujjwalayojana.com/about.html

16 A study of five communities in the Brong-Ahafo Region showed that 58% of the households that received the LPG start-up kit under the RLP never refilled their LPG cylinders nine months after the kit was first delivered. Cost and travel distance to filling stations were identified as critical barriers to refilling. Source: Asante. et al (2018). "Ghana's rural liquefied petroleum gas program scale up: A case study," *Energy for Sustainable Development*. 46, 94-102.

continue to rely on biomass for cooking over the long term. The Ghana Alliance for Clean Cookstoves (GHACCO), an NGO, called on the Government in November 2018 to define and implement a national clean cookstoves policy and potentially to link such a policy to a Nationally Appropriate Mitigation Action (NAMA) under the Paris Climate Treaty.

In its Sustainable Energy for All Action Plan (2011), the Government outlined its historical efforts to encourage use of improved biomass cookstoves by rural Ghanaians, describing them as having limited success[17]. The Action Plan states that near-term national strategy to address deforestation includes improvement in the production and efficient use of wood fuels (such as charcoal); and in the long term, fuel substitution to alternative sources of energy[18].

Domestic content policy

The Ghana Government has determined to require significant Ghanaian content and participation in the reformed and expanded LPG sector. This includes:

- A significant portion of the cylinders required in the transition to BCRM and expansion of the national customer base to be locally manufactured. Today, there are three SME cylinder manufacturers, one of which is state-owned. They are in aggregate capable of expanding to produce a portion, but not all, of the required cylinder inventory called for in the investment plan.
- Major LPG assets, such as the new bottling plants at the heart of the BCRM implementation, expected to be required to be majority-owned by Ghanaian participants. The percentage may be higher for certain classes of projects. There has been debate and discussion, not yet concluded, as to the percentage of Ghanaian ownership that will be required for different LPG project and asset types.
- Licenses and permits for owning and operating the new bottling plants being made available to successful tenderers who have existing LPG marketing licenses only.
- Achieving 98% local employment within five years from commencement of operations, except where another level is approved by the NPA.
- Maximizing Ghanaian content in all LPG activities.
- Setting organizational targets in LPG-licensed companies for the percentage of managerial and non-managerial positions held by Ghanaian citizens. Subject to finalization, notional targets are 80% for management and 100% for non-management.

Additionally, it is contemplated that the Ghana Gas Company (GGC) may be able to double its nameplate output capacity from approximately 170 KT per annum to approximately 340 KT as anticipated new gas production from the Jubilee oil and gas field comes on line. As of this writing, the amount of LPG to be

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17 Energy Commission: *Ghana Sustainable Energy for All Action Plan* (2011), pp. 19-22.

18 Ibid, pp. 34.

produced from expanded exploration and production in that field is not definitively known. GGC sells its LPG to Ghanaian downstream players[19] on long term contracts based on the LPG International Parity Price.

[19] Specifically, licensed Bulk Distribution Companies (BDCs), defined in detail in Chapter 14 (The Value Chain and its Transition) beginning on page 116.

10. Pricing

Primary objectives of the price structure in a developing LPG market are

- To prevent price abuses by the distribution system; and
- To balance fuel affordability for consumers with returns required by investors.

Additional objectives can include whether prices vary by distance from LPG sources, or not, and whether the market will be a high-service or low-service market. High service, for example, could include in-home exchange of a filled LPG cylinder for an empty cylinder (that is, home delivery). High service and low service trade off forms of access and availability for the consumer (and stronger cylinder asset control for the supply chain participants) against end-user fuel affordability.

Higher unit margins also strengthen three key investment factors in LPG companies:

1. The sustainable growth rate (the maximum rate at which customers may be added without creating negative cashflow) of the enterprise is higher;
2. The breakeven volume for a new enterprise is lower, thus reducing the investment risk;
3. The potential for generating required returns to investors and the capacity to service debt are increased.

Semi-regulated pricing

Ghana has been employing a form of semi-regulated LPG pricing, as shown in the table below.

Under this pricing scheme, the unit margins at each node in the supply chain are predetermined via regulation, using a national LPG price build-up formula.

Based on global LPG sector experience, there are six main choices of price system:

Table 7. Price structure modalities

LPG Price System	Description	Example Countries
Regulated, fixed margins, International Parity Price (IPP)[20], no subsidy	The government regularly updates the price structure as the applicable International Parity Price changes (typically monthly)	India, Indonesia, much of Latin and South America, Belgium, Spain
Regulated, fixed margins, actual sourced price, no subsidy	Maximum prices are revised regularly by each marketer as the international price is updated, according to the price formula (typically monthly)	Ghana, today
Regulated, fixed margins, common sourced price, no subsidy	The government regularly updates the price structure as the international price varies, per marketer	Kenya for petrol

20 IPP is a regional index price adjusted for standard cost of transportation from the regional price hub

LPG Price System	Description	Example Countries
Regulated, fixed margins, fixed end-user price, IPP with variable subsidy	One permanent national end-user price remains in effect until the government chooses to revise the pricing formula	Morocco, Tunisia, Brazil, Argentina
Regulated, fixed margins, variable end-user price, fixed subsidy on IP formula	The government regularly updates the price, which is discounted by a fixed subsidy amount, as the IPP changes	Dominican Republic (prior to removal of subsidy)
Non-regulated	The market sets its own prices	Kenya, France, Italy, Germany

The regulated price structures may be further modified by adding a cross-subsidy mechanism to account for varying inland transportation costs, such that the end-user price is kept relatively uniform throughout the country without disincentivizing the distribution network from serving remote users in favor of close-by users. Ghana has employed such a mechanism.

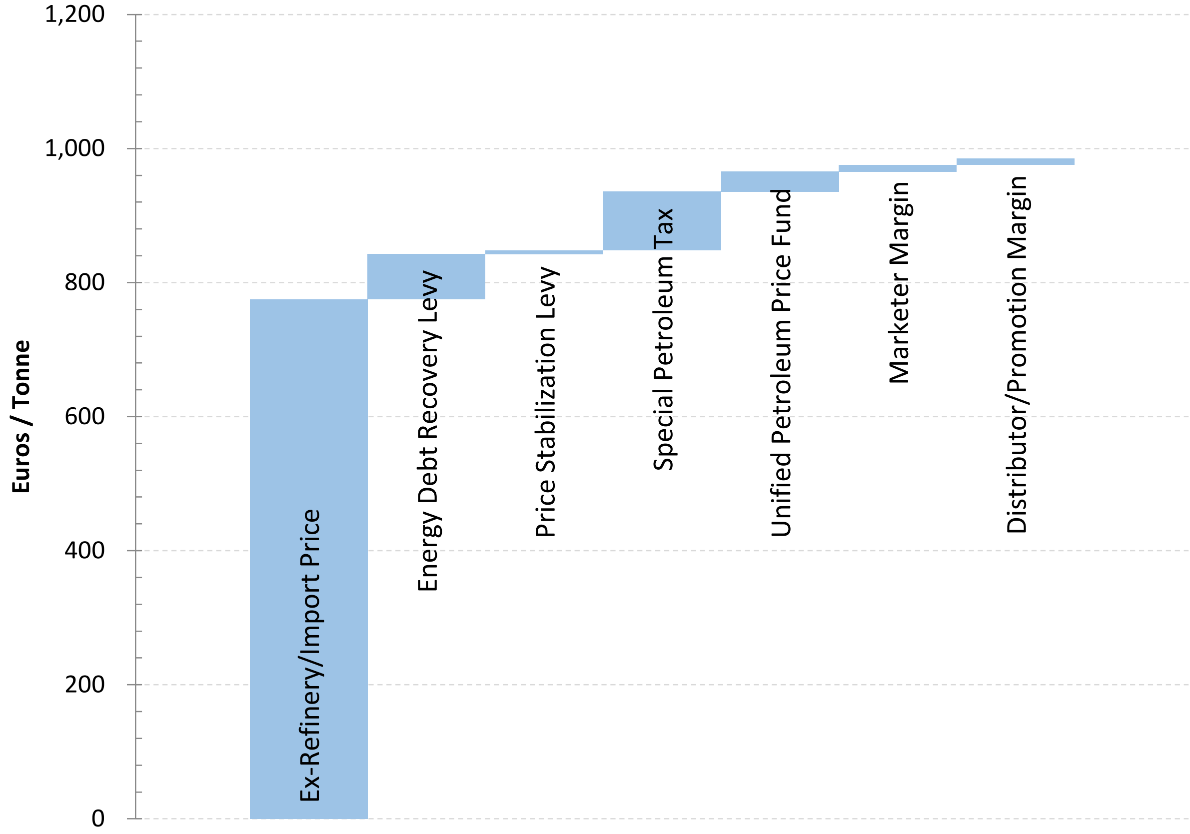
The price structure in Ghana is undergoing refinement in the ongoing NPA and task force processes, as of this writing. Its main components are source price (note: domestically produced LPG from the Ghana Gas Company and Tema refinery are priced in line with the prevailing International Parity Price), fixed margins corresponding to each supply chain node, and various taxes and levies.

Under consideration is an LPG levy to be added to the pricing formula for the purpose of capital cost recovery of the major investments to be made in cylinders and other infrastructure needed to attain the national goal of 50% of the population using LPG for cooking by 2030. The effect of this levy is estimated to increase end-user LPG prices during the 12-year recovery period by € 30 per tonne, approximately 3% of the present end-user price. This prospective levy is taken into consideration in the forecasting of demand and the structuring and modelling of investments described in Parts VI (LPG Demand Potential to 2030) and IX (Financing), respectively.

Current pricing

The following figure shows the price buildup formula presently in effect in Ghana. It is expected that the price buildup formula under BCRM will be similar, but with upward adjustments to provide for capital recoveries associated with new infrastructure and to provide margins to new/reformed nodes in the supply chain. The degree to which such capital recoveries and margins will ultimately affect the end-user price has not yet been determined by the Government.

Figure 5. Current LPG price build-up formula



Price Element	Amount (€/T)[21]	Description
Ex-Refinery/Import Price	775.3	International (regional) price / price charged by Ghana Gas Co. and by Tema Oil Refinery
Energy Debt Recovery Levy*	67.3	Levy to repay nonperforming bank loans to the energy sector
Price Stabilization Levy*	5.5	Levy to counteract price volatility
Special Petroleum Tax*[22]	87.3	Tax for increasing state revenue (enacted 2014)
Unified Petroleum Price Fund*	30.0	Subsidizes distance costs, to ensure prices are uniform nationwide
Marketer Margin	10.0	Maximum that a licensed LPG marketer may recover from its sales
Distributor/Promotion Margin	9.1	Maximum that a licensed dealer/retailer may recover
Total	**984.5**	

**These elements apply to all hydrocarbon products, not only to LPG*

As of this writing, the Government has not taken a final decision about pricing under BCRM, in which additional margins for additional supply chain nodes, and capital recovery costs for associated new infrastructure, must be allocated.

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21 Pricing elements from Ex-Refinery/Import through UPPF are defined in USD; the additional elements are defined in GHC. Exchange rates applied: GHC/Euro, 4.80; USD/Euro, 1.146.

22 The Special Petroleum Tax faces growing political opposition. It was recently converted from ad-valorem to fixed, and reduced in percentage from 17.5% to 13% (based on current pricing).

A critical issue in setting unit margins through regulation is the service model intended for the country. Margin choice implies service level.

With high unit margins for the marketing/filling/distribution part of the supply chain, services such as home delivery become viable. High unit margins, per industry norms, would be in the range € 200-400 per tonne. With low unit margins, in a range of € 50-100 per tonne, only a basic service level is viable, and the focus of the supply chain participants is, of commercial necessity, on increasing volume, both in order to cover fixed costs (including any debt service) and, with additional volume, to generate financial returns to owners and investors.

Two main pricing options are proposed for the BCRM supply chain.

Alternative 1: Ex-refinery price build-up

The first alternative builds up from the existing ex-refinery price (€ 775 per tonne as of this writing) and adds the elements required by the expansion of the supply chain for BCRM and sector growth. At the end-user level, prices are charged per kg for the amount of fuel in a full residential LPG cylinder, rather than per tonne.

These costs and margins are indicative, based on industry norms across Sub-Saharan Africa. The additional pricing elements may ultimately have different amounts associated, based on how the Government of Ghana determines to allocate costs (and associated responsibilities) and profits across the supply chain. That is, the Government may ultimately choose to allocate costs and profits differently, provide more or less margin to the supply chain participants at each node, and set a different maximum end-user price.

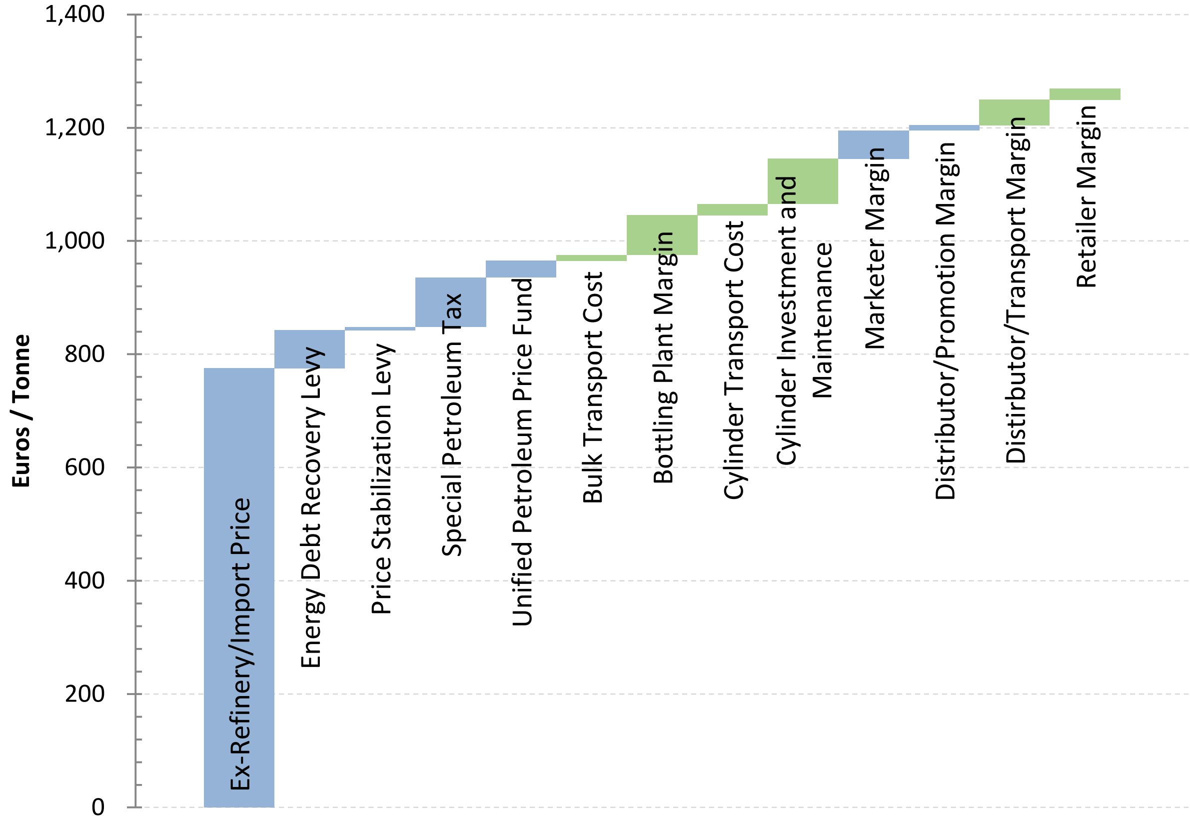
In this first alternative, the total increase of the indicative costs and margins is € 284.8 per tonne, a nearly 30% increase over current pricing. A price increase of such magnitude would be politically difficult to enact, and would likely result in significant opposition from the public[23].

This option is therefore presented for comparative purposes: it indicates that adding all the necessary costs and margins to the existing starting price from the current LPG national price build-up formula is in all likelihood a non-viable option, and therefore a different approach (as outlined further below) is required.

This alternative is detailed in the following figure.

[23] While there are no known studies of public reactions to LPG price increases, media reports of historical public responses to attempted large price increases to LPG in LMICs support the hypothesis that a major increase in price would be politically difficult, or impossible. The most recent example from West Africa is in Nigeria, where mass street protests, riots and strikes occurred in 2012 after the Government of Nigeria increased prices of petroleum products, including LPG. The Government quickly reversed the increases.

Figure 6. Prospective LPG price formula (alternative 1 – ex-refinery based)



Price Element	Amount (€/T)[24]	Description
Ex-Refinery/Import Price	775.3	International (regional) price / price charged by Ghana Gas Co. and by Tema Oil Refinery
Energy Debt Recovery Levy*	67.3	Levy to repay nonperforming bank loans to the energy sector
Price Stabilization Levy*	5.5	Levy to counteract price volatility
Special Petroleum Tax*[25]	87.3	Tax for increasing state revenue (enacted 2014)
Unified Petroleum Price Fund*	30.0	Subsidizes distance costs, to ensure prices are uniform nationwide
Bulk Transport Cost[E]	10.0	Cost of transport of LPG in bulk to the bottling plants (BPs)
Bottling Plant Margin[E]	70.0	Maximum that a bottling plant may recover from its sales
Cylinder Transport Cost[E]	20.0	Cost of transport of cylinders between BPs and distributors
Cylinder Investment and Maintenance[E]	80.0	Amortized investment cost of cylinder plus operating cost of cylinder inspection/testing, maintenance and scrapping
Marketer Margin	10.0	Maximum that a licensed LPG marketer may recover from its sales
Distributor/Promotion Margin	9.1	Maximum that a distributor may recover from sales, apart from cylinder transportation
Distributor/Transport Margin	45.0	Maximum that a distributor/cylinder transporter may recover

24 Pricing elements from Ex-Refinery/Import through UPPF are defined in USD; the additional elements are defined in GHC. Exchange rates applied: GHC/Euro, 4.80; USD/Euro, 1.146.

25 The Special Petroleum Tax faces growing political opposition. It was recently converted from ad-valorem to fixed, and reduced in percentage from 17.5% to 13% (based on current pricing).

Price Element	Amount (€/T)[24]	Description
		with respect to transporting of filled and empty cylinders
Retailer Margin	20.0	Maximum that a retailer (cylinder exchange point operator) may recover from refill sales
Total	**1,269.3**	

**These elements apply to all hydrocarbon products, not only to LPG*
[E]*Estimate based on Sub-Saharan Africa LPG industry norms*

Alternative 2: IPP price build-up

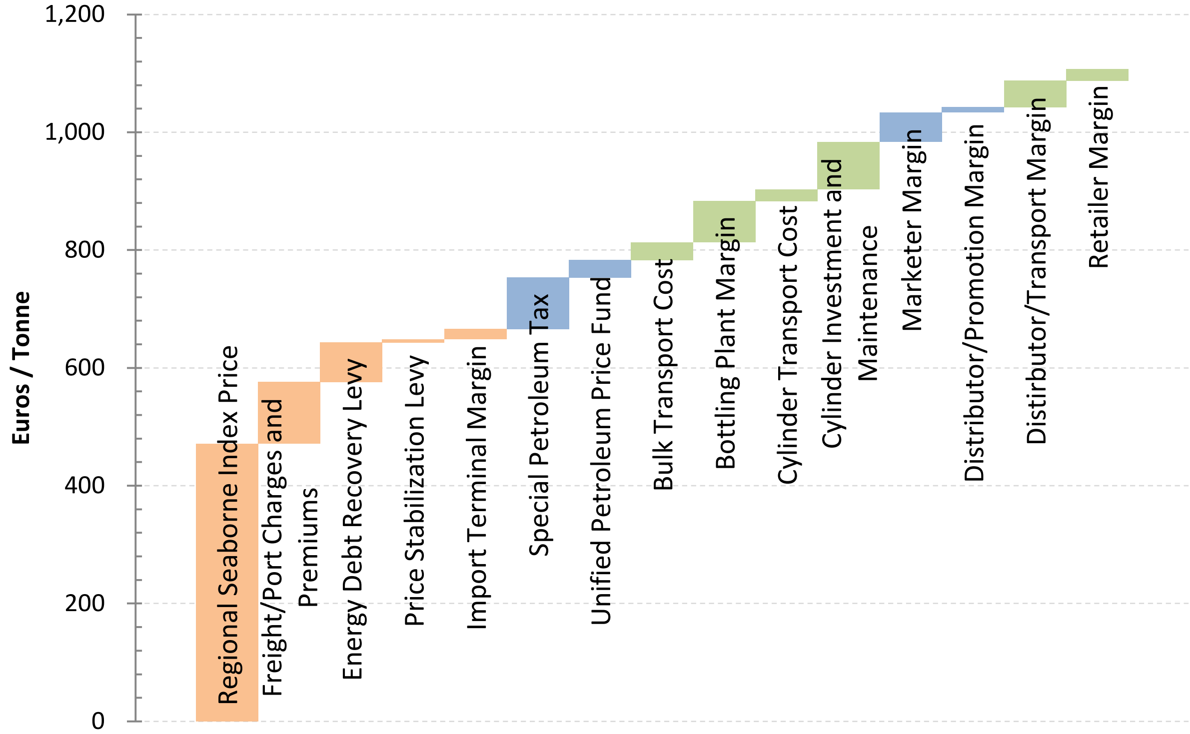
The second alternative builds up from the index price for LPG delivered to the country by sea, to arrive at a reduced Import Parity Price (IPP) of € 666 per tonne, embedding several of the levies within the IPP price. (The sub-IPP elements are shown in a different color in the figure below.)

This alternative has the same structure of margins, operating costs, and capital cost recovery within the domestic portion of the LPG supply chain as the first alternative, but it has a prospective increase to the end-user price of only € 123 per tonne, an approximately 12% increase. This compares very favorably to the first alternative's € 285 per tonne and 30%.

As in the first alternative, these costs and margins are indicative, based on industry norms across Sub-Saharan Africa. The additional pricing elements may ultimately have different amounts associated, based on how the Government of Ghana determines to allocate costs (and associated responsibilities) and profits across the supply chain. That is, the Government may ultimately choose to allocate costs and profits differently, provide more or less margin to the supply chain participants at each node, and set a different maximum end-user price.

This alternative is detailed in the following figure.

Figure 7. Prospective LPG price formula (alternative 2 – IPP based) (recommended)



The first five elements (orange) comprise the Import Parity Price (IPP) for purposes of the price build-up formula; permitted unit margins for existing (blue) and new (green) nodes of the supply chain are then layered atop the IPP to arrive at the maximum end-user price. Amounts per tonne may be directly divided by 1,000 to determine the LPG refill price per kg.

Price Element	Amount (€/T)[26]	Description
Regional Seaborne Index Price	471.3	Commodity index for ocean-delivered LPG to the region
Freight / Port Charges and Premiums	104.7	As described
Energy Debt Recovery Levy*	67.3	Levy to repay nonperforming bank loans to the energy sector
Price Stabilization Levy*	5.5	Levy to counteract price volatility
Import Terminal Margin	17.5	Maximum that the import terminal may recover from sales
Subtotal: Import Parity Price	**666.2**	The Import Parity Price = sum of the above elements
Special Petroleum Tax*[27]	87.3	Tax for increasing state revenue (enacted 2014)
Unified Petroleum Price Fund*	30.0	Subsidizes distance costs, to ensure prices are uniform nationwide
Bulk Transport Cost[E]	10.0	Cost of transport of LPG in bulk to the bottling plants (BPs)
Bottling Plant Margin[E]	70.0	Maximum that a bottling plant may recover from its sales
Cylinder Transport Cost[E]	20.0	Cost of transport of cylinders between BPs and distributors
Cylinder Investment and Maintenance[E]	80.0	Amortized investment cost of cylinder plus operating cost of cylinder inspection/testing, maintenance and scrapping
Marketer Margin	50.0	Maximum that a licensed LPG marketer may recover from its sales
Distributor/Promotion Margin	9.1	Maximum that a distributor may recover from sales, apart from cylinder transportation
Distributor/Transport Margin	45.0	Maximum that a distributor/cylinder transporter may recover with respect to transporting of filled and empty cylinders
Retailer Margin	20.0	Maximum that a retailer (cylinder exchange point operator) may recover from refill sales
Total	**1,107.5**	

**These elements apply to all hydrocarbon products, not only to LPG*
[E]Estimate based on Sub-Saharan Africa LPG industry norms

Why some level of price increase is necessary in the near and medium term

It may seem counterintuitive to plan an increase in end-user LPG prices as part of a program to increase LPG adoption and use rapidly nationwide, especially with respect to the rural poor.

However, the present level of free cash flow generated by the LPG ecosystem from each tonne of LPG is not adequate to meet four preconditions to the rapid, successful, sustainable scale-up of LPG supply and consumption:

1. Ensure cylinder safety and LPG handling safety to an acceptable level throughout the value chain;
2. Ensure that the full range of essential business (and regulatory) functions needed in a large-scale, well-functioning LPG ecosystem are performed with adequate completeness and acceptable quality;

26 Pricing elements from Ex-Refinery/Import through UPPF are defined in USD; the additional elements are defined in GHC. Exchange rates applied: GHC/Euro, 4.80; USD/Euro, 1.146.

27 The Special Petroleum Tax faces growing political opposition. It was recently converted from ad-valorem to fixed, and reduced in percentage from 17.5% to 13% (based on current pricing).

3. Enable investment at the rate necessary to achieve the national policy goal for LPG adoption and use by 2030; and

4. Support expanded availability of LPG in rural areas.

These four preconditions are in a rough hierarchy: First, without an acceptable level of safety, fear of explosions stagnates the development of the market by depressing demand. Second, if cost coverage is inadequate, key tasks are underperformed or not performed, and the ecosystem develops more slowly and more problematically. Third, if investment cannot occur fast enough, the policy goal can take far longer than 2030 to be realized, if ever. This can be because LPG businesses' cash flows are inadequate to attract enough capital and/or affordable capital, or because they are inadequate to allow LPG businesses to grow at the desired rate without facing growth-driven insolvency on a cash basis. Fourth, because costs and risks associated with serving rural areas are higher than urban and peri-urban areas (due to the combination of geographic remoteness, lower population density, lower incomes on average, and higher availability of freely gatherable firewood in rural areas), weak sectoral cashflow generated from urban and peri-urban areas may limit the sector's ability to expand as deeply as possible into rural areas.

Much as an electric utility must find a way to cover its costs of expansion of facilities through its rate base, so must the LPG sector cover its costs of infrastructural expansion.

Therefore, paradoxically, to serve many more poor and rural households, the LPG price must, for the near and medium term, increase in the case of Ghana.

It is not necessarily the case that the consumer must bear the entire burden through the end-user price. The use of concessional capital for financing LPG sector growth, improvements in LPG sourcing, sectoral economies of scale that are achieved over time, Governmental interventions (e.g., targeted subsidies), risk-sharing and cost-sharing structures, establishment of key projects as cost centers where possible (on a utility model) rather than as profit centers, and other mechanisms, can serve to reduce the cost burden on end-users, and in particular, on poorer and more rural end-users.

The most directly relevant of these mechanisms and trade-offs are discussed in more detail throughout the remainder of this document.

Once very rapid expansion of the LPG sector has occurred and effective, efficient operational disciplines are in force in industry and government, competitive forces and/or governmental action can benevolently adjust the allocation of costs and rents throughout the value chain.

Advantage of a cylinder deposit scheme over consumer purchase of cylinders

Under CCCM, cylinders are purchased by consumers at retail at their full retail price, which includes (i) recovery of costs for the cylinder supply chain and (ii) price mark-ups by the manufacturer and the participants in the cylinder distribution and retailing channel.

Under BCRM, cylinders are purchased by LPG marketing companies and made available at some percentage of the cylinder acquisition cost to the consumer, in the form of a cash deposit.

Effect on the consumer

The deposit entitles the consumer to possess a cylinder of a certain brand, and to have his/her cylinder (typically a different one with each refill) refilled, inspected and maintained for safety by the LPG marketing company. The consumer is insulated from wholesale and retail price mark-ups as well as from the full acquisition cost of the cylinder itself. The maximum percentage of the cylinder cost that a consumer must pay toward a cylinder may be set by law or regulation (such as 80%, in Cameroon) or by competitive forces (such as approximately 20%, in Morocco). The consumer may recover his/her deposit by giving up the cylinder to the appropriate LPG marketer's retailer or distributor.

The deposit percentage that will apply under BCRM in Ghana has not yet been determined definitively as of this writing.

Effect on industry

The cylinder deposit scheme mitigates the net cost to the LPG supply chain of deploying new cylinders under BCRM, by offsetting a material portion of the cylinder capital cost outlay. This source of cash decreases significantly the asset intensity of the LPG supply chain, from a cashflow perspective.

Balancing LPG cylinder affordability with LPG fuel affordability

The Government has the additional option to trade off additional cylinder affordability for both industry and consumers with fuel price.

Conventionally, the entirety of the capital cost of a cylinder is borne by, and divided between, industry and the consumer up front, as each new cylinder is acquired and enters the market. It is possible, however, to amortize a portion of the cost of the cylinder over a multiyear period by transferring a portion of its capital cost to the LPG fuel revenue stream.

Among the simplest mechanisms to do so is to introduce a capital cost recovery levy which is added to the price build-up formula.

As described more fully and precisely in Part VIII (Critical Path LPG Infrastructure Investment Projects to 2030) beginning on page 134, a levy of approximately € 0.03 / kg (€ 30 per tonne) applied to national LPG consumption over a ten year period, used to offset the acquisition costs of new cylinders, would provide enough funding that the up-front capital cost of new cylinders to industry, and to consumers (via deposit), could be cut by approximately 40%.

Because such a levy would apply to all LPG consumed in the country, not only to the LPG associated with new users, a relatively small levy amount applied to the relatively large quantity of LPG already consumed could create a disproportionately large first-costs benefit for the new LPG users (and for the associated cylinder inventory investments by industry).

Making such a trade-off is being considered by the NPA. The structuring and potential economics of such a cylinder investment scheme involving partial levy-based cylinder funding are discussed in Part IX (Financing) beginning on page 184.

11. National LPG Planning Process from 2017

Starting from its assignment by the President of Ghana in October 2017, the NPA undertook planning to implement the newly approved national LPG policy. It constituted a National LPG Policy Implementation Committee (Committee) to discuss and define the recommended implementation details of the National LPG Policy. It sent delegations to Morocco, Senegal, India, Cote D'Ivoire, Colombia and Peru to learn how those other countries had addressed/were addressing significant scale-up of LPG access and use by households for cooking.

The Committee was further tasked with the following:

1. Develop a new LPG price build-up formula

   The LPG price (including specific levies and margins) for cylinder fills and refills should be deregulated and be a full passthrough to ensure implementation of the CRM policy. To increase penetration from 25% to 50%, four key drivers were identified: availability of cookstoves, availability of cylinders, regularity of LPG supply, and the price of LPG. The market price of refills is about US $1/kg[28]. Approximately 20% of the LPG pump (retail) price is taxes.

2. Determine the number, size and types of cylinders in circulation

   The size would be 14.5kg, 6kg, and 3kg for households, and up to 70kg for commercial consumers.

3. Develop a cylinder recall strategy

   Consumers can turn in existing cylinders to an LMC and be credited against a deposit on a new cylinder (or make a cash deposit on a new cylinder).

4. Identify cylinder drop off points

   Consumers should register with only one LMC at a time, and drop off empty cylinders belonging to a given LMC only with a distributor of that LMC.

5. Value the assets of "high risk" micro-filling stations

   Approximately 650 stations (the count fluctuates with business' viability and license status) fill cylinders with LPG for consumers or for vehicles (called "autogas"). The majority are owned by sole proprietors with 1-2 stations each. GLiPGOA (mentioned previously) represents these smaller station owners. A separate association represents the larger station owners, who on average own 5 stations each. Autogas is currently about 45% of these stations' sales.

   LPG station operators will fall into two categories: a) those transitioning to cylinder distribution, who will require working capital and have possible stranded asset issues; and b) those transitioning to pure autogas sales.

   In a risk assessment by the NPA, the existing filling plants were classified into "high risk" or "low risk" based on their ability to meet safety standards. The "high risk" filling plants would be converted into

28 14.5kg cylinder (most common size in Ghana).

filled cylinder retail and distribution outlets. “Low risk” plants would be dedicated to supplying autogas, with improved safety standards. A significant difficulty is that retail operators were categorized as “high risk” if they operated in high population areas, seemingly unconnected from all other safety requirements. As mentioned above, 80% of the stations fall into the “high risk” category simply by virtue of their location.

The present station owners desire:

a) Fair compensation for lost revenue/profits and stranded assets;

b) A real opportunity to regain lost revenue/profit under CRM, including working capital to do so;

c) A reasonable transition period, ideally 3-5 years;

d) Abated pressure from banks during the transition and revenue-building period;

e) Limitation on competition, especially from new entrants, during the transition; and

f) A reasonable level of respect shown them by government officials.

As of this writing, outspoken disagreement between the GLiPGOA membership and the NPA has partly subsided, but the issues identified by the station owners remain on their horizon.

The Government is rightly concerned about the suggestion that compensation might be provided. Funding sources, whether commercial, concessional, or grant-based, are unlikely to commit funds to address operator concerns without providing a clear return – whether financial or, for a grantor, in measurable social impacts. Stranded assets cannot produce commercial returns; decommissioned stations cannot contribute positive social impacts.

6. Negotiate potential compensation (or other solutions) with LMCs whose outlets will be closed down

Station owners prefer the opportunity to grow out of their prospective difficulty, and want no new entrants in the market so they have time to consolidate. They cite as an exemplary case when the Bank of Ghana (BoG) required banks to increase statutory capital from 150 million Cedis (€ 27 million at 5.5 GHC/Euro) to 400 million Cedis (€ 72 million). BoG gave the banks two years, ending 31 December 2018, to accomplish it, and no new entrants were allowed in the banking sector during that period.

Areas of assistance to NPA through the Clean Cooking for Africa Program

Consistent with its long record of assistance to the Government of Ghana starting in 2011, GLPGP signed an MOU with the NPA in May 2018 to govern providing technical and finance-related support to the NPA and the Committee in the following areas:

1. Development of Health, Safety, Security and Environment (HSSE) Standards

   - Assist the HSSE Sub-Committee to develop HSSE standards for all the areas along the LPG supply chain such as bottling, transportation and distribution taking into consideration international best practices.

2. Development of Licensing, Permit and Legal Framework

- Work with the Sub-committee on licensing, permitting and legal framework to prepare a new license framework for the various operators along the supply chain, as well as the legal framework for all the supply chain activities.

3. Development of cylinder recall strategy

- Advise on international best practices for the recalling of cylinders currently in circulation; and
- Assist the NPA to develop a comprehensive strategy to recall the cylinders in circulation.

4. Investment study

- Conduct a detailed investment study with the NPA to understand the total cost of investment required to enforce safety along the entire LPG supply chain. The results of this work to date are presented in summary form in this report, and in detail in the companion *Ghana LPG Investment and Implementation* report.

5. Cooperate with the NPA to raise funds to support the implementation of the Cylinder Re-circulation Model.
6. Support NPA in the development and implementation of options aimed at expanding and optimizing the LPG supply chain for improved accessibility, affordability and safety.
7. Discuss and agree with the NPA, the nature and content of any engagements with Ghana downstream industry players towards the implementation of the new LPG policy.

This work is still ongoing as of this writing.

VI. LPG Demand Potential to 2030

This Part[29] provides an evidence base for use by investors, policymakers, industry and researchers to guide the development of LPG infrastructure and distribution systems in Ghana. It is comprised of two main chapters:

1. Modelling of a base case of LPG consumption, in which "business as usual" is projected into the future; and lower and upper bound scenarios of the demand which could be unlocked under CRM. The approach taken is to consider the characteristics which have given rise to the demand which was served in 2017, and to model how this demand would be reflected across (a) new users brought into the national LPG value chain under Ghana's expected LPG market reforms and expansion investments, and (b) concomitant growth in demand from existing users.
2. Modelling of expected future LPG consumption using Probit analysis (described in its chapter), and its price sensitivity.

The purpose of conducting two different analyses is twofold: First, given the reliability limitations of available data about Ghanaian LPG consumption, economics, and preferences at the household level, and likewise about competing fuels, using two different analytic methodologies provides a higher level of confidence in their findings, if they are generally consistent with each other.

Second, the two analyses have differing, complementary strengths. The demographic modelling of Chapter 12 includes a more granular, bottom-up approach for estimating which consumers, located where, are likely to adopt LPG, while the Probit modelling of Chapter 13 provides a deeper econometric exploration of demand including household economics and price elasticity of demand for urban and rural populations. Both analyses provide projections of where future demand can be unlocked, and how much adoption and consumption would occur, through a combination of increased LPG availability and measures to increase consumer preference for LPG. These projections are in rough agreement.

Because the demographic modelling analysis was performed following the Probit modelling analysis, the demographic modelling was also able to make use of, and build upon, aspects of the Probit modelling, as discussed in Chapter 12 in the section entitled *Detailed analysis and findings*.

Both chapters utilize Ghana Living Standards Survey 6 (GLSS 6) and other data sources to construct the models. Summary data from Ghana Living Standards Survey 7 (not yet published in full as of the time of this writing) were used to confirm extrapolations made from the GLSS 6 data set.

Because the approaches taken in the two analyses are different, the results differ slightly. However, both approaches predict that the governmental goal of 50% of the population using LPG as a primary cooking fuel is within reach, if the necessary reforms and investments are well and timely made. As mentioned in the Executive Summary (Part II of this report), the analyses predict that improving LPG availability, by itself, can be expected to have a major impact on the rate and amount of LPG adoption; additional measures to increase consumer preference for LPG for cooking (compared with wood and charcoal) and to improve affordability of LPG equipment and/or fuel could allow the governmental goal to be exceeded.

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29 The contents of this Part were developed with Dalberg Global Development Advisors (Chapter 12) and Economic Consulting Associates (Chapter 13) under engagement to GLPGP.

12. Demand Assessment through Demographic Matching Analysis

Summary

The assessment presents baseline consumption of LPG in Ghana in 2013 (the most recent year for which comprehensive statistical data are available), and a forecast of potential demand for LPG as a household fuel in 2020, 2025 and 2030. Forecasts are made reflecting a scenario of increased LPG availability to be achieved through planned and/or potential additional market and regulatory reforms and national infrastructure investment projects.

This chapter builds in part on the Ghana LPG demand assessment conducted for Clean Cooking for Africa/GLPGP by Economic Consulting Associates (ECA) in 2017, presented in Chapter 13 beginning on page 98.

Data sources

The Ghana Living Standards Survey Round 6 2012/2013 (GLSS 6), a nationally representative population survey conducted by the Ghana Statistical Service, was the primary data source for the assessment[30]. Where possible, this information was triangulated with the (limited) available aggregated data from the Ghana Living Standards Survey Round 7 2016/2017 (GLSS 7). The full GLSS 7 data had not been publicly released at the time of this writing.

Baseline residential LPG consumption (as household fuel) in 2017

The penetration of LPG has been increasing slowly, with 24.5% of total households reporting using LPG as a primary fuel for cooking in the 2017/2018 GLSS 7, compared to 22.3% of households in the 2012/2013 GLSS 6. Regional variations in LPG use are large; according to the GLSS 7, 36.9% of the urban population and 8.7% of the rural population used LPG in 2017. The GLSS 6 and GLSS 7 do not provide data on secondary fuel use. Overall, in 2017, most Ghanaian households still relied on biomass fuel for cooking, with 33% of households using firewood and 32% using charcoal as their main source of energy for cooking.

In 2017, a total of 358,900 MT of LPG was consumed in Ghana[31]. 165,753 MT was consumed in cylinders for household cooking by 1.66 million households. The national per capita consumption was 5 kg in 2013 and 5.53 kg in 2017. LPG consumption per capita by primary LPG user in 2017 was 24.8 kg. While there are no official estimates of the number of existing cylinders in circulation in Ghana, the National Petroleum Authority (NPA) indicates that there were 5.8 million LPG cylinders in circulation in Ghana in 2017.

Forecasted demand for LPG in 2020, 2025, and 2030

LPG demand in 2020, 2025 and 2030 was forecasted by modelling the incremental impact of three drivers of demand: (i) demographic changes, (ii) expanded availability of LPG through the implementation of the branded cylinder recirculation model (CRM) and corresponding investment in cylinder availability, infrastructure, and distribution systems across Ghana, and (iii) changes in underlying preferences for LPG that may result from increased investments in marketing, awareness, and safety. These drivers were combined to creates the following scenarios:

30 The GLSS 6 survey sampled 18,000 households across the country. Data were obtained from 16,772 households, representing a response rate of 93.2%.

31 NPA (2017)

Main Scenarios

- Scenario 1: Base case scenario, where forecasted consumption is derived by extrapolating historical growth trends for residential LPG consumption.
- Scenario 2: Market reform and expansion scenario, reflecting both planned and potentially additional policy and investment interventions. In the reform and expansion scenario, two sub-scenarios are considered, leading to a range of projected demand:
  - Scenario 2A: Lower-bound full LPG availability, incorporating demand growth from demographic changes, as well as the impact of expanded LPG availability to serve latent demand.
  - Scenario 2B: Upper-bound full LPG availability, incorporating the same demand drivers as Scenario 2A (demographic changes and expanded LPG availability), as well as additional changes in preferences that result in additional households switching to LPG.

In the base case scenario, which assumes that LPG adoption increases in line with historical trends, it is estimated that residential LPG consumption will grow to 276,060 MT by 2030. The number of households using LPG as primary fuel would grow to 3.05 million households by 2030, representing 31.5% of all households and, likewise, 31.5% of the population in 2030.

Under the market reform and expansion scenarios, which assume that an effective branded cylinder recirculation system is in place, it is projected that residential LPG consumption for cooking will grow from 165,753 MT in 2017 to between 404,415 MT and 530,420 MT by 2030, depending on the scenario. The number of households using LPG as a primary fuel would grow to between 4.47 million households (46% of all households) and 5.30 million households (55% of all households) in 2030, compared to 24.5% of households in 2017. This equates to a national per capita LPG consumption of between 10.4 kg and 13.7 kg in 2030, depending on the sub-scenario. Regionally, annual urban consumption will grow from 148,010 MT in 2017 to 301,442 MT in Scenario 2A, and will grow to 403,688 in Scenario 2B in 2030. Annual rural consumption will grow from 17,743 MT in 2017 to 102,973 MT in Scenario 2A, and will grow to 126,732 MT in Scenario 2B in 2030. These scenarios indicate that market reforms and infrastructure investments that improve LPG availability and cylinder access have the potential to drive large uptake of LPG in Ghana by 2030.

The demand forecasts outlined above do not model the impact of significant changes in LPG fuel prices, due to the lack of household-level consumption and price data in the GLSS 6 dataset. However, approximate estimates of sensitivity of demand to changes in LPG price were modelled. While industry experts expect LPG import prices to stabilize in Ghana due to the Price Stabilization and Recovery Levy, the restructuring and expansion of the supply chain and development of corresponding infrastructure has an expected cost of € 123 per tonne of LPG sold over a period of ten years (see Chapter 10 (Pricing) beginning on page 53). If the government were to determine that this cost must be borne entirely by consumers, with no offset through supply chain efficiencies, unit margin adjustments, reductions in petroleum sector taxes and fees applied to LPG, or other mechanisms, then the end-user price of LPG would increase by € 0.123 per kg, which is 12.5% above current prices. Across both the upper and lower bound scenarios, assuming all other prices for substitute cooking fuels remain constant, this level increase in the price of LPG (relative to 2017 prices) would decrease total national potential consumption by approximately 5.6%. This results in a total potential LPG consumption of between 381,880 MT (lower bound estimate) and 500,870 MT (upper bound estimate), depending on the demand scenario.

An important question for further study, and for consideration by policymakers, is whether a reduction in overall usage resulting from any potential relative increase in LPG price (compared to alternative fuels) would come mainly from lower per-user usage, or mainly from a lower quantity of users adopting LPG but still using that LPG at sustained, historical per-user rates. No data existed for modelling an accurate assessment of this question.

Despite the absence of such data, the modelling indicates that any negative impact of higher pricing on adoption rates in the lower bound scenario would be *de minimis*. (In the base case, no price increase applies.) That is because of two factors: First, the effect of an LPG price increase of up to 12.5% does not cause the cost of cooking a meal with LPG to become larger than the cost of cooking a meal with charcoal in Ghana. (Cooking with LPG is already more expensive than cooking with purchased firewood.) Therefore, the household economic case for switching to LPG, independent of the value placed on non-cost benefits of LPG, does not fundamentally change. Second, the marginal utility of the first LPG kilogram used by a household in a given time period would be much greater than the value of the last kilogram. Therefore, households are likely to rebalance their usage among multiple cooking fuels as the fuels' prices shift relative to one another, rather than eliminate one fuel altogether. Thus, one may expect similar adoption of LPG in the base case and lower bound scenario with a price increase up to the notional 12.6%. By extension, adoption in the upper bound scenario, which is based on adding measures to stimulate preference for LPG, independent of its relative price, should also be minimally affected by such a price increase.

However, if the main effect of a price increase in practice were, after all, a reduction of the growth in the percentage of households adopting LPG, then additional measures, such as consumer education and sensitization, a cylinder discounting levy (as discussed in Part IX), microfinance programs, steps to reduce the imported costs of LPG (as an offset to the higher price), waivers of certain petroleum-sector taxes otherwise applicable to LPG, and/or a scheme of targeted incentives, among others, would be required to realize the 2030 policy goal.

Conclusion

LPG consumption in Ghana has been rising modestly since 2010, with the proportion of households using LPG as their main source of energy for cooking growing from 18% in 2010[32] to 22.3% in 2013[33], and to 24.5% in 2017[34]. Growth during 2013-2017 was slower than the growth in 2010-2013, which may be attributable to a rise in LPG prices resulting from the government's phase-out of the LPG price subsidy in 2013. Projecting the 2013-2017 growth rate forward, 36.7% of households are expected to use LPG as the primary fuel for cooking in 2030. To unlock and serve latent demand, market reforms to implement a branded cylinder recirculation model and additional investments to improve availability and access will likely be needed. This would include significant investment in additional cylinders, storage, and refill and distribution capacity, particularly in areas with limited LPG infrastructure. This analysis suggests that such reforms and investments could increase LPG uptake by up to an additional 3.53 million households (relative to 2017), with the potential to reach an upper-bound of 55% of all households in Ghana by 2030. At the upper bound, annual LPG consumption would increase to 530,420 MT in 2030 (or 500,870 MT if the full

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[32] Ghana Energy Commission (2013, 2017)

[33] GLSS 6

[34] GLSS 7

effect of a recommended LPG price increase were to be borne by the consumer). Combining investments for improving LPG availability and cylinder access could help Ghana reach its policy goal of LPG use by 50% of the population by 2030. If a slower adoption rate were to be observed over time due to any relative LPG price increases required to be borne by consumers (or for any other reason), additional measures to stimulate LPG adoption and use would be needed to ensure the policy goal of 50% of households would be achieved by 2030.

Detailed analysis and findings

Using the latest publicly available data, the following were estimated:

1. Residential consumption of LPG for household cooking in Ghana in 2013 across urban and rural households, by region.

2. Potential future demand for LPG in Ghana in 2020, 2025 and 2030 under a scenario of sufficiency of LPG availability resulting from a systematically expanded LPG sector. This includes additional cylinder availability, improved refill and distribution system, with no disruption to the refills supply.

The Probit analysis (see Chapter 13 (Demand Assessment through Probit Analysis) beginning on page 98) estimated the potential LPG residential market size in 2030 under improved availability. This chapter builds on the work described in Chapter 13 in the following ways: (1) it disaggregates demand into urban and rural demand, (2) it introduces the impact of phasing infrastructure roll-out so that LPG is fully available in 2030 (as opposed to modelling the impact of full availability as of 2017 as in the Probit analysis), and (3) it models the potential impact of improved accessibility of LPG cylinders on total demand.

The analysis that follows estimates LPG demand in Ghana between 2013 and 2030 under a number of different conditions. First, an overview of the study and data used for the Ghana demand assessment is provided. This is followed by an overview of baseline household LPG consumption in Ghana in 2013. Finally, results from demand projections up to 2030 are presented.

Data sources

The demand for LPG was assessed using the sixth round of Ghana Living Standard Survey (GLSS 6) by the Ghana Statistical Service, conducted in 2012-2013. This was supplemented by initial summary statistics from GLSS 7, conducted in 2016-2017. GLSS 7 had not been published and its data were not available at the time of this analysis.

The GLSS 6 is a nationally representative, population-based household survey that was conducted over a 12-month period between October 2012 and October 2013. The GLSS 6 survey sampled 18,000 households across the country. Data were obtained from 16,772 households, representing a response rate of 93.2%.

Regarding energy use, the GLSS 6 captured data relevant for the demand assessment, as follows:

- Primary use: The survey asked respondents to list their main (primary) source of energy for cooking.
- Availability of fuel: The survey asked respondents their perception of fuel availability on a scale of one to four, where one indicated that it was unavailable, two indicated

rarely available, three indicated often available, and four indicated always available. This variable could be used as a proxy for the availability of LPG for all households. The GLSS 6 did not have any other variables that could be used to measure LPG availability more accurately.

The GLSS 6 did not capture data on the quantity of fuel used, the price paid for the fuel, the monthly household expenditure on fuel, the number of cylinders possessed by a household, and the distance travelled to purchase fuel. In addition, the GLSS 6 does not capture any data on secondary fuel use.

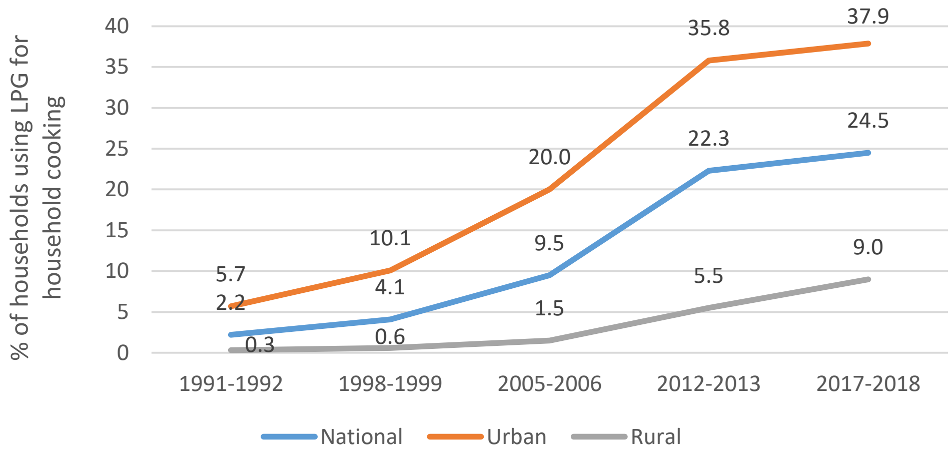
While the analysis heavily relied on household data from the GLSS 6, it was supplemented with data from other sources. Data on total and residential consumption of LPG (2009-2017) and cylinders in circulation were derived from the NPA. The number and location of refilling stations in Ghana were derived from the Ghana Energy Commission.

Baseline consumption of LPG as a household cooking fuel In Ghana In 2017

Overview of Ghana household cooking fuel use in 2017

Since 1991, the number of households that use LPG for cooking has grown steadily in Ghana (see Figure 8). However, in recent years, this growth has slowed and is out of line with the Government of Ghana's policy goals. The National Energy Policy of 2010 set a policy goal to increase the access of households to LPG to 50% by 2015. In 2012, the goal was revised by the Ghana Energy Commission to 50% by 2020[35]. Assessing national progress to 2017, Ghana's National LPG Promotion Policy set a new target of 50% access by 2030.

Figure 8. Percentage of Ghanaian households using LPG as a primary fuel (1991-2017) (% of total households, GLSS1-GLSS 7)[36]



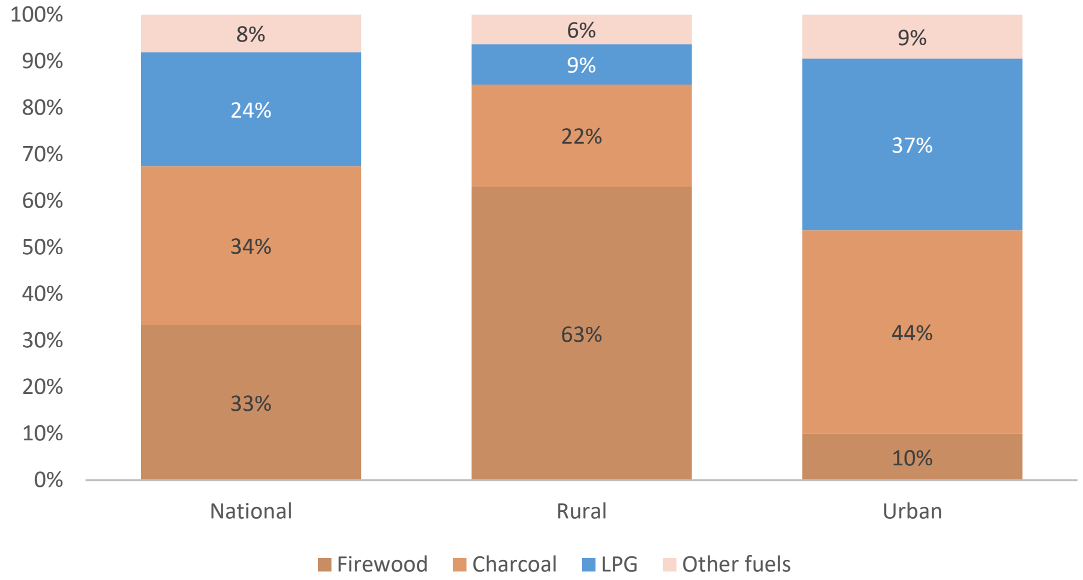
Fuel use varies by region and location; in 2013 and 2017, charcoal and LPG were the dominant cooking fuels in urban Ghana, while firewood dominated in rural Ghana, as shown in Figure 9. In 2017, 37% and 44% of urban Ghanaian households used LPG and charcoal as the primary cooking fuel, respectively. Even though LPG use has been increasing in urban Ghana, 63% of rural households continued to depend on firewood (down from 75% in 2013). Further, fuel use varies regionally in Ghana. 40 % of households in

35 Ghana Energy commission (2012)

36 Asante et al. (2018)

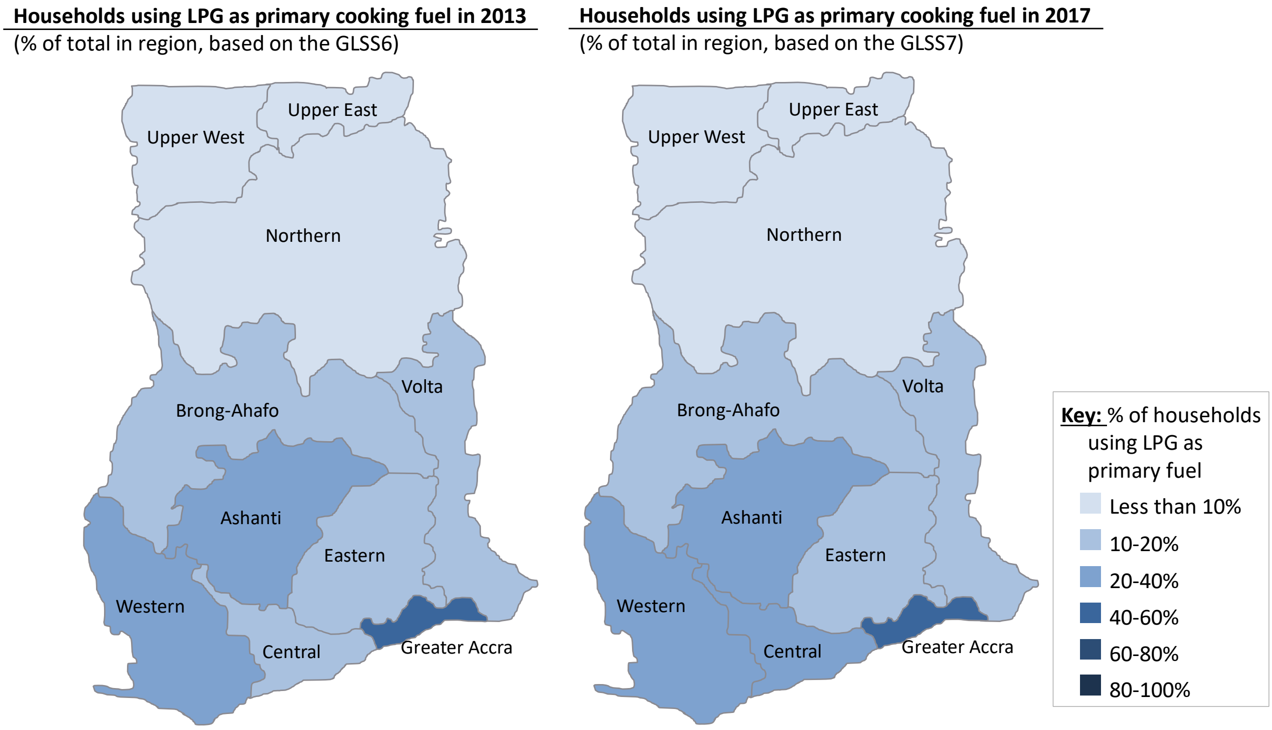
Greater Accra used LPG in 2017 compared to only 1% of households in northern rural Ghana. Across rural and northern areas, firewood was prevalent, except in Central, Eastern, and Ashanti regions, where charcoal was the main fuel used. Figure 10 shows LPG use by region in 2013 and 2017.

Figure 9. Reported primary cooking fuel use in Ghanaian households in 2017 (% of total households, GLSS 7, N=14009)[37]



37 The total number of households that reported using a specific fuel as their main source of energy for cooking for urban and rural households was tabulated and divided by the total number of households in each segment.

Figure 10. Reported LPG use as primary cooking fuel 2013-2017 (% of total households, GLSS 6 and GLSS 7)[38]



Low levels of rural access and use of LPG has motivated national policies to promote LPG use, such as the Rural LPG Promotion Program (RLP), which was initiated in 2013 to distribute stoves to rural households in selected districts at no cost to the consumer for the equipment. However, this program did not drive significant rural uptake of LPG, in part due to poor fuel and cylinder availability and long consumer travel distances to LPG refill stations.[39] Overall LPG consumption data show a clear relationship between basic transport infrastructure and LPG consumption. This is seen through the high LPG consumption in the southern part of the country, where road infrastructure is more developed. The existing LPG distribution infrastructure has grown along developed road networks, which has increased LPG consumption in proximity.

Figure 11 shows that in 2017 there were few refilling stations in the Northern, Upper West and Upper East regions of Ghana. These are also the regions with the highest poverty rates in Ghana.[40]

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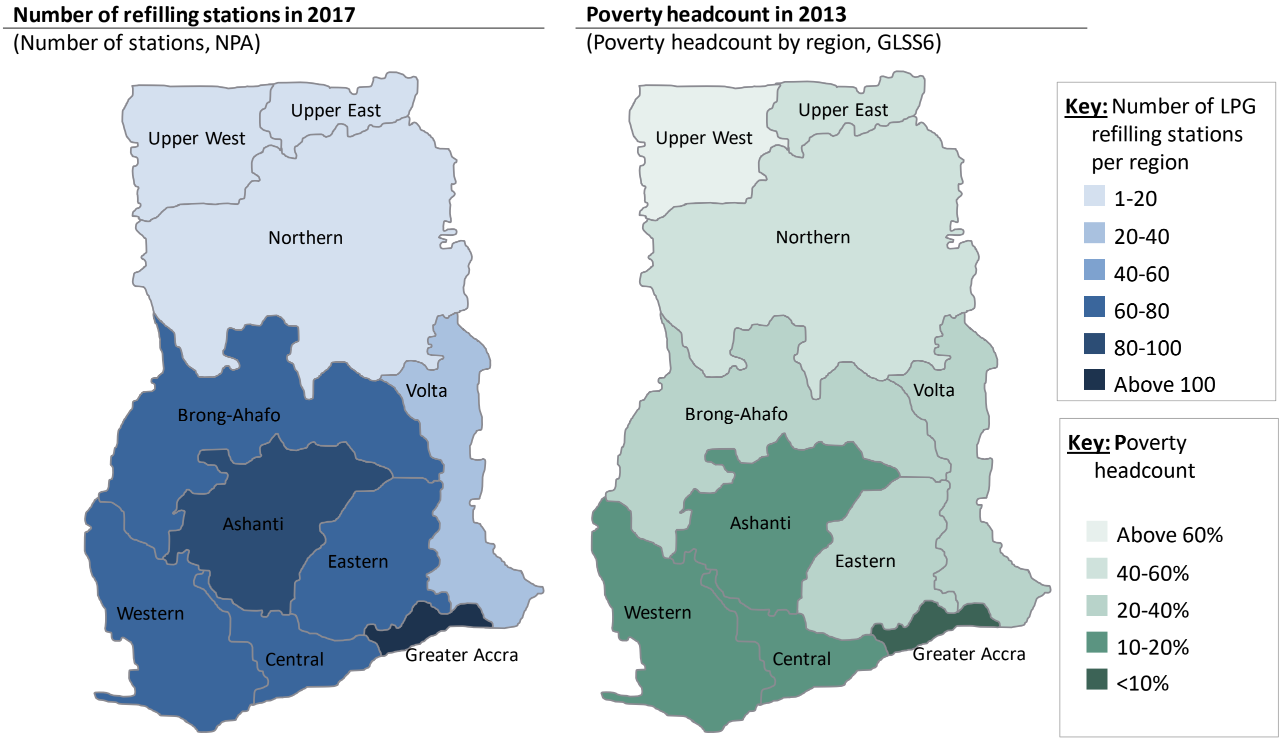
38 The total number of households using LPG as primary cooking fuel (main energy source for cooking) was tabulated and divided by the total number of households for each county.

39 A study of five communities in the Brong-Ahafo Region showed that 58% of the households that received the LPG start-up kit under the RLP never refilled their LPG cylinders nine months after the kit was first delivered. Cost and travel distance to filling stations were identified as critical barriers to refilling. Source: Asante. et al (2018). "Ghana's rural liquefied petroleum gas program scale up: A case study," *Energy for Sustainable Development*. 46, 94-102.

40 GSS 6 (2015).

Figure 11. Concentration of LPG refill stations (2017) and poverty rates (2013) by region



Baseline residential consumption of LPG in 2017

In 2017, 358,900 MT of LPG were consumed in Ghana across all categories of use. This section estimates the total and per capita baseline consumption of LPG for the residential sector in 2017.

Total residential LPG consumption in 2017

Total and per capita residential consumption of LPG in 2017 were calculated using two approaches: a top-down approach and a bottom-up approach. The top-down approach relied on total national-level LPG consumption data from the NPA. The bottom-up approach relied on GLSS 7 data and consumption per capita per existing LPG user to extrapolate total residential LPG consumption. In this analysis, a "user" is a member of a household that cooks primarily with LPG.

Top down approach: In 2017, 358,900 MT of LPG were consumed in Ghana across all sectors. LPG is sold in three ways: portable cylinders, bulk installations, and autogas (LPG used in transportation). Because residential LPG consumption is exclusively via portable cylinders, the assessment focuses only on LPG sold in cylinders. The estimates of total residential LPG consumption presented here are necessarily lower than industry estimates of national consumption, which include all forms in which LPG is sold. Total residential consumption, estimated at 55% of total consumption in 2017, was 197,395 MT. In 2017, 24.47% of Ghanaian households consumed LPG as a primary fuel (the GLSS 7 does not capture data on secondary fuel consumption). This means national per capita LPG consumption was 6.8 kg in 2017.

Bottom-up approach: In 2017, using the GLSS 7 data, a total of 1.66 million households out of 6.8 million total households consumed LPG as the primary fuel. While the GLSS 7 does include LPG consumption data, the full GLSS 7 dataset was not available for analysis at the time of writing. The GLSS 6 does not include data on fuel consumption and there were no other recent estimates of LPG consumption for primary fuel users in Ghana, that this analysis could draw on.

Therefore, LPG consumption per capita by existing users was estimated by taking ECA's (2017) approach (see Chapter 13), as follows. In 2013, 251,800 MT of LPG were consumed in Ghana. The United Nations Energy Statistics Database estimated that 144,300 MT of LPG were used for household cooking in 2012-2013. The World LPG Association annual statistics estimated an average of 122,000 MT was used for household cooking in 2012-2013. The average of these two estimates indicates that 133,100 MT of LPG were consumed in 2013. Consumption per capita per LPG user (22.6kg) was calculated by dividing total residential consumption for cooking (133,100 MT) by the mean household size in Ghana according to GLSS 6.

The population using LPG per GLSS 7 (7.09 million) was multiplied by the LPG consumption per capita per existing user (22.6kg) to estimate the total residential LPG consumption in Ghana in 2017 (165,753 MT).

Conclusion: In 2017, the top-down and bottom-up approach estimates differ from each other by 31,642 MT. Given that total residential consumption in 2016 was 157,900 MT, and that the top-down estimate would constitute an approximately 25% increase in LPG consumption in one year, the analysis proceeds with the bottom-up estimates. Ghanaian households consumed 165,753 MT of LPG in 2017. In 2017, LPG consumption per capita among users was 22.6 kg and national LPG consumption per capita was 5.5 kg[41].

Cylinders in circulation

The official number of existing cylinders in circulation in Ghana is not available. In 2017, the NPA assumed that the total number of existing cylinders was 5.8 million, out of which roughly 60% were 14.5kg and 40% were 6kg, and minimal quantities of other sizes.

Because the GLSS 6 survey captured no data on cylinder usage in Ghana, the number of cylinders per household was estimated using industry data (see Table 8). The Ghana Cylinder Manufacturing Company (GCMC) is the largest cylinder manufacturing company in Ghana and in 2013 it sold approximately 130,000 cylinders and had a 60% market share.[42] This indicates that approximately 216,667 cylinders were sold in total in Ghana during 2013. Assuming these cylinders were sold to 125,758 new households that began consuming LPG in 2013, an average of 1.72 cylinders are available per household (for simplicity, assuming all the cylinders in the market are used at the household level and none of these cylinders are being used to replace pre-existing cylinders). The KITE (2015) household survey, which sampled 200 households (urban, peri-urban and rural) across 4 regions in Ghana, found that 50.5% of sampled households had one cylinder, 38.3% possessed two cylinders and 10.7% possessed three cylinders. Based on this distribution, the study estimated Ghanaian LPG-using households owned 1.6 cylinders on average. Therefore, it is estimated that in 2013, a household using LPG, on average possessed 1.7 cylinders, resulting in a total of 2.5 million cylinders in circulation within households in Ghana (excluding supply-chain float). The data do not reveal the sizes of the cylinders. Further details on cylinders in circulation are provided in Chapter VIII (Critical Path LPG Infrastructure Investment Projects to 2030) beginning on page 134.

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41 The ratio of 22.6kg/5.5kg corresponds to the penetration rate of primary LPG users in the population of approximately 24.5%.

42 WIVP (2014)

Table 8. Estimation of cylinders in circulation in Ghana in 2013

Key variables in 2013	Estimate
Number of cylinders produced by GCMC in 2013[42]	130,000
GCMC market share (by volume sold)[42]	60%
Total cylinders sold in Ghana in 2013	216,667
Additional households using LPG in 2013[43]	125,758
Average number of cylinders per household	1.72
Total residential cylinders in Ghanaian households in 2013	2.5 million
Estimate of total residential cylinders in Ghana in 2017[44]	4.8 million

Conclusion:

Table 9 summarizes key data points related to baseline LPG demand in Ghana in 2013 and 2017 as discussed in the preceding sections.

Table 9. Summary of baseline LPG consumption in Ghana in 2017

Components of baseline LPG consumption	2017
Total LPG consumed in Ghana in 2017	358,900 MT
Total residential LPG consumed in cylinders by households in 2017	165,753 MT
Share of households consuming LPG as primary fuel in 2017 (GLSS 7)	24.47%
In urban households	37%
In rural households	9%
The annual per-capita consumption of LPG	5.5 kg
The annual LPG consumption per LPG user	22.6 kg

Household Cooking Economics and Prices of Fuels in 2018

Market prices of LPG and other fuels in 2018

Because GLSS 6 did not collect price data for fuels, representative price data were collected through a field survey at retail points conducted between June and August 2018. This survey sampled prices of main cooking fuels (LPG, charcoal, and firewood) in Northern Ghana (Tamale, 12 locations), Brong-Ahafo Region (Kintampo, 2 locations), and Accra (1 location). It sampled prices of fuels and stoves in urban areas (6 in Tamale, 1 in Accra), peri-urban areas (3 in Tamale, 2 in Kintampo), and rural areas (3 in Tamale). Because many stores only sell a subset of the main types of available fuels and stoves, complete data sets could not be collected in all locations. In addition, the survey was not able to differentiate between different conditions of firewood (wet vs. dry) that have different market prices. These data are therefore treated as indicative only. A more substantial data collection effort should be undertaken to assess the sensitivity of the analysis to fuel cost variations across different seasons.

The average price of the main cooking fuels is tabulated in Table 10. The 14.5kg LPG cylinder size is by far the most popular in the country. The price range under the average value includes lower-bound prices and the upper-bound estimates. Due to data availability limitations in remote, rural areas, only urban and peri-

43 This was calculated using the growth behaviour observed across the 2010, 2013, and 2017 household surveys to calculate the number of households in 2012 and that was subtracted from 2013 to get the new households in 2013.

44 NPA (2017) estimate

urban data points were collected for LPG and charcoal. It is important to note that, according to the GLSS 6, 30% of households that use firewood collect it and, as such, do not pay cash for it.

Table 10. Summary of retail prices of LPG, charcoal and firewood (2018 market research survey)

Fuel	Average price in GHC (Euro)
LPG (per kg)	GHC 5.28 (€ 0.96)[45]
Charcoal (per kg)	GHC 1.61 (€ 0.29)
Firewood (per kg)	GHC 0.42 (€ 0.08)

Relative cost of cooking a meal using different fuels in 2018

The cost of cooking a standard meal in Ghana was estimated using average prices collected in the Ghana market survey data. The calculation assumed that a standard meal requires 12.15 MJ of energy delivered to the pot for cooking and that an average household cooks a standard meal 2 times a day.[46] Global standard net calorific values and regional (African) stove thermal efficiency values were used for the analysis, as outlined in Table 11.

Table 11. Data summary for relative cost of cooking analysis[47]

Fuel	Net calorific value (MJ/kg)[48]	Stove thermal efficiencies (%)[49,50]	Stove efficiency used for analysis (%)	Average price per kg (GHC)
LPG	47.3	51%	51%	5.28
Charcoal	29.5	14%-25%	20%	1.61
Firewood	15.6	11%-19%	15%	0.42

Figure 12/Table 12 and Figure 13/Table 13 show the calculated costs per day, per month and annually for households for LPG, charcoal and firewood. The former considers the fuel cost and efficiency factors; the latter also includes an amortization of consumer equipment costs over their typical lifetimes.

45 This price is approximately 2% below the governmentally-established maximum end-user price (see Chapter 10 (Pricing) beginning on page 47), suggesting that competitive forces pushed street pricing slightly downward during the survey period.

46 This assumption is derived from Nerini (2017).

47 Assumed a standard meal requires 12.15 MJ of energy delivered to pot for cooking and that an average household makes a standard meal 2 times a day. Nerini (2017).

48 IPCC (2006)

49 EPA (2018)

50 Shen et al. (2017)

Figure 12. Average marginal cost per day of cooking per household across different fuels

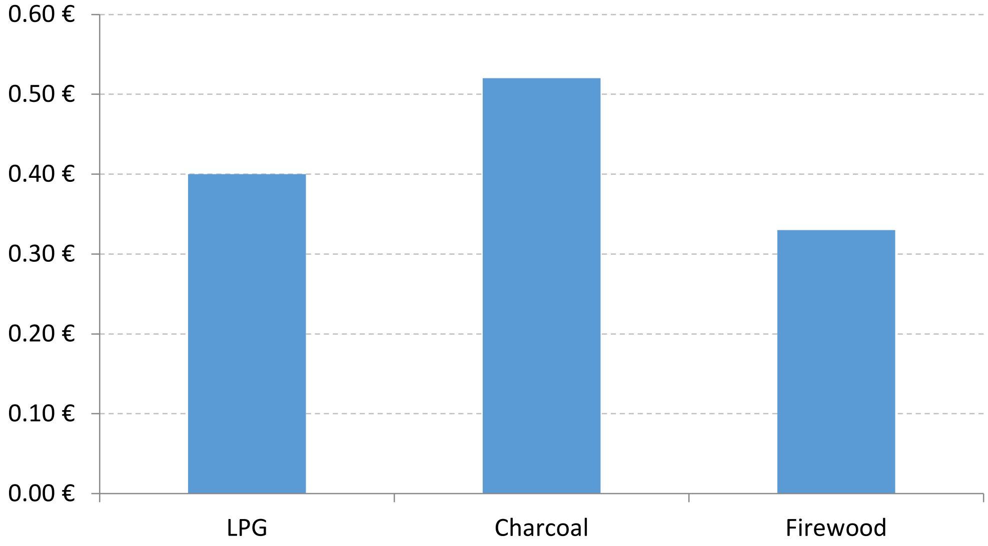

Table 12: Average marginal cost of cooking per household across different fuels (per day, monthly and annual)

Fuel	Estimated cost of cooking per household per day in GHC (Euro)	Estimated monthly cost of cooking for a household in GHC (Euro)	Estimated annual cost of cooking for a household in GHC (Euro)
LPG	GHC 2.24 (€ 0.40)	GHC 68.25 (€ 12.29)	GHC 819 (€ 147)
Charcoal	GHC 2.88 (€ 0.52)	GHC 87.50 (€ 15.75)	GHC 1,050 (€ 189)
Firewood	GHC 1.83 (€ 0.33)	GHC 55.57 (€ 10.00)	GHC 667 (€ 120)

Figure 13. Amortized average cost per day of cooking per household across different fuels (including amortized average cooking-equipment costs)

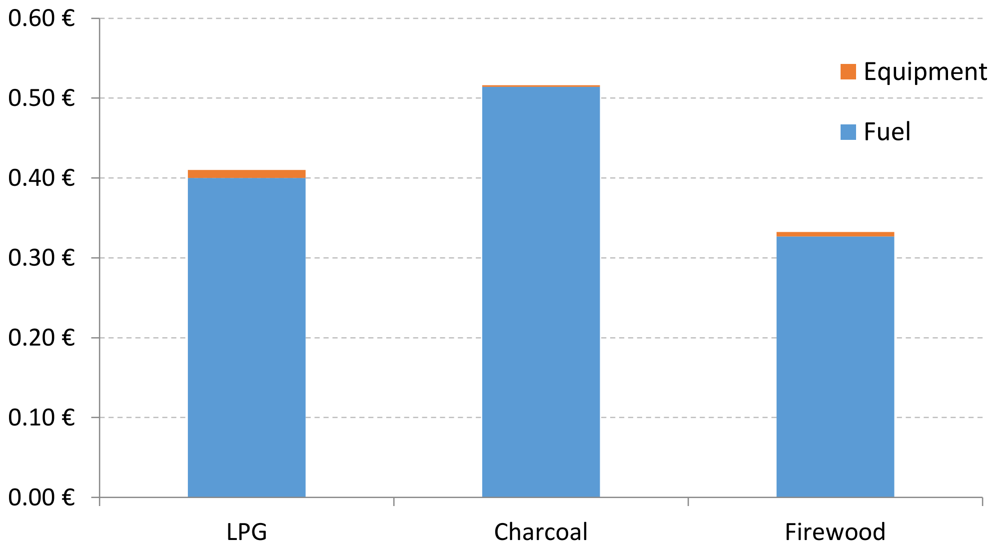

Table 13. Amortized average cost of cooking per household across different fuels (per day, monthly and annual, including amortized[51] average cooking-equipment costs)

Fuel (Stove) Type	Estimated cost of cooking per household per day in GHC (€)	Estimated monthly cost of cooking for a household in GHC (€)	Estimated annual cost of cooking for a household in GHC (€)
LPG	GHC 2.30 (€ 0.41)	GHC 69.91 (€ 12.48)	GHC 839 (€ 150)
Charcoal	GHC 2.91 (€ 0.52)	GHC 88.49 (€ 15.80)	GHC 1,062 (€ 190)
Firewood	GHC 1.86 (€ 0.33)	GHC 56.66 (€ 10.12)	GHC 680 (€ 121)

As shown in the foregoing table, the cost of the required cooking equipment, amortized over its useful life, does not materially change the costs to the consumer of cooking a meal, although it must be noted that the up-front cost to acquire the equipment requires adequate consumer savings, or, in lieu of savings, a mechanism to spread out the cost of the equipment over time. Two such mechanisms (microfinance and pay-as-you-go technology) are discussed in Chapter 18 (Consumer Empowerment) beginning on page 188; a third mechanism (a fuel-based levy that reduces significantly the up-front cylinder acquisition costs to industry and consumers) is discussed Chapter VIII (Critical Path LPG Infrastructure Investment Projects to 2030) beginning on page 134.

Based on the price points collected in three regions of the country and the user-reported measures of the amount of fuel used to cook an average meal, firewood offers a cost advantage to consumers, with an estimated average household spending € 120 for their annual cooking needs (€ 10.00 per month), at an average of € 0.33 per day. However, different types of firewood exist in the market and price varied depending on it being dry or wet wood (with the latter being less expensive). Charcoal is the most expensive fuel, costing the average household € 189 per year and € 0.52 per day. LPG is more cost-effective than charcoal and less than purchased firewood[52]. In addition, 30% of households that use firewood collect it and thus do not pay cash for it. Overall, these results should be taken with caution and considered only indicative, given the quality of the price data. They are consistent with the findings of the 2015 KITE survey, that show that charcoal is the most expensive fuel in terms of average monthly cost of fuel used, followed by LPG, with firewood the least expensive. This pattern was found to be consistent across urban, peri-urban and rural areas.

Forecasted demand for LPG in 2020, 2025 and 2030

Drivers of and barriers to LPG adoption in Ghana

LPG adoption in Ghana is restricted by limited availability and can be further enhanced by increased awareness and improved affordability. Addressing availability is hypothesized to result in unlocking latent/un-met household demand, and addressing awareness and affordability are hypothesized to increase demand. Unlocking latent LPG demand and developing increased demand will require investments that address all three factors.

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51 Dalberg Research field survey data (2018); assumed useful life of LPG equipment, 10 years; improved biomass stoves and basic charcoal stoves, 5 years; wood stoves, 2 years.

52 The KITE (2015) study reported significantly lower prices of firewood than the more recently obtained survey data, indicating that firewood, based on prevailing conditions, may present a greater cost savings relative to other fuels than the foregoing data show.

Both rural and urban Ghanaian households express concerns around the safety of LPG. The Ghana LPG Promotion Program initiated the 1990s and the Rural LPG Program, among others, have collectively carried out educational and promotional campaigns to educate urban and rural households, public institutions, and commercial operations on the benefits of LPG. Safety concerns persist in both urban and rural households due to frequent incidents of explosions, including a fatal explosion at an LPG retail filling station in Accra in October 2017. These safety risks could be the result of the use of non-inspected old cylinders and cylinder leakages, in the absence of a cylinder recirculation model (CRM), which moves the responsibility of cylinder inspection and maintenance away from the consumer back to the LPG marketers. Systemic improvements in the safety performance and design of the supply chain, and education of consumers about safe LPG use and its benefits, can address the barrier of safety concern.

Limited availability due to long distances travelled by consumers to access refilling stations has been shown to hamper LPG adoption in both rural and urban Ghana. Although refilling stations are more widely available in urban Ghana, studies show that customers do not like going to refilling stations because it usually requires them to take some form of transport to get to the stations, often queue, and fuel availability is uncertain once they arrive. In rural areas, the distance to refilling stations is often deemed prohibitive by the consumer and a recent assessment of the RLP in the Nkoranza district in the Brong-Ahafo region showed that rural RLP participants had to travel an average of 25 kilometres one way to refill their cylinders (which required them to incur transportation costs). Improving LPG availability locally, and improving reliability of supply in the LPG retail network, can address these barriers to LPG consumption.

Finally, affordability of initial LPG equipment (LPG stove, cylinder and accessories) and subsequent refills restricts adoption and sustained use of LPG by low-income households. Households not using LPG in Accra cite the initial investment in stove and cylinder as a critical barrier to LPG adoption. The cost of initial equipment (including the LPG fill) can vary between € 37 for a single burner stove with a 6kg filled cylinder and € 61 for a double burner with filled 14.5kg cylinder. Moreover, the amount required to be spent on an individual cylinder refill may be a barrier for poorer households, especially those affected by income seasonality, such as rural farmers. Improvement in LPG refill affordability and mechanisms to reduce or time-shift up-front costs to become an LPG consumer can address these barriers among affected households.

Overall approach to forecasting demand for LPG

This section forecasts household LPG demand in 2020, 2025 and 2030, extrapolating from the GLSS 6 data. Given the above-mentioned LPG adoption barriers, three distinct drivers of demand were modelled:

i. National demographic changes (e.g. through population growth, urbanization and income growth)

ii. Expanded availability of LPG through the implementation of the Branded Cylinder Recirculation Model (BCRM) and corresponding investment in cylinder availability, infrastructure, and distribution systems across Ghana

iii. Change in preferences for LPG that may occur due to investments in marketing, awareness-raising, safety, or other factors that may change preferences among non-users for LPG

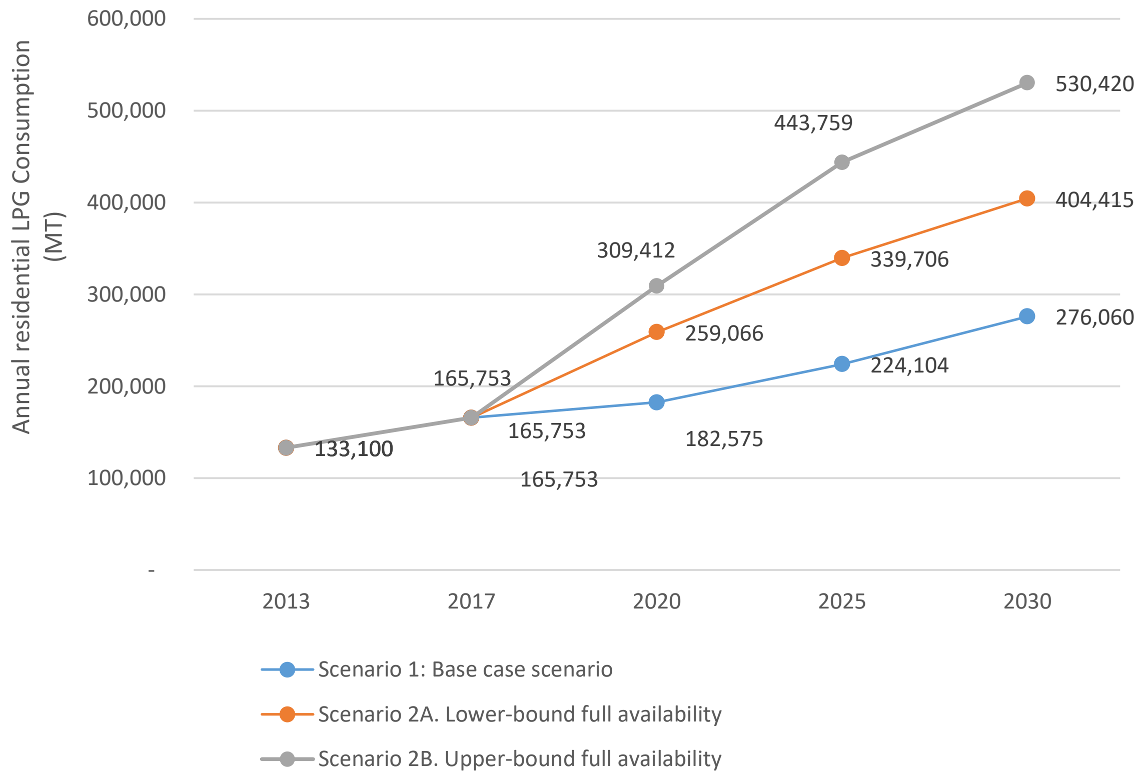
Note that improvements in the affordability of stoves and cylinders were not modelled as no large-scale subsidies have been planned in Ghana, yet.

The incremental contributions of the three drivers of demand were combined to create three scenarios of forecasted demand in 2030:

- Scenario 1: Base case scenario, where forecasted consumption is derived by extrapolating historical growth trends for residential LPG consumption.
- Scenario 2: Market reform and expansion scenario, reflecting both planned and potentially additional policy and investment interventions. In the reform and expansion scenario, two sub-scenarios are considered, leading to a range of projected demand:
    - Scenario 2A: Lower-bound full availability, incorporating demand growth from demographic changes, as well as the impact of expanded LPG availability to serve latent demand.
    - Scenario 2B: Upper-bound full availability, incorporating the same demand drivers as Scenario 2A (demographic changes and expanded LPG availability), as well as additional changes in preferences that result in additional households switching to LPG.

The methodology used to derive these three scenarios, as well as detailed results are below. A snapshot of overall results is provided in Figure 14.

Figure 14. Scenarios of forecasted residential LPG demand in Ghana (2013-2030)



Scenario 1: Base case demand

The base case demand scenario was forecasted by growing LPG adoption as per historical growth rates. The base case scenario was estimated by using national population projections in 2020, 2025, and 2030[53] and reported urbanization since 2009 to predict the urban population over the projected timeframe.[54] The number of households using LPG in 2013 and 2017 was used to forecast the expected number of households using LPG as a primary fuel in 2020, 2025 and 2030, assuming activity continues as has been observed after the LPG subsidy was phased out in 2013. Average annual LPG consumption per capita by LPG user was assumed to remain constant over time at 22.6kg, given the absence of consumption data. Total residential LPG consumption is forecasted to grow from 133,100 MT in 2013 to 276,060 MT by 2030, with a total of 3.05 million households consuming LPG (31.5% of all households), and a national per capita LPG consumption of 7.12kg.

Table 14. Base case projection – LPG penetration rates grow per historical growth rates[55]

Key variables	2010	2013	2017	2020	2025	2030
Total population in Ghana (millions)	24.51	26.34	28.96	30.96	34.42	38.75
Total households	6,128,026	6,585,313	7,239,147	7,738,801	8,604,761	9,687,552
% of households using LPG as a primary fuel for cooking	**18%**	**22.3%**	**24.5%**	**26.1%**	**28.8%**	**31.5%**
Number of households using LPG as a primary fuel for cooking	1,103,045	1,466,111	1,771,419	2,019,633	2,479,032	3,053,759
Number of urban households using LPG as a primary fuel for cooking	980,827	1,303,666	1,575,146	1,795,858	2,204,354	2,715,402
Number of rural households using LPG as a primary fuel for cooking	122,218	162,445	196,274	223,776	274,677	338,357
Total residential consumption of LPG (MT)	**99,715**	**133,454**	**165,753**	**182,575**	**224,104**	**276,060**

Scenario 2: Detailed methodology and results for LPG demand forecasts unconstrained by limited LPG availability

Overall approach

Two scenarios reflecting expanded LPG availability in Ghana through 2030 were developed (referred to as lower-bound and upper-bound full availability scenarios). The methodology employed to forecast future LPG demand considers three demand drivers including demographic changes, expanded availability, and

53 Population Pyramid (2017)

54 The Statistical Portal (2018)

55 National Petroleum Institute (2017)

change in preferences. Two scenarios are calculated that consider one or more of these drivers, using survey data and general demographic projections to derive future estimates of demand.

Both scenarios assumed that a branded CRM will be in place, with gradual expansion of supporting infrastructure. They also both assumed that infrastructure roll out will start in cities, then expand to peri-urban, and finally to rural centers, until this roll out covers approximately 98% of households by 2030. A propensity score matching approach is used to estimate latent demand for LPG. This matching approach leverages data on observed characteristics and purchasing behavior of LPG-using households to estimate the potential latent demand that is not being served for similar households that do not currently use LPG, due to availability constraints. Details regarding this matching approach, as well as the parameters and demand drivers that shape the various scenarios are presented in this section.

The households in the GLSS 6 data were divided into two groups:

Group 1: Households that do not currently use LPG as a primary fuel

- Group 1A: Households that are in areas that do not have LPG availability
- Group 1B: Households that are in areas that have LPG availability

Group 2: Households that currently use LPG as a primary fuel

Three different analyses were conducted to estimate potential growth pathways for LPG consumption under different assumptions of market development and population growth dynamics. These analyses are described below and laid out in Figure 15.

All households

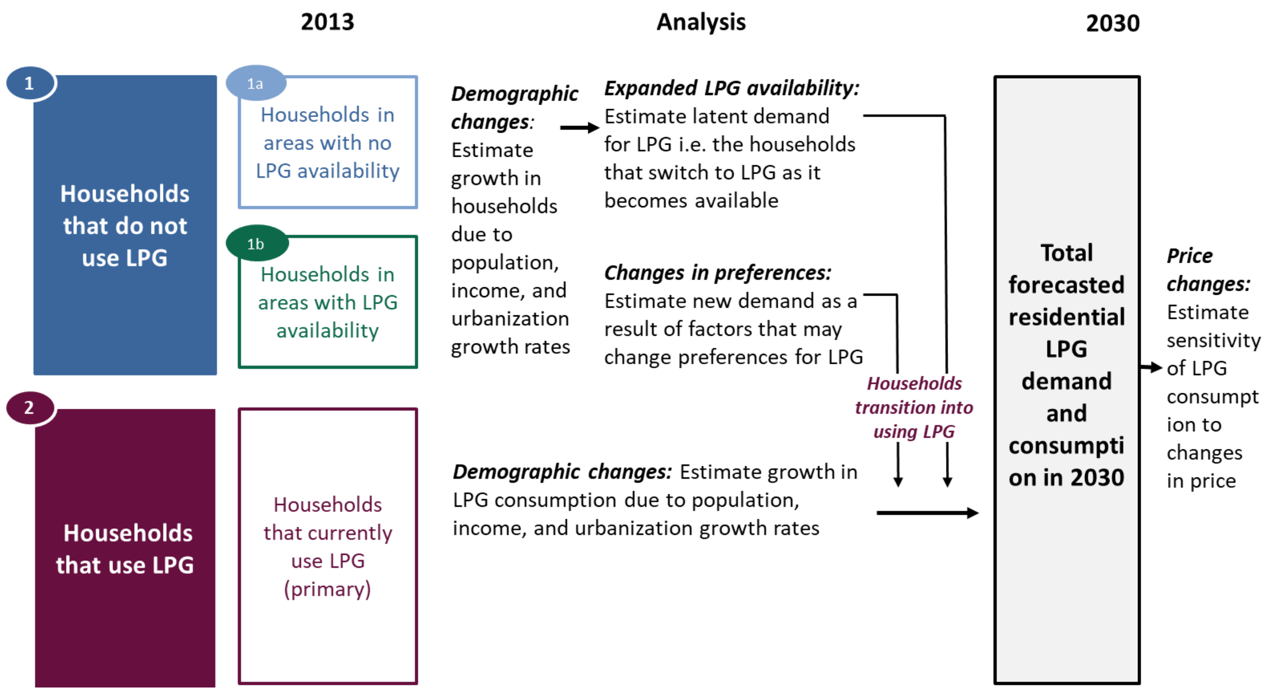
1. Demographic changes: Estimated LPG consumption growth due to population growth, urbanization, and income growth (without considering changes in availability or affordability)

Group 1

2. Group 1A – Expanded LPG availability from market expansion and CRM: Estimated latent demand for LPG among current LPG non-users living in areas where LPG is not sufficiently available
3. Group 1B – Changes in preferences: Estimated new demand as a result of investments in marketing, awareness-raising, safety, or other factors that may change preferences among non-users of LPG living in areas where LPG is sufficiently available

The impact of change in LPG price on overall demand was estimated to establish sensitivity of demand to price. It was not possible to model potential impact of improved access for households that currently consume LPG due to lack of consumption data in the data set.

Figure 15. LPG demand projection approach



Demographic analysis

Estimate incremental impact of population growth, urbanization, and income growth on residential LPG consumption

Population growth was projected to 2030 using population projections from NPA (derived from Ghana Statistical Service). Expected changes in urbanization were projected using historical data.[56] Income per household was expected to grow at 5% per annum, as per the modelling approach taken by ECA (2017) (see Chapter 13). Total residential LPG consumption was estimated by multiplying urban and rural population that will use LPG by the LPG consumption per capita of LPG users (22.6 kg). The LPG consumption per capita of LPG user of 22.6 kg was held constant between 2013 and 2030. The last row in Table 15 shows total consumption in 2030 as the LPG consumption per capita of LPG users rises to 25kg in 2030.

Table 15. Effect of demographic analysis on LPG consumption, 2013-2030 (GLSS 6, N=16,772)

Key variables	2013	2017	2020	2025	2030
Households consuming LPG due to demographic changes	1,466,111	1,771,419	1,933,734	2,194,294	2,519,749
Urban households consuming LPG due to demographic changes	1,303,666	1,575,146	1,719,476	1,951,166	2,240,560
Rural households consuming LPG due to demographic changes	162,445	196,274	214,258	243,128	279,189

[56] UN World Population Projections (2017)

Key variables	2013	2017	2020	2025	2030
Total LPG consumed by households due to demographic changes (assuming 22.6kg LPG consumption per capita by LPG users) (MT)	**133,100 MT**	**165,753 MT**	**174,810 MT**	**198,364 MT**	**227,785 MT**
Total LPG consumed by households due to demographic changes (assuming 22.6kg LPG consumption per capita by LPG users until 2020, rising to 25kg starting in 2025) (MT)	133,100 MT	165,753 MT	174,810 MT	219,429 MT	251,975 MT

Group 1A – Expanded availability analysis

> Estimate incremental impact of expanded LPG availability on LPG demand for households living in areas where LPG is unavailable

To estimate latent demand, LPG-using households (Group 2) were first identified in the sample data. Then, using a tailored propensity score matching approach, households with similar observed characteristics were identified in Group 1A, and matched to the Group 2 households to estimate their latent demand for LPG. As a first step, household characteristics that correlated with LPG usage (among households that currently use LPG) were identified in the data. Then, households with similar characteristics, in areas where LPG is currently not available (and therefore not currently used) were identified. The latent demand for these identified households was estimated assuming that they have similar LPG preferences (e.g., willingness and ability to pay for LPG, preferences for LPG, fuel purchasing habits) given similar observed household characteristics. In effect, this matching approach used the observed consumer behaviour in locations where LPG is available to estimate the consumer behaviour under improved availability in locations where LPG is not currently available. The detailed methodology is provided in the Annexes (Chapter 26 beginning on page 298).

A logit regression on Group 2 was used to identify the household characteristics that predict LPG usage and to estimate a probability of LPG usage per household. This regression considered three independent variables that have been identified in previous literature as predictive of LPG usage: (i) household head education, (ii) household income quintile, and (iii) household head age. An earlier analysis also considered location (urban/rural), household head gender and total household members, but found the coefficients to be not statistically significant as predictors given the other variables[57]. The coefficients from the regression were then used to estimate the probability that a household of certain characteristics would use LPG. The coefficients from the regression analysis were then used to calculate the probability of a household in Group 1A using LPG, were it available. The households in Group 1A were matched to similar households in

[57] Given the higher rates of LPG use by urban households, it may be counter-intuitive that location variables turn out not to be statistically significant in this case. Because household income is highly correlated with location, it is therefore likely driving the regression coefficients and dampening the explanatory/predictive power of the location variables.

Group 2 (current LPG users) to estimate the number of households that would use LPG in Group 1A, were LPG available (i.e. latent demand).

This estimation approach assumes that as LPG infrastructure is expanded, Group 1A would have access to LPG over time. For example, some areas will have greater access to LPG in five years, and others in ten years. As LPG becomes available for Group 1A households, certain households will start using LPG and will move into Group 2 and others would move into group 1B (i.e. would still not use LPG, even if it were available, likely due to other constraints such as affordability and preferences). To model the phased roll-out and the resultant change in LPG consumption, three steps were taken:

(a) Determine the number of households that fall in Group 1A in 2020, 2025 and 2030, as LPG availability increases in a phased approach across the country*:*

- The approach assumed a roll-out path for infrastructure development. This roll-out could be faster or slower, depending on the different scenarios and policy considerations. This roll-out path was modelled based on existing knowledge of how infrastructure development (based on stakeholder interviews) has taken place in Ghana, as described below.

- The roll-out plan assumed that infrastructure development: (i) tends to begin in urban areas and move to rural areas; (ii) tends to begin in areas where there is already some infrastructure to build from; and (iii) tends to move from a point of origin outwards.

- Three variables were considered at a cluster level: (i) if the household is in an urban location; (ii) the current LPG usage in both the province and district the household falls into; and (iii) the average LPG usage of all the neighbouring provinces. This allowed modelling for points (ii) and (iii) above, where the infrastructure development begins in areas where there is already some infrastructure to build from, and tends to move from a point of origin outwards.

- These variables were combined to form a score for each household, using the following equation that reflects these assumptions on the likely expansion path from areas with higher average usage to areas with lower average usage:

$$\begin{aligned} Score = w_1(Urban) &+ (Average\ LPG\ usage\ in\ the\ district) \\ &+ (Average\ LPG\ usage\ in\ the\ province) \\ &+ (Average\ LPG\ usage\ in\ all\ neighbouring\ provinces) \end{aligned}$$

- A higher score implies that the household will receive improved infrastructure before a household with a lower score. These households are then ranked the top scoring households transitioning to Group 2 over time. In this analysis it was assumed that infrastructure investment would increase somewhat linearly over time, with an <u>additional</u> 25% of households gaining access to LPG infrastructure in 2020; another 25% in 2025; and another 25% in 2030, reaching fully improved availability in 2030.[58] In this scenario approximately 98% of households will have access to LPG in the market by 2030, though not all of these households will be LPG users. Recall that 22.9% of households already have LPG infrastructure (they are in

[58] There is no definitive way in which infrastructure phasing can be modeled more precisely. At present, the ongoing upgrade of the import receiving line, the proposed LPG marine export terminal at Atuabo, and the 8-10 proposed additional bottling plants, for example, will bring a number of clusters online, but the timing of each project is presently unknowable.

Group 2) and 2% of households are unlikely to receive LPG infrastructure in the next 15 years, as they lack basic infrastructure. It should be noted that the assumption regarding the speed of infrastructure expansion—in this case assuming an additional 25% of households having access in each interval—is arbitrary. The primary interest is projecting demand in 2030 under various scenarios and assumptions regarding LPG availability, and less so in the speed of the transition in the intervening years until 2030. While other assumptions can be made regarding the speed of LPG infrastructure development between now and 2030 (e.g. accelerating expansion over time, or a slow-down in expansion over time), this will not affect the final demand estimates in 2030 which assume improved or full availability in 2030 regardless of the transition path.

(b) Estimate number of households in Group 1A that will start using LPG in 2020, 2025 2030 once LPG becomes available. As each household faces improved LPG infrastructure over time, the propensity score matching approach determines how many households in Group 1A will transition and begin using LPG.

(c) Estimate total LPG consumption from households that start using LPG by multiplying number of households that start using LPG with average LPG consumption per household (90.4 kg). Note, it was not possible to estimate the impact of improved availability on the quantity of LPG consumed at the household level, given the lack of consumption data in the data set. However, the last row in Table 16 shows how total consumption of LPG would change if LPG consumption per LPG using household increased to 100 kg in 2030. This analysis also excluded households using LPG as a secondary fuel, given the lack of secondary fuel data in GLSS 6.

Table 16. Impact of sufficiency of LPG availability on household LPG demand (GLSS 6, N=16,772)

	2020 (an additional 25% of households come online)	**2025** (an additional 25% of households come online)	**2030** (an additional 25% of households come online)
Additional households consuming LPG due to expanded availability	932,041	1,552,452	1,953,871
Total LPG consumed by households due to expanded availability (assuming 22.6kg LPG consumption per capita by LPG users) (MT)	**84,256 MT**	**140,342 MT**	**176,630 MT**
Total LPG consumed by households due to demographic changes (assuming 22.6kg LPG consumption per capita by LPG users until 2020, rising to 25kg starting in 2025) (MT)	84,256 MT	155,245 MT	195,387 MT

Group 1B – Change in preferences

Estimate additional LPG demand from households due to investments in marketing, awareness-raising, safety, or other factors that may change preferences (following planned market and supply chain reforms and needed infrastructure investments)

In addition to the estimated increase in LPG consumption due to expanded availability, it may be possible to further increase LPG consumption by changing the underlying preferences for LPG for some consumers. In particular, GLSS 6 shows that 51% of households in the top income quintile in Ghana did not use LPG as a primary fuel for cooking, even in places where LPG is readily available. It is not well understood why these relatively affluent households do not use LPG. Presumably there are other reasons that drive the underlying preferences for using other fuels. Existing studies suggest that perceptions of safety affect purchasing preferences; Ghana has experienced fatal gas explosions due to unsafe practices at cylinder refill centres in residential areas and this has negatively affected the perception of the safety of LPG.[59] A GLPGP study in Accra showed that LPG 'access seekers' are concerned about safety and quality of the cylinder.[60] This means that there are households that have access to LPG and could afford it but are not consuming LPG. A successful national cylinder recirculation system facilitates improved availability and safety.

Even under the full availability estimates, there are still households in the top two income quintiles that do not consume LPG in 2030 (16% of households in quintile 5 and 49% of households in quintile 4). The top two income quintiles in Ghana can afford LPG (the upfront costs and refills), indicating that they are neither constrained by affordability nor availability. With concerted investments in marketing, awareness, and improvements in perceptions of safety, a proportion of households currently not using LPG, may start using LPG in the future via a change in underlying preferences. A study of a clean cooking awareness program in Kenya found it to be 20% effective in increasing uptake. However, given that this study targeted low-income households that cited affordability as a key reason for lack of LPG adoption, the effectiveness of a similar program among high-income households could be greater.

Given the absence of income-stratified analysis of the effectiveness of such marketing/awareness programs, it was assumed that 50% of the households in the upper two income quintiles would begin using LPG, if investments in marketing and awareness were made or perceptions of LPG safety improved. The results are summarized in Table 17; interventions to change preferences could encourage an additional 779,073 households to start using LPG and use an additional 75,084 MT of LPG in 2030 (or an additional 83,058 MT of LPG if LPG consumption per capita by LPG users increased to 25 kg).

Table 17. LPG demand by households not currently using LPG, due to preferences changes (GLSS 6, N=16,772)

	2020	**2025**	**2030**
Additional households consuming LPG due to changes in preferences	503,464	690,845	830,576
Total LPG consumed by households due to changes in preferences (assuming 22.6 kg LPG consumption per capita by LPG users) (MT)	45,513 MT	62,452 MT	75,084 MT
Total LPG consumed by households due to demographic changes (assuming 22.6kg LPG consumption per capita by LPG users until 2020, rising to 25kg starting in 2025) (MT)	45,513 MT	69,084 MT	83,058 MT

[59] *GOIL to invest over ¢50m in Cylinder Re-circulation Module*, April 2018. www.myjoyonline.com/business/2018/April-25th/goil-to-invest-over-gh50m-in-cylinder-re-circulation-module.php

[60] WIVP (2014)

Summary: Forecasted potential LPG demand in 2020, 2025, and 2030

The results of each of the analyses are summarized in Table 18 and Table 19. They show that combining investments in improving LPG availability and investments in marketing have the potential to drive large uptake of LPG in Ghana.

Table 18. Estimated total LPG demand, lower-bound scenario, by demand driver (2020-2030)

Drivers of incremental demand	**Analysis**	**Total household LPG consumption assuming 22.6kg LPG consumption per capita per LPG user) (Number of new households consuming LPG)**		
		2020	**2025**	**2030**
Demographic changes	Impact of population growth, income and urbanization changes	174,810 MT (162,315 new households)	198,364 MT (260,560 new households)	227,785 MT (325,454 new households)
Expanded availability	Additional impact of expanded LPG availability through CRM (latent demand)	84,256 MT (932,041 new households)	140,342 MT (620,411 new households)	176,785 MT (401,419 new households)

Table 19. Estimated total LPG demand, upper-bound scenario, by demand driver (2020-2030)

Drivers of incremental demand	**Analysis**	**Total household LPG consumption (assuming 22.6kg LPG consumption per capita per LPG user rising to 25kg in 2025) (Number of new households consuming LPG)**		
		2020	**2025**	**2030**
Demographic changes	Impact of population growth, income and urbanization changes	174,810 MT (162,315 new households)	219,429 MT (260,560 new households)	251,975 MT (325,454 new households)
Expanded availability	Additional impact of expanded LPG availability through CRM (latent demand)	84,256 MT (932,041 new households)	155,245 MT (620,411 new households)	195,245 MT (401,419 new households)
Change in preferences	Additional impact of investments in marketing, awareness, and other factors that could changes preferences (new demand)	45,513 MT (503,464 new households)	69,084 MT (187,382 new households)	83,058 MT (139,730 new households)

These analyses can be combined to form three different demand scenarios, as shown in Figure 16:

Scenario 1: Base case

- Forecasted LPG demand based on historic growth of LPG. Total annual LPG consumption for household cooking is projected to grow to 276,060 MT by 2030, resulting in national per capita consumption of 8.3kg per year.

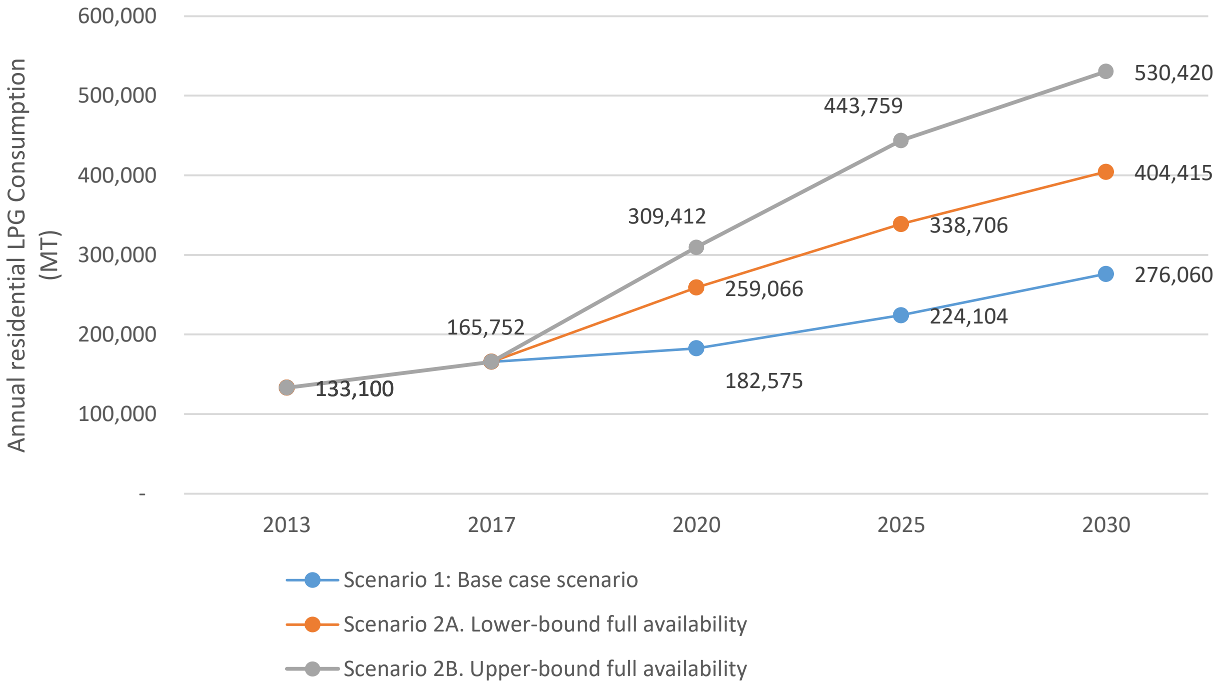
Scenario 2: Market reform and expansion scenario

- 2A. Lower-bound full availability scenario: Forecasted LPG demand based on demographic changes and the impact of expanded LPG availability, assuming 22.6kg LPG consumption per capita by LPG user between 2020 and 2030. Total annual LPG consumption for household cooking is projected to grow to 404,415 MT by 2030, with 4.47 million households consuming LPG in 2030. This represents an LPG usage penetration of 46% of households (46% of the population), with a national per capita consumption of 10.44 kg per year.

- 2B. Upper-bound full availability scenario: Forecasted LPG demand based on demographic changes, the impact of expanded LPG availability, and change in preferences, assuming 22.6kg LPG consumption per capita by LPG user through 2020, rising to 25kg in 2025. Total annual LPG consumption for household cooking is projected to grow to 530,420 MT by 2030, with 5.3 million households consuming LPG. This represents an LPG usage penetration of 55% of households (and 55% of the population), with a national per capita LPG consumption of 13.69kg per year[61].

The estimated range for total LPG consumption in 2030 under the scenarios of improved availability and an effective cylinder exchange program represents a level of consumption that is between two and four times the total consumption in 2017. These scenarios are depicted in Figure 16 below. Note that in both the base case and the lower-bound estimate, the average LPG consumption per capita by LPG users has been kept constant, in the absence of data about the growth rate of consumption by existing LPG users. The total consumption in the base case and lower-bound scenario could be larger if increases in LPG consumption per capita by LPG users occur.

Figure 16. Scenarios of forecasted residential LPG demand (2013-2030)



61 These consumption estimates assume that primary LPG users will continue to stack LPG with other fuels in 2030. Were primary LPG-using households to use LPG exclusively by 2030, the consumption per capita per LPG user would increase to 38kg (calculated from GACC (2016)) and the total annual LPG consumption for household cooking would increase to 806,238 MT.

Figure 17. Percentage of households using LPG by 2030, by demand driver (LPG as primary cooking fuel)

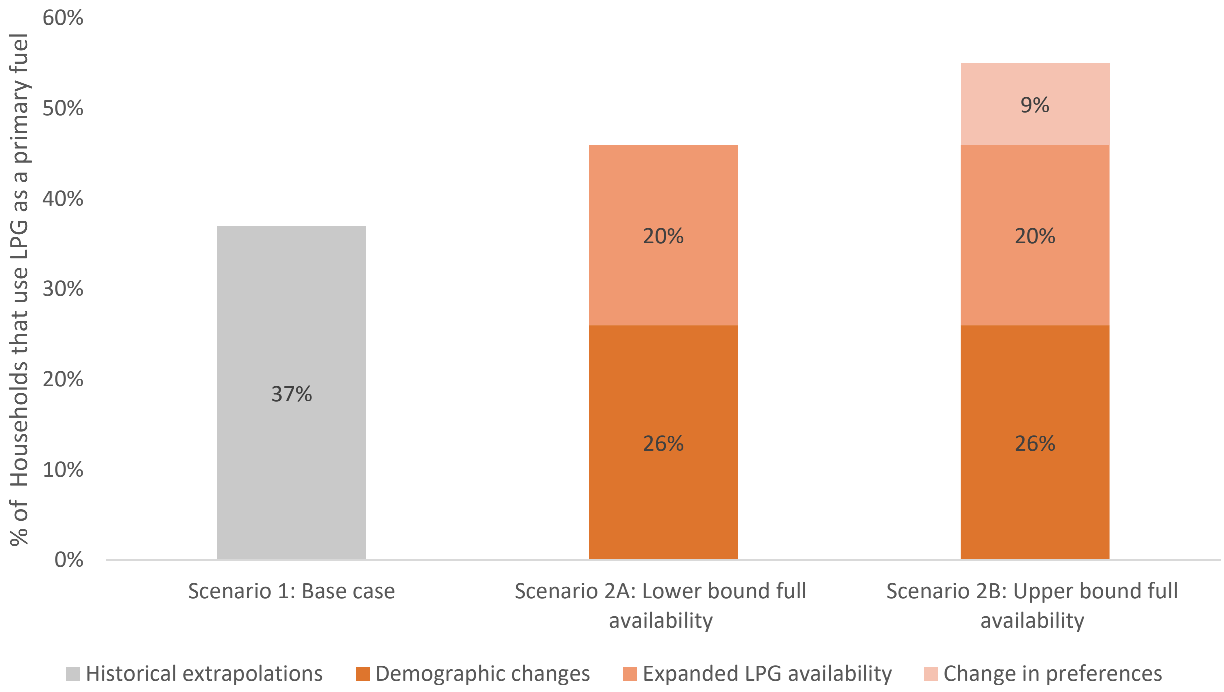
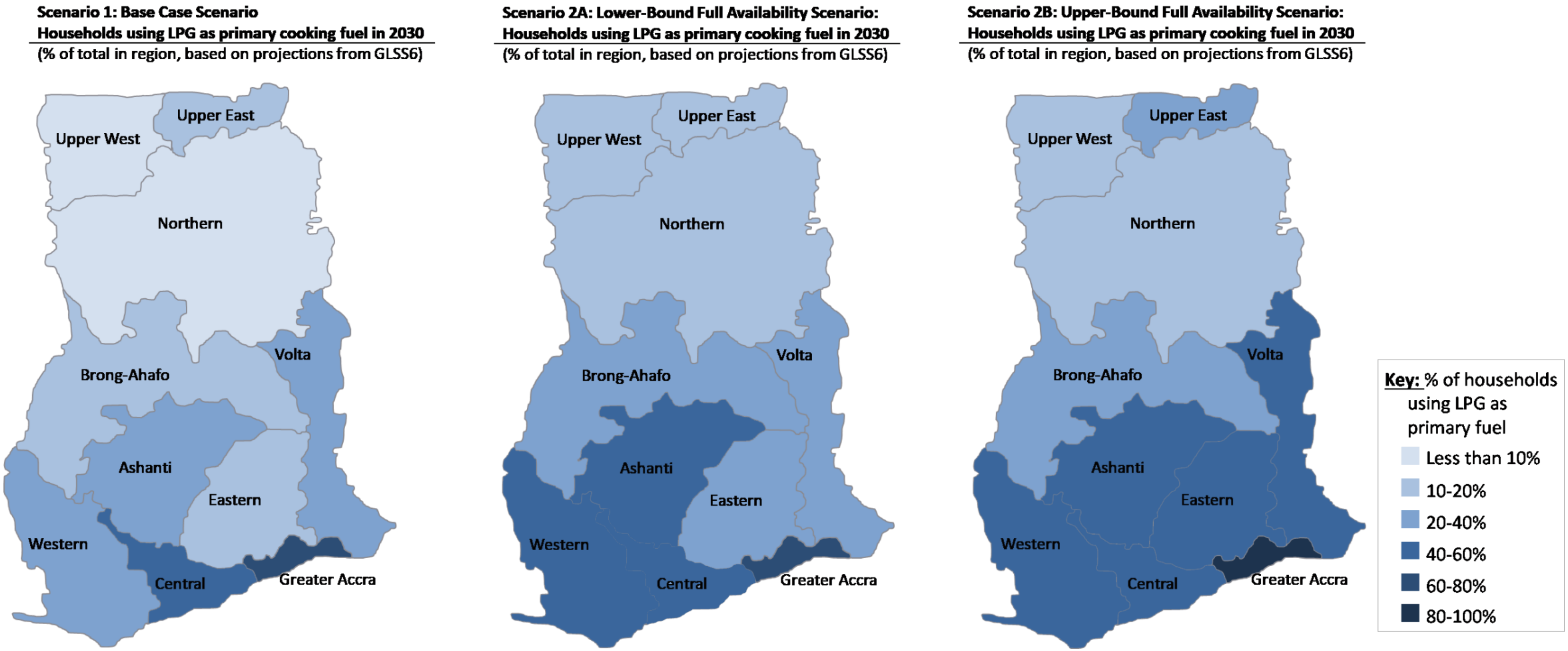


Figure 18[62] below shows potential household LPG demand across Ghana's regions in 2030. While rural users will see a greater percentage increase in their total residential consumption as it grows from 14,748 MT in 2013 to between 102,973 MT and 126,732 MT in 2030, urban users will have a greater absolute increase from 118,352 MT in 2013 to between 310,442 MT and 403,688 MT in 2030, depending on the scenario.

62 In the base case scenario overall consumption grows as it has in the recent past, and usage deepens in areas already using LPG (Central) while changes in other areas are slow. In scenario 2A (lower bound), the base case is not considered. Instead, only demographic changes and changes in availability are considered. As Central already has availability, changes are minimal there. Changes are greater in areas that previously had no availability. Scenario 2B then builds on 2A, and deepens penetration in all regions due to increased preference-driven switching to, and use of, LPG.

Figure 18. Maps of scenarios of projected LPG demand in 2030



Sensitivity of demand forecasts to LPG price changes

The demand forecasts outlined above do not separately model the impact of significant changes in fuel prices, due to the lack of household-level consumption and price data in the GLSS 6 dataset. Conducting a meaningful demand sensitivity analysis requires positing a forecast or view for not only how LPG prices may be likely to evolve over time, but also a perspective on future prices for alternative fuels. Unfortunately, such detailed, reliable price forecasts are not available. Additionally, the Government of Ghana partially regulates domestic LPG prices. Therefore, future prices will depend in part on the government's future policy priorities, factors that are outside the scope of this analysis. While it is not possible to model the potential impact of relative price changes of LPG compared to other fuels, given the absence of reliable data, the following discussion provides approximate estimates of the sensitivity of demand to material, intermediate- and long-term changes in LPG prices.

There are two main avenues for changes in LPG price in Ghana. First, Ghana imports LPG at regional prices, which means that price is determined in part by the relative global and regional stability of LPG price indices. Global and regional prices are expected to remain relatively stable for the next 8-10 years. Second, at present there are predefined price mark-ups set by regulation throughout the supply chain[63]. These mark-ups may change structurally if the Government of Ghana changes its mark-up formula upon, or after, implementation of BCRM for its LPG sector. Thus, long-term LPG pricing trends are determined by the Government and by the international LPG market. While significant change in the international price of LPG is not expected to occur during the forecasted years, potential shifts in pricing may occur, and these are problematic to predict. (See Chapter 10 (Pricing) beginning on page 53 for details on the current and potential Ghana pricing formulae and Chapter 33 (Note Regarding Long-Term LPG Pricing and Availability) on page 325 for a discussion of potential structural recalibration of international LPG prices after 2028.)

That said, to make LPG fully available to the country, significant investments in cylinders, bottling plants, pallets, cylinder cages and distribution will need to be made (see Chapter VIII (Critical Path LPG Infrastructure Investment Projects to 2030) beginning on page 134 for details). Based on the allocation of supply chain functions across nodes, this would require a net increase in the cost of LPG of € 0.093-0.123 per kilogram over ten years (dropping thereafter as all anticipated investments are fully depreciated and all debts retired). If Government ultimately chooses to have the expanded supply chain capability through 2030 paid for entirely by the consumer, it would therefore add an expected € 0.123 per kg (12.5%) to the current end-user LPG price, based on the recommended maximum-pricing formula set forth in Chapter 10. It should be noted that the pricing formula imposes a cap on what the companies in each node in the supply chain may charge per tonne or kilogram for their sales volumes, not a fixed amount that will be collected from every tonne of LPG sales.

Although the ultimate level of passthrough to end-users of anticipated net new costs[64] of the expanded BCRM supply chain has not yet been decided by the Government, the recommended pricing-formula cap value of € 0.123 per kg was used to evaluate potential price sensitivity of demand, as described further below. See Chapter 16 (Investments at the Firm Level) beginning on page 165 for a discussion of the extent to which companies at the main supply chain nodes can price lower than their notional margin caps

[63] NPA (2017)

[64] The pricing and sensitivity analysis exclude potential cost savings from possible future efforts by Government to change the LPG sourcing modailities utilized by the country as import volumes increase.

(€ 0.123/kg in aggregate across the supply chain), on a commercially sustainable basis, while servicing debt and generating adequate (if reduced) returns to equity.

The GLSS 6 surveyors collected price data from the local market in the GLSS 6 Enumeration Areas between 2012 and 2013. These prices were collected just before petroleum sector price deregulation took place in Ghana (LPG subsidies were phased out in late 2013), and more recent detailed price and consumption data are not available. (It has been noted earlier in this document that the rate of consumption growth slowed after 2013.) Using GLSS 6, ECA (2017) (see Chapter 13) modeled variations of market demand curves by calculating how the probability of being an LPG user changes with LPG prices for both urban and rural households, considering when LPG is rarely/not available, versus LPG being often/always available. The accompanying analysis concluded that urban users are less sensitive to price than rural users[65]. Rural users tend to have strongly non-linear demand elasticity if they consider LPG to be available. This relationship is less steep for LPG supply-constrained rural households. ECA (2017) cautions against overreliance on these price elasticity curves, given the data limitations.

Nonetheless, using the 2017 demand curves generated in the Probit analysis and the end-user LPG price in 2017[66], possible changes in total LPG consumption due to changes in price can be estimated. Across both the upper and lower bound scenarios, assuming all other prices for substitute fuels remain constant, a 12.5% increase of the price of LPG per kg (relative to 2017 prices) would decrease total national potential consumption by approximately 5.6%. This results in a total potential LPG consumption of between between 381,880 MT and 500,870 MT under the lower-bound and upper-bound demand scenarios, respectively. These results should be interpreted with caution, given the above-mentioned challenges in estimating a demand curve.

While demand is likely to respond to price changes, particularly among lower income quintiles, what matters most are relative price changes that take into account the future price of LPG relative to the future price of alternate cooking fuels. It has not been possible to reliably forecast the prices of alternate fuels as part of this analysis; therefore, the foregoing findings are best used to provide directional guidance regarding price sensitivity.

Potential effect of a targeted LPG subsidy

The foregoing analysis regarding price sensitivity focuses on the possibility of a reduction in LPG use if end-user LPG prices rise significantly. The reverse effect may also be considered: the demand curves from the Probit analysis indicate that a sustained decrease in the end-user LPG price will proportionately stimulate greater LPG use, especially among lower income groups.

Because the price in Ghana is semi-regulated, it may be lowered in two ways:

1. The Government may change the national LPG pricing formula to cause the end-user price to be lower. This implies reducing the unit margins, and thus the profitability, of the firms in the supply chain, rendering them less bankable and less capable of investing in growth, managing growth, and

65 As footnoted previously in this document, income strata in the survey population appear to mask urban/rural strata. The statement about urban/rural preference made in association with the Probit analysis (which used a complementary approach), is notionally equivalent to the statement that households with higher incomes are less price sensitive than households with lower incomes, based on the GLSS 6 data set.

66 € 0.93 per kg at the then-current exchange rate.

maintaining safety. Any price decrease via regulation must therefore consider the extent to which industry profitability can be sustained at an adequate level, whether through major increases in the volume of LPG handled per company, or through improvements in efficiency (such as from economies of scale).

2. The Government may provide a targeted subsidy to the poor to offset their cost of LPG fuel.

Pricing approach

In Ghana, as shown in Chapter 16 (Investments at the Firm Level) beginning on page 165, firms in the LPG sector cannot withstand substantial reductions in unit margins without imperiling their ability to generate the cashflows required to provide the typical financial returns demanded by equity sources and to cover debt service. (Of the main types of firm, Bottling Plants are less sensitive to changes in unit margin than marketers, based on the financial modelling in Chapter 16. This modelling presents the potential cost benefit of rationalizing unit margins for BPs, based on an optimal—and recommended—allocation of cylinder investment responsibility in the BCRM supply chain.)

Targeted subsidy approach

Targeted subsidies have helped LPG sectors in some LMIC markets serve a portion of the households that otherwise could not afford to use LPG as the primary cooking fuel on a steady basis. However, in Ghana, the Government took the policy decision to end all petroleum-related subsidies, phasing out subsidies on LPG during 2013. Therefore, reinstating a subsidy on LPG is not being considered. Rather, the Government desires that the LPG sector, under BCRM and supported by significant scale-up investment (as outlined in this report) and potentially other promotional measures, will reach the national goal for LPG use without requiring a fuel subsidy.

Key issues related to subsidies, all of which Ghana experienced to some extent in the past, include:

1. As usage grows, the subsidy grows, putting strain on the Government's fiscal resources;

2. As usage grows, the Government's ability to pay the subsidy timely may suffer, putting financial strain on the intermediaries who obtain LPG at market price, sell it at the subsidized price, and then are reimbursed the difference by Government;

3. The subsidy can have unintended leakages (the subsidy is exploited by those who are not meant to receive it, through subterfuge or other means), which inflates the subsidy amount and dilutes the overall utility of the subsidy; and

4. The subsidy can create market distortions, such as the period of price arbitrage between petrol and LPG in Ghana that led to an unintended boom in vehicular LPG use (which was also a form of leakage).

A fifth case, seen in Cameroon, is where avoidance of uncontrolled LPG subsidy growth has limited the ability of the market to grow. In that country, the Government budgets an annual maximum LPG subsidy amount, and the LPG sector only imports as much volume of LPG as would qualify for the budgeted subsidy.

It should be noted that many LMICs, such as India, have a long history of using LPG fuel subsidies as an arm of national development and social policy. Over several decades, India and countries like it have demonstrated that it is possible to fine-tune their LPG subsidy systems to avoid the above-mentioned issues. Should a future Government of Ghana determine that an LPG subsidy to benefit the poorest is desirable, the Government can apply the targeting learnings from other LMICs to do so in a way that minimizes the foregoing problems.

In view of the Government's continuing policy against subsidizing LPG, this study does not explore in depth the potential use of, and impact from, a new LPG subsidy.

Savings potential from alternate LPG sourcing modalities and unit margin reallocation

As the LPG sector grows, the Government may also investigate deconstruction of the importation chain and measures to capture economies of scale in importation (in facilities and cargoes), to reduce the landed cost of LPG. Additionally, as described in Chapter 16 (Investments at the Firm Level) beginning on page 165, Government may choose to reallocate unit margins throughout the supply chain in a way which reduces the overall margin requirement of the chain. Together, such efforts suggest a target savings in the range of € 80-100 per tonne[67], based on preliminary costing of importation alternatives and the financial analysis of Chapter 16, If realized, such savings could significantly offset the notional, potential price increase of € 123 per tonne.

Methodological limitations

The analysis is impacted by a few methodological limitations detailed below. It is important to note that these limitations have led to an underestimation of total residential LPG demand in 2020, 2025, and 2030, mainly due to the exclusion of secondary fuel users, as the household level survey does not include secondary households. The incremental demand due to BCRM has been overestimated.

There are three limitations of the data set used:

- GLSS 6 (2012/2013): As GLSS 7 was yet to be published at the time of conducting this analysis, GLSS 6 was used for most of the analysis, and the national data points from GLSS 7 were used to ensure an accurate growth rate between 2013 and 2017. The data therefore do not reflect the most recent trends in Ghana.
- Lack of data on secondary fuel users: The GLSS 6 dataset only captures information on primary LPG use. The exclusion of secondary fuel users from the household level survey underestimates the projected LPG demand. It is expected that the actual fuel usage would be higher than estimated, and the fuel usage per capita for secondary users would be lower (as secondary usage households tend to use less fuel than primary usage households).
- Lack of consumption data: The GLSS 6 does not include information on the monthly or annual fuel consumption (for any fuel). This means that the potential increase in per household fuel consumption over time could not be measured. It is likely that the fuel consumption for households using LPG would increase, especially under conditions of improved availability, access, or price. As a result, the projected consumption is likely to be an underestimation of the total consumption.

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[67] € 50-70 from importation chain rationalization, optimization and scale-effects, and € 30 in reduction of the margin cap to BPs.

Sufficient availability analysis

There are two potential limitations in the methodology used for this analysis, both of which could potentially underestimate the projected demand:

- Infrastructure development: In this analysis, a roll-out plan and timing for infrastructure development was assumed.
    - *Roll-out plan* is based on the current understanding of infrastructure development and observations of past LPG infrastructure development in Ghana. However, this could change due to changes in government priorities, which would affect the number of households transitioning to LPG at different points in time.
    - *Timing* for infrastructure development was assumed, and different timings could result in different number of households transitioning to LPG (as demographic changes affect the number of potential households).
- Perceptions of availability: The analysis separated households into two groups according to their perception of LPG availability. Group A considered LPG to be rarely available, unavailable, or inapplicable. Group B considered LPG to be always or often available. It was assumed that households in Group B would not start consuming LPG due to improved availability, as they already consider LPG to be available. It was only possible to model the impact of improved availability on Group B. However, as these data are self-reported, perceptions of availability may vary by location. For example, a rural household may consider LPG to be available if it is less than 10 km away, whereas an urban household may consider it to be available if it is less than 5 km away. These differences in perceptions of availability may reduce the potential impact of improved availability. A household in Group B may benefit from improved LPG availability and may therefore consume more or start using LPG, which could not be modelled in this analysis. As a result, this likely represents a slight underestimation of the LPG demand.

13. Demand Assessment through Probit Analysis

Summary

Given the limitations of the available household data in Ghana, it was determined to conduct two separate demand assessments using different approaches, in order to increase confidence in the overall findings, if the two sets of findings are indeed in close alignment.

The findings of the two approaches proved to be consistent.

This chapter addresses the demand potential for LPG to be scaled up as a clean household cooking fuel in Ghana using a Probit analysis of household energy use performed with GLSS 6 data. As in the preceding chapter, the analysis assumes sufficiency of LPG cylinder and fuel availability will be achieved across the national territory, where logistically feasible, and adequate consumer-awareness will be developed.

Demand and consumption potential

Under GLSS 6 demographic and socio-economic conditions (2012-2013), and an assumed increase in LPG availability and distribution in the country sufficient to serve the potential demand, the market potential for LPG household cooking is estimated to grow from 120.8 KT in 2013 to between 333.6 and 402.1 KT by 2030, based solely on population increase and income trends.

This range falls within the lower and upper bounds of the Demographic Matching Analysis described in the preceding chapter.

The main areas for LPG demand potential are unambiguously 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.

Analysis of (limited) available 2013 LPG price data suggests that price-sensitivity would remain an important driver of demand, particularly in rural settings where income levels are lower. For urban households for whom LPG is widely available, usage is estimated to drop below 35% should current real prices rise above GHC 7.50/kg (€ 1.36/kg). 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 reduces prediction reliability. 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.

Background

According to GLSS 6, 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.

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 the cylinder recirculation model set forth in the 2012 SE4All Action Plan, the LPG companies own the cylinders and are responsible for maintenance and repair to ensure optimal performance over time.

The objectives of the Probit analysis were 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 following the phase-out of LPG subsidies) under a consumer-controlled cylinder model (CCRM) (i.e., cylinders owned and controlled by the customers, not by industry), which currently characterises Ghana.

Estimation of potential market size

Methods

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 for control for socioeconomic and demographic variables, such as age, income, and education. Its geographic stratification allowed for estimating the potential LPG market[68] in all ten regions of Ghana in the same year (2013), and it also allowed 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[69].

For the first variable, possible answers included: wood, charcoal, gas (LPG), electricity, kerosene, crop residue, sawdust, animal waste, or other. The Probit model was defined 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 may 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 the 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. This probability estimate is then combined with household cooking energy

68 The potential market is the existing, currently-served market plus the unserved or underserved demand that could be served were LPG made sufficiently available.

69 Note that the GLSS 6 questions did not differentiate between bottled gas (LPG) and natural gas. Given there was no domestic usage of natural gas in Ghana at the time of the survey, it has been assumed that all the gas used and reported was LPG.

needs in order to estimate the total potential market size of LPG in Ghana under conditions of improved fuel availability and accessibility.

The 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 the Probit analysis of potential market share, the responses for gas were transformed 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 discussion of the limitations of this response variable in Chapter 27 (Probit Analysis – Potential Limitations)). Comparing these two groups allows an estimation of the increase in the probability of gas use due to improved access to gas.

The econometric strategy employed was to identify the relationship between LPG availability and household LPG use. Should a significant relationship exist (as hypothesized), one 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 program of investment to improve LPG access and increase supply chain reliability, and through raising 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 the estimate of the price effect, described further below.

The Probit equation is:

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

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 the key explanatory variable: a dummy variable of whether the household considers gas to be "always/often available" or not, X is a vector of the demographic and socioeconomic controls, and the β parameters are estimated via maximum likelihood.

Estimating household LPG consumption in 2013

The 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.

The first step is estimating 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. The next step is to 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[70], and the World LPG Association annual statistics, which estimates an average of 122.0 KT of domestic LPG consumption for the same years[71].

The average of these two estimates (133.1 KT) was then combined with GLSS 6's percentage of households using LPG (22.3%)[72] 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[73], 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[74], the results are also reported assuming 27.3 kg of LPG per LPG user per year[75]. This number serves as an upper bound for the analysis. This figure is reported as well in order to provide a conservative range of potential LPG use in household cooking[76]. Both numbers (22.6 and 27.3 kg of LPG per LPG-user per year) were used for the projections of total LPG household cooking market size to provide lower and upper bounds, depending on the extent LPG is used across all cooking needs.

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

The 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. The focus is on the potential increase in market size that would result from an improvement in supply such that 100% of households desiring LPG consider LPG to be "always" or "often" available.

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70 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). knoema.com/UNSDESD2015/un-statistics-division-energy-statistics-database-2015?location=1000850-ghana

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

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

73 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.

74 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.

75 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.

76 Subsequent investigation, as described in Chapter 12 and the associated Annex Chapter 26, identified 38 kg per capita per year as the maximum potential LPG consumption by an LPG user if LPG is used exclusively for cooking of all meals in the user's household. The value of 27.kg 3 was utilized here for sake of conservatism. While there is evidence from other countries that fuel stacking decreases over time with rising incomes and evolution of cooking habits and cooking culture as LPG is added into the household energy mix, there is no known evidence to date to support a view that the average LMIC household would end all use of all alternative fuels for cooking an average daily calorific value within the twelve-year study period (to 2030).

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 (see "Results" beginning on page 103).

Two different potential market sizes are determined: LPG-using households consuming 22.6 kg and 27.3 kg of LPG per person per year as the lower and upper bounds, respectively. The former can be considered a low case where LPG supply availability improves but households continue to fuel stack at average historical levels due to household cooking preferences, lack of (or an ineffective) 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 reducing somewhat their fuel stacking due to LPG being more available, reliable and accessible, increased preference for LPG such as from awareness-building, as well as the ability to afford LPG for daily cooking needs.

Annex Chapter 27 (Probit Analysis – Potential Limitations) beginning on page 303 discusses the challenge 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. The 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), was deemed 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, such as those promoted by the Government of Ghana through its Rural LPG Promotion Program (RLP)[77].

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 Chapter, the prediction is simplified, and it was assumed for purposes of the Probit model that price is unchanged. The effect of possible price changes was then considered through construction of probability curves of urban and rural LPG utilization based on price (see the section *Estimating the impact of price on LPG demand* on page 108 for details).

The utilized price data has important limitations as further discussed in Annex Chapter 27.

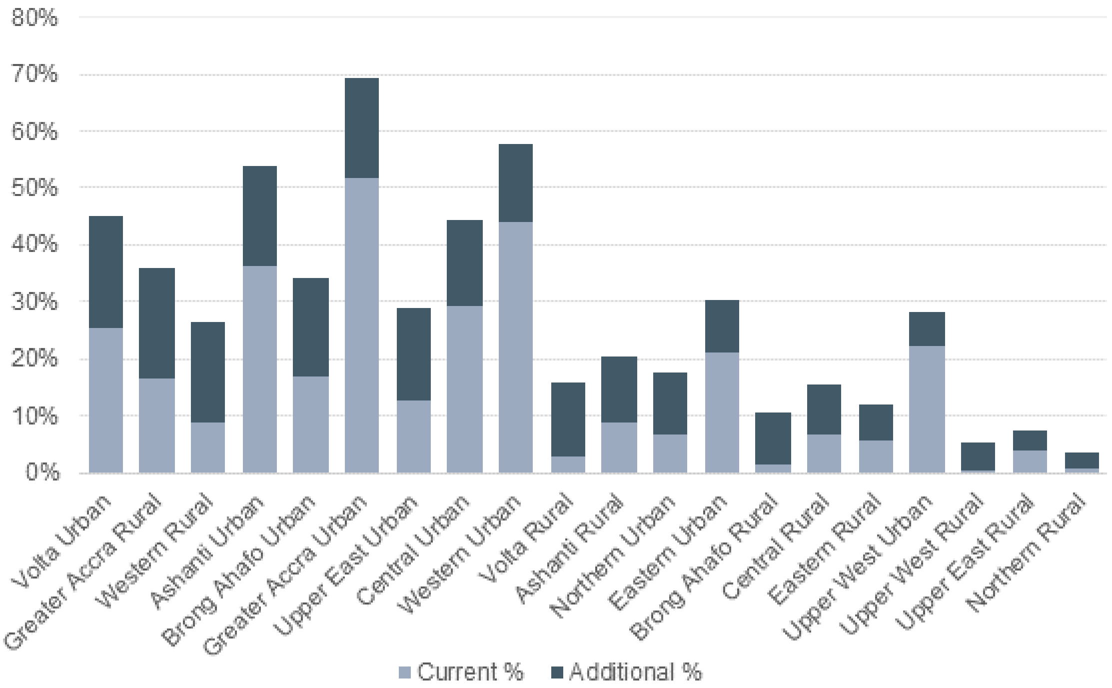
77 www.modernghana.com/news/534312/1/govt-launches-lpg-cook-stove-program.html

Results

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

The 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 19, 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, such as in Volta and Brong-Ahafo, could see 400-500% increases in LPG-using households, albeit from a much lower baseline and at lower overall volumes.

Figure 19. Current and potential % of households using LPG by region (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 20 reports the current and potential LPG percentage and volume results for each region:

Table 20. Summary of current and potential LPG markets by region (2013 baselines)

Region	Current LPG use	Potential LPG use	2013 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**[78]	**216.43 ± 20.14**

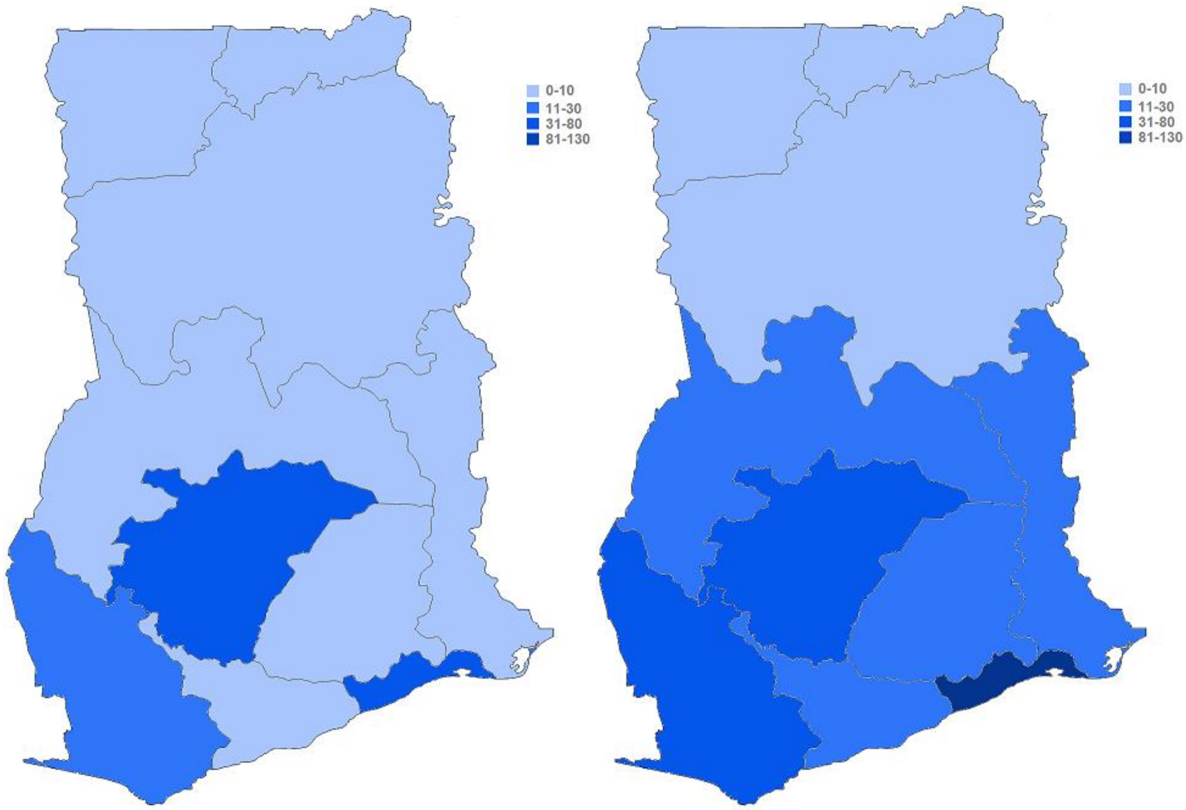
Source: ECA analysis and GLSS 6.

The total Ghanaian population in 2013 was about 25.9 million according to World Bank data; the LPG per capita consumption for cooking is therefore estimated to have been 4.7 kg/capita in 2013.

Figure 20 illustrates both the actual and potential (under increased availability) LPG market sizes for 2013 from Table 20 with a map of Ghana's regions. It shows that 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 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 to some extent with freely-gathered biomass, but that LPG penetration among wood-gathering households would be limited relative to nationwide penetration without incentivizing measures being taken.

[78] Note that this value slightly differs from the 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. The Census data were used to calculate the percentage of urban households in each region because that information is not directly reported in GLSS 6.

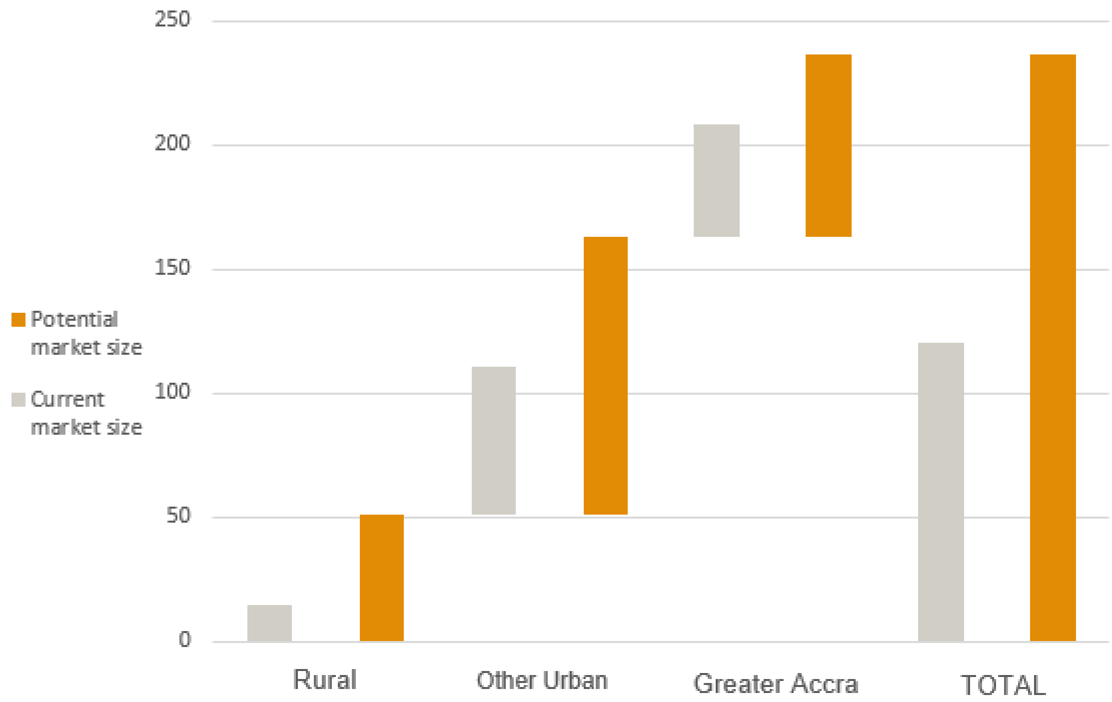
Figure 20. Ghana's Current (left, 2013) and Potential (right) market size, by Region (KT)



Note: This map assumes the upper bound of LPG consumption for the potential market (on the right)

Figure 21 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 an approximately 343% increase in the size of their LPG markets, 69% of the nationwide increase in LPG sales would be in urban markets.

Figure 21. Current and potential size of LPG market (KT) for 2013



Note: The current size of the Ghanaian LPG market is estimated by multiplying the GLSS 6 estimate of current LPG use by the UN estimate of LPG use per household. The potential market for LPG via Probit model of LPG use is then estimated, with gas being "always" or "often" available for all respondents. The Probit estimate controls for age of household head, sex of household head, the size of the household, and total household income.

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

The above estimates only take into account the demographic and socio-economic situation based on GLSS 6 data collected in 2013. It is also of interest to determine what the Ghanaian LPG household cooking market potential may look like 5, 10, and 15 years hence.

For this, the numbers were re-run under the simple assumptions that Ghana's rural and urban populations will follow an average of their growth rates for 2011-2014,[79] and income per household grows at 5% per annum[80]. 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, it is assumed that the other demographic controls (age and sex of household head, and average household size) will remain unchanged over this period. The results for the forecasted population and income values for 2020, 2025, and 2030 are presented in Figure 22.

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

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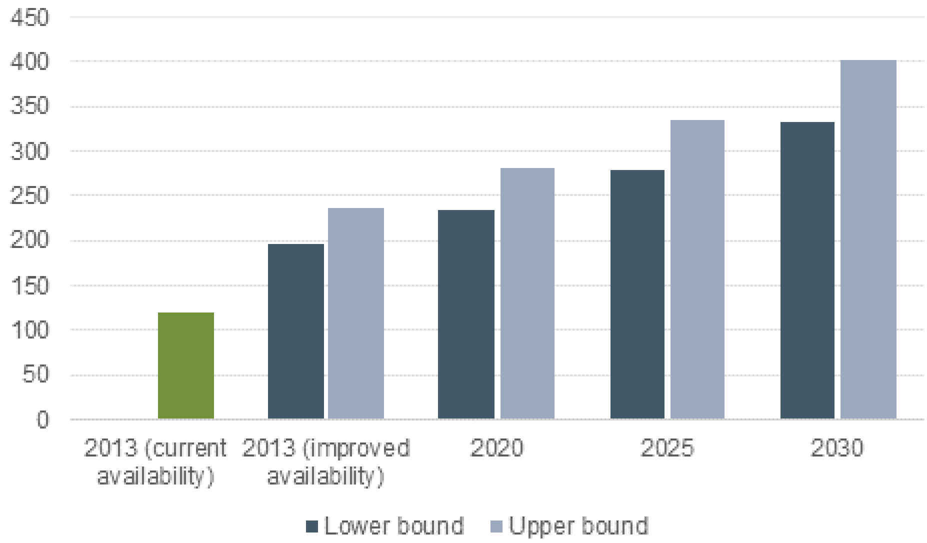
[79] 1.03% and 3.7% per annum, respectively. Source: World Bank. databank.worldbank.org/data/reports.aspx?source=2&series=SP.POP.GROW&country=GHA

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

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 22. Forecast of potential (not actual uptake) LPG household cooking market size (KT)



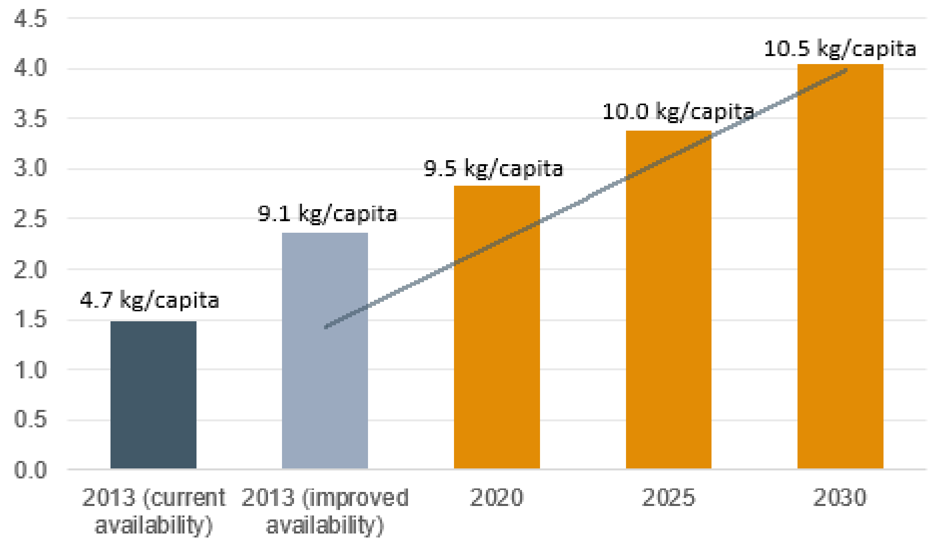
Note: Results of Probit model. Applies 5% per annum growth rate to income, 1.03% growth rate to rural populations, and 3.7% growth rate to urban populations.

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 approximately 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 22 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 23 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 38.18 million 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 23. Modelled build-up of LPG-using households (millions) and LPG use per capita to 2030



Notes:

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. It is assumed that the number of persons per household stays constant at 2013 levels. LPG use per capita is reported above each bar.

The 2013 usage occurred in part under subsidized pricing. LPG subsidies were phased out over the course of 2013. The 2013 improved availability case (shown above) does not yet take post-subsidy pricing into account in full, and is presented as a theoretical building block in the Probit model. That is, the model projects not only forward, but also retroactively to 2013 based on a scenario of immediately improved availability. In practice, of course, expanded availability will not be immediate. The above chart is therefore not meant to serve as a consumption or user population forecast during interim years. Rather, it represents a theoretical build-up from multiple demand factors to 2030. Accordingly, the ramp-up of users and consumption from improved availability will occur more slowly than shown in the bars above, but will converge to the 2030 value (10.5kg per year per capita) as predicted by the model. This effect is depicted in the dark line.

Estimating the impact of price on LPG demand

The above analyses ignore the potential demand-dampening effect of future 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)[81].

To estimate the price effect on LPG demand, the Probit model was used again. In this case, the surveyed price of gas was included 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).

The GLSS 6 surveyors' reported LPG market prices were used (see Annexes, Chapter 27, for a discussion of the drawbacks of this price data). After data cleaning,[82] this left only 223 observed LPG price points which,

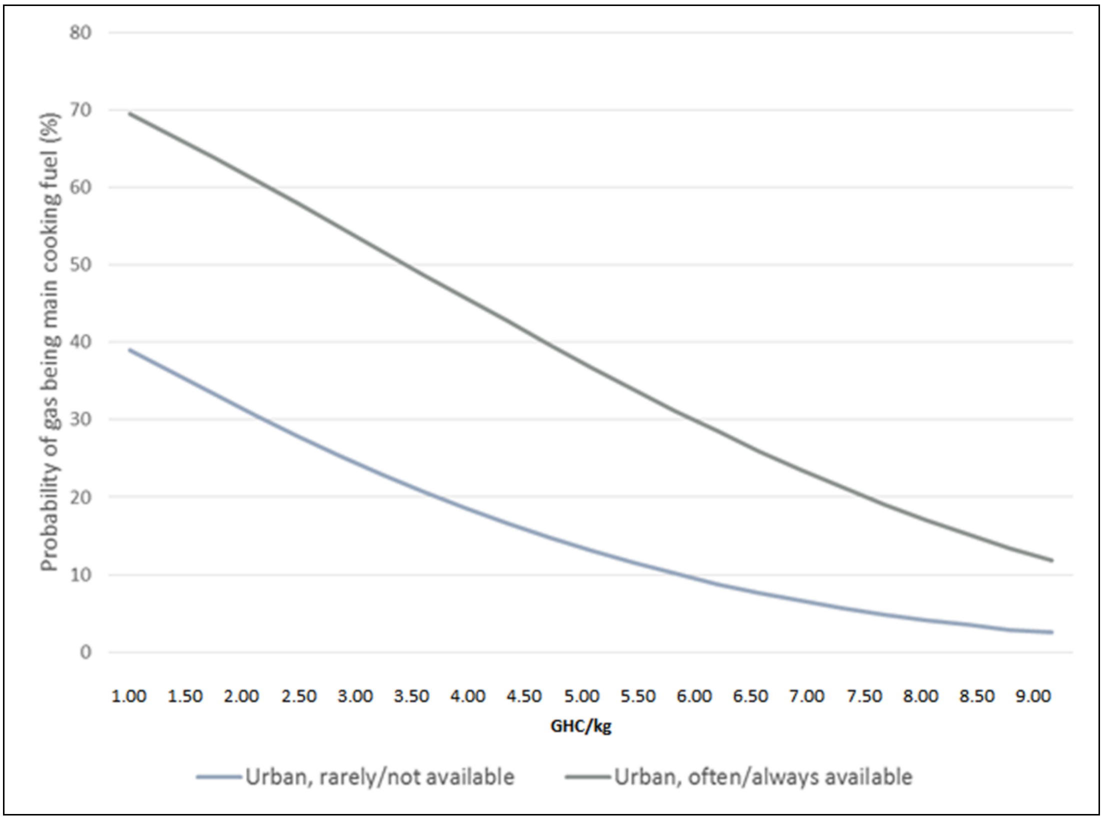
81 This trend is ultimately dependent on LPG import prices.

82 Extreme data outliers and cases where the size of the LPG cylinder being priced was not made clear were removed.

when applied to every household within each market's respective Enumeration Area, give 3,103 household-price observations.[83]

This analysis was run 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 the resulting curves compared for each group of perceived availability. The demand curves for urban households are presented in Figure 24 and the demand curves for rural households in Figure 25.

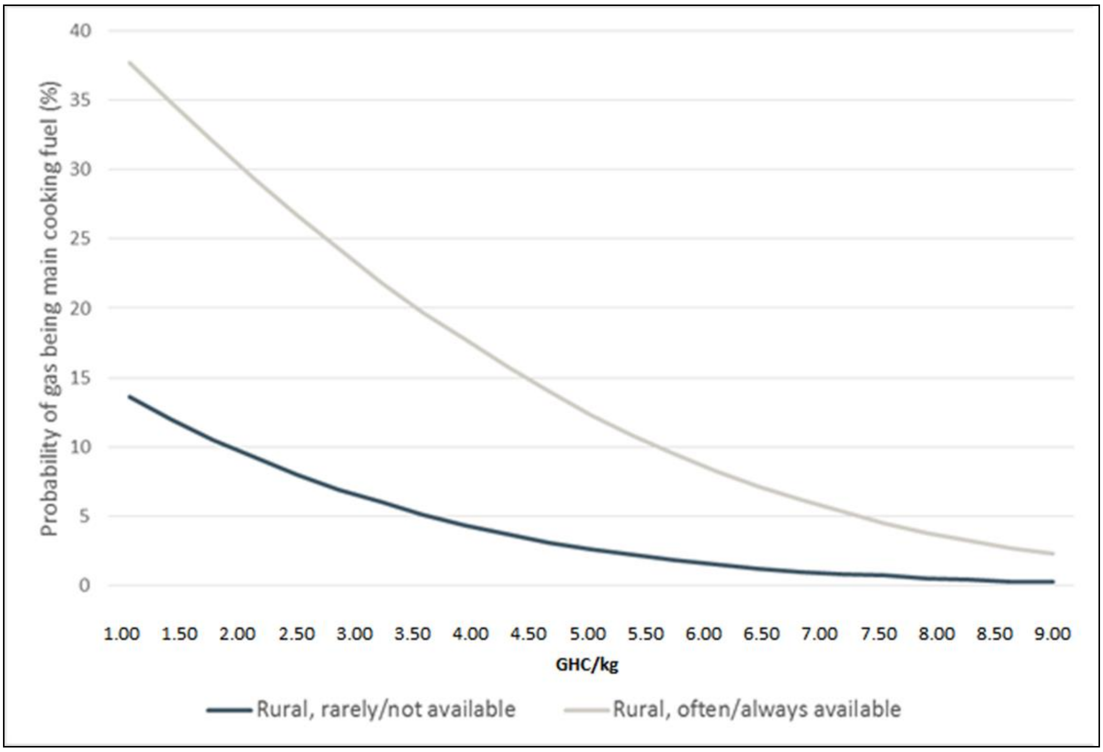
Figure 24. Probability of LPG use by price – urban households (2016)



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. The nominal price scale is adjusted for domestic price inflation, which was 17.5% in 2016, 12.4% in 2017, and is expected to be approximately 9.5% for 2018.

[83] LPG prices were collected by GLSS 6's enumerators from the local market rather than from individual households.

Figure 25. Probability of LPG use by price – rural households (2016)



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. The nominal price scale is adjusted for domestic price inflation, which was 17.5% in 2016, 12.4% in 2017, and is expected to be approximately 9.5% for 2018.

In Figure 25 one sees a strongly non-linear demand elasticity for rural users with broadly available LPG.

Their probability of LPG use as the main cooking fuel drops from above 10% at current nominal prices (approximately 5.4 GHC/kg, or € 0.98/kg) to approximately 4% if the price rises above approximately GHC 7.50/kg[84] (€ 1.36/kg). That represents an approximate 2% decline per 10% increase in price.

The decline is less steep for LPG supply-constrained rural households, but demand is never high to begin with, only being above 5% if the price is less than approximately GHC 5.0/kg (€ 0.91/kg) and dropping close to 1% for prices above GHS 7.50/kg (€ 1.36/kg). This represents an approximate 0.5% decline per 10% increase in price. 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 24) are less sensitive to price, but even urban users who are not supply constrained see their LPG usage probability drop below 35% should real prices rise to above GHC 7.50/kg (€ 1.36/kg). This represents an approximately 5% decline per 10% increase in price. However, these negative price effects would presumably be offset to some extent in the future as Ghanaian incomes rise. Furthermore, given the

84 The choice of GHC 7.50 for comparative purposes is arbitrary.

concerns expressed about the price data in Annex Chapter 27 (Probit Analysis – Potential Limitations), one must use caution against interpreting too much into the presented elasticity estimates.

For urban users who are supply constrained, LPG usage probability drops from approximately 12% to 6% should prices rise above GHC 7.50kg (€ 1.36/kg), representing a decline of approximately 2.5% per 10% increase in price.

Price sensitivity conclusions from the Probit analysis

The graphs above show that the impact of good LPG availability, compared to poor or no availability, shifts the demand curve upward by 3X or more when end-user LPG prices are high, and by around 2X when prices are low. They also show that this effect is stronger for rural (and by correlation lower-income) households than for urban ones.

Should the end-user price increase significantly from its recent level of approximately € 0.98/kg as a result of change to governmental price policy or to an intermediate- or long-term shift in the international supply price, the analysis predicts a potentially sharp drop-off of main LPG use among rural users, and a more modest drop-off among urban users.

The model indicates that, starting from the current pricing level (just under € 1 / kg), if prices are increased by a notional maximum of € 0.123/kg (GHC 0.69/kg) for purposes of recovering investment in new infrastructure and distribution over ten years[85], a 12.5% increase, the probability of urban users to use LPG who have access is likely to fall by 6% (six percentage points), by urban users without access by 4%, by rural users with access by 2%, and by rural users without access by 0.5%.

While it was beyond the scope of the analysis, based on the available data, to stratify the demand response by income level, one may reasonably assume, based on the experience of Senegal and other countries which withdrew LPG price subsidies that led to later price increases, and to the experience of Brazil and other countries with widespread LPG use by the poor and volatility in incomes among the poor and permitted volatility in LPG price, that the drop-off effect would be significant in the lowest income quintiles, and modest or negligible in the highest. For example, after Senegal ended its LPG subsidy in 2005, the bottom income quintile saw LPG use drop by more than 20%, but there was negligible change in LPG use in the other four quintiles.

As presented in the demographic analysis of the preceding chapter, the demographic model predicts an expected decrease in forecasted LPG use of roughly 5% overall for every 10% increase in end-user price, based on current pricing levels. Note that this value represents a reduction in the overall level and rate of growth of LPG use from improved availability and preference-affecting measures, not an absolute decline.

To counteract the effects of potential price increases, incentivizing measures related to LPG refill affordability for rural/poor households could be considered by the Government and/or providers of aid, as has been done successfully by the Government of India and, during an earlier era, by the Government of Brazil, as two examples.

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85 See Chapter 10 (Pricing) beginning on page 47 for details.

Conversely, it should be noted that favourable demographic trends in household income will tend to increase LPG usage. At a constant price, LPG usage becomes more affordable as incomes rise. (This effect has been seen in numerous LMICs, with Brazil being a leading example.)

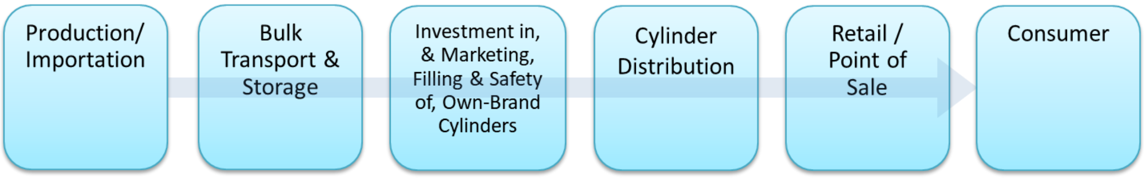
VII. LPG Supply Chain Development and Planning

14. The Value Chain and its Transition

The generic LPG value chain

As a point of reference, it is useful to contrast the current Ghana value chain with that found in almost all markets globally. The LPG value chain found in almost every country in the world comprises six fundamental nodes, as shown in the following figure, implementing with greater or lesser completeness the Branded Cylinder Recirculation Model (BCRM):

Figure 26. Generalized LPG value chain (BCRM)



The nodes, defined by their main functions, are:

1. *Production/Importation*. LPG is sourced from importation and/or as a by-product from the production of natural gas or from petroleum refining. Importation in Sub-Saharan Africa is typically by sea to a terminal, using LPG carriers (ships) at the small end of the size range (and high end of the cost range, per tonne), or overland in tractor-trailers or bobtail trucks (lorries).

2. *Bulk Transport and Storage*. The LPG is moved in bulk from its points of importation or production into large-scale storage facilities. Such facilities may be co-located with importation or production facilities, or may be located strategically in other areas.

3. *Investment in, and Marketing, Filling and Safety of, Own-Brand Cylinders*. Cylinders are acquired and deployed into the market at this node, which has corresponding responsibility and liability for cylinder safety and property rights in the cylinders, such that the lifetime cylinder safety responsibility and liability are matched with the lifetime income stream from refills of the cylinders. Branding, universally done using uniquely assigned and registered colors, creates a marketing and asset control advantage for the LPG marketer, ease of accountability when there is a cylinder safety incident, and ease of distinguishing between competitors for the consumer. The cylinder is provided onward through the chain to the consumer through a chain of cash deposits. In global LPG industry terms, the businesses operating at this node are called "Marketers".

   Note: In Ghana, the term "marketer" has a meaning distinct from how the term is used in most of the global LPG industry. This distinction is explained further below.

4. *Cylinder Distribution.* Each marketer develops a network of contracted distributors, who own and/or operate depots and the trucks (lorries) and other vehicles that transport full cylinders to retail points (also called "cylinder exchange points") from medium to large-scale filling facilities and return empty cylinders to the filing facilities for inspection, maintenance and refill. The generic LPG industry term for these businesses is "Distributor". Distributors provide the main cylinder logistics function in

coordination with the Marketer. In national LPG markets that sustain high-enough unit margins to support it, the distribution function may also include optional home delivery of filled cylinders and pick-up of empty cylinders by the distributors.

5. *Retail / Point of Sale.* Also referred to as Cylinder Exchange Points, this node is where the consumer interacts with the LPG cylinder distribution system. A new customer obtains his/her branded cylinder by paying a cylinder deposit plus the purchase price of the LPG it contains. An already-existing LPG customer brings his/her empty cylinder to a nearby retail location to exchange it, for the posted refill price, for a full cylinder of the same brand. The empty cylinder is then "recirculated" to the filling facility of the brand-owning Marketer by the distributor network, giving rise to the term "Cylinder Recirculation Model". A high density of retail points located conveniently near to the consumers, supported by an adequate volume of cylinders, is critical to ensuring sufficient LPG availability to stimulate and to serve LPG demand.

6. *Consumer*. A first-time user interacts with the retail node to obtain a new, filled cylinder of a given brand, paying an initial cylinder deposit plus the cost of the fuel; an existing user exchanges his/her empty cylinder there for a full one of the same brand, paying for the fuel cost.

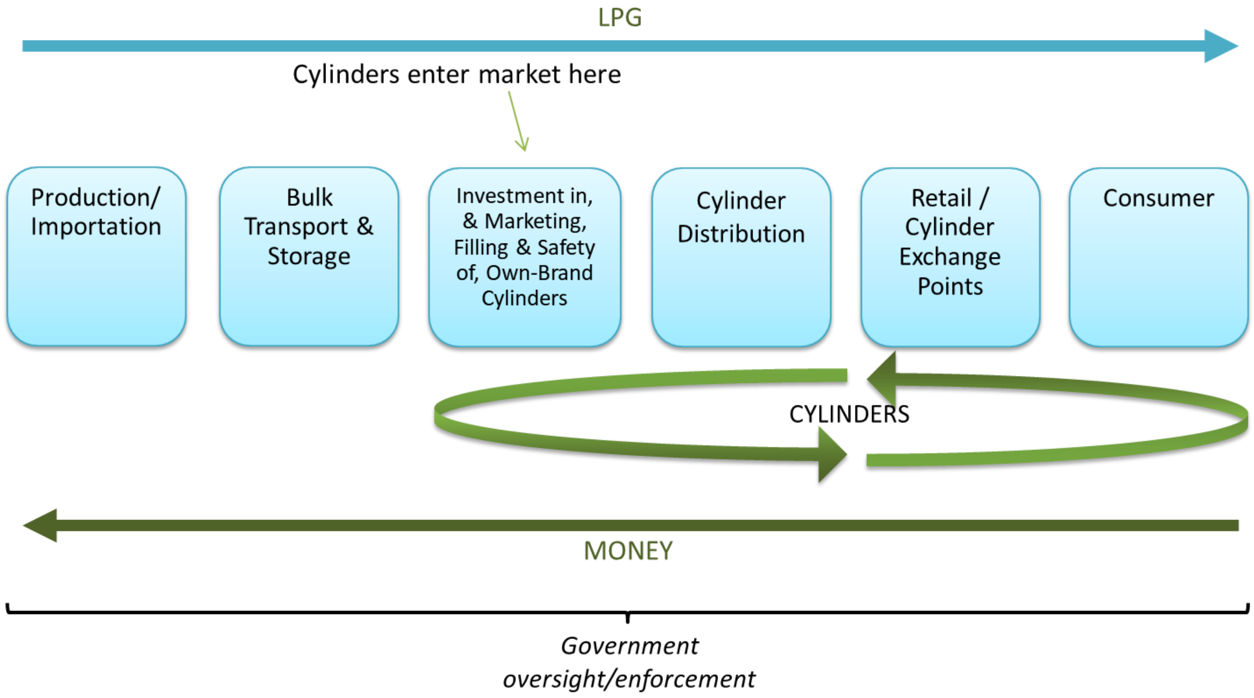
Based on prevailing national policy, regulation, and market design, various nodes may be structured as profit centers or cost centers. Vertical integration (a single company operating across multiple nodes) may or may not be permitted. Competition may be focused on attracting and retaining consumers, and/or in nodes further upstream from the consumer. (Examples of competition within the chain, not focused on attracting and retaining consumers, can consist of competing to acquire and control supply of LPG in bulk, competing for distribution and for retail presence, and interfering – legally or otherwise – with the cylinder inventories and logistics of rivals to influence market shares.)

LMICs with very high levels of LPG penetration and use by their populations, such as India and Morocco, have established the first two or three nodes (looking left to right) on a shared-asset utility model, as cost centers, with either state or common industry ownership thereof. That approach has helped to shift the focus of competition away from the interior of the supply chain to the acquiring and servicing of the consumer in those countries.

There are many potential variations to the value chain structure; nodes may potentially be merged or overlap, in whole or in part. Nevertheless, this basic structure, with good regulatory oversight, has been shown to be sustainably scalable to serve 80%+ of the populations of numerous LMICs, and 95%+ in some, while delivering adequate public safety over time.

The operation of the BCRM value chain may be diagrammed more explicitly as follows:

Figure 27. Generalized LPG value chain (BCRM) with operational flows

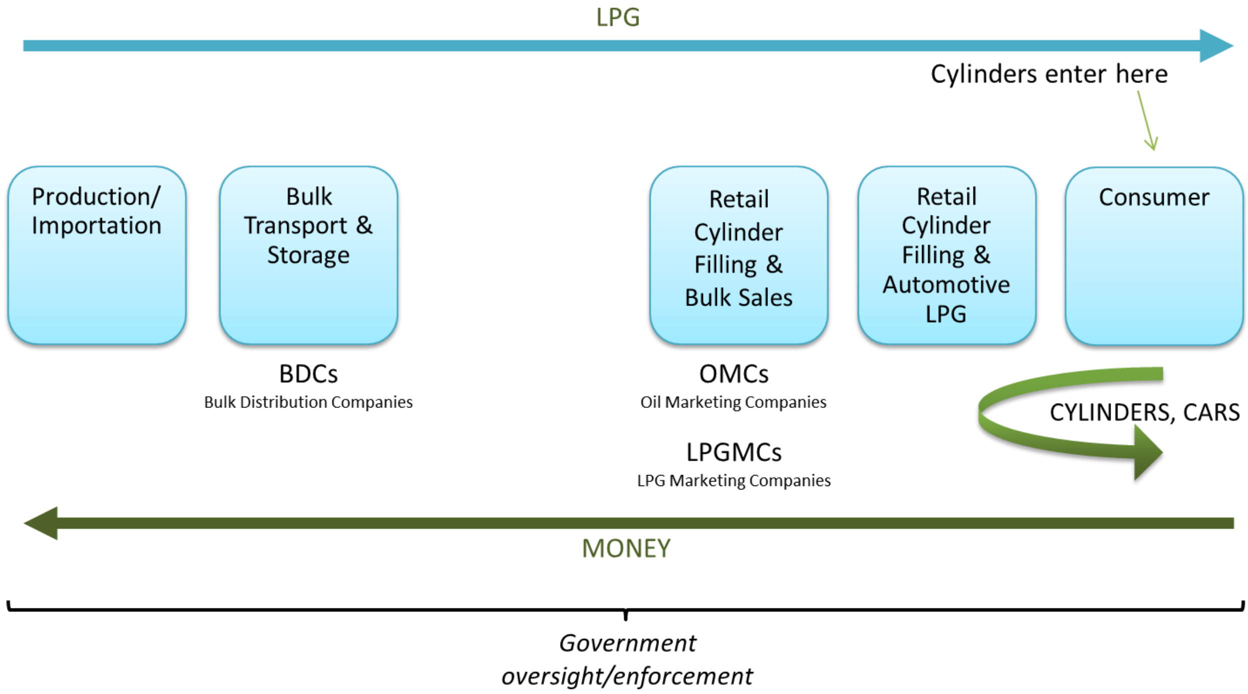


As one moves from production/importation toward the consumer along the chain, the number of players tends to increase, somewhat geometrically. This is indeed the case in Ghana, discussed below.

Existing Ghana LPG value chain

The Ghana LPG value chain originally operated under BCRM, described above and, in more detail, in Part IV (A Brief History of LPG in Ghana) beginning on page 34. Over many years, Ghana's value chain slowly devolved into the Consumer-Controlled Cylinder Model (CCCM), which has been increasingly in effect for more than a decade. Ghana's current value chain and its operation are shown in the following figure:

Figure 28. Existing Ghana LPG value chain (CCCM)



A key feature of the existing Ghana value chain is that all cylinders are generic (unbranded). The cylinders' origins and ownership, and the party responsible for any safety incident caused by an untested, unsafe cylinder, therefore cannot be definitively determined.

The nodes of the value chain are:

1. *Production/Importation*. This sourcing node carries forward.

2. *Bulk Distribution Companies (BDCs).* These companies obtain LPG from sources of importation and/or production, and sell it downstream, in bulk. They typically operate facilities for importation and storage, and may also have bulk transport facilities. They are prohibited from selling LPG to consumers[86].

3. *Oil Marketing Companies (OMCs), LPG Marketing Companies (LPGMCs).* These companies are, respectively, licensed sellers of petroleum products generally, which can include LPG, and licensed sellers of LPG only. They may refill consumers' LPG cylinders themselves, through their own microstation facilities, or they may sell LPG on a wholesale basis to retailers, who perform the cylinder filling function for the consumer.

4. *Retail cylinder-filler (also called Dealer).* Retailers/dealers own and/or operate microfilling stations located among, or near to, concentrations of end-consumers. They purchase LPG in bulk from OMCs or LPGMCs, store it in a tank, and decant it from the tank into end-users' cylinders. These cylinders may be residential, or they may be installed in an automobile that has been converted to run on LPG. In principle, the retailer should inspect the cylinder for safety; in practice, such inspections are incomplete. Even when safety inspections are partially performed, unsafe cylinders are not

[86] An exception applies in the case of governmentally-registered bulk customers, such as industrial users of LPG.

consistently taken out of circulation. These omissions are partly due to retailers lacking a comprehensive set of inspection equipment, expertise and systems; partly to their economic incentive to avoid bearing the cost of performing thorough, rigorous, multi-stage inspections of cylinders for which no one party can in the value chain be held accountable, and partly due to the desire not to alienate a consumer by confiscating an unsafe cylinder owned by that consumer.

5. *Consumer.* The Ghanaian consumer is the largest single investor, in aggregate, in the assets of the value chain, because the consumer pays for the market's inventory of cylinders. The consumer purchases his/her own cylinder at retail price. He/she transports it to a microstation for refilling via a decanting process performed while the consumer waits. The half-circular arrow in the value-chain diagram indicates that the cylinders do not recirculate throughout the distribution system; they remain with the consumer, under his/her control. The consumer pays for the refill on a per-kg basis. (There is some room for manipulation of the kilograms charged-for *vs*. the kilograms actually decanted under this system.) The consumer then takes the filled cylinder home.

Limited vertical integration

The Government's regulatory measures restrict companies' ability to operate across multiple supply chain nodes. (The main exception is that OMCs and LPGMCs can own and operate microstations as well as sell in bulk to independent microstations.) Moreover, rather than license a single node (such as the cylinder investment, branding, refilling and marketing node) and issue permits for business operations in adjacent nodes, as is done in most LPG markets globally, the NPA issues a distinct license at every node.

Factors which motivate this approach can include limiting the aggregation of market power within individual companies (the largest petroleum-sector companies in Ghana historically having been foreign-owned); combatting corruption that may be made easier to perpetrate and to hide when companies span multiple nodes; creating greater opportunity for revenue generation, via increased numbers of licenses and license renewals, to support the activities of the regulator; creating greater opportunity (whether or not actually seized) for patronage (i.e., awards of licenses and contracts) through greater vertical fragmenting of the market; encouraging of competition at every node in the chain.

There are benefits to allowing vertical integration in a still-developing LPG market, including ease of regulatory oversight, increased capability for industry self-regulation or cooperative public-private policing of the sector, potential reduction of industry costs and margin requirements, improved bankability (weakly bankable nodes benefit from stronger bankability in other nodes, when companies span both nodes), and others. However, the philosophy and norm of no, or limited, vertical integration is being carried forward from CCCM in the design parameters of the Government for BCRM, as of this writing.

As a work-around to this licensing philosophy, some companies had established subsidiaries dedicated to a specific supply chain node. Each subsidiary has its own operations and its own license specific to that node.

High fragmentation

The high fragmentation of the supply chain, horizontally as well as vertically, further reduces its bankability, when taken as a whole, and increases its investment risk. This topic is taken up in detail in Part IX (Financing) beginning on page 184.

It also imposes a high burden on the regulator, who must oversee a very large number of companies and proprietorships compared to the level of revenue to the regulator generated by the system.

The missing node

It is important to note that the node labelled "Investment in, and Marketing, Filling and Safety of, Own-Brand Cylinders" from the BCRM value chain is missing.

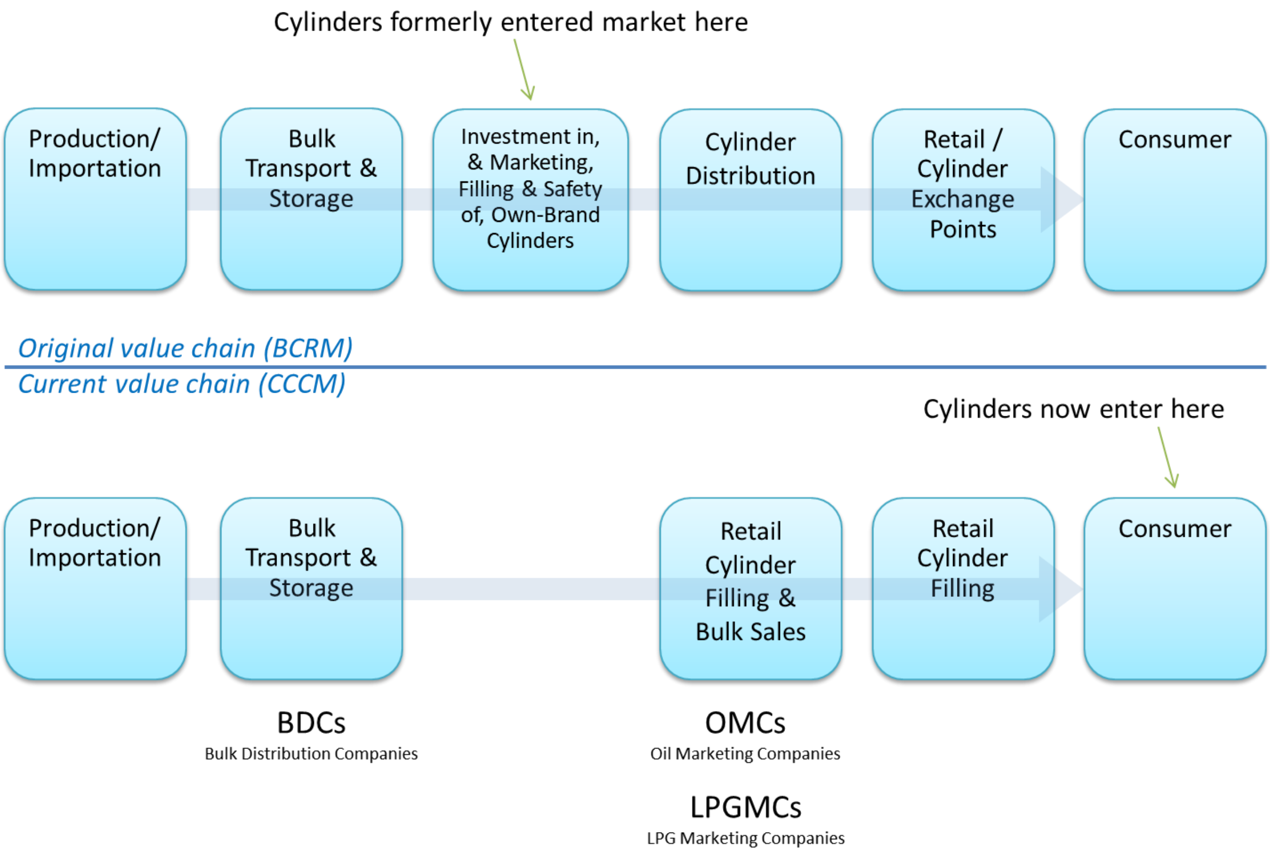
That node's cylinder-refilling function and its distribution network-design function have migrated to the microfilling/decanting operations of the OMCs, LPGMCs, and retailers/dealers. The node's investing- and deploying-of-cylinders function has migrated to the consumer. And finally, the node's most critical function—ensuring (investing in) cylinder safety and filling operations safety—has, in practice, not migrated, but instead has degraded and faded away. Rigorous multipoint inspection and maintenance of cylinders to ensure their safety is lacking. Over time, this condition leads to an ever increasing rate of safety incidents and, among these, fatalities and large-scale losses of property.

The implications of having cylinders enter the value chain through consumers and be under the consumers' control are discussed in depth in Part V (LPG Enabling Environment), which begins on page 39.

Summary of the transition challenge

The transition to BCRM from CCCM, motivated strongly by issues of public safety associated with the current CCCM value chain, represents a major reform and planning task for the Government, and a major challenge of adaptation of business models and changes to the potential scope and scale of operations for the LPG sector. Figure 29 contrasts the original and current value chain models in Ghana for service to residential consumers.

Figure 29. Original (to 2000s) and current (2018) LPG value chains serving households in Ghana



A depiction of the supply chain as it is likely to exist under BCRM, based on what has been contemplated and recommended and subject to final decision-making by the Government, is presented in Figure 33 on page 126.

Ghana CCCM supply chain nodes and participants

Production and importation

Production comes from three main sources:

1. The Ghana Gas Company, whose present volume sold into the Ghanaian market is about 70 KT per year out of a nameplate capacity of about 170 KT, towards which it is ramping its production. This production is approximately 30% butane, 70% propane.

2. The Tema Oil Refinery, whose production volume is approximately 23 KT. This production is approximately 70% butane, 30% propane.

3. Purchase of imports by the BDCs. Imported LPG is approximately 90% butane, 10% propane. Data on individual BDCs are presented later, in the BDC subsection.

Importation is primarily from Equatorial Guinea and the Americas.

Under the future growth scenarios described in this report, importation will increase significantly its share as a source of supply[87].

As discussed in Chapter 20 (Summary of Main Project Risks, Mitigations and Mitigation Sources) beginning on page 214, adequate LPG is expected to be available for importation through at least another ten years. This ignores the additive potential to the surplus of bio-LPG, introduced in commercial quantities at competitive price points by multiple producers during 2018. Should the global LPG surplus end, net importers such as Ghana must then compete for LPG with sectors such as plastics and chemicals, which choose among feedstocks including LPG based on price. That sector consumes approximately one third of global LPG production for feedstock use at current price levels. Historically, as LPG prices have risen compared to feedstock alternatives, plastics and chemical producers switch from LPG to other feedstocks. This rebalances global LPG supply and demand across all other consuming sectors. If global LPG prices rise after ten years due to an end to production surpluses, Ghana can continue to expect adequate availability of imported LPG, albeit at a potentially higher price.

It is expected that the prices of Ghana's domestically produced LPG will continue to be linked to the region's international LPG reference price. This is both a good business practice and good policy practice for avoiding unintended arbitrages and resulting market distortions. Chapter 10 (Pricing) beginning on page 53 discusses LPG pricing considerations in Ghana in detail.

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87 The mix of propane and butane from each LPG source is not the same, and a significant increase in the propane content has infrastructure and safety implications. Ghana Gas-produced LPG is at least 50% propane; imports have historically been 20% propane, 80% butane, intended to be roughly compatible with the Tema Oil Refinery mix, which is 30% propane/70% butane. The mix difference can affect gas safety: stored propane has a much higher vapor pressure than butane. A significant increase in propane content would require upgrades or replacement of butane-rated infrastructure with propane-rated. (Ghana national standards allow for gas vapor pressures up to 9 Barg, and the Ghana Gas Company has publicized that its LPG gas vapor pressure is 7.5 Barg.) Gas economics could also be affected; a tonne of butane is normally priced higher than a tonne of propane, because butane has higher heat content.

There are three importation sites, with capacities as shown in the following table:

Table 21. Import storage capacities (2018)

Location	Company	Dedicated to Cylinder and Autogas Market	Dedicated to Power Generation
		Butane/Propane (MT)	**Propane (MT)**
Tema	Tema Oil Refinery	8,700	
	Fueltrade	4,000	
	Blue Ocean	4,320	
	Quantum (not yet in service)	600	16,000
Atuabo	Ghana Gas Company	4,320	
	Quantum truck loading facilities	750	
Takoradi	Genser (floating storage)		30,000
Total		22,690	36,000

The largest size of LPG oceangoing carrier that can be accommodated (at the Tema Jetty) is 26,000 MT. However, it is not possible to offload a full cargo at once. LPG discharges take place concurrent with Bulk Road Vehicle (BRV) loadings, which are constrained by the land storage capacity and its vehicular discharge rate. If import quantities are higher than the storage facilities can accommodate, the LPG carrier is moved to anchorage to await creation of ullage space in the storage facility, after which the ship is moved to the berth again to continue with discharge.

Bulk Distribution Companies (BDCs)

The concept of the BDC was introduced in 2006 in order to shift power from international oil majors and traders to the Ghanaian private sector within the oil and gas sector, in connection with deregulation of the sector. A concern at that time was that, in a deregulated market, large foreign companies would dominate the Ghanaian market and drive local Ghanaian companies out of it. BDC licenses were provided solely to Ghanaian firms. The policy objective was realized, with Ghanaian entrepreneurs investing in Ghanaian organizational capability and infrastructure in order to source, trade in, and store petroleum products from international markets and sell them onward to Ghana’s Oil Marketing Companies (OMCs).

A BDC is permitted under its license to import LPG (or to purchase it from the Ghana Gas Company or Tema Oil Refinery) and to sell LPG to OMCs and LPGMCs, but not to retailers. A BDC may sell LPG to bulk customers (such as industrial users), which must be registered as a bulk customer with the NPA.

A BDC license may only be obtained by a Ghanaian citizen or company, or a joint venture between a foreign and Ghanaian entity. LPG sector BDCs are required to maintain a minimum storage capacity 6,000 m^3. This requirement has kept the BDC node in the chain from attracting a proliferation of small players. A BDC may also have associated OMC/LPGMC activities.

The Tema Oil Refinery uniquely straddles the nodes of producer and BDC, in practice.

There were a total of nine BDC’s involved in LPG procurement in Ghana in 2017 as shown in Figure 30, with three dominating:

Figure 30. BDCs by market share (2017)

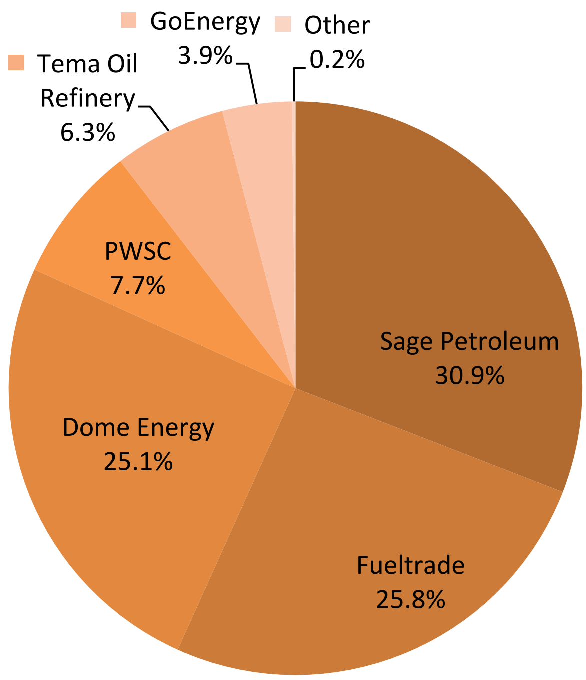


Table 22. BDC volumes and market shares (2017)

BDC	Volume (MT)	Market Share[88]
Sage Petroleum	110,902	30.9%
Fueltrade Ltd.	92,758	25.8%
Dome Energy Resources Ltd.	89,918	25.1%
Petroleum Warehousing and Supply Co. Ltd.	27,813	7.7%
Tema Oil Refinery	22,765	6.3%
GoEnergy Company Ltd.	14,075	3.9%
Others: Blue Ocean Investments Ltd. Mobile Energy Resources Ltd. XF Petroleum & Engineering Ltd.	701	.2%
Total	358,932	100.0%

Sage Petroleum is the leading BDC by market share. It is the Ghana Gas Company's exclusive contract lifter of LPG. It is part of a corporate group with both OMC and BDC units. It sells to the licensed OMCs/LPGMCs.

Second is Fueltrade, which has no OMC affiliate.

Dome Energy procures propane for Genser Power for use in power generation.

GoEnergy, sixth, is a subsidiary of GOIL. In addition to importing LPG, also it buys from other BDCs.

88 Amounts do not add exactly due to rounding.

Oil Marketing Companies (OMCs) and LPG Marketing Companies (LPGMCs)

152 companies were licensed as Oil Marketing Companies (OMCs) or LPG Marketing Companies (LPGMCs) as of the end of 2017.

OMCs are typically larger, multistation, multifuel petroleum distribution companies that pursue a national marketing and retailing strategy. The market leader is Ghana Oil (GOIL), a partially state-owned company with approximately 8% market share in LPG and 52 microstations located in nine of Ghana's ten regions.

The existence of a license does not guarantee LPG activity. Of these 152 licensed companies, only 81 reported any LPG sales volumes for 2017. Of those 81, 39 were pure LPG players (LPGMCs). The top 10 (of the 81) had a combined LPG market share of 45%. By global standards, this is a highly fragmented market.

The following figure and table show the top market shares for 2017:

Figure 31. LPG marketers (OMCs and LPGMCs) market shares (2017)

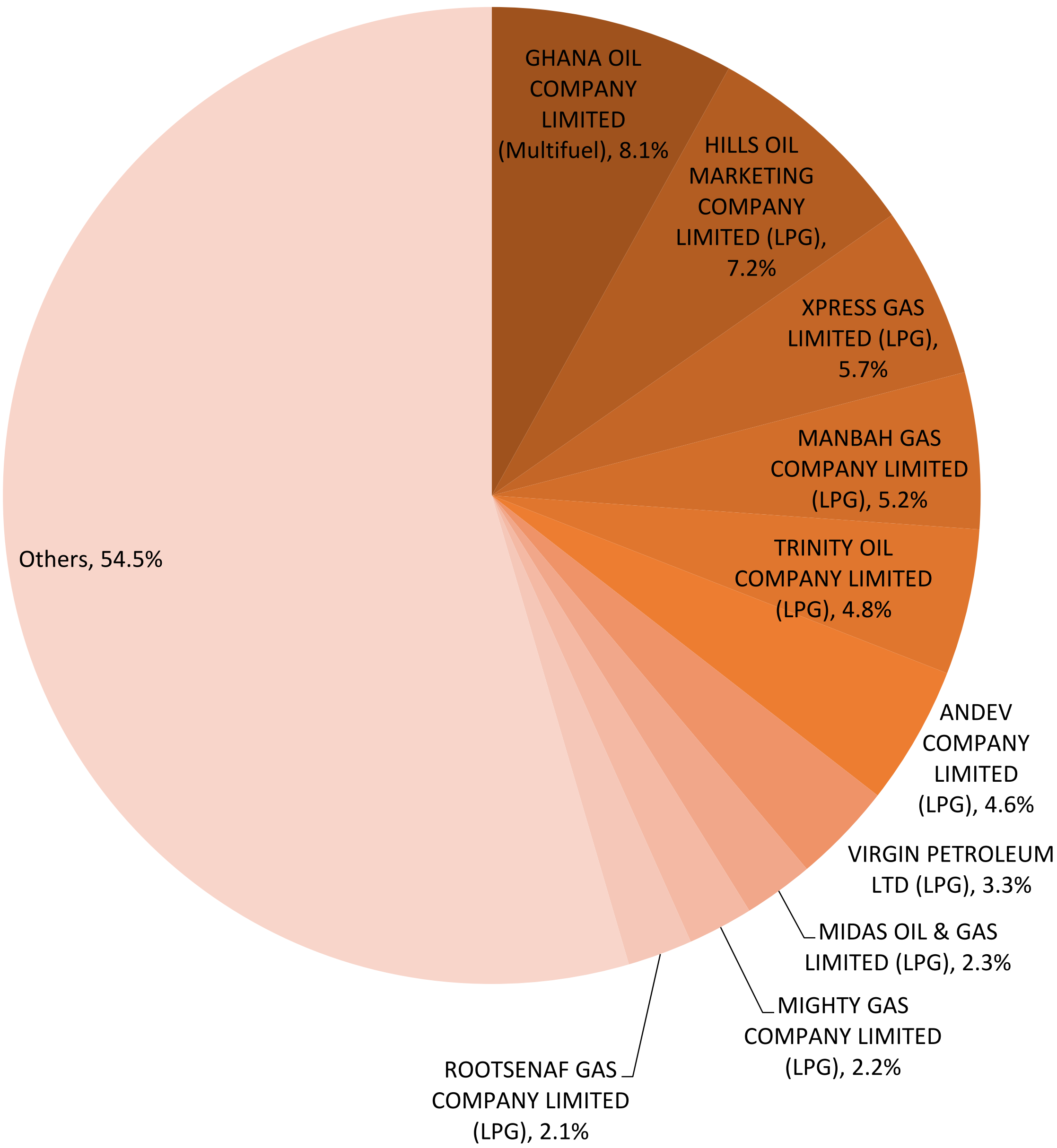


Table 23. LPG marketers (OMCs and LPGMCs), volumes and market shares (2017)

Company	LPG Sales (MT)	LPG Market Share	Type
Ghana Oil Company Limited	22,298.9	8.1%	Multifuel
Hills Oil Marketing Company Ltd.	19,939.1	7.2%	LPG
Xpress Gas Limited	15,696.8	5.7%	LPG
Manbah Gas Company Limited	14,303.2	5.2%	LPG
Trinity Oil Company Limited	13,341.6	4.8%	LPG
Andev Company Limited	12,713.7	4.6%	LPG
Virgin Petroleum Limited	9,216.4	3.3%	LPG
Midas Oil & Gas Limited	6,403.8	2.3%	LPG
Mighty Gas Company Limited	5,978.8	2.2%	LPG
Rootsenaf Gas Company Limited	5,936.6	2.1%	LPG
Others (71)[89]	150,874.0	54.5%	Multifuel: 41 LPG: 30
Total	276,702.8	100%	Multifuel: 42 LPG: 39

There are two main differences between an LPGMC and an OMC, defined in their respective governmental licenses:

1. The OMC operates service stations for petroleum products that may include LPG; the LPGMC operates only LPG stations;

2. The OMC has double the capitalization requirement for a license (GHC 4 million from recognized financial institutions) than an LPGMC (GHC 2 million).

An OMC or LPGMC license may only be obtained by a Ghanaian citizen or company, or a joint venture between a foreign and Ghanaian entity. The licensee must have a minimum of seven filling facilities. This requirement has kept the OMC/LPGMC node in the chain from hyperfragmenting, by forcing station operators with fewer than seven facilities to operate under a dealer (retailer) contract to an OMC or LPGMC.

OMCs and LPGMCs typically operate a hybrid distribution system to serve the household market: they build, own and operate microstations of their own and, in parallel, develop and utilize networks of third-party distributors and dealers to reach additional household consumers.

Because LPGMCs' business strategies do not depend on other petroleum products and associated assets, LPGMCs have historically been more aggressive and more successful, as a group, in penetrating the residential LPG market than the OMCs. In a 2014 study, it was found that pure LPG companies' stations outperformed multifuel companies' stations 11 to 1, measured in volume per station. Individually, however, LPGMCs tend to be smaller entities, financially and organizationally, than OMCs.[90]

Ghana's OMCs and LPGMCs are listed, together with basic LPG statistics about each, in Annex Chapter 30 (Profiles and Statistics of LPG Sector Actors in Ghana) beginning on page 314.

89 Two OMCs that had some LPG activity in 2017 had no LPG activities in 2018, as of this writing.

90 WIVP (2014)

A few LPGMCs have started to experiment with BCRM business models and the associated logistics in advance of the implementation of BCRM.

Transportation services

Transportation of LPG must be carried out under Ghanaian regulation by dedicated Bulk Road Vehicle (BRV) operators. As of this writing, Ghana has 193 LPG BRVs in operation. These earn a small unit margin for moving LPG in bulk from bulk storage facilities to the microstations. (See Chapter 10 (Pricing) beginning on page 53 for the margin details.)

Microstations and Retailers/Dealers

There are approximately 650 microstations in Ghana.

The LPG microstations are grouped into three categories:

1. COCO: Company-owned (by OMC/LPGMC) and company-operated (by OMC/LPGMC)
2. CODO: Company-owned (by OMC/LPGMC) and dealer-operated
3. DODO: Dealer-owned and dealer-operated, under contract with an OMC or LPGMC

The notion of "Company" is suggestive of the relative size and the organizational form of the parties: OMCs and LPGMCs (COCO and CODO) are companies; retailers/dealers (DODO) may be companies but most often are sole proprietorships, with a majority of the retail microstation operators in Ghana having but one station.

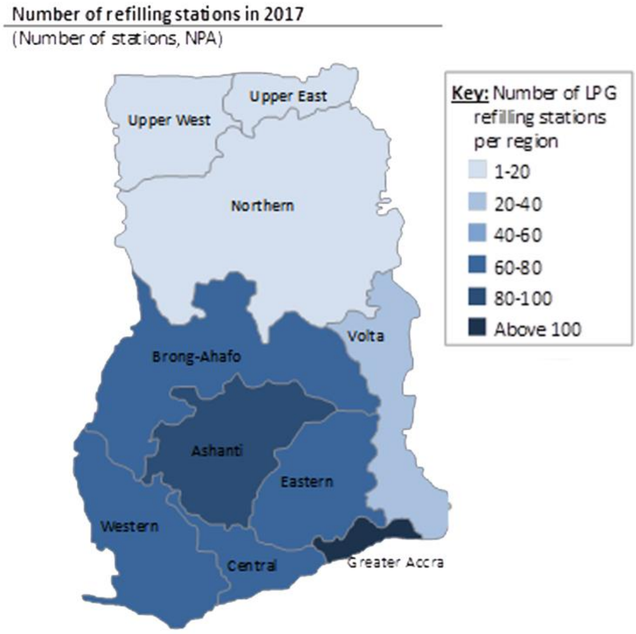
Licensing for new stations has been halted by the NPA in anticipation of the transformation of the value chain from CCCM to BCRM. Despite the halt in new licenses, the number of microstations fluctuates during the year as some go out of business, some new ones legitimately bypass the halt through grandfathering provisions, and some change hands or consolidate.

The sheer quantity and geographic spread of the microstations creates a regulatory enforcement challenge for the Government, although it also provides a relatively easy way to generate revenue for the regulator: namely, by charging licensing and ongoing license renewal fees to all of them.

According to the association of small microstation operators, the Ghana LPG Operators Association (GLiPGOA), the capital outlay to establish a microstation is on the order of USD \$100,000 - \$150,000. Often, these stations are financed with bank loans, secured by the station LPG tanks as collateral.

Geographically, the stations are almost entirely clustered in the south of Ghana, as shown in the map below:

Figure 32. Density map of Ghana LPG microstations (2017)



The microfilling stations serve both residential LPG cylinders and vehicles retrofitted to accept LPG as their fuel in lieu of petrol.

The future value chain under BCRM

As of this writing, final determination by the Government on the structure, parameters and rules for the BCRM value chain had not yet been made. This section describes what is known (that is, what is highly probable based on Government statements and actions to date), together with the main alternatives still being contemplated.

The following two figures show the main alternative ways that the BCRM value chain is likely to be structured. Nodes which will experience significant restructuring of their functions and responsibilities are highlighted in green in the figures.

The two alternatives differ in respect of one critical decision: allocation of cylinder ownership, branding, and liability functions between a new Bottling Plant (BP) node and a revised marketer (OMC/LPGMC) node.

In both cases, the business model of the existing retailer would undergo profound change. However, as is discussed in Chapter VIII (Critical Path LPG Infrastructure Investment Projects to 2030) beginning on page 134, the number of distributors and retail (cylinder exchange) points must undergo massive expansion in order to achieve the governmental policy goal, and to satisfy the latent national demand; the existing microstation locations represent less than 20% of the total locations that would be required.

A discussion of the supply chain nodes under BCRM follows the figures.

Figure 33. LPG value chain, post-BCRM (alternative 1 – OMCs/LPGMCs own cylinders/brands)

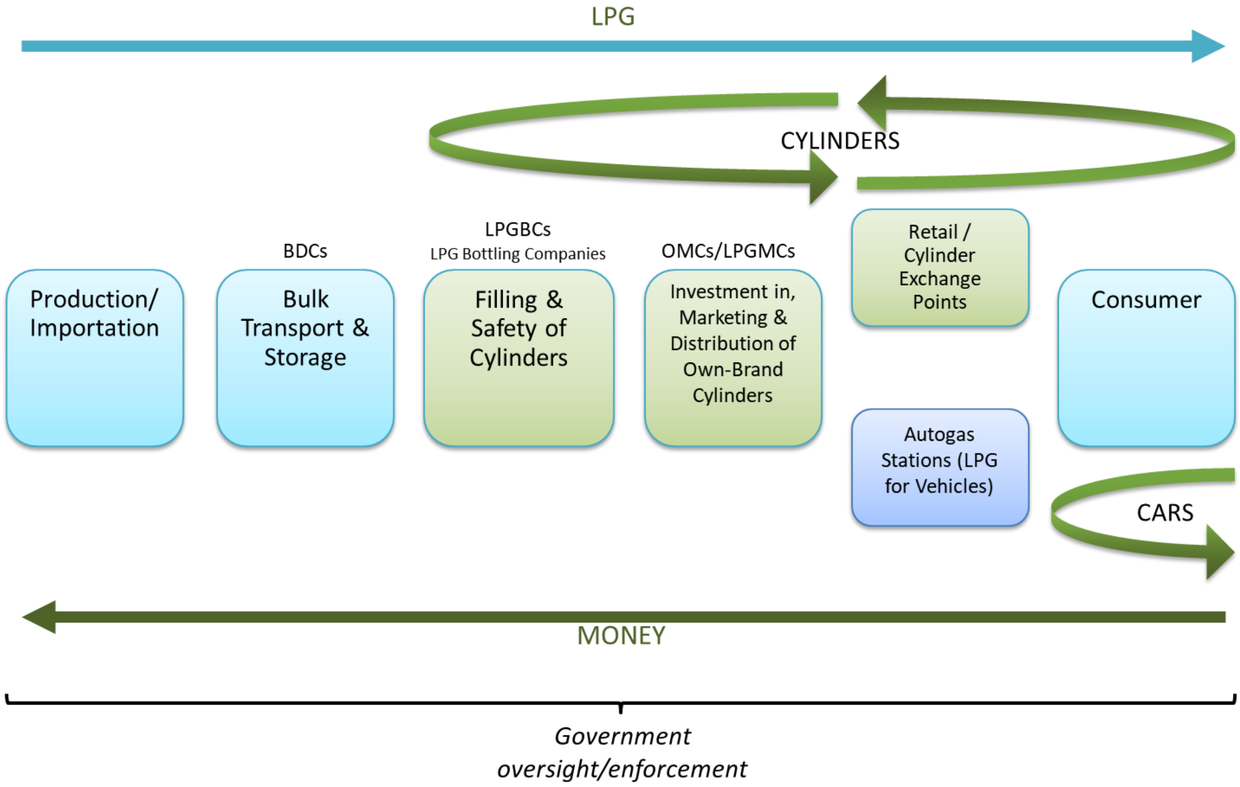
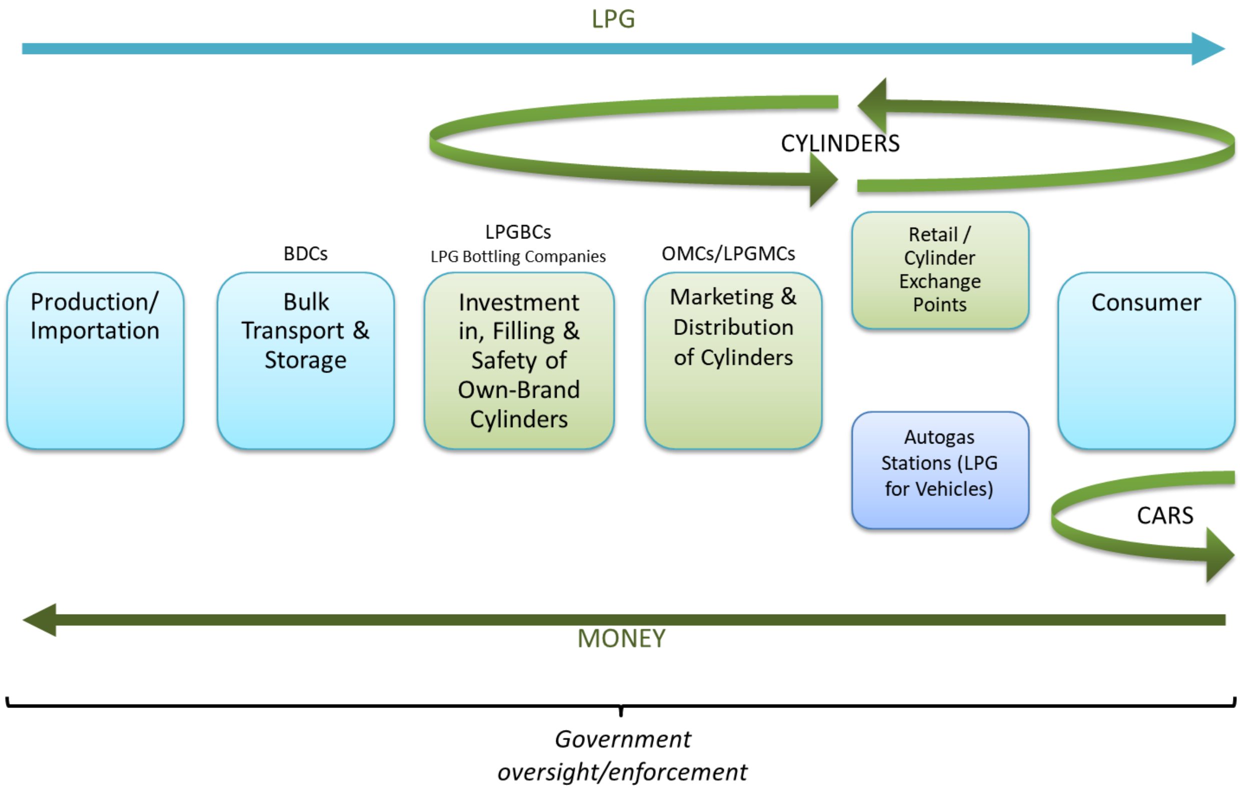


Figure 34. LPG value chain, post-BCRM (alternative 2 –bottlers own cylinders/brands) (recommended)



The vital reasons that the second alternative is recommended are that

- It is of critical importance for the success of BCRM over time that the investment, branding, deployment, inspection, maintenance, scrapping as needed, and refilling of cylinders is concentrated in a single node. This node would be called the “marketer” node in most other countries in standard LPG industry terminology. In Ghana, the term “marketer” is, instead, assigned to companies involved in the existing distribution system (e.g., OMCs, LPGMCs).

- The Bottlers have much larger individual shares of the cashflows created in the value-chain, and have a mix of immobile, lower-risk assets (filling plants and storage) and mobile, higher-risk assets (the cylinders), compared with the much more fragmented marketers, which have negligible LPG-related immobile assets and face significantly more competitive pressure. This makes the bottlers much more bankable than the marketers, for the same cylinder assets.

- Additional reasons are described in Chapter 20 (Summary of Main Project Risks, Mitigations and Mitigation Sources) beginning on page 214.

The Government of Ghana is considering a split of those linked responsibilities across two nodes: a Bottling Companies node (LPGBCs), which would be responsible for cylinder inspection, maintenance, scrapping, and a “marketing” (in the Ghanaian sense) node, which would be responsible for cylinder investment, branding, and deployment. The marketer node companies would contract with bottling plant node companies for the cylinder tasks allocated to the bottling plants.

As of this writing, the NPA is contemplating the licensing and commissioning of 8-10 large, regional bottling plants that would serve the consumption needs of the nation, with the long-term possibility to add satellite plants at a later stage of market expansion.

There are three main risks, based on international LPG sector experience, and one main advantage, based on Ghana’s circumstances and history, associated with the contemplated split of cylinder responsibilities across two nodes in the chain:

Risks:

- Bankability of the marketing companies, as discussed above.

- There could be potentially dozens of cylinder brands competing throughout the country, because there are some 81 existing licensed marketers (using the Ghanaian definition) of LPG. This level of fragmentation makes brand differentiation is highly problematic for the consumer; it is more challenging for the regulator to oversee; it is more difficult for financing sources to perform due diligence, justify transaction costs, and manage investments; due to economy-of-scale factors inherent to the LPG business, the investments and costs associated with cylinder acquisition and cylinder operations are likely to be somewhat greater. Even with encouragement by Government of a 2:1, 3:1 or even 4:1 consolidation of players, the brand count would remain impractically high.

- By separating cylinder investment and branding from cylinder safety responsibilities, the responsibility and incentive for investing in the safety of the cylinders is diffused, and may lead to suboptimal safety performance and greater difficulty in enforcing accountability (that is, assigning blame) for safety incidents.

Advantage:

- The existing licensed marketers (using the Ghanaian definition) of LPG are, pardoning the tautology, already-existing marketers of LPG in cylinders, as well as of LPG for vehicles. This suggests that it should be relatively easy from a political, regulatory, consumer awareness, and customer relationship standpoint to have the existing Ghanaian OMCs and LPGMCs continue in their historical role as the to-be-branded locus of LPG services to the consumer. The OMCs and LPGMCs may resist sharing brand equity (which would be carried forward in their autogas business) with cylinder brands controlled by Bottling Plant companies.

The second value chain alternative (Figure 34) moves all the "marketer" functions (using the global industry definition) to the Bottling Plant entities. Under this alternative, there would be up to 8-10 cylinder brands, based on how many different companies build and operate new, regional LPG bottling plants. The existing "marketers" (using the Ghanaian definition) under this alternative would be more like master distributors, partnering with the bottling plant companies to develop, expand and operate distribution networks.

The set of advantages of the second alternative is the inverse of the set of risks from the first: (i) a simplified universe of cylinder brands for the consumer; (ii) easier regulatory oversight; (iii) larger investment transactions with easier due diligence and stronger underlying balance sheets; (iv) economy-of-scale benefits in capital costs and operating costs; and, most importantly, (v) very straightforward and direct alignment of the safety of, accountability and liability for, refill income from, and investment in, cylinders.

A third choice would be to allow companies to operate in both the bottling plant and marketing nodes at the same time. However, the Government has determined not to allow this.

Recognizing the commercial advantages of operating across both nodes at once, some companies bidding on licenses for the 8-10 new bottling plants have established holding-company structures, through which different operating units can exist as separate entities, each operating in a different node of the supply chain, with aggregated financial gains coming to (and possibly overall managerial oversight coming from) the holding company level.

Under both of the foregoing alternatives, LPG cylinders will recirculate between the user and the regional filling facility (via truck transport by authorized road transport companies). The user drops off an empty cylinder at a local retail point of sale and exchanges it for a full cylinder, paying the cost of the refill to the retailer.

The nodes in common to both alternatives, defined by their main functions, are:

1. *Production/Importation*. This node is carried forward.
2. *Bulk Transport and Storage.* This node is carried forward, except that the end-point for bulk deliveries is a microstation only for autogas sales; the end-point for the cylinder market is the new Bottling Plant node.
3. *Retail / Cylinder Exchange Points.* Existing microstations would be transitioned in one of two ways:

i) Licensed to sell LPG for vehicle use (autogas) only; or

ii) Licensed to operate as a distributor and/or cylinder exchange point operator for residential LPG cylinders.

An issue of contention in the national planning debate, described below in more detail, is a third potential outcome for existing microstation operators: closing down.

Thousands of new retail points will be required to serve the demand expected to be unlocked through sector reform, new investment to expand infrastructure and distribution, consumer empowerment programs, and LPG promotion and education. These can be dry goods shops, food markets, energy products retailers—indeed, any sort of retail establishment located near to consumers that meets the requirements for safe storage and handling of LPG cylinders. A retail point with as few as a dozen cylinders in inventory can be viable, especially when selling other consumer products as well[91].

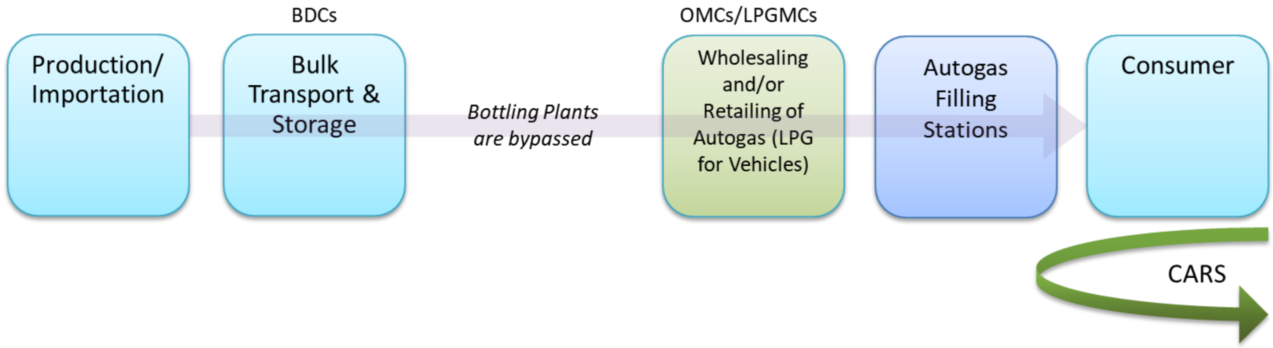
4. *Autogas Stations*. Microstations which sold LPG refills for both residential cylinder-owners and for vehicles (i.e., autogas) would, in some cases, be permitted by the NPA to continue operating their autogas business while closing down their non-autogas business. This splits the "last mile/kilometer" of the distribution system into a distinct residential (and small business) cylinder-exchange subchain and a distinct vehicular filling subchain (see Figure 35. Autogas stations would obtain their LPG in bulk from the OMC/ LPGMC node, and the LPGBC node would be bypassed.

5. *Consumer*. The consumer must trade in his/her old, generic cylinder for a new, branded one under BCRM. The details of the trade-in program terms and operation are still being determined by the Government as of this writing. A new LPG consumer obtains his/her branded cylinder from a retail point by making a cash deposit (this gives him/her the right to use a cylinder) and paying for the LPG it contains. When that cylinder becomes empty, the consumer returns it to the retail point and exchanges it for a full cylinder of the same brand, paying for the quantity of LPG in the replacement cylinder. If the consumer stops using LPG (such as to switch to natural gas or electricity for cooking), s/he may return the cylinder to the retail point and receive back his/her deposit.

The following figure shows the anticipated autogas value chain in isolation, as referenced above. To the extent commercially viable and sustainable, OMCs and LPGMCs may be expected to operate concurrently in both the autogas subchain and the residential cylinder subchain.

91 By way of example: A small shop proprietor surveyed in Accra was found to sell two main products, eggs and LPG—food and the fuel to cook it without pollution, all in one place.

Figure 35. Autogas-only value subchain, post-BCRM



As discussed more fully below, current microstations, serving both household and automotive customers, are expected to be required to choose between their autogas and cylinder businesses, and in up to 80% of cases to relocate their facilities for reasons of enhancing public safety, under the contemplated new NPA rules.

Transitioning the microstations

A question that led to significant political debate during 2017 and 2018 is what the transition portends for the present microstation owners. As shown in the foregoing figures, their roles in both residential cylinder filling and autogas change under BCRM, potentially in a very significant way.

Splitting their vehicular from residential cylinder refill business would reduce revenues for most stations, at least in the near term. This could make debt coverage difficult or impossible for station owners with sizeable bank loans. Moreover, in accordance with the President's policy directive of 12 October 2017, high risk stations must be moved away from populated areas, or shuttered.

An initial NPA review of the stations classified approximately 80% as being in high risk areas. (Resulting from subsequent discussions between NPA, the Ministry of Energy (MoE), and GLiPGOA, an intermediate "medium risk" category was created, with an opportunity for the risk profile of such stations to be improved before a final determination is made.)

Stations which convert to LPG cylinder distribution depots or retail points would require working capital to finance their cylinder inventory, and would potentially lose revenue and debt service capacity from giving up existing vehicular LPG business, at least in the near term.

The Ministry of Energy and NPA have encouraged microstation operators to consider consolidating their operations to increase their collective financial strength, as well as to plan for a change of role.

The station operators initially responded with a threatened national strike and a lawsuit against the Government. However, the strike was brief and ultimately not effective, and the lawsuit was dismissed. Since then, the political debate has subsided (but not ended), and the government is moving forward with its planning, without an agreed solution in place for the small microstation operators. The microstation operators continue to mount public-relations challenges to the Government's plan, as of this writing.

Because of the political sensitivity of this debate, GLPGP was requested not to make a recommendation about potential solution parameters.

Future responsibilities of Bottling Plants (BPs) and LPG marketers (OMCs/LPGMCs)

As part of implementing BCRM, the Government will determine whether investment, branding, and safety responsibility for the nation's inventory of LPG cylinders lie with the companies occupying the new Bottling Plant node or will be added to the OMC/LPGMC node.

As of this writing, the NPA has indicated a preliminary preference for the latter, with the intention of encouraging consolidation among the companies in that node to reduce the extent of fragmentation, facilitate and simplify branding, strengthen the consolidated entities financially and operationally, and make regulating them more efficient and effective.

The following table describes the consequences for these two nodes under each alternative:

Table 24. Comparison of brand-ownership alternatives under BCRM

Supply chain node	Brands owned by the Bottling Companies	Brands owned by the Marketing Companies
LPG Bottling Companies (LPGBCs)	• The 8-10 BPs each own a corresponding cylinder brand, invest in new branded cylinders, distribute them through the OMCs/LPGMCs • BPs are allocated additional margin associated with the cylinder investment • BDCs sell bulk LPG to the BPs • BPs distribute their full cylinders and reclaim their empty cylinders through the OMCs/LPGMCs and their retail networks	• The 8-10 BPs inspect, maintain, and refill cylinders under contract on behalf of the OMCs and LPGMCs • BPs receive LPG in bulk on behalf of the OMCs/LPGMCs
LPG Marketers (OMCs / LPGMCs)	• The 8-10 BPs are contracted by appropriately licensed OMCs and LPGMCs to inspect, maintain and refill the branded cylinders owned by the OMCs/LPGMCs • OMCs/LPGMCs receive filled branded cylinders from the BPs for distribution through their retail networks, and reclaim empty cylinders from their networks on behalf of their BP partners	• Appropriately licensed OMCs and LPGMCs each own a corresponding cylinder brand, invest in new branded cylinders • The OMCs/LPGMCs each contract with a BP for inspection, maintenance, and refilling of their cylinders • The OMCs/LPGMCs are allocated additional margin associated with the cylinder investment and to cover the service costs they pay to the BPs • The OMCs/LPGMCs distribute full cylinders and reclaim empty cylinders through their retail networks • BDCs sell bulk LPG to the OMCs and LPGMCs

Under either alternative, the Bottling Plants would have as a condition of licensing a minimum storage capacity of 250 MT (two days' worth, if operating eight hours a day and filling a minimum of 1,000 cylinders an hour) and a minimally sufficient maintenance facility to check for dents, leakages, replacement of valves, and so on.

A historical factor influencing the choice of how to allocate cylinder investment and branding responsibility between BPs and marketers in the value chain is the branding of the autogas. If cylinder investment and cylinder branding are assigned to the BP node, but autogas branding remains in the OMC/LPGMC node, it could potentially create an undesired brand conflict for the marketers and their distribution channels between the two subchains (autogas and cylinder).

How to decide the tradeoff between preserving historical branding advantages perceived by the OMCs and LPGMCs and maximizing investment bankability and safety accountability for major new cylinder assets is expected to be determined by the Government during early 2019.

Commissioning of Bottling Plants

The NPA has established general specifications, and a process, for proposals and bidding by the private sector to obtain licenses to become Bottlers (that is, to construct and operate the new regional bottling plants) starting in 2019. Initial responses have been received for each plant, with some companies (such as GOIL) proposing to own and run multiple plants, and some plants receiving multiple competing responses from private sector companies.

As mentioned in Chapter 9 (Complementary Policy Initiatives) beginning on page 50, the Government has instituted a Ghanaian ownership requirement. For BPs, this requirement is 100% equity ownership in the LPG Bottling Company by a Ghanaian citizen or Ghanaian corporate entity.

The license terms also require the license to have the capability to upgrade the plant to 750 MT of storage within five years and to have a minimum US $1.2 million (or equivalent) of evidenced trade financing in the form of equity cash on account or a trade or credit facility with one or more reputable institutions. Licensees will have two years from the date of obtaining a construction permit to put their plant(s) into operation.

A full discussion of planning for the Bottling Plants and other new assets, including cylinders, is covered in the next Part of this report.

As of this writing, the following prospective licensees and bidders for the Bottling Plants are publicly known, together with their status:

Table 25. Bottling Plant license applicants and status

Company	**Status**
Ghana Gas Company	Approved
Ghana Oil Company (GOIL)	Approved (bidding for three plants)
Quantum Terminals	Application in review
Puma Oil[92]	Application in review

92 Puma is a midstream and downstream oil and gas company, majority-owned by the trader Trafigura of Singapore and by Sonangol of Angola.

GOIL intends to construct three Bottling Plants, at Tema, Kumasi and Talame. GOIL has announced it will spend an initial GHC 50 million (approximately € 9 million) toward development of the plants and an expanded footprint of its LPG distribution centers.

Quantum intends to construct three Bottling Plants, at Tema, Atuabo and Kumasi. The Tema plant would have 900 MT of storage and throughput of 19,000 cylinders per day. Quantum would bring its own financing, through Arch Holdings as lead financial partner, with a preliminary cost estimate of US $37 million. The Atuabo plant would commence construction in the first half of 2019, with 300 MT of storage and throughput of 2,000 cylinders per day (below the license requirement), at an estimated cost of US $25 million. Details of the Kumasi plant have not been announced.

Future importation, production and bulk storage capacity

The present national capacity and planned additions to capacity are adequate in the near and medium term for the forecasted increase in importation, production, and storage volumes under the growth scenario corresponding to the national LPG policy goals, and therefore these are not further analyzed in this report. Over time, if the anticipated consumption is exceeded, adding capacity to these categories of infrastructure may be necessary, and should in turn be duly studied and planned.

VIII. Critical Path LPG Infrastructure Investment Projects to 2030

This Part describes the key infrastructure projects to be undertaken to achieve the Government of Ghana's policy goal of 50% of the population using LPG for cooking by 2030.

Adoption and rolling out of BCRM will lead to many changes, including:

1. Reduced risk for the population, because refilling points will be regionalized in, notionally, 8-10 high-efficiency Bottling Plants (BPs) located away from populated areas;

2. Reduced risk for the end-user when using LPG, because, through the recirculation of cylinders to the BPs, there will be rigorous inspection and repair of cylinders with every refill cycle, and unsafe cylinders will be systematically replaced by safe ones at no additional cost to the end-user; and

3. Clear responsibility will exist for the maintenance of the cylinder. The responsibility would ideally be assigned to the BP companies, each of which invests in cylinders for its region, controls its cylinder's brand, and obtains a stream of profits from refilling its cylinders over their lifecycles.

The implementation of BCRM concerns not only the construction of BPs (none of which currently exist in Ghana), but also, in parallel, defining the enabling environment for the sector as whole, as discussed in Part V (LPG Enabling Environment).

From the perspective of lead times to develop critical infrastructure and put it into operation, the NPA has prioritized the specification and bidding for licenses to construct and operate the BPs. The Bottling Plant license terms published by NPA allow for a two year construction period once all permits have been obtained. Two years is a conservative estimate, based on best practices for LPG planning and construction in Sub-Saharan Africa. The NPA is hopeful that a first plant can be operational by 2020.

As described in the prior Chapter, the governmentally-determined business model for the BPs has not been finalized as of this writing. Thus, precise planning for the new infrastructure, business activities, and investments remains, temporarily, a moving target. Nonetheless, applications have been received and in some cases approved by NPA for licenses to construct and operate BPs from multiple companies, as detailed in Table 25 in Chapter 14.

This Part describes GLPGP's recommended scenario of the sizing and locations of the BPs and estimates the costs and conditions for the construction thereof, to achieve the national LPG use goal in the context of BCRM. The estimates of costs have been built on the basis of international technical standards for construction of BPs[93]. This Part also discusses the financial modalities and expectations for the LPG marketers under that scenario.

It is important to note that governmental decisions that are still pending, if decided differently from what is recommended and anticipated as of this writing, would require the scenario to be revisited in future using changed assumptions.

93 Like the API, the ASTME includes all relevant standards for the construction of LPG BPs.

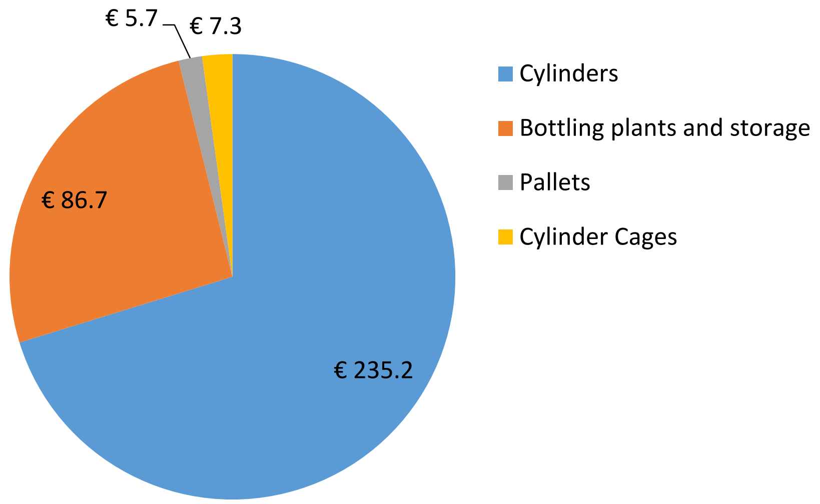
Upon completion of these investment projects, Ghana would have a network of high-standard BPs with the capacity and capability to address the safety, productivity, and quality needs of refilling of cylinders at scale. The marketers would have a corresponding, reliable, commercial model around which to plan and carry out business expansion, develop deeper and broader retailing footprints, and participate in sector-wide expansion financing.

The acquisition of cylinders, being a procurement task, is addressed in detail in Part IX (Financing). The quantity of cylinders in circulation and their velocity (rotation rate, in industry terms) along the value chain is related to the required capacities of the BPs.

The total investment requirement is summarized in the following table:

Table 26. Capital investment requirements to 2030 for LPG sector scale-up

Category	Capital requirement (mm Euro)	Supply chain node
Cylinders	€ 235.2	Bottler or marketer[94]
Bottling plants and storage	€ 86.7	Bottler
Pallets	€ 5.7	Bottler or marketer[94]
Cylinder Cages	€ 7.3	Retailer
Total	**€ 334.9**	



The BPs and marketers together represent 98% of this total, comprising cylinders, bottling plants and adjacent bulk storage, and pallets. Cylinder cages would be deployed for the management of cylinder inventory in the distribution and retailing part of the supply chain.

As shown in the foregoing chart, cylinders represent the largest single asset type by far for the LPG sector's desired expansion, followed by the property, plant and equipment of the BP companies.

94 The final determination by Government of which node shall be required to invest in, brand and deploy cylinders into the market and maintain and ensure their safety has not been completed as of this writing.

15. Investments at the Sector Level

This Chapter describes the investments necessary over time to achieve the governmental policy goal of LPG adoption and use by 50% of the population for cooking by 2030 in aggregate, at the sector level. This investment stream is calibrated in four main ways, and may be recalibrated in future as needed:

1. *Demand*. The growth of the sector, target user population and usage volume of the policy-goal investment scenario fall within the lower and upper bounds of the demand assessments set forth in Part VI (LPG Demand Potential to 2030) beginning on page 66;
2. *Financial returns available to investors and lenders*. The financial returns of the investments are consistent with identified requirements of anticipated participants in the capital stack, as described in Part IX (Financing) beginning on page 184;
3. *Normative LPG industry operational and cost-structure ratios*. The operational performance of the supply chain nodes is consistent with LPG industry operating and costing norms for Sub-Saharan Africa LPG markets where BCRM is practiced;
4. *Future growth dynamics.* To the extent the demand estimates prove to be greater than actual demand, the rate of investment can be slowed or halted in any year to rebalance supply, capacity, capacity utilization, and supply-chain growth with actual demand and the actual rate of demand growth. If demand estimates prove to be lower than actual demand, the rate of investment can be accelerated up to the sustainable growth rate limit of the businesses in the supply chain, or can be continued beyond 2030, to catch up to actual demand and, potentially, to the rate of demand growth.

Chapter 16 examines the investment economics and returns at the firm level.

The key metric which ties together all aspects of the financial and operational modelling of the investments, and of the firms, is the number of cylinders required to be in national circulation (i) for the expected usage to be served reliably by the supply chain, and (ii) for the LPG supply chain to generate adequate cashflows to pay for required operations, growth, and the anticipated financial returns required by investors and debt payments required by lenders.

The number of cylinders required is a function of

1. The number of users;
2. The frequency of refilling of their cylinders;
3. The mix of sizes of cylinders; and
4. How and how quickly the cylinders recirculate within the supply chain.

The investments are staged in a series of approximately linear steps over ten years, both to optimize returns and minimize execution risk, except that a significant boost to branded cylinder inventory is required at the very start in order to launch BCRM.

The number of users is projected in Part VI. As elsewhere in this document, a “user” is a member of a household that uses LPG for cooking. Because Ghana has no modern history with cylinder recirculation, this analysis utilizes industry standard operational parameters for modelling. These are detailed hereafter.

The refill frequency is solved for through analysis of other operational, inventory and usage statistics, and is evolved over time to converge with industry norms for BCRM in equivalent- and larger-sized LPG markets (measured in usage per capita) in Sub-Saharan Africa. The industry term for this parameter is the cylinder rotation rate, which is a function of multiple drivers that include gross and average consumption level by households, the mix of cylinder sizes, the efficiency of the supply chain including its logistics, the level of diversion (loss, whether temporary or permanent) of cylinders to competitive interventions (legal or illegal) and to mishandling in distribution, the extent of ongoing cylinder maintenance and scrapping required, and other factors. The rotation rate is a key metric for an LPG business to assess and predict the earnings generated by the cylinder inventory it owns or manages. A declining rotation rate in a given geography is a leading indicator of saturation of that geography's LPG market, all other things being equal, and is a reason to slow or pause further investment.

The main cylinder sizes in Ghana for households are 6kg and 14.5kg, with existing data about the mix of sizes.[95] That mix has been assumed to continue in this analysis. For purposes of the analysis, cylinders are defined using a measure of kge (kg-equivalent). That is, a 6kg LPG cylinder (for example) is treated as equivalent to 0.414 14.5kge cylinders, or 12/29ths of a 14.5kg cylinder, the most common size of cylinder in Ghana. Where "kg" is used regarding cylinders, it indicates a specific cylinder size; where "kge" (or "kgeq") is used, it indicates a weighted average of sizes.

The combination of expected (and desired) LPG adoption and consumption rates by households, cylinder rotation rates, associated cylinder inventory requirements, and other factors drives the sizing and costing of the LPG infrastructure that will be required to serve future demand. The sector-level modelling of the needed infrastructure and investments was performed regionally, because (i) the necessary regional data exist, (ii) regional variations in the key parameters are large enough to be material, and (iii) the national LPG expansion strategy[96] is based on implementing regionally centralized bottling facilities.

Summary of projected LPG volumes

As discussed in detail in Chapter 10 (Pricing) beginning on page 53 and Part VI (LPG Demand Potential to 2030) beginning on page 66, LPG end-user pricing may be increased by the Government in connection with the launch of BCRM in order to cause the consumer to pay, in full or in part, for new supply-chain functions and for infrastructure capital cost recovery. The notional maximum extent of such a price increase is proposed to be € 0.123 per kg, which, if passed on fully to the end-consumer, is modelled to result in reduction in consumption volume of approximately 5.6% but negligible effect on the percentage of new households adopting LPG (and requiring cylinders).

A reduction in consumption without a corresponding reduction in the number of users implies a reduction in the refill rate. However, the cylinder inventory requirement does not decline materially, because the refill rate is only one of many factors affecting the national cylinder requirement.

The cylinder requirement is calculated for each region using a 2017 baseline of its residential LPG consumption and cylinders, the population served per existing cylinder, its rate of population growth, the

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95 A final decision by Government regarding what cylinder sizes will be permitted under BCRM, and what if any alternate sizes in use in Ghana must be discontinued, is still pending as of this writing. The analysis in this Part is based on the latest guidance from NPA taken together with survey data about the existing national cylinder inventory, classified by cylinder size.

96 Ministry of Energy (2017); NPA (2018)

implied cylinder rotation rate, working stock requirements, and cylinder replacement inventory requirements related to the trade-in of existing unbranded cylinders and their replacement with branded cylinders, including governmental and industry expert analysis of the number of existing cylinders which can be refurbished and the number which can be scrapped, and the expected level of average consumption per LPG user in 2030 (25kg) from the demand projections.

These elements are shown in the following set of tables:

Table 27. LPG consumption by region (2017)

			LPG consumption[97]	
Region	**Population[98]**	**LPG penetration rate**	**In residential cylinders (MT)**	**As Autogas and in bulk (MT)**
Upper West	811,124	6.1%	1,237	1,375
Upper East	1,216,680	6.6%	2,008	1,050
Northern	2,925,831	3.4%	2,487	1,935
Brong-Ahafo	2,723,050	11.4%	7,761	19,094
Ashanti	5,533,011	23.2%	32,091	19,947
Eastern	3,099,641	17.1%	13,251	11,220
Western	2,954,789	24.4%	18,024	5,869
Volta	2,491,293	17.2%	10,713	16,146
Central	2,479,279	23.1%	14,318	15,627
Greater Accra	4,721,889	54.1%	63,864	23,895
Total	**28,956,587**	**22.9%**	**165,753**	**116,15T**

Applying the region by region penetration projections from Part VI, and solving for an average penetration target of 50% nationally in 2030 for achievement of the governmental policy goal, the following regional breakdown of future regional consumption results for residential cylinders:

Table 28. Estimated cylinder filling volumes and penetration by region in 2017 and 2030

Region	LPG volume in cylinders (2017)	LPG volume in cylinders (2030)	Population (2030)	Penetration rate (2030)	Persons per cylinder (2017)	Persons per cylinder (2030)
Upper West	1,237 T	8,625 T	1,092,706	26.1%	22.8	5.0
Upper East	2,008 T	8,655 T	1,639,103	17.5%	21.1	7.4
Northern	2,487 T	17,786 T	3,941,688	14.9%	40.9	8.7
Brong-Ahafo	7,761 T	35,217 T	3,668,505	31.8%	12.2	4.1
Ashanti	32,091 T	111,272 T	7,454,090	49%	7.3	2.9
Eastern	13,251 T	32,163 T	4,175,895	26%	8.8	5.3
Western	18,024 T	61,281 T	3,980,687	51%	7.1	2.9
Volta	10,713 T	40,365 T	3,356,256	40%	8.8	3.4
Central	14,318 T	38,797 T	3,080,005	38%	7.3	3.5
Greater Accra	63,864 T	131,111 T	6,361,274	68%	3.2	2.2
Total	**165,753 T**	**485,272 T**	**38,750,208**	**50%**	**7.2**	**3.4**

[97] NPA (2018)

[98] GLSS 7 (2018)

This projection reflects an average level of LPG use by an LPG user through 2030 of 25kg per year, as discussed in Part VI (LPG Demand Potential to 2030). The standard industry metric of 12.5kg/capita of annual nationwide consumption projected for 2030 is in line with the levels of already better-developed LPG markets in Sub-Saharan Africa, such as Senegal and Cote d'Ivoire. This corresponds to 50% of the population cooking with LPG at an average level of usage among them of 25kg/capita.

It is possible that more than 50% of the population will cook with LPG, or that users will expand their LPG use to more than 25kg per year, on average. New users may ramp up their LPG use as they gain familiarity with the use of LPG to cook an increasing portion of their meals. Others may immediately cook exclusively with LPG, far exceeding the average consumption level. The theorized maximum usage level of an average Ghanaian household that uses LPG for cooking, as discussed in Part VI, is 38 kg per year, if LPG is used exclusively for cooking all meals every day. A "user" means a member of a household that cooks with LPG.

For purposes of this Part, incremental investment in LPG infrastructure through 2030 will result in the capacity for 50% of the population to have LPG access, via a cylinder in the home, and to use LPG at or above the present average level among existing users in the country.

The following table shows the estimated cylinder rotation rates for each region:

Table 29. Estimated cylinder rotation rates by region to 2030

Region	2017	2020	2022	2024	2026	2028	2030
Upper West	2.40	2.45	2.50	2.55	2.60	2.65	2.70
Upper East	2.40	2.45	2.50	2.55	2.60	2.65	2.70
Northern	2.40	2.45	2.50	2.55	2.60	2.65	2.70
Brong-Ahafo	2.40	2.45	2.50	2.55	2.60	2.65	2.70
Ashanti	2.90	2.92	2.93	2.95	2.97	2.98	3.00
Eastern	2.60	2.63	2.67	2.70	2.73	2.77	2.80
Western	3.00	3.02	3.03	3.05	3.07	3.08	3.10
Volta	2.60	2.63	2.67	2.70	2.73	2.77	2.80
Central	2.90	2.92	2.93	2.95	2.97	2.98	3.00
Greater Accra	3.00	3.02	3.03	3.05	3.07	3.08	3.10
National rotation rate	2.85	2.86	2.88	2.89	2.91	2.94	2.96

The foregoing data, in combination, predict cylinder inventory requirements:

Table 30. Cylinder requirements to 2030, nationally and by region
(000s of 14.5kge units)

Region	2017	2020	2022	2024	2026	2028	2030
Upper West	36	55	91	125	158	190	220
Upper East	58	76	107	137	166	194	221
Northern	71	112	186	257	325	391	454
Brong-Ahafo	223	297	427	552	672	788	900
Ashanti	763	957	1,284	1,608	1,928	2,245	2,558
Eastern	351	405	486	566	643	718	792
Western	414	517	690	861	1,030	1,198	1,363
Volta	284	361	494	624	750	874	994
Central	340	404	503	602	700	796	892
Greater Accra	1,468	1,653	1,912	2,167	2,420	2,670	2,917

Region	2017	2020	2022	2024	2026	2028	2030
Total 14.5kge	**4,009**	**4,836**	**6,180**	**7,499**	**8,793**	**10,064**	**11,312**
14.5kg	3,322	4,007	5,121	6,214	7,286	8,339	9,372
6kg	1,661	2,004	2,560	3,107	3,643	4,169	4,686
6kg+14.5kg	4,983	6,011	7,681	9,320	10,929	12,508	14,059

With an existing estimated national cylinder inventory of 4.0 million 14.5kge (4.98 million total units), of which 2.0 million 14.5kge (2.49 million unit) are expected to require scrapping and replacement due to their safety condition[99], the net cylinder investment requirement to 2030 is approximately 9.5 million 14.5kge cylinders (11.8 total cylinder units).

These required cylinder inventories, rotation rates, and total LPG refill volume in each region over time are the key determinants of the required capacities of the bottling plants over time.

Bottling Plant capacities

The required total bottling capacity is estimated to be 557 KT per year, with one or two shifts of operations (labor) depending on the region, to serve the consumption corresponding to the national policy goal. This nameplate capacity allows for 16% of flexibility to cover all peak needs throughout the year.

In two regions (Greater Accra, Ashanti), a second bottling plant would be eventually required as the capacity of the first plant is outgrown. (The location of each second regional plant should be chosen to optimize transport logistics costs for the cylinders within the region.)

The investment projects are designed to cover expansion of bottling capacity across three phases, following step-wise the growth in the number of cylinders and associated refills required to achieve the national goal.

The three phases of investment are:

1. Years 2019-2020: 8 BPs totaling 302 KT of bottling capacity
2. Years 2023-2024: 2 additional BPs and an increase to 429 KT of overall bottling capacity
3. Years 2028-2029: For the 10 BPs, an increase to 557 KT of bottling capacity

Location of the BPs

The following two tables show the number of BPs and their locations across the three phases and their capacity requirements, respectively.

Table 31. Bottling Plant regional rollout to 2029

Region	City	2019-20	2023-24	2028-29
Upper West	Wa			
Upper East	Bolatanga	1	1	1
Northern	Tamale			
Brong-Ahafo	Sunyani		1	1

[99] NPA (2017)

Region	City	2019-20	2023-24	2028-29
Ashanti	Kumasi	1	2	2
Eastern	Koforidua	1	1	1
Western	Sekondi	1	1	1
Volta	Ho	1	1	1
Central	Cape Coast	1	1	1
Greater Accra	Accra	2	2	2
Total		**8**	**10**	**10**

Table 32. Bottling Plant capacity requirements by region to 2030

<table>
<tr><th>Region</th><th>City</th><th>2020 to 2022</th><th>2024 to 2026</th><th>2028 to 2030</th></tr>
<tr><td>Upper West</td><td>Wa</td><td rowspan="4">46,000 MT</td><td rowspan="3">51,000 MT</td><td rowspan="3">74,000 MT</td></tr>
<tr><td>Upper East</td><td>Bolatanga</td></tr>
<tr><td>Northern</td><td>Tamale</td></tr>
<tr><td>Brong-Ahafo</td><td>Sunyani</td><td>35,000 MT</td><td>49,000 MT</td></tr>
<tr><td>Ashanti 1</td><td rowspan="2">Kumasi</td><td rowspan="2">55,000 MT</td><td>55,000 MT</td><td>55,000 MT</td></tr>
<tr><td>Ashanti 2</td><td>23,000 MT</td><td>45,000 MT</td></tr>
<tr><td>Eastern</td><td>Koforidua</td><td>31,000 MT</td><td>50,000 MT</td><td>68,000 MT</td></tr>
<tr><td>Western</td><td>Sekondi</td><td>31,000 MT</td><td>44,000 MT</td><td>56,000 MT</td></tr>
<tr><td>Volta</td><td>Ho</td><td>22,000 MT</td><td>33,000 MT</td><td>45,000 MT</td></tr>
<tr><td>Central</td><td>Cape Coast</td><td>27,000 MT</td><td>34,000 MT</td><td>45,000 MT</td></tr>
<tr><td>Greater Accra 1</td><td rowspan="2">Accra</td><td>45,000 MT</td><td>52,000 MT</td><td>60,000 MT</td></tr>
<tr><td>Greater Accra 2</td><td>45,000 MT</td><td>52,000 MT</td><td>60,000 MT</td></tr>
<tr><td>Total</td><td></td><td>302,000 MT</td><td>429,000 MT</td><td>557,000 MT</td></tr>
</table>

In Phase 1, eight BPs will be located in the above-mentioned regions, sited according to current regional consumption of LPG. The three Northern regions (Upper West, Upper East and Northern) will be supplied by the bottling plant of the Brong-Ahafo region. A regional depot, comprising a large fenced area with guards and forklifts to load and unload pallets of cylinders, under the control of the BP of Brong-Arafo, would be set to have a stock of cylinders to be dispatched to the marketing companies (OMCs/LPGMCs) and distributors.

In Phase 2, one BP will be constructed in the Northern region (Tamale) to supply the regions of Upper West and Upper East during Phases 2 and 3. If there is a strong acceleration of cylinder uptake and refill volume growth in these two regions, the construction of an additional BP there could be justified. The minimum recommended size of a BP is 20,000 MT of refilling per year, which ensures a minimum turnover (revenue) to cover a sufficient organizational structure of skilled staff needed to deliver on quality and safety in the refilling, inspection and maintenance of cylinders.

Primary transportation of bulk LPG to the BPs

The estimated cost of primary transportation of LPG to the BPs from the main supply points (Atuabo and Tema) is 23 €/ton in Phase 1 and close to 30 €/ton in Phase 3, when the northern volumes will have grown. (This cost will be covered via the national LPG pricing structure described in Chapter 10 (Pricing) beginning on page 53.)

Bottling Plant investment

The total required investment across the three phases, starting in 2019, is estimated to be € 86.7 million, based on indicative costing analysis of the facilities. Technical details and cost line-item details of the plants are presented in the companion *Ghana LPG Investment and Implementation* report.

The BP investment represents about € 156 per tonne of bottling capacity, a reasonable productivity level for the investment by international LPG industry standards.

The investment per phase is:

- Phase 1: **€ 52,8 M** for 302,000 MT of bottling capacity
- Phase 2: **€ 21,6 M** for the additional 127,000 MT of bottling capacity
- Phase 3: **€ 12,3 M** for the additional 128,000 MT of bottling capacity

Due to the required high level of productivity, the plants have been designed and costed with automatic pallet loaders. The investment need includes 18,000 pallets at an indicative cost of € 5.7 million.

Also included are facilities for painting and re-testing of cylinders within the BPs during the implementation of BCRM, through the construction of a dedicated "cylinder maintenance hall." This avoids transportation cost of cylinders to and from an external refurbishment plant, and provides an additional buffer stock of cylinders and pallets to cover cylinders' downtime for maintenance.

Breakdown of the BP investment per region

Table 33. Summary of Bottling Plant investment by region and phase

Region	Phase 1	Phase 2	Phase 3	Total
Upper West (Depot)	50,000 €	-	-	50,000 €
Upper East (Depot)	50,000 €	-	-	50,000 €
Northern	50,000 €	8,286,117 €	1,659,000 €	9,995,117 €
Brong-Ahafo	7,109,867 €	20,000 €	428,750 €	7,558,617 €
Ashanti 1	7,098,923 €	- €	- €	7,098,923 €
Ashanti 2	- €	5,902,211 €	905,900 €	6,808,111 €
Eastern	6,671,705 €	49,640 €	837,500 €	7,558,845 €
Western	6,258,395 €	49,640 €	408,750 €	6,716,785 €
Volta	5,764,277 €	511,154 €	428,750 €	6,704,181 €
Central	6,192,179 €	47,292 €	428,750 €	6,668,221 €
Greater Accra 1	6,761,309 €	- €	408,750 €	7,170,059 €
Greater Accra 2	6,761,309 €	6,761,309 €	6,761,309 €	20,283,927 €
Total	**52,767,964 €**	**21,627,363 €**	**12,267,459 €**	**86,662,786 €**

About the cylinder depots in the northern regions

The € 50,000 for the Upper West, Upper East and Northern regions in Phase 1 is an estimate for the fencing of the plot of land, a forklift to load and unload pallets of cylinders, and a simple office with genset[100] .

[100] A genset is a device generating electricity from a diesel engine, typically used during electrical grid blackouts or in off-grid locations.

These facilities will serve as a central dispatch depot, supplied by large carriers of palletized cylinders from the Brong-Arafo Bottling Plant in Phase 1, and from Tamale in Phases 2 and 3. The cost of primary transportation of cylinders in pallets from the BP to the regional cylinder depot is estimated at € 22-28€/tonne in the first instance, depending on the exact location of the depot.

Import terminal capacities

In the LPG supply chain, the current LPG receiving capacities in the marine terminals are sufficient, and the existing means of primary transport of the product are sufficient but may require to be redeployed, assuming that the other investments described in this report (cylinders, pallets, and cages) are timely made.

LPG cylinder investment

It is estimated that the number of cylinders in circulation by 2030 will be 11.47 million of 14.5kge. This number includes all cylinders in use, in stock, sitting idle, located with consumers, at distribution points, at the BPs, in transition (recirculation) in trucks, and in transition for maintenance.

If the current number of cylinders in circulation is estimated at 4.0 million 14.5kg-equivalent cylinders (about 5 million summing the number of 6kg and 14.5kg), investment in an additional 7.3 million of 14.5kge LPG cylinders is required during 2019-2030, matching the bottling plant capacity investment.

Out of the existing 4.0 million 14.5kge cylinders, it is assumed that 2.0 million will have to be scrapped and replaced by new ones[101]. (The process of safety auditing and hydrotesting of every cylinder will produce an exact count of the number to be scrapped and replaced.) The remaining 2.0 million will also be inspected and hydrotested and will receive essential maintenance including change of valve, repainting and branding.

The total investment need of 9.3 million cylinders includes the 7.3 million additional cylinders (2019-2030) and the 2.0 million replacement cylinders (2019-2022). Depending on the final procurement process chosen to be used for these cylinders, the provisional estimate of the required investment in cylinders is € 235 million through 2030.

By comparison, the National LPG Policy Implementation Committee estimated that 12.4 million cylinders are expected to be needed to run the BCRM from the outset, based on 4 million households with two cylinders per household, 2 million held at the dealer level, 1 million en route to the BPs, 1 million at the BPs for refilling, and 0.4 million in maintenance. (These amounts do not include any scrappage of cylinders.)

The gap is explained by a difference in counting: one calculation sums all the cylinders, while the other uses a uniform size equivalence in order to apply a common rotation rate, in order to ensure consistency with the fuel consumption volumes generated by the cylinders in circulation.

Diameter of the cylinders

For the consistency and the productivity of the BP design and investment, all cylinders received to be refilled are supposed to have a harmonized diameter of 300-310mm, corresponding to the width of the cylinder conveyors, and the dimensions of the cylinder pallets. Since the bottling plants will be equipped

[101] NPA (2018)

with carousels and conveyors, the width of the conveyor is fixed and cannot be changed. The selection of standardized cylinders of 5kg, 6kg, 9kg, 12kg or 14.5kg would have to match the size of conveyor and pallet, unless there is a justification to build a separate carousel with adapted conveyors for the new cylinder diameter(s). This width assumption has been made to ensure bottling of the existing 6kg and 14.5kg cylinders only. The refilling head of the scale in the carousel will be adapted to the two existing valves to enable bottling: the clip-on valve and the "camping gaz" valve.

Concerning the "camping gaz" valve

The "camping gaz" valve is not an ideal choice of valve, but it has been disseminated in many markets. This valve requires a permanent safety control and periodic replacement, because leakages can occur very easily, such as from the presence of dust or sand from the handling of the cylinder. Prevention of problems is difficult, due to often-harsh conditions of use of this small cylinder on the ground.

Cylinder distribution network investment

The responsibility for the implementation of the distribution network of the cylinder refills and the means of transportation of refills/cylinders will be defined in the forthcoming licensing rules. It is expected that the OMCs and LPGMCs will have the primary role of transitioning and further developing the distribution and retail-point networks throughout the country.

Pallets

To achieve high throughput, the BPs have been designed with an automatic pallet loader. The 14,000 pallets represent an additional investment of € 5.7 million.

Cages (display racks)

In the retail network, an estimated 300,000 cylinders (four days' consumption) will be stocked in safety cages, placed outside retail locations such as small shops and petrol stations. The cost of the cages is estimated at approximately € 7.3 million.

Limitations of underlying data

Due to the lack of availability of certain key data, like the market volumes of LPG in cylinders, per region, and the size and condition of the national cylinder inventory, the calculations in this Chapter were based upon assumptions which may, upon further detailed investigation, require updating for improved accuracy. It was beyond the scope of this reporting effort to perform a detailed audit and field survey for bottom-up calculation of key values and ratios.

Total investment

Set forth below are the components of the total investment for the BPs, cylinders, pallets and cages of € 334.9 million, or about € 8.6 per capita in 2030.

It is noteworthy that the total investment in cylinders of € 235.2 million represents about 70% of the total investment, consistent with a usual 60% ratio benchmark when taking into account the adequate prior investment in import terminals and bulk depot capacity.

The following table provides a summary of the investment:

Table 34. Summary of investment to 2030, by asset type

Asset type	Amount (€ mm)	Per capita (2030)
10 Bottling Plants	86.7 M €	2.2 €/capita
Additional cylinders	184.6 M €	4.8 €/capita
Cylinders to replace scrapped existing cylinders	50.6 M €	1.3 €/capita
Subtotal Cylinders	*235.2 M €*	*6.1 €/capita*
Pallets	5.7 M €	0.1 €/capita
Display racks/cages	7.3 M €	0.2 €/capita
Total[102]	**334.9 M €**	**8.6 €/capita**

Note: The cost of additional vehicles (BRVs and cylinder trucks) is excluded from the overall investment plan, because vehicular services for bulk LPG distribution are adequate through 2030, and there is no constraint on the use (or acquisition and financing) of cylinder-transport vehicles. The costs associated with road transport are presented in Table 38 on page 154 for reference.

The investment cost to develop LPG for clean cooking in Ghana comes to under € 9/capita, comprising a complete change of value chain model to BCRM from CCCM, the replacement of about 50% of the existing cylinders and investment in new cylinders to reach 50% penetration of the population.

One may extrapolate this figure to about € 20/capita for 100% penetration rate, inclusive of the import terminal.

Measured on a per-household basis, the € 8.6/capita value is approximately € 33 per household. Adding the cost of a typical basic Ghanaian LPG stove (€ 37), the cost per household comes to approximately € 70. This value is consistent with infrastructure and equipment costs experienced by other LMICs executing major LPG scale-up programs.

Investment in LPG infrastructure (cylinders and bottling plants and bulk depots) can last up to 50 years, if the BCRM is well enforced, and if its safety rules and maintenance requirements are fully observed.

102 Amount does not add exactly due to rounding.

Overview of investment project assumptions and methodology

The assumptions and methodology are based on what the NPA has indicated to GLPGP, as described in detail in Chapter 14 and as follows:

1. 8-10 BPs will be constructed in 8-10 different locations that must be identified by the NPA. (In this report, 10 BPs are used.) The locations will then define the areas the consumption of LPG is attached to, in reference to the projected refilling volumes.

2. The approximately 650 LPG microstations, active and inactive, will be divided into those permitted to pump autogas, and under what conditions, and those others permitted to transition into retail points (cylinder exchange points, or CEPs). It is essential that no disruption or shortage of refill supply occur at the start of the implementation.

3. The OMCs and LPGMCs will own and/or contract with the CEPs. The OMCs/LPGMCs will be licensed to develop cylinder distribution networks for BCRM. In parallel, it is possible that the closure of some LPG microstations for cylinder business and the transformation of others into a CEP could result in compensation to the owners. The present study does not evaluate this possibility or estimate its economic effects, because any such compensation possibility as of this writing is entirely hypothetical, and subject to ongoing debate among the government and stakeholders.

4. Investment in the cylinders and branding should come from the BP companies, which must be confirmed by the NPA. Reasons for having the BPs be the cylinder investing and branding entities are set forth in Chapter 14 and, from an investor and risk management perspective, in Chapter 20 (Summary of Main Project Risks, Mitigations and Mitigation Sources) beginning on page 214.

5. The pricing structure will have to include a margin for the BPs to cover the bottling cost, their investment, and cylinder maintenance and painting.

6. The specification of the LPG.

The specification of the LPG must be precisely defined in regulation, because it affects the mass balance of the BP and the quality and efficiency of combustion in car engines (autogas). For other purposes, such as for industrial users (bulk customers), it may be necessary or desirable to use more propane. The fuel specification for autogas typically requires 50-60% propane for best performance. LPG for domestic cylinders is ideally butane, which contains more heat per kilogram than propane and can be safer to handle than propane, because butane liquefies under much lower pressure than propane. The current standard in Ghana specifies a maximum LPG vapor pressure that corresponds to approximately 70% propane content[103].

It is recommended to segregate, if possible, the specification of LPG into 3 types:

- 60% minimum propane for autogas (potentially up to 80% propane)
- 80% minimum butane for domestic cylinders (potentially up to 100% butane)
- 90% maximum propane for industrial use (potentially up to 95% propane)

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[103] The Ghana standard is a maximum of 9 Barg (bars of pressure relative to atmospheric pressure) at 37.8°C. *Source:* Ghana Standards Authority. LPG produced by the Tema Oil Refinery is approximately 5.5 Barg (roughly 30% propane/70% butane) and by the Ghana Gas Company, 7.5 Barg (roughly 50% propane). Imported LPG is according to its purchase specification.

Segregation into three different mix specifications could have three different prices structures, one per mix. This recommendation aims at ensuring a low safety risk for households and proper frames of use of the propane and butane produced by Ghana. A more detailed calculation of the availability of propane and butane can be performed to adjust these specifications, as a follow-on topic of study[104].

Methodology

The methodological approach used is to estimate the projected filling volume per Bottling Plant from 2017 to 2030, described earlier in this Chapter and introduce appropriately sized plants in multiple phases.

A central assumption had to be made about whether Bottling Plants or markets would become the cylinder investment and ownership entities in the supply chain. For the reasons referenced above, it has been assumed that the recommended case, where BPs are the cylinder investment and ownership entities, will be implemented. If, however, the Government determines otherwise, the investment in cylinders and the economics (income, costs, investment returns and risks) related to the cylinder investment shift from the BPs to the OMCs and LPGMCs. Aggregated at the sector level, the associated cashflows simply shift among the nodes. At the firm level, the effect is pronounced, reflecting a different in business model for both the BP node and the marketing node in the supply chain.

The steps are:

1. Utilize the demand data and projections by region described in Part VI, cross-checked with the 2016 and 2017 sales of every LPG microstation for residential use and combined with relevant parameters regarding the cylinders' operating cycle (supply-chain velocity and bufferage), to project the cylinder inventory requirements and the refill volumes for each region over time;

2. Scale these as necessary for alignment with the governmentally-defined policy goal of 50% of the population using LPG for cooking by 2030 (this creates a mid-case scenario, referred to as the Policy Goal Scenario, between the upper and lower bounds presented in Part VI);

3. Project the step-wise capacity required of the sector through 2030 in adequate anticipation of consumption year by year, while maintaining high stability in the year-over-year pace of investment in order to help the sector to absorb and deploy capital and to grow with minimum risk of operational and financial disruption or discontinuity;

4. Calculate the filling capacity required at each regional BP to serve the consumption in its region over time, concluding with 50% adoption and use by 2030 in accordance with the policy goal[105];

By calculating the annual bottling volume per BP, the required capacity of the PB's main elements (scales, storage, etc.) can be defined from the rules defined by the NPA, taking into account good operational practices and adequate capacity buffer to absorb peaks of consumption.

[104] A high LPG propane content requires propane-rated facilities due to the higher pressure required for propane liquefaction. This report does not consider the implications to infrastructure costs and specifications of a potential high-propane LPG subsector that would serve vehicular and industrial users.

[105] As discussed previously, the pace and scale of investment would, in practice, be adjusted in each year or each multiyear phase (based on the type of asset), based on whether demand rises faster or slower than projected.

Then, the equipment and facilities of each BP are specified and the cost of construction estimated (land cost not included).

Note: This report does not consider the future of the autogas segment.

Assumptions

The number of circulating cylinders (also called the "cylinder park")

The official number of existing cylinders in circulation in Ghana is not available, since the OMCs and LPGMCs have had, and still have, no responsibility for investment in cylinders and their maintenance. Moreover, the cylinders are generic, purchased directly by the end-user from a shop supplied by a wholesaler. A cylinder in circulation is any cylinder, in use or idle at home, in the plant, shop, or warehouse, or on a truck.

Cylinder park technical and physical condition

The implementation of BCRM will change the status of cylinder ownership and the responsibility for cylinder safety and maintenance. It is recommended that 100% of the existing generic cylinders be audited and tested. The safety testing of the entire cylinder park will require about 3 years.

Without knowing the physical condition and safety integrity of the existing cylinders, based on private sector and governmental interviews it was assumed that 50% of the cylinders would not meet safety standards after testing in the BP or the cylinder factory, and therefore must be scrapped and replaced. It is also assumed that all cylinders of size different than 6kg and 14.5kg will be scrapped and replaced by new ones of those standard sizes, in order to harmonize all cylinders with the diameter of the conveyors in the BPs. It is also assumed that the valve must be harmonized to 3 or 4 maxima, also for the productivity of the BP.

Beyond the replacement of the 2.4 million total cylinders (2.0 million 14.5kge) to be scrapped by new ones, the remaining cylinders will have to be repaired and identified by the BP with proper brand and operational markings, like date of validation, date of next revalidation, and serial number.

For estimating the retesting and repairing cost, the calculation was based on the ratio used in the LPG industry for a cylinder park that is 30 years old, in well-maintained condition and transported with pallets (not in bulk onto the trucks):

- The number of cylinders to be repaired: 0.95% of the cylinder park;
- The number of cylinders to be retested annually: 10% of the cylinder park, if the safety procedures in the bottling plants are properly applied;
- In the case of no mark of year of construction, the cylinder is supposed to be scrapped and replaced;
- Every cylinder more than 40 years old must be scrapped;

- Every cylinder more than 10 years requesting a hot repair[106] must be scrapped.

These criteria have no influence on the rest of this analysis but need to be defined and known by the bidders.

Current cylinder size breakdown

The breakdown of the current cylinder park by sizes, provided by GCMC, the leading Ghana cylinder manufacturer, is as follows, noting that two sizes represent 90% of the park. Based on this, all calculations have been done on "14.5kg equivalent" (kge) basis, meaning that about 2.4 cylinders of 6kg are counted as one cylinder of 14.5kg:

Table 35. Cylinder park breakdown by size

Cylinder size	Percent of total
6kg	30%
14.5kg	60%
Others (3, 12.5, 45kg)	10%

The recommendation of the BCRM implementation committee is to only have 3 sizes: 3kg, 6kg, and 14.5kg. The 6lg and the 14.5kg can be filled on the same conveyor and move on the same carousels, while the 3kg has a lower diameter and must have its own conveyor and carousel.

The regional centralization of filling in BPs requires a harmonization of the diameter of the foot and shroud of the cylinder. In this study, the width of the conveyors, corresponding to the diameter of the cylinders, is assumed to be only for cylinders with a diameter between 300 and 310mm, which are the diameters of the 6kg and of the 14.5kg, together representing 90% of the sizes in the country. In case cylinders of 3kg are demanded in large numbers by some segments of end-users, either manual bottling lines would be added in investment Phase 1, or a small dedicated carousel will be added, likely in Phases 2 and 3. Any cylinder with a different diameter will have to be excluded and scrapped.

Calculation of operating projections per region

Population[107]

While projections could be made based on either households or persons (users) of LPG, for purposes of calculating capacities and investment requirements, population has been used. That is because consumption of LPG for cooking is linked to the number of meals cooked, which varies not with households (each region having its own average household size), but with the number of persons across the using

106 Hot repair describes a series of treatments in a specialized oven to reduce the deformations of steel plate due to shocks in transportation of the cylinders. Usually the oven of a cylinder factory is to be used for these treatments. Here, it is recommended that any old cylinder seen as requiring hot repair is scrapped, because the cost of the hot repair can be 60% of the cost of a new cylinder.

107 Sources given by NPA: www.theatlas.com/charts/HJ04buM3M
www.statsghana.gov.gh/docfiles/2010phc/Projections_Districts_2015 to 2020_submit.xlsx

households. Cylinders themselves, conversely, are linked to the count of households (or, more properly, to the number of "kitchens", in that the concept of a household, from a cooking standpoint, might involve more than one family group at a time, with shared cooking duties[108]).

LPG consumption for cooking

The consumption information provided by the NPA is limited to the list of liftings (loading of bulk trucks in the BDC facilities) by the OMCs and the LPG Marketing Companies (LPGMCs) and reported by the BDCs.

The reported volumes do not identify the destination of the lifting, whether LPG stations or bulk customers; it is a combination of all the segments. These volumes are translated to sales of LPG in the service stations for two segments of use: autogas (car fuel) and domestic cylinder use (mainly cooking).

Since the BCRM centralizes cylinder refills and separates them from automotive refills, the autogas volumes in each region must be separated from the residential volumes in order to determine required BP refill capacities as the residential market grows.

In the northern half of Ghana in 2017, the residential kg/capita was below 3kg, while it was 5.7kg/capita for the country as a whole, corresponding to a 24.5% LPG penetration rate nationwide.

Because the official desegregated LPG volumes per segment (cylinders, bulk customers and autogas) for 2017 could not be determined, it was decided to estimate the LPG volume for domestic use in cylinders in each region calculated from the LPG penetration rate reported in GLSS 7, applied to the projected average annual consumption by LPG users of 25kg/capita from the demand assessment.

The following table gives the estimate of LPG consumption in cylinders, summing to more than 165 KT in 2017, representing 5.72kg per capita.

Table 36. Population and residential LPG consumption by region in 2017

			LPG consumption			
Region	**Population**	**LPG penetration rate**	**In residential cylinders (MT)**	**Autogas, bulk and cylinders (MT)**	**Autogas and bulk only (MT)**	**% of LPG volume in cylinders**
Upper West	811,124	6.1%	1,237	2,611	1,375	47.4%
Upper East	1,216,680	6.6%	2,008	3,057	1,050	65.7%
Northern	2,925,831	3.4%	2,487	4,422	1,935	56.2%
Brong-Ahafo	2,723,050	11.4%	7,761	26,854	19,094	28.9%
Ashanti	5,533,011	23.2%	32,091	52,039	19,947	61.7%
Eastern	3,099,641	17.1%	13,251	24,471	11,220	54.1%
Western	2,954,789	24.4%	18,024	23,894	5,869	75.4%
Volta	2,491,293	17.2%	10,713	26,858	16,146	39.9%
Central	2,479,279	23.1%	14,318	29,945	15,627	47.8%

[108] GLSS 7 survey data indicate that approximately 5% of Ghanaian households do not cook for themselves.

Greater Accra	4,721,889	54.1%	63,864	87,758	23,895	72.8%
Total	**28,956,587**	**22.9%**	**165,753**	**281,910**	**116,157**	**58.8%**

Sources: NPA, GLSS 7

The proportion of LPG in cylinders is almost 59% of the overall distributed LPG volume of 282 KT, and the remaining 41% (116 KT) represents the autogas and the bulk customers segments.

The analysis of the dataset containing the lifting to the LPG microstations does not allow for direct estimation of the volume of the bulk customer and autogas segments.

An estimate for the bulk customers segment, from indicators in the liftings file, would be on the level of 15-16 KT (likely 10% of the cylinder segment, a very common ratio in African LPG markets).

The estimate for the autogas segment is thus around 100 KT, giving an average microstation output for LPG autogas around 225 MT[109] of LPG per year per station, consistent with what has been reported on the ground in interviews in LPG stations.

The change of model to BCRM will transform many of the current cylinder refilling microstations into a cylinder exchange activity in the same locations. The closing of LPG dispensing stations for BCRM implementation may affect the supply to LPG-fueled cars. To avoid supply disruption while implementing new safety rules for autogas dispensing, it is strongly recommended to focus, as much as possible, on locating the autogas dispensing pumps in service stations. A 5 MT buried tank in each could comply with the NPA safety regulations and would be adequate to supply the current number of autogas vehicles.

Projection of LPG consumption to 2030

It has been assumed that the LPG consumption progression rate varies between the southern regions and the northern regions and that LPG consumption will progress more quickly going north, compared to the south, where LPG in Greater Accra has already exceeded 50% penetration of the population.

For 2018 and 2019, an LPG annual volume growth of 2% was assumed and, for the following years up to 2030, a linear interpolation so as to reach the required volumes to achieve the policy goal.

The resulting 2030 volume of 485,272 MT was determined by applying 50% to the average user consumption value of 25kg per capita in 2030, and therefore is independent from the current LPG volumes of 2016-2017.

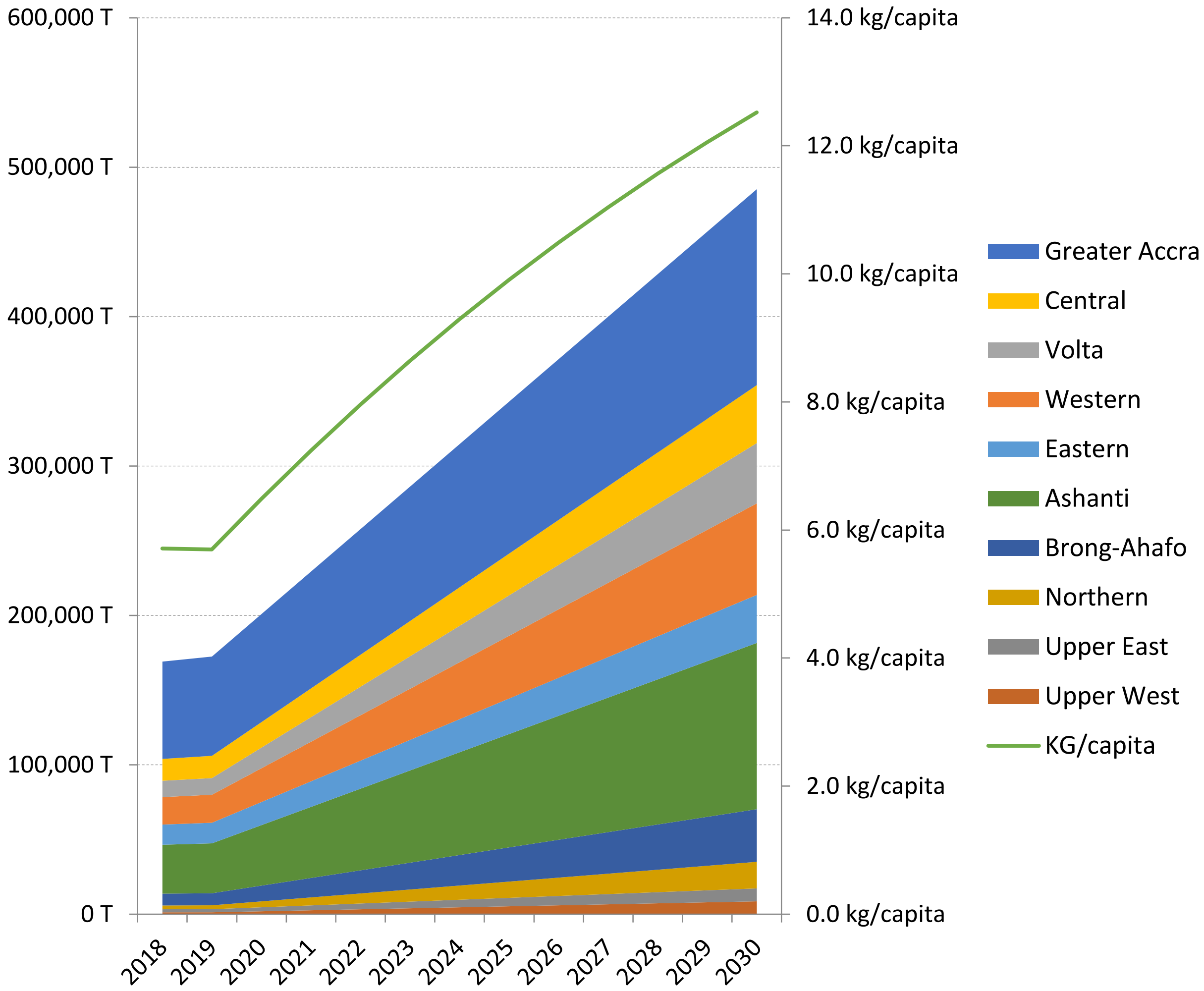
The penetration rate and consumption level per region were determined by applying the region-by-region growth projections for each from the demand analyses to the 2017 starting values. The consumption rate ramps, as in the demand scenarios, to 25kg per capita per user, to give the projected LPG volume per region over time.

The projected volume and penetration data are summarized in Table 28 on page 138.

109 The NPA station file of 2016 reports only 443 stations with sales volume, compared to the 645 officially registered. In the case that the 100 KT is sold through 645 stations, the average would be 155 MT per station per year.

The following figure shows the total consumption per region that the investments in supply chain capacity will track (areas, left axis), and the corresponding national consumption per capita (users plus non-users) (line, right axis):

Figure 36. Projection of consumption by region to 2030 for investment sizing (Policy Goal Scenario)



Note: Linearity of the projected consumption, done for investment purposes, (i) anticipates projected demand growth per the demand studies, ensuring adequate supply is in place adequately in advance of demand to be served, and (ii) serves to minimize the potential for volatility in the requirement to absorb and deploy capital by the supply chain for expansion.

Analysis of LPG supply infrastructure requirements

LPG production capacity

In 2017, the LPG production of Ghana was about 70 KT produced by Ghana Gas in the Atuabo Gas processing plant from offshore natural gas extraction. The balance between the LPG production and the consumption is imported. The data are summarized in Table 21 on page 120. The annual volumes from 2017 were considered and projected forward to 2030.

The current total storage capacity of 22,690 MT could supply more than 544,000 MT/year of LPG for cylinder with a storage ratio of 24 (i.e., 24 fillings per year). Assuming the autogas and bulk customer segments remain at approximately the same level, this import storage capacity is sufficient to cover about a 600,000 MT market.

If the storage ratio were to be optimized to 36, the storage capacity could accommodate a total supply volume of more than 800,000 MT/year, including the current volume of autogas (approximately 100,000 MT/year) and bulk customers (approximately 16,000 MT/ year).

In conclusion, except for operational purposes and aiming at optimizing the investment cost of the import facility to get the lowest throughput cost per tonne, there is no necessity to increase the existing import capacity.

Projected bottling capacity and number of bottling plants

The bottling capacity requirement is defined by the peak consumption in a year, increased by a safety factor. The peak of consumption is related to the seasonality.

There being no definitive information available on the consumption seasonality of the LPG in cylinder use in Ghana, the bottling capacity has been calculated conservatively at 120% of the annual consumption target.

The following table shows the theoretical need of bottling in the different regions.

Table 37. Theoretical maximum bottling capacity required to 2030 (MT)

Region	City	2020	2022	2024	2026	2028	2030
Upper West	Wa	2,300	4,600	5,750	6,900	9,200	10,350
Upper East	Bolatanga	3,450	4,600	6,900	8,050	9,200	10,350
Northern	Tamale	4,600	8,050	11,500	14,950	18,400	20,700
Brong-Ahafo	Sunyani	12,650	18,400	24,150	29,900	35,650	41,400
Ashanti	Kumasi	47,150	63,250	79,350	95,450	112,700	128,800
Eastern	Koforidua	18,400	21,850	26,450	29,900	33,350	37,950
Western	Sekondi	26,450	35,650	44,850	52,900	62,100	71,300
Volta	Ho	16,100	23,000	28,750	34,500	41,400	47,150
Central	Cape Coast	20,700	25,300	29,900	35,650	40,250	44,850
Greater Accra	Accra	83,950	97,750	110,400	124,200	138,000	151,800
Total		**235,750**	**302,450**	**368,000**	**432,400**	**500,250**	**564,650**

Bulk transportation

In the LPG supply chain, the mass primary transport, bottling, and cylinder primary transport must satisfy an economic transportation optimization.

The positioning of the BP must be as close as possible to the sales area, as large as possible to minimize bottling costs, yet cannot be in an urban area due to safety concerns.

The mass primary transport must be favored over the cylinder primary transport, because the former transports only the product

Definition of terms used in the adjacent paragraphs:

- **Mass primary transport**: semi-trailer transport of the liquid product
- **Cylinder primary transport**: transport of large quantities of bottles (8-900 bottles) from the filling center to the warehouse.

while the latter transports the product and the weight of the cylinder steel (the weight of the steel of the cylinder is approximately equal to the weight of the LPG it contains when full).

As a general rule, it is more economical and professional to have BP capacity above 20KT/year, to minimize the per-unit bottling cost and ensure a higher safety level and refilling quality.

When the consumption of a region is less than 20KT/year, it was assumed to have a cylinder depot supplied by the BP of a neighboring region, as shown in Table 31 on page 140. This rule must be weighed against the cost of cylinder secondary transport.

It is recommended that the rollout of the BPs, as much as possible, be based on economic criteria, rather than on administrative sequencing. This will ensure that the highest probability new LPG users, in the most numbers, with the strongest underlying business fundamentals for industry, are served first.

The growth in number of BPs from 8 to 10, and the increased capacity projection for 305,000 T/year to 556,000 T/year, are shown in Table 31 on page 140 and Table 31 on page 141, respectively.

Estimate of the cost of primary bulk transportation

The calculation of the cost of primary transportation of bulk LPG from the depots to the BP varies from 23€/T in 2020 to 30€/T in 2030, taking into account the growth of volume in the northern regions, which are located father away from supply. This calculation could also help define the transportation cost in the price structure to set the perequation fee for primary bulk transportation. (See Chapter 10 (Pricing) beginning on page 53 for details.) 30€/T is recommended to make uniform the ex-BP price nationwide, via a transportation differential.

Table 38. Bulk transport costs by region to 2030
(€ mm, except €/MT values)

<table>
<tr><th>Trip</th><th>Distance</th><th>2020</th><th>2022</th><th>2024</th><th>2026</th><th>2028</th><th>2030</th><th>€/MT (2030)</th></tr>
<tr><td>Atuabo-Bolgatanga</td><td>880 km</td><td rowspan="4">1.10 €</td><td rowspan="4">1.68 €</td><td rowspan="3">1.93 €</td><td rowspan="3">2.46 €</td><td rowspan="3">3.00 €</td><td rowspan="3">3.53 €</td><td rowspan="3">100.6 €</td></tr>
<tr><td>Atuabo-Wa</td><td>760 km</td></tr>
<tr><td>Atuabo-Tamale</td><td>720 km</td></tr>
<tr><td>Atuabo-Sunyani</td><td>410 km</td><td>1.17 €</td><td>1.45 €</td><td>1.73 €</td><td>2.02 €</td><td>57.3 €</td></tr>
<tr><td>Tema-Kumasi</td><td>275 km</td><td>1.55 €</td><td>2.10 €</td><td>2.64 €</td><td>3.19 €</td><td>3.73 €</td><td>4.28 €</td><td>38.4 €</td></tr>
<tr><td>Tema-Koforidua</td><td>100 km</td><td>0.22 €</td><td>0.26 €</td><td>0.31 €</td><td>0.36 €</td><td>0.40 €</td><td>0.45 €</td><td>14.0 €</td></tr>
<tr><td>Tema-Secundi</td><td>250 km</td><td>0.79 €</td><td>1.06 €</td><td>1.33 €</td><td>1.60 €</td><td>1.87 €</td><td>2.14 €</td><td>34.9 €</td></tr>
<tr><td>Tema-Ho</td><td>170 km</td><td>0.33 €</td><td>0.45 €</td><td>0.58 €</td><td>0.71 €</td><td>0.83 €</td><td>0.96 €</td><td>23.8 €</td></tr>
<tr><td>Tema-Cape Coast</td><td>180 km</td><td>0.43 €</td><td>0.54 €</td><td>0.65 €</td><td>0.76 €</td><td>0.87 €</td><td>0.98 €</td><td>25.1 €</td></tr>
<tr><td>Tema-Accra</td><td>30 km</td><td>0.30 €</td><td>0.35 €</td><td>0.40 €</td><td>0.45 €</td><td>0.50 €</td><td>0.55 €</td><td>4.2 €</td></tr>
<tr><td>Price km.tonne 0.07 €/MT</td><td>Total</td><td>4.72 €</td><td>6.45 €</td><td>9.01 €</td><td>10.97 €</td><td>12.93 €</td><td>14.89 €</td><td>30.0 €</td></tr>
<tr><td></td><td>€/MT</td><td>23 €/T</td><td>25 €/T</td><td>29 €/T</td><td>30 €/T</td><td>30 €/T</td><td>31 €/T</td><td></td></tr>
</table>

65% of the cost of transportation is generated from Tema, 35% from Atuabo.

These calculations can potentially be adjusted downward, as soon as there is substantial market growth, allowing transporting companies to find synergies in logistics by reducing the time a truck remains idle.

Projection of storage capacity of the BPs

The LPG storage capacity of a BP is calculated to address the risks of supply disruptions during the primary bulk transportation of LPG to the BP. The primary transportation can be by bulk road tankers (BRT), pipeline or train. The time necessary for a truck, for example, to transport LPG to the BP without difficulties corresponds with the vicinity of the BP from the depot where the truck is loading the LPG, taking into account the queueing of the truck, the change of driver, any labor working hours constraint, the break time for the driver, the traffic speed, the quality of the road, *etc*.

If the BP is located within 50km distance, one or two daily round trips can easily be done, and the storage capacity can be reduced accordingly, because the risk of trucks being delayed is very low. The proximity of the BP with the terminal does not require excess storage capacity (which is expensive). The factor used to summarize this is the "tank rotation rate per year"; that is, how many times the storage facility is refilled in a year.

The following tank rotation rates are recommended to calculate the size of the storage capacity:

- "**24**" (i.e. 24 fillings in a year, or a filling every two weeks) for a very distant BP to have more storage capacity, reduce any risk of supply disruption and avoid any scarcity situation due to the long transportation time;
- "**36**" for BPs less than one day transport from the source of the product, and
- "**52**" for any BP located near the import terminals and/or refineries, where the product is located.

The following tank rotation rates were used to calculate the storage capacity of each BP:

Table 39. Standard tank rotation rates for each Bottling Plant

Region	Rotation Rate
Upper West	24
Upper East	24
Northern	24
Brong-Ahafo	36
Ashanti	52
Eastern	52
Western	52
Volta	52
Central	52
Greater Accra	52

The foregoing schedule of rotation rates takes the following into account:

- It will not be possible to change the capacity of the storage every year or two;
- The size of tanks—especially spherical tanks—are more or less standardized, the typical sizes being 250 MT, 500 MT, 1000 MT, and 2000 MT.

- For bullet tanks, there is no standard size, but the overall diameter is more or less standardized: 2.5m, 3m, and 3.5m. These diameters are imposed by transport convenience. The ratio length of a bullet/diameter is more or less observed; around 10. For economic reasons, it is useful to multiply the number of bullets. Four bullets of 50 T are far cheaper than one of 200 T.

- Financially, a spherical tank is cheaper than a multiple bullet of the same size. A 250 MT spherical tank is less costly than 300 MT of bullets. For operational reasons, the 10-year inspection of a sphere requires a stoppage for more than one month; thus, it is wise not to have only one sphere or bullet.

Figure 37. Examples of spherical and bullet LPG storage

The following table summarizes the recommended rules for tank sizing and type:

Table 40. Mapping of storage capacity to tank type and size

Desired storage	Bullet type	Spherical type
300 T	6x50 T	
400 T	8x50 T	
500 T	10x50 T	1x 500 T
1000 T		1x 1 000 MT
1500 T		1x 1000 MT+ 1x500 MT
2000 T		2x 1000 MT

The final projection of the storage capacities of the BPs is as follows:

- 7,750 T in Phase 1, corresponding to a rotation rate of 39. This rotation is possible because the biggest part of the volumes are located close to the loading depots.

- In Phase 3, the storage capacity will be of 13,250 T, with a rotation rate of 42.

These rotation rates ensure an excellent return on the storage investment.

Table 41. Projected storage capacity by region by investment phase

Region	City	Phase 1	Phase 2	Phase 3
Upper West	Wa	1,250 MT	2,000 MT	3,000 MT
Upper East	Bolatanga			
Northern	Tamale			
Brong-Ahafo	Sunyani		1,250 MT	1,500 MT
Ashanti 1	Kumasi	1,250 MT	1,250 MT	1,250 MT
Ashanti 2			500 MT	1,000 MT
Eastern	Koforidua	1,000 MT	1,000 MT	1,500 MT
Western	Sekondi	1,000 MT	1,000 MT	1,250 MT
Volta	Ho	500 MT	750 MT	1,000 MT
Central	Cape Coast	750 MT	750 MT	1,000 MT
Greater Accra 1	Accra	1,000 MT	1,000 MT	1,250 MT
Greater Accra 2		1,000 MT	1,000 MT	1,250 MT
Total		**7,750 MT**	**10,500 MT**	**14,000 MT**
Average rotation rate		**39.0**	**40.7**	**39.8**

Strategic reserve storage capacity

The consumption of LPG for cooking in 2030 in line with the national policy goal will be approximatively 485,000 MT per year, or 40,000 MT per month. The existing LPG storage capacity (22,690 MT + 36,000 MT), plus storage at the new BP sites of 14,000 MT, for a total of about 73,000 MT, will store over 50 days' consumption of LPG at the 2030 volume. 30 days' consumption is a usual rule in the LPG industry, especially when the country is surrounded by, and importing from, producing countries.

Any storage capacity above that level will result in an unneeded increase in the asset intensity of the supply chain, and would therefore result in an increase of the cost for the supply chain and/or an increase in the price to the end-user. In the event additional temporary storage capacity is needed, such as for transitions, a floating storage can easily be added on a temporary basis.

Primary transport capacity

There are about 300 Bulk Road Tankers (BRTs) in Ghana including the 193 officially registered with the NPA for LPG transport differential. (The Ghanaian licensing term for these tankers is Bulk Road Vehicle, or BRV.)

Those 193 BRTs are large enough to ensure the transport of the projected volume for 2030. 157 BRTs cover the exact need of primary transportation for 2030 (485 KT).

The calculation is based on one BRT of 24 MT average capacity transporting 3,120 MT per year, assuming an average round trip of two days, working five days per week.

Estimated number of cylinders necessary to meet the national target

The projected number of cylinders required year by year is presented in Table 30 on page 139, starting from the number of existing cylinders (net of cylinders to be scrapped) in 2017.

The usual methodology used in the LPG industry is based on the average cylinder rotation rate (the average annual number of refills per cylinder), which include all the cylinders in the country. It directly affects the financial return on the cylinder investment. The rotation rate is applied to one size-equivalent: for Ghana, this is 14.5kg (the dominant size). It is necessary to convert all the other sizes to 14.5kg equivalent for purposes of the calculation.

The rotation rate under CCCM would be somewhat different from that under BCRM. Therefore, the methodology estimates the 2017 rotation rate were BCRM in effect, by layering in the effects of additional elements affecting the velocity of cylinders in the recirculation cycle that are different, or absent, under CCCM.

In 2017, the NPA estimated that the total number of existing cylinders was 5.8 million, out of which roughly 60% were 14.5kg and 40% were 6kg, and minimal other sizes. The average rotation rate for 2017, were BRCM in effect in 2017, would be 2.85 in 14.5kge cylinders. The national result is consistent with other developing-stage LPG markets practicing BCRM (similar to Cameroon, for example). It is strongly influenced by the regions around Greater Accra, where the number of cylinders per household is higher compared to the other regions.

To be conservative in the modelling, very modest growth in the rotation rate was permitted year over year in each region, even though the rotation rate usually increases significantly with major additions of cylinders into a market. It is likely that the rotation rate will improve significantly in Ghana due to the proposed, massive investment in new cylinders, by making the distribution process more productive and allowing the distributors' truck drivers to be more efficient in collecting empty cylinders. If the rotation rate were to improve from 2.9 to 3.6, the number of cylinders required for investment would be reduced by about 3 million.

The 11.3 million 14kge cylinders in circulation in 2030 (see Table 30), translated into non-kg equivalents, become 14 million distinct cylinders, assuming a constant proportion of 6kg and 14.5kg in the marketplace.

Calculation of the annual quantities of cylinders to be acquired

The total number of additional cylinders (7.3 million of 14.5kge) to be invested should be seen as a flow of annual investments rather than a one-time investment. In the present case, the annual flow of investment is about 650,000 cylinders per year.

Table 42. Projected 14.5kge cylinder quantities required to 2030
(in two-year increments)

Region	2020	2022	2024	2026	2028	2030
Upper West	19,459	35,704	34,304	32,984	31,740	30,564
Upper East	17,909	31,422	30,190	29,029	27,933	26,899
Northern	40,263	73,996	71,094	68,360	65,780	63,344
Brong-Ahafo	73,734	130,206	125,100	120,288	115,749	111,462
Ashanti	193,713	327,497	323,797	320,158	316,581	313,064
Eastern	53,324	81,352	79,344	77,408	75,543	73,745
Western	102,745	172,962	171,072	169,212	167,383	165,583
Volta	77,305	132,877	129,596	126,435	123,389	120,451
Central	63,108	99,875	98,746	97,637	96,546	95,473

Greater Accra	185,274	258,239	255,416	252,640	249,909	247,222
Total	**826,833**	**1,344,130**	**1,318,659**	**1,294,153**	**1,270,553**	**1,247,806**
Cumulative Total						**7,302,134**

Translated into non-kge, the 7.3 million of 14.5kge become 10.8 million cylinder units.

Cylinders to be scrapped and replaced at the launch of BCRM

At the launch of the BCRM, all existing cylinders in the hands of the end-users will have to be tested and certified for compliance with the safety requirements of LPG cylinders. The non-certified ones will be scrapped and replaced by new ones. In the absence of trusted data, since the current cylinders belong to the end-users, most of the stakeholders linked with the sector are estimating that about half of the existing cylinders would have to be scrapped and replaced.

Assuming 4.9 million existing cylinders (4 million 14.5kge), about 2.5 million cylinders (2 million 14.5kge) would have to be replaced equally over the first three years.

Total number of cylinders for investment

The total number of 14.5kge cylinders for investment will be 7.3 million + 2.0 million, making 9.3 million of 14.5kge, or 11.8 million in non-kge.

This investment plan can self-adjust the pace of the investment downward, based on actual consumption and the actual level of increase of the rotation rate, either for proper balancing of assets with consumption, or to improve the return on investment through improved asset utilization with scale.

Annual cylinder quantities in the first three years

The following table shows the number of cylinders for investment in the initial phase, in 14.5kge:

Table 43. Annual cylinder quantities 2019-2021

Cylinder category	2019	2020	2021
New cylinders	413,417	413,417	672,065
Replacement of scrapped cylinders	666,667	666,667	666,667
Total for BCRM launch	1,080,084	1,080,084	1,338,732

Total cylinder investment

The total investment for all the cylinders to 2030 is € 235.2 million, comprised of:

- € 185.5 million for the additional 7.3 million 14.5kge cylinders, representing an annual investment flow of about € 15 million.
- € 49.7 million for the cylinders to be replaced during the first years of the launch of BCRM.

The following table details the staging of the entire cylinder investment:

Table 44. Total cylinder investment required to 2030
(€ mm, shown in two-year increments)

Category of cylinder	2020	2022	2024	2026	2028	2030
New 14.5kge cylinders	20.91 €	33.99 €	33.34 €	32.72 €	32.13 €	31.55 €
Replacement of scrapped cylinders	33.71 €	16.86 €				
Total investment[110]	54.62 €	50.84 €	33.34 €	32.72 €	32.13 €	31.55 €
Cumulative total						**235.2 €**

Investment in cylinders is an annual process, adjusted according to market trends. The pace of investment may be accelerated if consumption is greater than forecast, up to the sustainable growth rate of the firm, and decelerated if the market starts to saturate (that is, the demand for new cylinders stabilizes with respect to demographic trends).

An important driver and metric is the cylinder rotation rate in a given area, which increases as the distribution network becomes more efficient and productive, ensuring no cylinders remain idle, no scarcity or problems of refill supply, and no illegal cross-filling or diversion of cylinders by competitors. When the rotation rate eventually stabilizes or declines in an area absent any other major factors, it indicates saturation of the market area at its then-current level of consumption.

The investment calculation has been made on the basis of the following assumptions for the procurement of new cylinders:

- Import parity (CIF), import taxes and import audit service are not included;
- The specifications of the cylinder (propane specs) are the basic-level ones, and could be improved;
- The valve (clip-on) is included and mounted;
- The unit price for 14.5kge cylinders: 25.3 € (139 Cedis[111]).

Determining the number of cylinders in the working stock

To insure a fluid and efficient cylinder filling process and good availability of cylinders in the distribution network for the end-user, the theoretical cylinder working stock in terms of maximum daily consumption, taking seasonality into account, is as follows:

- Pallets:
  - — In the BP: 1.5
  - — On the trucks (cylinder primary transport): 1
  - — In the warehouse or cylinder regional depot: 2

[110] Based on quotations obtained and valid for September 2018, import audit services costs excluded. The cost of a 6kg cylinder is typically higher per kg than a 14.5kg cylinder, per kg.

[111] Using an exchange rate of 5.5 cedis per Euro

— On the trucks (secondary transport): 1

- Cages:

— In the distribution network: 4

Overall, the working stock represents 9.5 days of consumption.

These figures assume that the equipment (bottling plant and trucks) are optimally used.

If not, a minimum stock is required (for example, an 800-cylinder truck will need a stock minimum of 800 cylinders).

The total number of cylinders in the working stock grows from 506,000 in 2020 to 865,000 in 2030 and is included in the counts of existing cylinders not scrapped and additional cylinders purchased.

Table 45. Cylinder working stock levels by region to 2030
(in 14.5kge, shown in alternate years)

Region	2020	2022	2024	2026	2028	2030
Upper West	4,924	6,605	8,286	9,967	11,648	13,329
Upper East	6,767	8,272	9,776	11,280	12,784	14,288
Northern	10,002	13,483	16,965	20,447	23,928	27,410
Brong-Ahafo	26,564	32,782	39,000	45,218	51,436	57,654
Ashanti	101,976	119,818	137,660	155,501	173,343	191,185
Eastern	38,950	43,160	47,370	51,579	55,789	59,999
Western	56,996	66,739	76,481	86,224	95,966	105,709
Volta	34,779	41,472	48,166	54,860	61,553	68,247
Central	43,012	48,487	53,963	59,438	64,913	70,388
Greater Accra	182,245	197,059	211,873	226,688	241,502	256,316
Total	**506,215**	**577,877**	**649,539**	**721,201**	**792,863**	**864,525**
Net change	**506,215**	**71,662**	**71,662**	**71,662**	**71,662**	**71,662**

Determining the number of pallets and cages (display racks)

Pallets will be used in the BPs, on the cylinder trucks and in the warehouse. Standard pallets contain 35 cylinders of 300mm diameter cylinders (both 14.5kg and 6kg). 3kg cylinder pallets are quite different.

Because the BPs have been designed with a pallet feeder, the cylinders must be palletized in the BP.

As in most well-developed LPG markets, the cylinder should be transported in pallets to ensure safety (for example, 2 cylinders cannot be in contact when in transportation, per ADR[112] rules). It is recommended that all the transportation of cylinders from and to the BPs be executed in pallets for safety reasons.

[112] The RID/ ADR is an international agreement of safety rules concerning the transportation of hazardous goods, including LPG in cylinders and in bulk. These rules are applicable and followed in most countries. www.unece.org/trans/danger/publi/adr/adr2017/17contentse0.html

Pallets have a positive side-effect of increasing productivity at the Bottling Plant, because the discharging of a cylinder truck with a forklift accelerates offloading, reduces safety problems, and ensures good control over the accurate counting of cylinders.

The cylinders in the retail network will be presented in cages or display racks (see Figure 38 below). The cages will be placed outside the retail shop, petrol station, dedicated gas-seller, *etc.*, preferably in the shade.

These cages will be designed to ensure the following functions:

- Store the cylinders, preferably in a vertical position;
- Protect the cylinders against shock and severe weather;
- Make the cylinder delivery easy for the deliveryman and the seller;
- Protect against theft.

About 300,000 cylinders, corresponding to 4 days' consumption, will be stored in the cages.

The estimated cost of a cage is around 20 €/cylinder. A 20 cylinder cage would cost around 400 €.

Figure 38. Examples of cylinder cages

The following table sets forth the number of pallets and cages to be added:

Table 46. Quantities of new cylinders, cages and pallets to 2030
(shown in alternate years)

Number	2020	2022	2024	2026	2028	2030	Total
14.5kge cylinders	826,833	1,344,130	1,318,659	1,294,153	1,270,553	1,247,806	**7,302,134**
Pallets	8,373	1,185	1,185	1,185	1,185	1,185	**14,300**
Cages	213,143	30,173	30,173	30,173	30,173	30,173	**364,010**

The pallet requirement by region are as follows:

Table 47. Quantities of new pallets to 2030 by region
(shown in alternate years)

Region	2020	2022	2024	2026	2028	2030
Upper West	81	28	28	28	28	28

Region	2020	2022	2024	2026	2028	2030
Upper East	112	25	25	25	25	25
Northern	165	58	58	58	58	58
Brong-Ahafo	439	103	103	103	103	103
Ashanti	1,687	295	295	295	295	295
Eastern	644	70	70	70	70	70
Western	943	161	161	161	161	161
Volta	575	111	111	111	111	111
Central	711	91	91	91	91	91
Greater Accra	3,015	245	245	245	245	245
Total	**8,373**	**1,185**	**1,185**	**1,185**	**1,185**	**1,185**
Cumulative						**14,300**

Main elements of investment

The breakdown of the total investment requirement of € 335 million by type of asset is shown in Table 34 on page 145.

The following tables break out the investment for each type of asset by region and by investment stage.

Table 48. Total Bottling Plant investment requirement by region and investment phase

Region	Phase 1	Phase 2	Phase 3	Total
Upper West (Depot)	50,000 €	- €	- €	**50,000 €**
Upper East (Depot)	50,000 €	- €	- €	**50,000 €**
Northern	50,000 €	8,286,117 €	1,659,000 €	**9,995,117 €**
Brong-Ahafo	7,109,867 €	20,000 €	428,750 €	**7,558,617 €**
Ashanti 1	7,098,923 €	- €	- €	**7,098,923 €**
Ashanti 2	- €	5,902,211 €	905,900 €	**6,808,111 €**
Eastern	6,671,705 €	49,640 €	837,500 €	**7,558,845 €**
Western	6,258,395 €	49,640 €	408,750 €	**6,716,785 €**
Volta	5,764,277 €	511,154 €	428,750 €	**6,704,181 €**
Central	6,192,179 €	47,292 €	428,750 €	**6,668,221 €**
Greater Accra 1	6,761,309 €	- €	408,750 €	**7,170,059 €**
Greater Accra 2	6,761,309 €	6,761,309 €	6,761,309 €	**20,283,927 €**
Total	**52,767,964 €**	**21,627,363 €**	**12,267,459 €**	**86,662,786 €**

Table 49. Total cylinder, pallet and cage investment requirement by region and investment phase (€ mm)

Asset type	2020	2022	2024	2026	2028	2030	Total
Additional cylinders (14.5kge)	20.91 €	33.99	33.34	32.72	32.13	31.55	**184.63 €**
Cylinders to replace scrapped existing cylinders	33.71 €	16.86					**50.57 €**
Subtotal Cylinders	54.62 €	50.84	33.34	32.72	32.13	31.55	**235.20 €**
Pallets	3.32 €	0.47	0.47	0.47	0.47	0.47	**5.66 €**
Cages	4.26 €	0.60	0.60	0.60	0.60	0.60	**7.28 €**
Total	**62.20 €**	**51.92**	**34.42**	**33.80**	**33.20**	**32.62**	**248.15 €**

Bottling Plant design

Bottling Plant design, operation and outfitting are addressed in the companion *Ghana LPG Investment and Implementation* report.

16. Investments at the Firm Level

This Chapter examines the economics of the sector-level investments at the firm level. The two relevant supply chain nodes are Bottling Plants (BPs) and marketers (OMCs/LPGMCs).

Methodology

In the ideal case, multiple firms would volunteer financial information and business plans showing how they would grow their businesses, and this body of information would then drive a bottom-up investment scenario. In Ghana, this was not possible, because (i) key governmental decisions about the business models of, and margins available to, multiple main LPG supply chain nodes requiring investment had not yet been made, through the time of this writing; (ii) businesses were, in general, unwilling to share proprietary internal business information, except to a recognized financing source interested to discuss a transaction; (iii) businesses were also, in general, concerned about violating applicable competition law by disclosing internal financial or operating data that could eventually be viewed by the public; (iv) for smaller firms in marketing, retailing and distribution, standardized financial statements often did not exist at all; (v) for OMCs, LPG financial data typically were aggregated with data about non-LPG operations, and not practical to extract; and (vi) the NPA requested formally that bilateral discussion with Ghanaian companies be kept to a minimum during the NPA's uncompleted national planning process for LPG sector reform. The NPA's concern is especially understandable in light of the highly public, politicized disagreement between members of the association of smaller LPG microstation owners, GLiPGOA, and the NPA about the economic, legal and operational path forward for the microstations under BCRM.

In the absence of volunteered financial and business planning information from a critical mass of individual firms, the alternative was chosen to construct a pro-forma model of firms and investments at the key supply chain nodes.

This choice involved making certain assumptions about future unit margins, potential costs of capital (i.e., financial return requirements), and key operating parameters affecting the cash flow generation potential and growth rates capacity of the different types of firms. Details behind the key assumptions are described in Chapter 10 (Pricing) beginning on page 53 and Chapter 18 (Consumer Empowerment) beginning on page 188.

Where possible, the pro forma cases have been benchmarked against information provided under conditions of confidentiality, or through public non-binding disclosures and announcements, by representative firms. The pro forma cases are in line with such benchmarks.

The critical types of firm examined in this Chapter with respect to future investment are:

- Bottling Plants;
- Marketers (LPGMCs and the LPG-specific activities of OMCs treated on a stand-alone basis).

These two types of firm represent 98% of the investment requirement to 2030.

These additional firm categories were not modelled, for the following reasons:

- *Bulk Road Vehicles and Cylinder Trucks*. The existing fleet of Bulk Road Vehicles (BRV) is adequate to transport all future expected LPG volumes to 2030, assuming business-as-usual growth in autogas. Truck service to carry cylinders is not growth-constrained, and access to vehicle financing is not a barrier to capacity growth.

- *Production and Importation*. The sole expected source of significant additional domestic production is the potential addition of supply and production capacity at the Ghana Gas Company (GGC), which has adequate recourse to its own financing for this. However, even if GGC expands its LPG output, total supply will be dominated increasingly by importation. Growth in importation is not constrained operationally or financially today, and has the existing growth capacity to achieve the usage desired by the Government and forecasted in this report.

- *Bulk Storage and Importation*. With addition of labor shifts and/or faster rotation of fuel inventory, such facilities can increase their capacities and capacity utilization rates to meet the tonnage required through 2030 without significant new investment.

- *Retail (Cylinder Exchange) Points*. The anticipated main source of new retailing facilities is existing shops already offering non-LPG products to the public. To the extent outside financing of cylinder inventory is required at this level, it would be accomplished through small-scale entrepreneurial lending from domestic lending sources, with creditworthiness determined by those lenders, and/or through credit that OMCs/LPGMCs choose to extend. The lack of standardized financial and accounting reports at this level of the supply chain, together with the challenge of diligencing thousands of individual retail-point owners, does not make large-scale financing

As noted in Part XII (Recommendations for Further Technical Assistance and Research), it could be a subject of useful future study to examine these additional nodes in more detail.

The following examinations of prospective firm-level economics are based on representative models of

1. A Bottling Plant with 10% market share that invests in and owns cylinders;

2. A Bottling Plant with 10% market share that does not invest in cylinders;

3. A marketer (LPGMC or the LPG unit of an OMC viewed on a standalone basis) with a 5% market share that invests in and owns cylinders.

Cases 1 and 2 (BPs with and without cylinder investment/ownership) are mutually exclusive.

For marketers, the only major capital investment they would need to make under BCRM is in cylinder inventory, if the Government's decision turns out to allocate the main cylinder functions to the marketers. Therefore, the case of a marketer without any cylinder investment was not evaluated.

Despite the restrictions and limitations affecting the gathering and evaluation of firm-level data, partial information was obtained on a confidential, voluntary basis and was used for benchmarking the pro-forma models. These data were in line with the models.

The models include the use of an LPG volume-based capital recovery levy fund to support the cylinder investment. If implemented in Ghana, this levy would shift a notional 40% of the capital cost of all new cylinders to this fund. The fund would pay for the shifted 40% through an increase of € 0.03 per kg of LPG in the national pricing formula over 12 years, expiring in 2030. Use of an LPG capital recovery levy is currently being contemplated by the Government. This approach is discussed in detail in Chapter 18 (Consumer Empowerment) beginning on page 188.

Each model includes a sensitivity analysis to revenue per tonne and to the percentage of equity vs. debt utilized for the required investment in new assets.

Finally, the pro-forma capital structure and costs of capital (debt and equity) used for modelling the firms' capitalization and financial returns are based on the outcomes of detailed discussions with the major Ghana banks and other financial sector institutions, and with DFIs that are active in other sectors in Ghana, regarding relevant transaction benchmarks and applicable lending and investment policies and limitations.

Bottling Plant with cylinder investment

This pro-forma Bottling Plant is modelled on the basis of a 10% share of the bottling-node volume in the supply chain, including investment in 10% of the national cylinder requirement in each year. It is thus a composite (at 1/10th scale) of the notional 10 new Bottling Plant businesses that are to begin their construction starting in 2019.

Revenue is made from the permitted unit margin under the national price formula for filling of cylinders. In this case, the unit margin comprises both a filling fee component (€ 70 per tonne) and a cylinder investment and maintenance fee component (€ 50 per tonne). The total, €120 per tonne, is less than the total of the maximum allowed unit margin amounts shown in the recommended pricing formula of Chapter 10, which sum to € 150 per tonne[113]. This is done for two reasons: (i) it demonstrates that an adequate profit and financial return can be created by a BP at a lower level of revenue per tonne than the permitted maximum; (ii) it demonstrates that there is enough spare margin available to the BP, while still generating adequate profit and financial returns, that the BPs can afford to pay for a cylinder capital cost recovery levy applied to their LPG volumes instead of the consumer paying. The potential workings and benefit of such a levy is discussed in detail in Chapter 19.

Assumptions

The following are the main financial and operating assumptions:

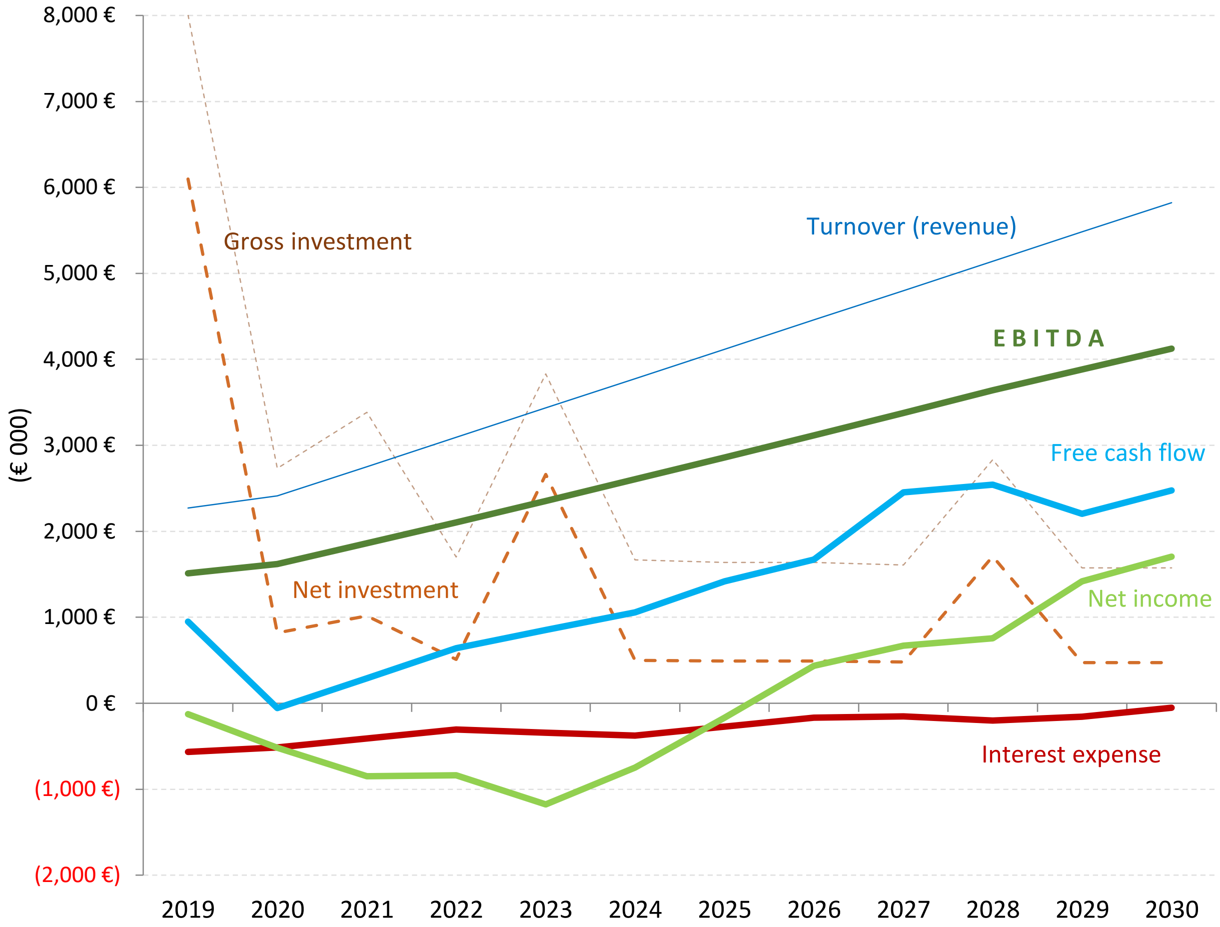
Item	Value
Market share of the firm	10%
Cost of cylinder (14.5kge)	23.2 €
Cylinder deposit (as % of cost)	70%
Net cylinder cost to marketer	30%
BP margin per tonne (includes cylinder margin)	120 €/t
Annual rate of margin increase	0%
Company income tax rate	20%
Tranches of capital increase (loans and equity)	3
Blended cost of debt	8.93%
Loan tenors	3-8 years
Minimum required rate of return to equity	20%

113 The relevant margin elements from the price formula shown in Figure 7 (from page 56) for this BP are "Bottling Plant Margin" (€ 70) and "Cylinder Investment and Maintenance" (€ 80). All other elements apply to other nodes in the supply chain.

Capitalization:	
Non-concessional debt (at 10%)	35%
Concessional debt (at 8%)	40%
Equity	25%

These parameters result in the following financial characteristics and performance of the firm over time:

Figure 39. Bottling Plant with cylinder investment: financial performance



The selected metrics are as follows:

Gross investment	Value at purchase of invested assets
Net investment[114]	Gross investment less cylinder deposits received via the distribution network
Turnover (revenue)	Tonnage x margin/tonne
EBITDA	Turnover less operating costs
Net income	EBITDA less depreciation[115], interest expense and taxes
Free cash flow	Net income adjusted for non-cash charges

114 The effect of the proposed capital recovery levy to offset the cylinder acquisition costs borne by the firm would reduce the net investment amount by an additional 40%. The effect of the proposed levy has not been included in this analysis.

115 Note: The model assumes that the gross investment amount is useable for purposes of determining depreciation. Such treatment would be subject to the approval of the actual firm's accounting and tax advisors and the relevant tax authorities.

Table 50. Bottling Plant with cylinder investment: pro-forma financial data (values in € 000s except as noted)

	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	TOTALS
Cylinders Acquired & Deployed *(000 units)*	**108**	**108**	**134**	**67**	**66**	**66**	**65**	**65**	**64**	**64**	**62**	**62**	**931**
Price of Cylinder	25	25	25	25	25	25	25	25	25	25	25	25	
Gross Capital Cost of Cylinders	2,731	2,731	3,383	1,700	1,667	1,667	1,637	1,637	1,607	1,607	1,577	1,577	23,522
	Y1-3 includes replacement of scrap cylinders												
Cylinder Deposits Received	765	765	947	476	467	467	458	458	450	450	441	441	6,586
Net Cylinder Cost	819	819	1,015	510	500	500	491	491	482	482	473	473	7,057
Investment in BP Facilities (PP&E)	5,277				2,163					1,227			8,666
Tonnage *(KT)*	19	20	23	26	29	31	34	37	40	43	46	49	396
BP margin/tonne	120	120	120	120	120	120	120	120	120	120	120	120	1,440
Total BP margin	2,270	2,411	2,752	3,093	3,434	3,776	4,117	4,458	4,799	5,141	5,482	5,823	47,557
TURNOVER (REVENUES)	**2,270**	**2,411**	**2,752**	**3,093**	**3,434**	**3,776**	**4,117**	**4,458**	**4,799**	**5,141**	**5,482**	**5,823**	***47,557***
Personnel costs (per tonne)	25	24	24	23	23	22	22	21	21	20	20	20	
Non-personnel operating costs (per tonne)	15	15	15	15	15	15	15	15	15	15	15	15	
OPEX/tonne	40	39	39	38	38	37	37	36	36	35	35	35	
Total OPEX	757	792	892	988	1,081	1,171	1,258	1,342	1,422	1,499	1,599	1,698	14,500
EBITDA	**1,513**	**1,618**	**1,860**	**2,105**	**2,353**	**2,605**	**2,859**	**3,117**	**3,377**	**3,641**	**3,883**	**4,125**	33,057
Depreciation	**(1,074)**	**(1,620)**	**(2,297)**	**(2,637)**	**(3,187)**	**(2,974)**	**(2,755)**	**(2,406)**	**(2,387)**	**(2,498)**	**(1,952)**	**(1,940)**	(27,725)
OPERATING INCOME (EBIT)	**439**	**(2)**	**(437)**	**(532)**	**(833)**	**(369)**	**104**	**711**	**990**	**1,144**	**1,931**	**2,185**	5,331
Interest Expense	(566)	(514)	(410)	(307)	(342)	(377)	(273)	(168)	(153)	(199)	(157)	(52)	(3,518)
OPERATING PROFIT BEFORE TAXES	**(126)**	**(516)**	**(847)**	**(838)**	**(1,175)**	**(746)**	**(169)**	**543**	**837**	**944**	**1,775**	**2,133**	1,814
Income Tax	0	0	0	0	0	0	0	(109)	(167)	(189)	(355)	(427)	(1,246)
Tax Holiday	no	no	no	no	no	no	no	no	no	no	no	no	
NET INCOME (NI)	**(126)**	**(516)**	**(847)**	**(838)**	**(1,175)**	**(746)**	**(169)**	**434**	**670**	**755**	**1,420**	**1,706**	567

Capital infusions are structured into three tranches. The first two tranches are concurrent. The third tranche is split, with new money for cylinders in 2027 and for a plant expansion in 2028:

(in 000s)	**Tranche 1**	**Tranche 2**	**Tranche 3**
Cylinders	**2019**	**2023**	**2027**
Debt	1,107 €	694 €	669 €
Concessional Debt	1,265 €	793 €	764 €
Debt amortization in years	*2-5*	*6-9*	*10-12*
Equity	791 €	496 €	478 €
Total	**3,164 €**	**1,983 €**	**1,910 €**
Plant	**2019**	**2023**	**2028**
Debt	1,847 €	757 €	429 €
Concessional Debt	2,111 €	865 €	491 €
Debt amortization in years	*2-8*	*6-12*	*11-12*
Equity	1,319 €	541 €	307 €
Total	**5,277 €**	**2,163 €**	**1,227 €**

The following table shows debt service, EBITDA coverage of debt service, and free cash flows, and calculations of notional terminal value in 2030 and the corresponding IRR for equity:

Table 51. Bottling Plant with cylinder investment: debt coverage, FCF, TV and equity IRR
(values in € 000s except as noted)

Total Debt Service	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	TOTALS
Total Principal	6,330	0	0	0	3,109	0	0	0	1,433	920	0	0	11,792
Principal Repayments	0	1,159	1,159	1,159	1,159	1,169	1,169	1,169	603	709	1,169	1,169	11,792
Total Interest	566	514	410	307	342	377	273	168	153	199	157	52	3,518
Total Debt Service	566	1,672	1,569	1,465	1,501	1,546	1,442	1,337	757	909	1,326	1,222	15,310
EBITDA	**1,513**	**1,618**	**1,860**	**2,105**	**2,353**	**2,605**	**2,859**	**3,117**	**3,377**	**3,641**	**3,883**	**4,125**	33,057
EBITDA Coverage of Debt Service	3	1	1	1	2	2	2	2	4	4	3	3	
EBITDA after Debt Service	**948**	**(54)**	**291**	**640**	**853**	**1,059**	**1,417**	**1,780**	**2,621**	**2,733**	**2,557**	**2,903**	17,747
Taxes	0	0	0	0	0	0	0	(109)	(167)	(189)	(355)	(427)	(1,246)
Cashflow after Debt Service & Taxes	**948**	**(54)**	**291**	**640**	**853**	**1,059**	**1,417**	**1,671**	**2,453**	**2,544**	**2,202**	**2,477**	16,501

Operating Cash Flow	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	TOTALS
Net Income	(126)	(516)	(847)	(838)	(1,175)	(746)	(169)	434	670	755	1,420	1,706	567
+ Depreciation & Amortization	1,074	1,620	2,297	2,637	3,187	2,974	2,755	2,406	2,387	2,498	1,952	1,940	27,725
+ Non Cash Charges	0	0	0	0	0	0	0	0	0	0	0	0	0
Free Cashflow from Operations	948	1,105	1,450	1,798	2,011	2,227	2,586	2,840	3,057	3,253	3,371	3,646	28,293
- Principal Debt Repayments		1,159	1,159	1,159	1,159	1,169	1,169	1,169	603	709	1,169	1,169	11,792
Cashflow after Debt Service (FCF)	**948**	**(54)**	**291**	**640**	**853**	**1,059**	**1,417**	**1,671**	**2,453**	**2,544**	**2,202**	**2,477**	16,501
											Tax Adjusted EBITDA	3,300	
											Terminal Multiple	5.0x	
											Terminal Value	**16,499**	
- Equity Fundings	2,110				1,036					784			3,931
Net FCF to Equity (Net of Investment)	(1,162)	(54)	291	640	(184)	1,059	1,417	1,671	2,453	1,760	2,202	18,976	29,069
Total Equity Fundings	3,931												3,931
IRR to all Equity Classes	**47%**												

The equity IRR, based on the notional capital stack, is a healthy 47%, including a terminal value of approximately € 16.5 million in 2030.

If unit margins are higher than the € 120 used for this analysis, the equity rate of return increases significantly, and if less leverage is used, it falls significantly, as shown in Table 52:

Table 52. Bottling Plant with cylinder investment: IRR sensitivity to margins and capital mix

IRR to all Equity Capital

Revenue/t	47%	
120 €/t	**47%**	*Modelled amount*
150 €/t	**121%**	*Amount in price formula*
160 €/t	174%	
165 €/t	214%	
170 €/t	269%	

IRR to all Equity Capital

Revenue/t	Equity % of Capitalization		
47%	20%	25%	50%
120 €/t	**57%**	**47%**	**28%**
150 €/t	**261%**	**121%**	**47%**
160 €/t	694%	174%	54%
165 €/t	2338%	214%	58%

Bottling Plant without cylinder investment

This pro-forma Bottling Plant is modelled on the basis of a 10% share of the bottling-node volume in the supply chain, excluding investment in 10% of the national cylinder requirement in each year, which in this case must be done by the companies in the marketer node. It is thus a composite (at 1/10th scale) of the notional 10 new Bottling Plant businesses that are to begin their construction starting in 2019, if the marketers (OMCs and LPGMCs) are assigned all responsibilities for cylinder investment and management, excepting filling and maintenance, which the BPs would perform.

Revenue is made from the permitted unit margin under the national price formula for filling of cylinders, set here to € 70 per tonne per the recommended pricing formula of Chapter 10.

Assumptions

The following are the main financial and operating assumptions:

Item	Value
Market share of the firm	10%
BP filling margin per tonne	70 €/t
BP cylinder maintenance margin per cylinder	€ 5
Annual rate of margin increase	0%
Company income tax rate	20%
Tranches of capital increase (loans and equity)	3

Blended cost of debt	8.93%
Loan tenors	3-8 years
Minimum required rate of return to equity	20%
Capitalization:	
Non-concessional debt (at 10%)	35%
Concessional debt (at 8%)	40%
Equity	25%

These parameters result in the following financial characteristics and performance of the firm over time:

Figure 40. Bottling Plant without cylinder investment: financial performance

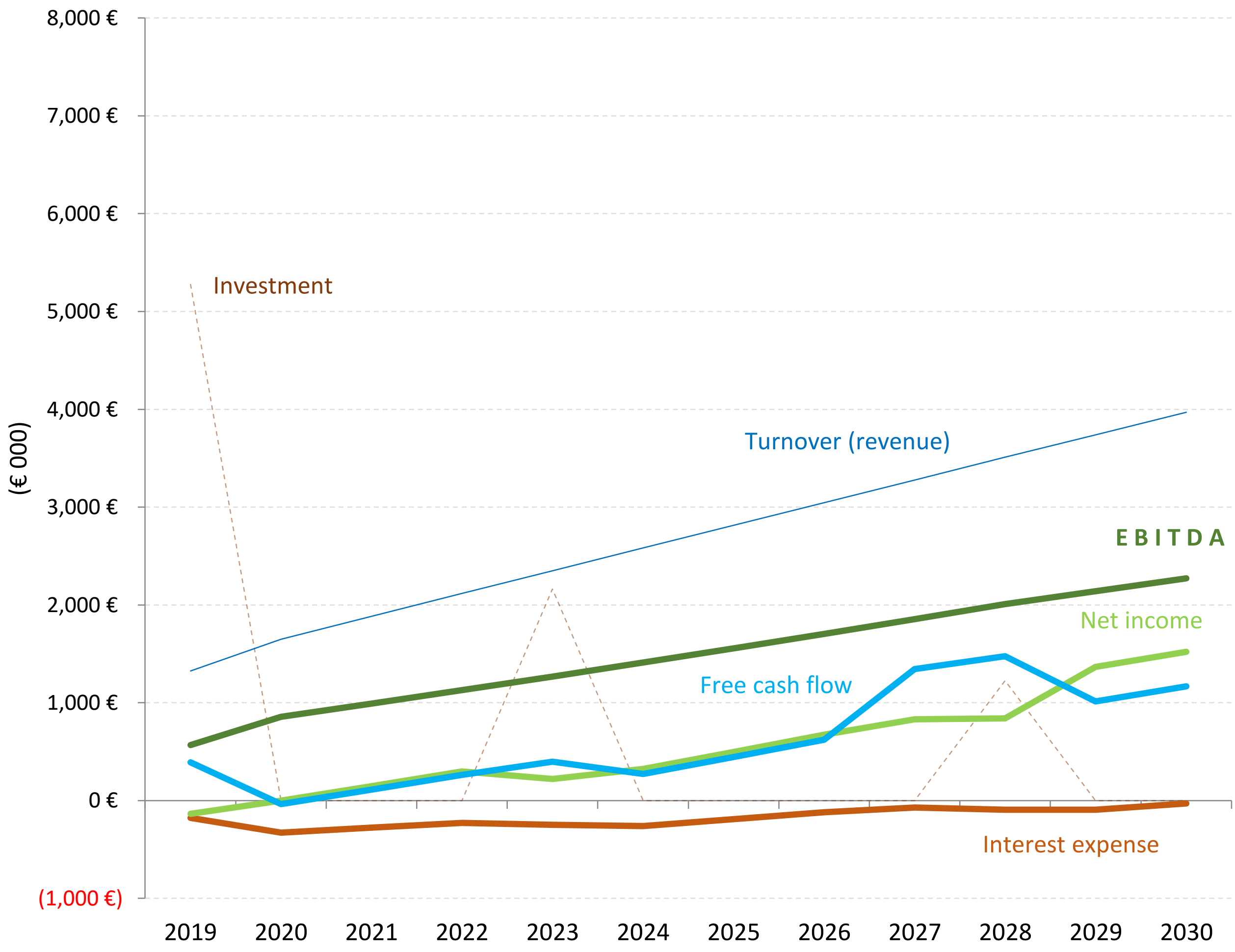


Table 53. Bottling Plant without cylinder investment: pro-forma financial data
(values in € 000s except as noted)

	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	TOTALS
Investment in BP Facilities (PP&E)	5,277				2,163					1,227			8,666
Tonnage *(KT)*	19	20	23	26	29	31	34	37	40	43	46	49	396
Filling Fee *(€ per tonne)*	70	70	70	70	70	70	70	70	70	70	70	70	
LPG Filling Service Income	1,324	1,406	1,605	1,804	2,003	2,202	2,402	2,601	2,800	2,999	3,198	3,397	27,741
Maintenance Service Income		243	278	312	346	380	413	446	478	510	542	574	4,521
TURNOVER (REVENUES)	**1,324**	**1,649**	**1,883**	**2,117**	**2,349**	**2,582**	**2,814**	**3,046**	**3,278**	**3,509**	**3,740**	**3,970**	**32,263**
Personnel costs (per tonne)	*25*	*24*	*24*	*23*	*23*	*22*	*22*	*21*	*21*	*20*	*20*	*20*	
Non-personnel oper. costs (per tonne)	*15*	*15*	*15*	*15*	*15*	*15*	*15*	*15*	*15*	*15*	*15*	*15*	
OPEX/tonne	*40*	*39*	*39*	*38*	*38*	*37*	*37*	*36*	*36*	*35*	*35*	*35*	
Total OPEX	757	792	892	988	1,081	1,171	1,258	1,342	1,422	1,499	1,599	1,698	14,500
EBITDA	**568**	**857**	**991**	**1,128**	**1,268**	**1,411**	**1,556**	**1,705**	**1,856**	**2,010**	**2,141**	**2,272**	17,763
Depreciation	(528)	(528)	(528)	(528)	(744)	(744)	(744)	(744)	(744)	(867)	(339)	(339)	(7,375)
OPERATING INCOME (EBIT)	**40**	**329**	**463**	**601**	**524**	**667**	**812**	**961**	**1,112**	**1,143**	**1,802**	**1,933**	10,388
Interest Expense	(177)	(328)	(278)	(227)	(249)	(261)	(190)	(118)	(72)	(93)	(93)	(31)	(2,117)
OP PROFIT BEFORE TAXES	**(137)**	**1**	**186**	**373**	**275**	**406**	**623**	**843**	**1,039**	**1,050**	**1,709**	**1,902**	8,271
Income Tax	0	(0)	(37)	(75)	(55)	(81)	(125)	(169)	(208)	(210)	(342)	(380)	(1,682)
Tax Holiday	no	no	no	no	no	no	no	no	no	no	no	no	
NET INCOME (NI)	**(137)**	**1**	**148**	**299**	**220**	**325**	**498**	**674**	**831**	**840**	**1,367**	**1,522**	6,589

Capital infusions are structured into three tranches:

(in 000s)	**Tranche 1**	**Tranche 2**	**Tranche 3**
PP&E	**2019**	**2023**	**2028**
Debt	1,847 €	757 €	429 €
Concessional Debt	2,111 €	865 €	491 €
Debt amortization in years	*2-8*	*6-12*	*11-12*
Equity	1,319 €	541 €	307 €
Total	**5,277 €**	**2,163 €**	**1,227 €**

The following table shows debt service, EBITDA coverage of debt service, and free cash flows, and calculations of notional terminal value in 2030 and the corresponding IRR for equity:

Table 54. Bottling Plant without cylinder investment: debt coverage, FCF, TV and equity IRR
(values in € 000s except as noted)

Total Debt Service	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	TOTALS
Total Principal	3,958	0	0	0	1,622	0	0	0	0	920	0	0	6,500
Principal Repayments	0	565	565	565	565	797	797	797	232	232	692	692	6,500
Total Interest	177	328	278	227	249	261	190	118	72	93	93	31	2,117
Total Debt Service	177	894	843	793	815	1,058	987	916	304	325	784	723	8,617
EBITDA	**568**	**857**	**991**	**1,128**	**1,268**	**1,411**	**1,556**	**1,705**	**1,856**	**2,010**	**2,141**	**2,272**	17,763
EBITDA Coverage of Debt Service	3.21x	0.96x	1.18x	1.42x	1.56x	1.33x	1.58x	1.86x	6.10x	6.19x	2.73x	3.14x	
EBITDA after Debt Service	**391**	**(37)**	**148**	**336**	**454**	**353**	**570**	**789**	**1,552**	**1,685**	**1,356**	**1,549**	9,146
Taxes	0	(0)	(37)	(75)	(55)	(81)	(125)	(169)	(208)	(210)	(342)	(380)	(1,682)
Cashflow after Debt Service & Taxes	**391**	**(37)**	**111**	**261**	**399**	**272**	**445**	**621**	**1,344**	**1,475**	**1,015**	**1,169**	7,464

Operating Cash Flow	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	TOTALS
Net Income	(137)	1	148	299	220	325	498	674	831	840	1,367	1,522	6,589
+ Depreciation & Amort	528	528	528	528	744	744	744	744	744	867	339	339	7,375
+ Non Cash Charges	0	0	0	0	0	0	0	0	0	0	0	0	0
Free Cashflow From Operations	391	528	676	826	964	1,069	1,242	1,418	1,575	1,707	1,706	1,861	13,964
- Principal Repayments	0	565	565	565	565	797	797	797	232	232	692	692	6,500
Cashflow after Debt Service (FCF)	**391**	**(37)**	**111**	**261**	**399**	**272**	**445**	**621**	**1,344**	**1,475**	**1,015**	**1,169**	7,464
										Tax Adjusted EBITDA		1,818	
										Terminal Multiple		5.0x	
										Terminal Value		**9,088**	
Less: Equity Fundings	(1,319)				(541)					(307)			(2,167)
Net FCF to Equity (Net of Investment)	(928)	(37)	111	261	(142)	272	445	621	1,344	1,168	1,015	10,257	14,386
Total Equity Fundings	2,167												2,167
IRR to all Equity Classes	**35%**												

The equity IRR, based on the notional capital stack, is 35%, including a terminal value of approximately € 9.1 million in 2030. This is materially below the values for the case of a Bottling Plant making cylinders investments (47%, € 16.5 million).

If unit margins are higher than the € 70 used for this analysis, the equity rate of return increases significantly, and if less leverage is used, it falls significantly, as shown in Table 55:

Table 55. Bottling Plant without cylinder investment: IRR sensitivity to margins and capital mix

IRR to all Equity Capital

Revenue/t	35%
70 €/t	35%
72 €/t	38%
74 €/t	41%
76 €/t	45%
78 €/t	49%

IRR to all Equity Capital

	Equity % of Capitalization		
35%	20%	25%	50%
Revenue/t			
70 €/t	41%	35%	22%
72 €/t	45%	38%	24%
74 €/t	49%	41%	25%
76 €/t	55%	45%	27%
78 €/t	60%	49%	29%

Marketer (LPGMC / OMC) with cylinder investment

This pro-forma LPG marketer is modelled on the basis of a 5% share of the marketing-node volume in the supply chain, including investment in 5% of the national cylinder requirement in each year. A pure-LPG business model—no other petroleum-sector products—is assumed.

Revenue is made from the permitted unit margin under the national price formula for investment in and maintenance of cylinders, for recovery of transportation costs, and marketing margin (in aggregate, € 150 per tonne[116]), as shown in the recommended pricing formula of Chapter 10.

Assumptions

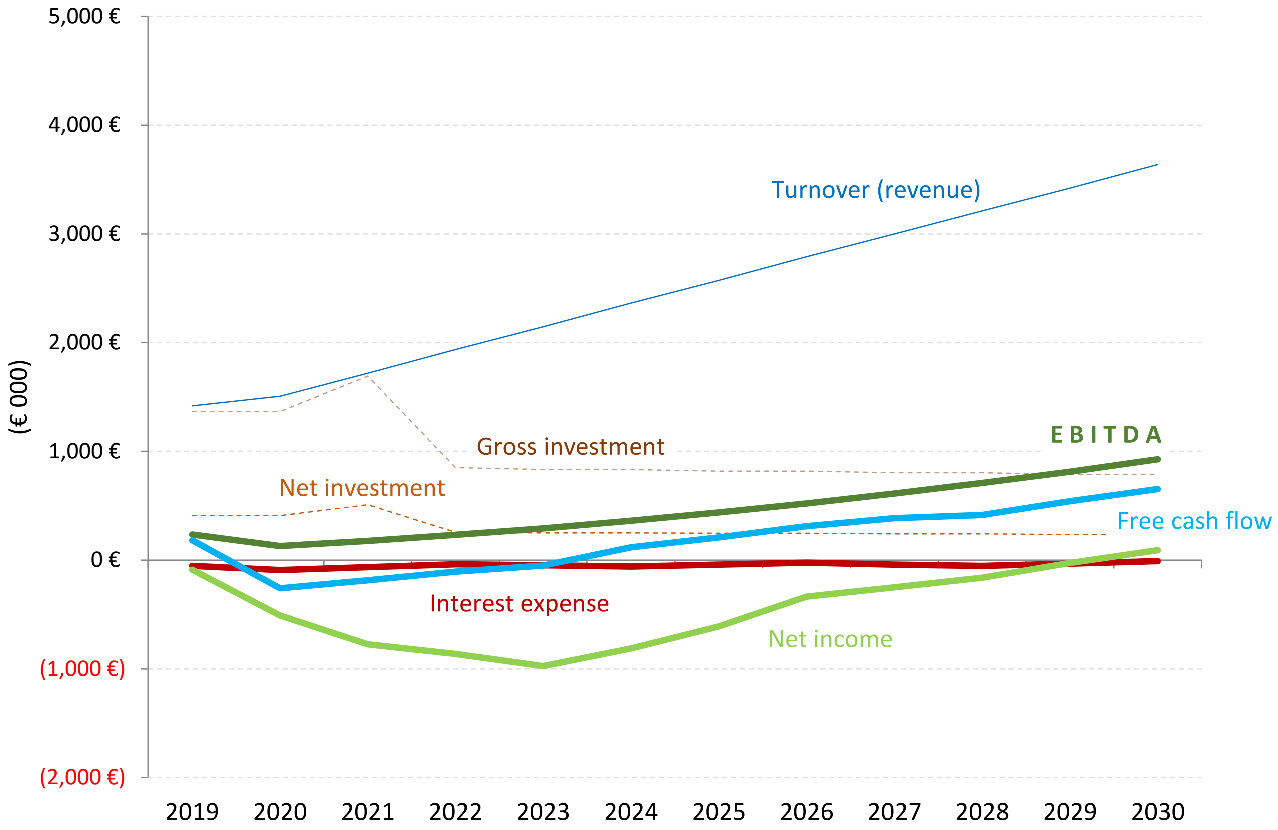
The following are the main financial and operating assumptions:

[116] The relevant margin elements from the price formula shown in Figure 7(from page 56) for this LPGMC/OMC are "Cylinder Investment and Maintenance" (€ 80), "Cylinder Transport Cost" (€ 20), and "Marketer Margin" (€ 50). All other elements apply to other nodes in the supply chain.

Item	Value
Market share of the firm	5%
Cost of cylinder (14.5kge)	25.3 €
Cylinder deposit (as % of cost)	70%
Net cylinder cost to marketer	30%
Total margin per tonne (includes cylinder margin)	150 €/t
Fees payable to BP:	
Bottling fee	€ 70/t
Maintenance fee (per 14.5kge cylinder)	€ 5/cylinder
Annual % of cylinder inventory requiring maintenance (starting in year 2)	10%
Distributor transportation fee	€ 10/t
Annual rate of margin increase	0%
Company income tax rate	20%
Tranches of capital increase (loans and equity)	3
Blended cost of debt	8.93%
Loan tenors	4-5 years
Minimum required rate of return to equity	20%
Capitalization:	
Non-concessional debt (at 10%)	35%
Concessional debt (at 8%)	40%
Equity	25%

These parameters result in the following financial characteristics and performance of the firm over time:

Figure 41. Marketers with cylinder investment: financial performance



As in the case of the Bottling Plant with cylinder investment, “Net Investment” is the gross investment less the cylinder deposits received via the distribution network. Net income is rendered highly negative by the depreciation of the cylinder assets.

Comparing this chart to the similar chart for the Bottling Plant that makes cylinder investments (Figure 40 on page 173), it is evident how much lower the profitability ratio and cash flow generation capability are of the LPG marketing company, compared with the Bottling Plant company.

Table 56. Marketer with cylinder investment: pro-forma financial data
(values in € 000s except as noted)

	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	TOTALS
Cylinders Acquired & Deployed *(000 units)*	**54**	**54**	**67**	**34**	**33**	**33**	**32**	**32**	**32**	**32**	**31**	**31**	**466**
Price of Cylinder	25	25	25	25	25	25	25	25	25	25	25	25	
Gross Capital Cost of Cylinders	1,366	1,366	1,691	850	834	834	819	819	803	803	788	788	11,761
	Y1-3 includes replacement of scrap cylinders												
Cylinder Deposits Received	956	956	1,184	595	584	584	573	573	562	562	552	552	8,233
Net Cylinder Cost	410	410	507	255	250	250	246	246	241	241	236	236	3,528
Tonnage (KT)	9	10	11	13	14	16	17	19	20	21	23	24	198
Margin/tonne	150	150	150	150	150	150	150	150	150	150	150	150	1,800
Total margin	1,418	1,508	1,718	1,935	2,145	2,363	2,573	2,790	3,000	3,210	3,420	3,638	29,715
TURNOVER (REVENUES)	**1,418**	**1,508**	**1,718**	**1,935**	**2,145**	**2,363**	**2,573**	**2,790**	**3,000**	**3,210**	**3,420**	**3,638**	**29,715**
Opex per tonne													
Bottling Plant filling charge	70/t	70/t	70/t	70/t	70/t	70/t	70/t	70/t	70/t	70/t	70/t	70/t	
Distributors transportation of refills	10/t	10/t	10/t	9/t	9/t	8/t	8/t	7/t	7/t	6/t	6/t	5/t	
Commercial costs (sales, training, technicians, etc.)	20/t	20/t	19/t	18/t	17/t	16/t	15/t	14/t	13/t	12/t	11/t	10/t	
Other OPEX	25/t	25/t	24/t	23/t	22/t	21/t	20/t	19/t	18/t	17/t	16/t	15/t	
Total OPEX/tonne before cylinder maintenance	125/t	125/t	123/t	120/t	118/t	115/t	113/t	110/t	108/t	105/t	103/t	100/t	
Total OPEX before cylinder maintenance	1,181	1,256	1,403	1,548	1,680	1,811	1,929	2,046	2,150	2,247	2,337	2,425	22,014
Bottling Plant cylinder maintenance		122	139	156	173	190	206	223	239	255	271	287	2,261
Total OPEX	1,181	1,378	1,541	1,704	1,853	2,001	2,136	2,269	2,389	2,502	2,608	2,712	24,275
EBITDA	**236**	**130**	**176**	**231**	**292**	**361**	**437**	**521**	**611**	**708**	**812**	**926**	5,440
Depreciation	**(273)**	**(546)**	**(885)**	**(1,055)**	**(1,221)**	**(1,115)**	**(1,006)**	**(831)**	**(822)**	**(816)**	**(806)**	**(800)**	(10,175)
													0
OPERATING INCOME (EBIT)	**(37)**	**(416)**	**(708)**	**(824)**	**(930)**	**(754)**	**(569)**	**(310)**	**(211)**	**(108)**	**6**	**125**	(4,735)
Interest Expense	(53)	(93)	(66)	(40)	(46)	(58)	(42)	(25)	(40)	(53)	(32)	(11)	(559)
OP PROFIT BEFORE TAXES	**(90)**	**(509)**	**(775)**	**(863)**	**(976)**	**(812)**	**(610)**	**(335)**	**(251)**	**(161)**	**(26)**	**115**	(5,294)
Income Tax	0	0	0	0	0	0	0	0	0	0	0	(23)	
Tax Holiday	no	no	no	no	no	no	no	no	no	no	no	no	
NET INCOME (NI)	**(90)**	**(509)**	**(775)**	**(863)**	**(976)**	**(812)**	**(610)**	**(335)**	**(251)**	**(161)**	**(26)**	**92**	(5,317)

Capital infusions are structured into three tranches:

(in 000s)	**Tranche 1**	**Tranche 2**	**Tranche 3**
Cylinders	**2019**	**2023**	**2027**
Debt	554 €	347 €	334 €
Concessional Debt	633 €	397 €	382 €
Debt amortization in years	*2-5*	*6-9*	*10-12*
Equity	395 €	248 €	239 €
Total	**1,582 €**	**991 €**	**955 €**

The following table shows debt service, EBITDA coverage of debt service, and free cash flows, and calculations of notional terminal value in 2030 and the corresponding IRR for equity:

Table 57. Marketer with cylinder investment: debt coverage, FCF, TV and equity IRR (values in 000s except as noted)

Total Debt Service	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	TOTALS
Total Principal	1,186	0	0	0	744	0	0	0	716	0	0	0	2,646
Principal Repayments	0	297	297	297	297	186	186	186	186	239	239	239	2,646
Total Interest	53	93	66	40	46	58	42	25	40	53	32	11	559
Total Debt Service	53	389	363	336	343	244	227	211	226	292	271	249	3,205
EBITDA	**236**	**130**	**176**	**231**	**292**	**361**	**437**	**521**	**611**	**708**	**812**	**926**	5,440
EBITDA Coverage of Debt Service	4.46x	0.33x	0.49x	0.69x	0.85x	1.48x	1.92x	2.47x	2.70x	2.42x	3.00x	3.71x	
EBITDA after Debt Service	**183**	**(260)**	**(187)**	**(105)**	**(51)**	**117**	**209**	**310**	**385**	**416**	**541**	**676**	2,235
Taxes	0	0	0	0	0	0	0	0	0	0	0	(23)	(23)
Cashflow after Debt Service & Taxes	**183**	**(260)**	**(187)**	**(105)**	**(51)**	**117**	**209**	**310**	**385**	**416**	**541**	**653**	2,212

Operating Cash Flow	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	TOTALS
Net Income	(90)	(509)	(775)	(863)	(976)	(812)	(610)	(335)	(251)	(161)	(26)	92	(5,317)
+ Depreciation & Amort	273	546	885	1,055	1,221	1,115	1,006	831	822	816	806	800	10,175
+ Non Cash Charges	0	0	0	0	0	0	0	0	0	0	0	0	0
Free Cashflow From Operations	183	37	110	191	245	303	395	496	571	654	780	892	4,858
- Principal Repayments	0	297	297	297	297	186	186	186	186	239	239	239	2,646
Cashflow after Debt Service (FCF)	**183**	**(260)**	**(187)**	**(105)**	**(51)**	**117**	**209**	**310**	**385**	**416**	**541**	**653**	2,212
											Tax Adjusted EBITDA	741	
									Terminal Multiple 5.0x		Terminal Value	**3,703**	
- Equity Fundings	(395)				(248)					(239)			(882)
Net FCF to Equity (Net of Investment)	(212)	(260)	(187)	(105)	(299)	117	209	310	385	177	541	4,356	5,033
Total Equity Fundings	882												882
IRR to all Equity Classes	**24%**												

The equity IRR, based on the notional capital stack, is 24%, including a terminal value of approximately € 3.7 million in 2030. This rate of return is just adequate to satisfy equity providers. An increase in costs or decrease in volume or unit margins compared to the projections could make the investment unattractive to equity Funders, based on guidance received from the Ghanaian and international financial sectors.

The sensitivity of the return to equity with respect to changes in unit margin and in leverage is shown in the following table:

Table 58. Marketer with cylinder investment: IRR sensitivity to margins and capital mix

IRR to all Equity Capital

Revenue/t	24%	
140 €/t	10%	
145 €/t	17%	
150 €/t	**24%**	*Amount in price formula*
155 €/t	33%	
160 €/t	44%	

IRR to all Equity Capital

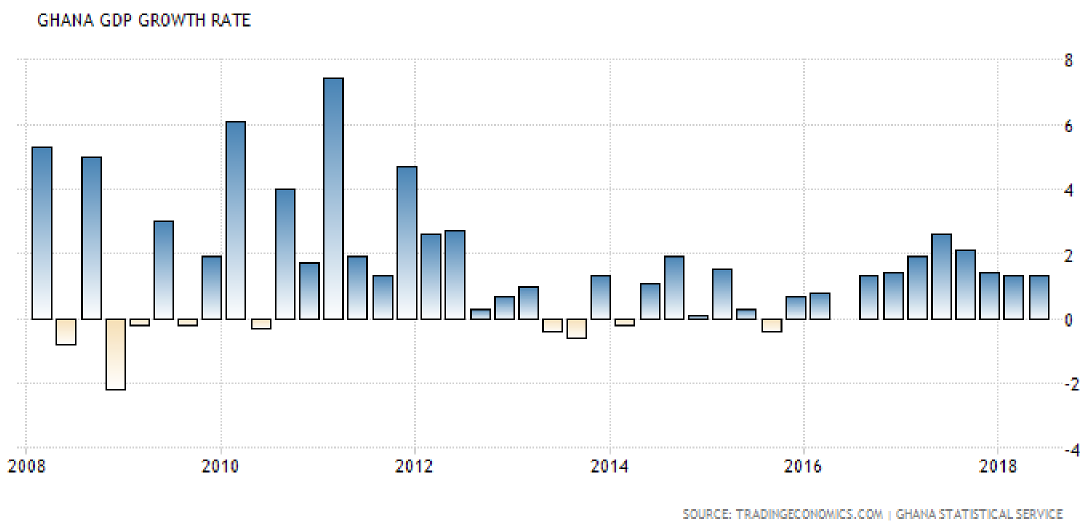
Revenue/t	Equity % of Capitalization		
24%	20%	**25%**	50%
140 €/t	11%	**10%**	7%
145 €/t	18%	**17%**	13%
150 €/t	**26%**	**24%**	**18%**
155 €/t	36%	**33%**	24%
160 €/t	51%	**44%**	30%

IX. Financing the Investments

17. Financial and Investment Environment

Annual GDP growth in Ghana ranged from 4% in 2007 to 8.5% in 2017, with a ten-year high of 14% in 2011 and a low of 3.7% in 2016. GDP growth rate between 2012-2018 averaged 6.13%. While GDP growth will spike to 7.6% in 2019, it is expected to taper off to 5.1% in 2023, according to the IMF.

Figure 42. Ghana historical GDP growth rates



Political and economic outlook[117]

- Ghana's overall political stability is not in question, but the fiercely contested political landscape is expected to give rise to significant tension between the ruling New Patriotic Party (NPP) and the opposition National Democratic Congress.
- The NPP's ambitious industrialization program is expected to enjoy some success but will proceed more slowly than planned, given a tight fiscal position, challenges in the local financial sector and the critical need to preserve debt sustainability.
- Oil and gas production will support GDP growth during 2018-19. As oil production gains start to ebb in the latter part of the forecast period (2018-22), non-oil growth will support a still robust overall growth rate as gains from an industrialization program are felt.
- Inflation is expected to fall modestly from 2019, owing to stronger domestic demand, rising global commodity prices and a weakening currency. These factors will remain in place in 2019-22, keeping inflation relatively close to the maximum official target of 10%.

[117] Source: Economist Intelligence Unit (2018)

- The cedi will remain prone to periods of volatility, given a dependence on commodity exports for hard-currency earnings and changing trends in investor sentiment towards emerging markets.
- The current-account deficit will fall from 4.2% of GDP in 2017 to an average of 3.1% of GDP a year in 2018-22 as higher oil exports are only partly offset by stronger import demand and higher profit remittances.

Economic growth[118]

Overall real GDP growth prospects remain favorable for 2019, with growth forecast at 5.9% boosted by the ramping-up of new oil and gas production from the Tweneboa-Enyenra-Ntomme (TEN) and Sankofa fields. On top of this, production from Ghana's first oilfield, Jubilee, is expected to pick up after a series of technical problems in 2016 and development work in 2017-18. However, oil driven growth rates will mask constraints expected elsewhere in the economy.

Growth in the services sector will be affected by what is expected to be a period of retrenchment in the banking sector from 2018, ahead of a large increase in banks' minimum capital requirements at the end of the year that some banks will struggle to meet (with the BoG likely to grant some extensions, prolonging the process).

Growth is expected to ease to 4.9% in 2020 as Ghana is affected by weaker global economic conditions and election-related uncertainty. Growth is then expected to recover to 5.6% in 2022, reflecting the development of new oil and gas resources and stronger non-oil performance as the government's policy reform efforts to boost the private sector start to bear fruit. The resolution of the border dispute with Côte d'Ivoire is expected to see new exploration and development work take place, while efforts to better integrate locally produced gas into the wider economy (especially for power provision, but also for industrial production and domestic uses) will accelerate.

Table 59. Ghana key economic indicators 2017a-2022e

%	2017a	2018e	2019e	2020e	2021e	2022e
Real GDP	8.5	7.1	5.9	4.9	5.3	5.6
Private consumption	4.9	4.8	4.6	3.9	4.4	4.6
Government consumption	3.8	2.4	4.8	6.2	2.9	3.2
Gross fixed investment	8.9	7.5	6.4	5.2	6.0	6.5
Exports of goods & services	11.6	9.2	7.0	5.4	6.0	5.8
Imports of goods & services	4.7	4.9	5.1	4.3	4.7	6.4
Domestic demand	5.4	5.1	5.0	4.4	4.7	5.9
Agriculture	8.4	3.7	3.2	3.4	3.3	3.5
Industry	16.7	12.6	7.5	5.1	5.5	5.9
Services	4.3	5.8	6.2	5.4	5.9	6.2
Other key indicators						
CPI, average %	12.4	10.0	9.5	9.5	8.5	9.1
Government balance, %GDP	-5.9	-5.8	-4.5	-5.0	-4.1	-3.5
Current-account balance, %GDP	-4.2	-2.8	-3.1	-4.0	-2.9	-2.7
Money market rate, average %	22.4	18.5	17.5	18.0	16.0	15.5
Exchange rate GHS: USD	4.35	4.52	4.96	5.47	5.82	6.01

[118] Source: Economist Inteligence Unit (2018)

Financial sector overview

Domestically, Ghana provides a broad range of private sector financial resources: approximately US$ 16.5 billion in banks, and US$ 5-6 billion in pension funds, mutual funds, and insurance companies.

As a result of long-term structural improvements in the macroeconomic environment, bank credit to the private sector has increased significantly and competition among financial institutions has increased. As of August 2018, 34 licensed commercial banks operated in the country[119].

Soundness indicators suggest the banking system is liquid and well capitalized, subject however to two exceptions: first, increased capital reserve requirements have been imposed by the Bank of Ghana for year-end 2018, and second, a bad experience with non-performing energy sector loans which required a governmental bailout, taking the loans off the banks' balance sheets and establishing a levy (tax) to offset the loan losses.

As of December 2018, a new rule will require Ghana's banks to have a capitalization of at least GHC 400 million (about € 73 million), and 20 Ghanaian banks have increased their capitalization to this level as of this writing. Ghanaian banking regulations also restrict banks from entering into a single transaction of a quantum in excess of 25% of shareholders' funds, and 10% in the case of a related-party transaction. Any one Ghanaian bank, therefore, could, in principle, deploy up to GHC 100 million (about € 18 million) toward a given third-party LPG project, subject to internal policies concerning concentration of exposure within any one sector. (Oil and gas, in this case, would be the sector, with LPG treated as a sub-sector.)

Bank loan portfolios are, in fact, still often concentrated in a few key sectors and with large borrowers. Rapid expansion of domestic branch networks, alongside rapidly expanding cross-border operations by parent banks, has increased potential for strategic and operational risk. From 2009 the sector has experienced a general deterioration in loan books, partly driven by high domestic arrears accrued by the government, with the amount of non-performing loans (NPLs) representing 22.9% of the total loans in November 2017, but eased to 22.7% in December 2017. At 22.9%, the NPL ratio is now at a level never seen before; the current rate only rivals those last seen in 2002. At the time, the NPL ratio was reported to have risen from 12% in 2000 to 19% in 2002.

Authorities have continued efforts to strengthen the banking and financial sectors by withdrawing licenses from five commercial banks in August 2018. In September 2017. Mobile banking, taking advantage of high rates of mobile phone subscription (139% in 2016), is well developed and growing in Ghana. A variety of products are available to consumers, from payment systems for university students to balance inquiries on savings accounts.

Capital markets have been developing at a rapid pace, though from a very small starting position, and despite that equity markets were adversely affected by the global financial crisis and experienced a slump through late 2008 to mid-2009. As of August 2018, the Ghana Stock Exchange (GSX) had over 42 listed companies, with a market capitalization of more than GHS55 billion. The GSX has been fully automated since 2008. Current regulations allow foreigners to invest in securities listed on the stock exchange without

[119] PwC (2018)

exchange-control restrictions. Ghana also became the second sub-Saharan country, after South Africa, to access global capital markets through the issue of a sovereign Eurobond, with a 10-year USD 750 million issue in 2007. Subsequently, Corporate Bonds and Notes, as well as Ghana government securities trade on the GSX. As of May 10, 2018, Ghana received a sovereign rating of B3 and B- by Moody's and Standard and Poor's, respectively, for a 30-year Eurobond.

Approximately 15 licensed primary dealers on the GSX, including banks, discount houses and brokerage firms, operate in the country's security markets and all bids, on both competitive and non-competitive basis, must be submitted via primary dealers. There are also 11 fixed income dealers and 28 Associated members. The market's investor base is relatively diversified; in June 2009 commercial banks held 27.4 percent of all outstanding government securities, with other notable holders included the Bank of Ghana (39.9 percent), insurance companies (0.9 percent), the Social security and National Insurance Trust (5.1 percent), firms and fund managers (5.6 percent), and retail investors (19 percent). In December, 2006, foreign investors were provided foreign currency accounts with domestic banks and can place bids on longer-term government issues with maturities (3+ years).

In December 2017, there were 27 Non-Life and 22 Life insurance companies, 3 reinsurance companies, 78 broking companies and one reinsurance broker, as well as 7,000 insurance agents in Ghana, which are regulated by the National Insurance Commission and governed by the Insurance Act 2006. The required minimum capital is as follows: Insurance company—GHC 15 million; reinsurance company—GHC 40 million; reinsurance broker—GHC 1 million, and insurance broker—GHC 300,000.

Ghana financial sector capacity for LPG financing

The Ghana financial sector is too small, with too limiting a set of investment and lending conditions, to be able to finance the full national LPG investment plan at the level described in this report.

It is, however, interested to co-fund justified projects up to its allowed limits.

The Ghana Investment Promotion Centre has expressed willingness to consider bundling of similar projects (e.g., the 8-10 new Bottling Plants) into a single meta-transaction for its purposes, which include providing relief on import duties on capital equipment and, for transactions above USD $50 million, seeking parliamentary approval for tax holidays.

18. Consumer Empowerment

Microfinance program

In each partner country of the Clean Cooking for Africa Program, the Global LPG Partnership has engaged with local partners to design and, where possible, launch and complete a pilot program in LPG microfinance. In most Sub-Saharan African countries, microfinance for LPG is a first-of-its-kind effort for both the LPG sector and the microfinance and banking sectors.

The purpose of these microfinance programs is to determine whether LPG demand and consumption can be unlocked and sustained on a commercial basis through replicable, profitable microloans which help consumers who cannot afford the full up-front cost of the equipment required to become an LPG user at one go, or who may have seasonally variable incomes that make it difficult to do so except at particular times of year.

These programs are collectively called “Bottled Gas for Better Life”.

The first instance was launched in 2017 in Southwest Cameroon. The Cameroon data obtained represent a potential benchmark for the Ghanaian program, which remains pending final approvals to commence as of the time of this writing.

The following table summarizes the status of these programs across the three active Clean Cooking for Africa partner countries as of this writing:

Table 60. Summary of LPG microfinance program status by country

	Cameroon				**Kenya**	**Ghana**
	Phase I	Phase IA	Phase II	Phase IIA	Phase I	Phase I
Households	150 (target reached)	50 (target reached)	680 (target), 416 registered as of this writing	150 (target)	150 (target), 63 registered at time of reporting	150 (target)
Location	One community in South West Cameroon	One community in South West Cameroon	10 communities across Centre, Littoral, South West, North West, West regions	TBD	One community in Nyandarua County	One community in Brong Ahafo Region
Project period	March - October 2017	November 2017 - May 2018	April - April 2019	TBD	August 2018 - June 2019	TBD
Status	Complete	Complete	In progress	Not yet started	In progress	Not yet started

Overview of Ghana microfinance sector

65% of the population in Ghana remains financially excluded in terms of formal banking (i.e., is unbanked).[120] This unbanked segment comprises a large number of women and low-income households. MFIs in Ghana, therefore, are tasked with servicing these financially vulnerable groups.

Growth of the Ghanaian microfinance sector has been slowed both by informality and regulation. Ghanaian microfinance, overseen by the Bank of Ghana (BoG) as the central regulatory body, is segmented into three tiers on the basis of the degree of formality and corresponding regulation: formal, semi-formal and informal.[121]

- Tier 1: Formal financial institutions such as Rural and Community Banks (RCBs), Finance Houses, and Savings and Loans companies.
- Tier 2: Financial Non-Governmental Organizations (FNGOs) – deposit-taking and profit-making organizations with a primary social purpose of making credit available to the most impoverished sections of society – and providers of *susu*, a traditional, community-centric means of saving, informally practiced in Ghana.
- Tier 3: Informal moneylenders and non-deposit-taking FNGOs.

Because Ghana still operates under the Consumer Controlled Cylinder Model (CCCM), LPG providers do not typically extend credit to consumers for the purchase of cylinders or stoves, which are the customer's responsibility to obtain under CCCM. Extension of credit might be offered by LPG marketers, as the future providers of cylinders to consumers, under the Branded Cylinder Recirculation Model (BCRM), once implemented, to accelerate their rate of customer acquisition or to improve their competitiveness among some consumers; however, extending credit comes at the expense of working capital and operating cashflow. The anticipated price structure for the BCRM supply chain, as described in Chapter 10 (Pricing) beginning on page 53, does not contemplate any additions to unit margins to offset the negative working capital and cashflow effects of extending consumer credit at large scale. The extent to which LPG companies extend consumer credit in Ghana will only be possible to determine after BCRM is in place and in practice.

Within Ghana's financial sector, there is intensive debate over the degree of regulation required by the different microlending segments. In 2011, public outcry over instances of fraud, embezzlement and bank closures led the BoG to issue strict new guidelines on unregulated MFIs.[122] The new regulations required that even non-deposit-taking FNGOs maintain minimum levels of capital and liquidity, and submit periodic reports to the BoG, making Ghana one of the few countries in the world that subjects non-deposit-taking

120 Trombetta et al. *Microfinance institutions and micro & small enterprises in Ghana: The potential of the missing middle*. International Growth Center, February 2017.

121 Bank of Ghana (2011). Operating Rules and Guidelines for Microfinance Institutions.

122 Trombetta et al. *Op cit*.

financial institutions to prudential regulation.[123] This considerably increased transaction costs that were ultimately transferred to clients, a majority of whom could ill-afford it.[124]

FNGOs are the most likely to serve low-income households that remain excluded by formal financial institutions, which either lack the capacity to serve them or are unwilling to serve them, because of the perception that consumer lending to households is too risky and too inefficient. Loans offered by FNGOs are usually designed to be accessible to lower-income people and are secured against salary or incoming payments, rather than collateral or capital. The BoG's regulatory constraints, however, have made it difficult for FNGOs to serve the very populations they were designed for. A March 2018 BoG publication listed 272 of 707 licensed MFIs as "active but distressed or folded up",[125] due to their inability to meet regulatory requirements. Interest rates are also relatively high, often exceeding 5% per month.

Program design

The National Petroleum Authority (NPA) determined in May 2018 that it would become directly involved in shaping the LPG microfinance program developed by the Clean Cooking for Africa/GLPGP expert team with Ghanaian local project partners, including the approval of the selected partners.

The LPG operational partner is to be Xpress Gas, and Planters Capital the main financial partner.

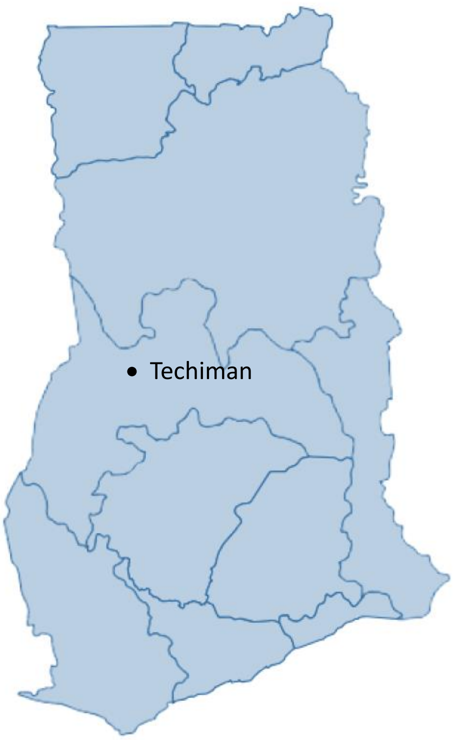
Xpress Gas is one of only a very few LPG companies in Ghana that are operating, in some part of their business, according to the main principles of the BCRM, in anticipation of BCRM's implementation nationwide. Planters Capital is a Tier 3 (non-deposit-taking) MFI.

GLPGP negotiated a multiparty agreement for the Ghana microfinance pilot program. The program will cover 150 non-urban households switching to LPG from biomass and charcoal for cooking.

The borrowing households will receive loans to cover the purchase of LPG equipment (double burner stove, 14.5kg cylinder and required accessories), which cost 359 GHC in total (€ 65.27). Households will make an initial security deposit of 71.80 GHC (€ 13.05), followed by six equal monthly payments. A market rate of interest of 4% per month will be charged on the principal, excluding the security deposit, in line with Planters Capital's usual lending rates.

The mutually selected project area is Techiman, Brong Ahafo Region, where both Planters Capital and Xpress Gas have operations.

Prior to launch of the program, GLPGP and the partners will select a specific target community and plan in detail the program



Bottled Gas for Better Life location in Ghana

[123] *Ibid*.

[124] Ayayi, A. G., & Peprah, J. A. (2018). *Cost implications of microfinance regulation: lessons from Ghana*. Journal of Sustainable Finance & Investment, 8(3), 259-274.

[125] Bank of Ghana (2018), *State of the Financial Sector in Ghana.*

activities, such as consumer sensitization, registration, credit screening (to the extent desired or required by the operational partners) and baseline surveying of participants.

The NPA has urged selecting a tightly-knit village community for purposes of the program pilot, so that loan recipients can easily co-guarantee each other against default[126]. While such communities are not universal in Ghana, they represent an initial frontier where loan performance may be superior, thereby creating a base of success for the project partners, motivating efforts to expand to large scale among similar communities and, from that stronger base, to expand to serve other sorts of community over time.

The NPA gave its approval to the selection of Planters Capital and Xpress Gas during the third quarter of 2018, and facilitated registration of the program with the Bank of Ghana, as required by Ghanaian law. Final approval of the program by the entirety of the parties remains pending as of this writing.

Monitoring and evaluation

Depending on the project location, the University of Liverpool and Kintampo Health Research Centre, as part of the Clean-Air (Africa) Research Group funded by the UK National Institute for Health Research (NIHR), have expressed interest to conduct an independent evaluation of the pilot phase of *Bottled Gas for Better Life* in Ghana. The University has secured funding from the National Institute of Health Research from early 2019 through mid-2021 that could include this project.

Issues and lessons from Ghanaian microloan program preparation

Selection of microfinance institution

For the reasons described earlier, the microfinance sector in Ghana proved much more difficult to navigate than in the other Clean Cooking for Africa Program partner countries of Cameroon and Kenya. The NPA contacted five MFIs on GLPGP's behalf about the microfinance project. All of the MFIs expressed reluctance to lend to households due to the historically high level of non-performing loans in the Ghana microfinance sector, and the minimum capital requirements imposed by the Bank of Ghana. The NPA was skeptical that any MFI would participate, even if GLPGP were to underwrite the loan amount, noting that the target group was mostly unbanked persons, and that it would be difficult to achieve a loan repayment level of more than 80% even with pre-screening of participants.

The NPA facilitated a meeting with Ecobank (a large pan-African bank), which was unwilling to co-sponsor the loan or be involved in loan collections, and insisted on a 100% guarantee from GLPGP on loan defaults, because the program was deemed too risky for Ecobank to underwrite. Ecobank also wanted to lend to GLPGP or to an MFI for onlending, instead of directly to the loan recipients.

Some MFIs, unwilling to lend to households, would participate in a microloan pilot with commercial users such as street food vendors presently using charcoal who could be converted to using LPG – such vendors are even more exposed to toxic smoke than household cooks. As the current Terms of Reference for Ghana within the Clean Cooking for Africa program specify designing and, if possible, launching a *household* LPG conversion program, a microfinance program for commercial LPG users could be considered at a later stage.

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[126] Such a co-guarantee was incorporated into the recently-launched *Bottled Gas For Better Life* program design for Kenya.

A successful small-business commercial program could, in turn, also catalyze more household LPG adoption.

The NPA was of the view that many MFIs were taking advantage of the high interest rate environment in Ghana. NPA recommended a number of MFIs that were charging below-market rates. The NPA also suggested that the LPG equipment should be provided for free[127] to low-income Ghanaians. GLPGP stressed the importance of the microfinancing model so that the program would be self-sustaining; partners should be able to continue or scale the program on a commercially viable basis beyond the pilot phase, even without GLPGP or other external grant support.

Through references from LPG marketers, GLPGP was introduced to Planters Capital, an MFI headed by a former senior executive at Beige Capital, a Ghanaian retail bank serving mostly individuals and SMEs. Planters Capital and the GLPGP Country Manager were able to negotiate successfully the terms of a partnership agreement for the microfinance program.

Selection of LPG marketer

Bottled Gas for Better Life in Ghana will be conducted in connection with the transition to BCRM. Therefore, a key requirement of the selected LPG marketing partner was that it should be an early adopter of cylinder re-circulation in its business model, either via home delivery or exchange of marketer-branded cylinders (empty cylinder for full) at the marketers' distribution points.

There are few such companies in Ghana. NPA's initial preferred partner for the microfinance program was the Ghana Oil Company (GOIL), an oil and gas company in which the major shareholder is the Government of Ghana. GOIL is also the leading LPG marketing company by market share (approximately 6%). As GOIL did not have the cylinder re-circulation model in place, and had no immediate plans to do so, GLPGP was unable to engage GOIL as a partner.

The partner eventually selected was Xpress Gas, which runs a portion of its business utilizing BCRM in four regions: Techiman (the selected Bottled Gas for Better Life project area), Accra, Edubiase and Tepa. Home delivery is provided at no extra cost to the consumer. Xpress Gas is in the process of transitioning its entire business to the re-circulation model. It has recalled about 500 unbranded cylinders to date from customers and these will be rebranded as Xpress Gas cylinders.

Education and sensitization

The pilot projects in Cameroon and Kenya have shown that sensitization activities are crucial in influencing adoption of LPG among communities of non-users. Non-LPG users are far more likely to adopt LPG if they are aware of the benefits of LPG, of how to cook local dishes using LPG, and of the health hazards of continuing to cook with charcoal, firewood and kerosene. As a point of comparison, researchers in India recently found that LPG usage and willingness to pay were higher among women who received information about the health benefits of LPG compared to traditional fuels, compared to women who only gained access to LPG without receiving the health information.

[127] The NPA also oversees the Rural LPG Promotion Program, financed by the Ministry of Energy, which has provided LPG equipment free of charge to rural Ghanaians.

Education focused on household economic decision-making is also important. In Kenya, GLPGP learned that many families were unaware that LPG, when used exclusively, would be cheaper on a long-term basis than charcoal. As LPG must be purchased in cylinders every few weeks while charcoal can be purchased in much smaller amounts on a daily basis, many perceived LPG to be the more expensive fuel, when in fact charcoal was the more expensive fuel over time. In Cameroon, a woman who was interviewed after a Bottled Gas for Better Life sensitization event stated: "I can use a [12.5kg] bottle of gas for one month and a half. I will not regret it, because if I calculate the charcoal or the firewood [I'd use], it will be more expensive than the gas I'm using." LPG usage per capita among this group of microfinance participants who attended the sensitization event was high, suggesting sustained and near-exclusive use of LPG for cooking. More attention to educating users about the cost advantages of LPG compared to other fuels is likely to encourage – beyond initial adoption – more sustained use of LPG over time.

As observed in Cameroon, endorsements from consumers and village leaders have resulted in neighboring villages expressing interest in adopting LPG through the microloan program. As the program expands in each country, GLPGP and its partners will be better able to employ such "word-of-mouth" publicity, engaging new LPG users as ambassadors to increase adoption in their own and neighboring communities. In addition, GLPGP's Bottled Gas for Better Life education, participant sensitization and launch events have been well covered by local media. This helps spread word about the microfinance program, including in areas as yet unserved by the program, and – through GLPGP's own outreach efforts and, potentially, those of complementary groups working on SDG7, including Sustainable Energy for All – into other Sub-Saharan African countries as well.

Expansion potential

Where it has been launched, Bottled Gas for Better Life has garnered interest not only from households but also from small businesses in the food services sector. A future phase of the program may involve business microloans for the purchase of LPG for commercial use. Loans to small and medium enterprises (SMEs) should constitute a lower risk lending activity to MFIs than household lending, since the LPG is used for an income-generating purpose, and many small business owners in Cameroon, Kenya, and Ghana already belong to organized credit and savings groups.

Street food vendors could be one target group – a sector dominated by women. They are particularly vulnerable since they are exposed for long hours daily to hazardous cooking smoke from firewood or charcoal, both professionally and presumably at home as well (a double health burden). Moreover, their cooking often mirrors what happens at the household level. The food vendors' embracing of LPG for cooking would be a catalyst to greater acceptance of LPG for household cooking.

There is also an opportunity to expand the program through creating synergies with other energy services. GLPGP has received extensive interest from companies in the off-grid solar energy sector to collaborate on delivering LPG for cooking and solar home systems as a bundle to customers, either via microfinancing schemes and digital repayments, or potentially using nascent pay-as-you-go technologies.

Additional funding sources for program expansion and underwriting

As the program expands over time, it is hoped that MFIs will become more comfortable with the concept and commercial viability of LPG microfinancing. The eventual goal is that the MFIs will be able to fully fund the loans on their own, and guarantees from GLPGP (or any other third-party guarantor) to eliminate risk on delinquent loans will not be needed.

However, in addition to loan funds, funding is required for each rollout of *Bottled Gas for Better Life* for:

- Staff to manage the project, including the initial outreach to government and to potential partners to recruit them into the program, and to oversee program rollout. Eventually it is hoped that MFIs and LPG marketers will undertake this type of partnership directly, but our experience is that having an external catalyst at this early stage helps tremendously in coordination and management of challenges.
- Printing of publicity collateral and educational materials on LPG use and safety.
- Sensitization and awareness-raising events, such as cooking demonstrations, and additional publicity efforts such as door-to-door canvassing in peri-urban and rural communities. In Cameroon for example, this cost around US$1,000 (including staff travel and collateral printing) for each community where eventually about 50-100 loan registrations would be obtained.
- Transportation, assembly and storage of equipment, prior to distribution to participants. Some of the MFI partner units in Cameroon were unwilling to store LPG equipment in their offices due to security or insurance concerns. This meant that any equipment uncollected by participants on the designated delivery date had to be transported back to suppliers' facilities, or incur extra costs for local storage.
- Hiring temporary staff to conduct baseline and end surveys for participants (M&E) as these are not business-as-usual operations for MFIs.

In current iterations of the program, the above activities have been funded by GLPGP using supplemental funding from a combination of donors apart from EU/KfW. It is envisioned that once proof of concept for LPG microfinancing is established, MFIs will be able to take on all or most of these costs (which should benefit from economies of scale with larger numbers of loans). Sensitization efforts could also be funded by a development finance institution, other donor, or supplemental project funding from other mechanisms (e.g., carbon credits).

Performance expectations based on prior Bottled Gas for Better Life programs

Because the Ghana microfinance program could not be launched prior to the time of this writing, it is not possible to provide performance data from the program here. However, results from the completed program in Cameroon may be indicative of what is possible in Ghana, noting that conditions in the two countries with respect to their LPG sectors and their microfinance sectors have certain key differences.

Key results from the first instance of Bottled Gas for Better Life, in Cameroon

As part of the LPG Adoption in Cameroon Evaluation (LACE) studies, led by Dr. Daniel Pope at the University of Liverpool, the LACE research team studied the cooking, health and livelihood impacts from the first Bottled Gas for Better Life pilot in Cameroon. The researchers collected data on fuel use, cooking practices, health and loan management aspects before and after LPG adoption by the program's participants. The data collected was compared to data from control households that did not receive the loan offer.

110 beneficiaries completed household surveys prior to receiving the LPG equipment, and again after the 6-month loan period. Additional surveys were completed by 1,000 randomly selected households in both beneficiary and control communities (Botaland village). Measurements of fine particulate matter ($PM_{2.5}$) in

kitchens and inhaled by primary cooks were measured in 35 beneficiary households over 48-hour periods. Qualitative in-depth interviews were conducted with a subset of beneficiary and control households.

Main results:

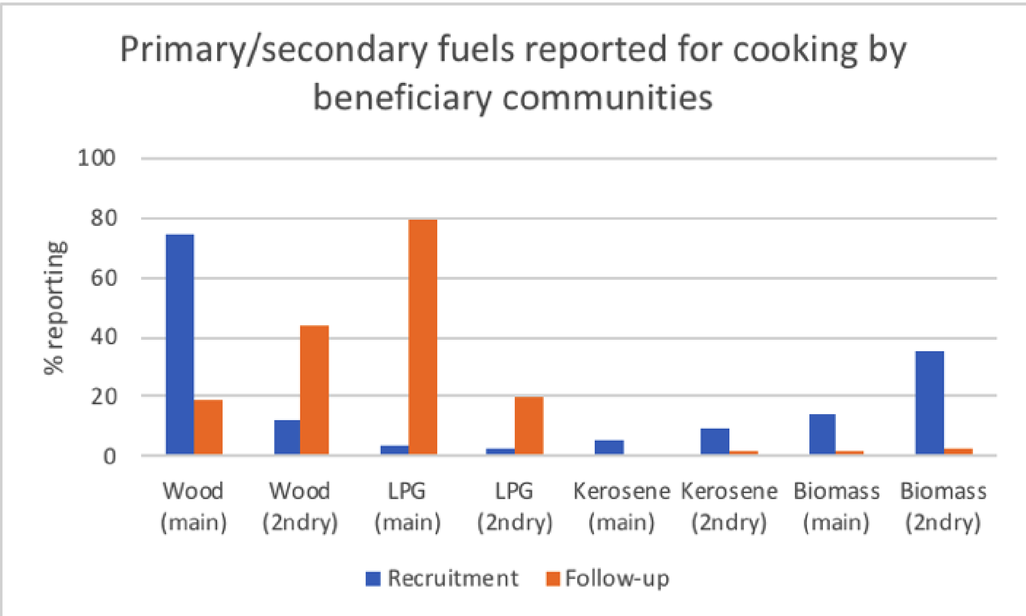
- The beneficiary sample covered a range of socio-economic status, with 24% earning below the national monthly average household income of 50,000 XAF (€ 78). Only 38% owned their own property and 45% rented their homes.
- Most households repaid the loan (89%), although 41% reported difficulty making repayments. The main reasons for delays in payments are reported below.

Table 61. Reported delays in making payments, by reason (Cameroon, as benchmark) (n=56 out of 110 l 41.2%)

Reason for delay	No.	%
Family problems	4	7.1
Financial problems	9	16.1
Health (own or child)	16	28.6
Work problems	12	21.4
Bereavement	3	5.4
Travel	9	16.1
Other	3	5.4

- Amongst program participants, primary fuel used shifted from wood (75%) and other biomass (15%) to LPG (79%) after the loan period, although no household yet used LPG exclusively. In comparison, almost no change was observed in a control community where the microloan was not offered.

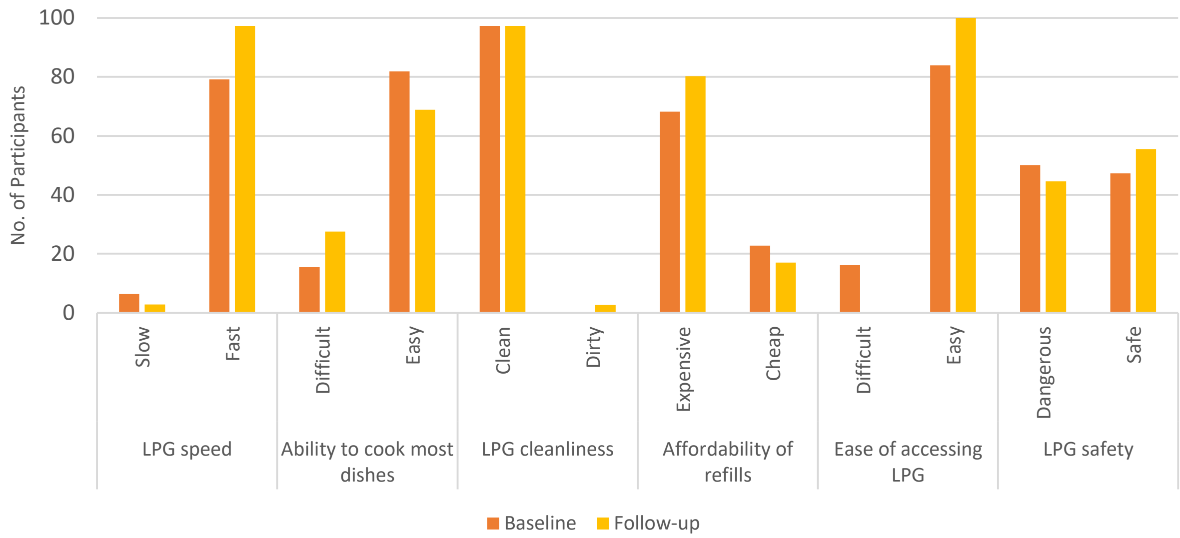
Figure 43. Cooking fuel use reported by LPG microloan beneficiaries (benchmark)



- Levels of $PM_{2.5}$, responsible for most of the disease related to household air pollution, reduced significantly. Exposure in primary cooks was recorded to be below the World Health Organisation's (WHO) indoor air pollution interim target I (WHO-IT1 of 35 ug/m^3), which confirmed LPG's health protective role.

Significant reductions in headaches (46% to 9%), eye problems (66% to 8%), cook burns (25% to 3%) and child burns (9% to 0%) were also observed after families adopted LPG through the loan program. Changes in perceptions of LPG over the loan period are shown in the chart below. These results indicate that future iterations of the program need to address the need for education on cooking local dishes using LPG, as well as the affordability of LPG refills.

Figure 44. Change in perceptions of LPG by microloan recipients (benchmark)



Key findings from 20 face-to-face qualitative interviews conducted with loan recipients include:

- Most borrowers reported using their gas stoves every day, some up to three times a day.
- Interviewees reported preferring cooking with their gas stove (to a three-stone fire) due to a faster cooking speed, and it being cleaner and easier to use.
- Both loan recipients and non-recipients found gas cheaper to cook with than purchased firewood, measuring their comparative spending on each over the refill cycle of a gas cylinder.
- Interviewees reported planning to continue using LPG after the loan was repaid.
- Most non-recipients of loans reported that if they had taken a loan, they would have been able to pay it back on time.

Ghana microloan program parameters

Table 62. Ghana microloan project parameters

Households	150 (target)
Location	Techiman, Brong Ahafo Region
Project Period	To be determined

LPG Equipment Provider	Xpress Gas
Microloan Funder	Planters Capital
Financial Facilitator	Planters Capital
Exchange Rate (Sept. 2018)	1 GHC=0.20 USD[128]
Equipment Costs per household	359 GHC (US$71.80)
Total Equipment Cost (per pilot)	53,850 GHC (US$10,770)
Interest Rate Charged	4% per month on principal, excluding 71.80 GHC (US$14.36) security deposit
Total Interest Cost (per household)	68.92 GHC (US$13.78)
Microloan Amount (per household)	427.92 GHC (US$85.58)
Total Loan Amount (per pilot)	64,188 GHC (US$12,838)
Loan Repayment Terms	Security deposit of 71.80 GHC (US$14.36) followed by 6 monthly repayments
GLPGP's role in financing loans	50% guarantee on the loss of the remaining principal of delinquent loans
Loan Repayment Performance	To be determined
LPG Consumption (per capita per year, annualized)	To be determined
MFI Compensation for M&E Surveys (per household)	To be determined
Comments	MOU with Xpress Gas and Planters Capital pending execution as of this writing

Pay-as-you-go technologies

Pay-as-you-go technologies have been successful in off-grid lighting and electrification at shrinking significantly the size of individual purchase transactions for the consumption of energy. This has made off-grid electricity more affordable, on the dimension of transaction size, for households who find it difficult to accumulate the savings necessary to make a larger, single purchase, such as to own solar PV home equipment outright.

In LPG markets with unregulated end-user pricing and a strong mobile payments and wireless data services environment, such as in urban East Africa, new and established LPG distribution companies have begun experimenting with business models and technologies to apply the pay-as-you-go approach to LPG cylinder refills.

Their business premise is that by making the size of individual purchase transactions much smaller (and therefore much more frequent), many poor consumers who otherwise would not adopt and use LPG due to the size of purchase transactions can be persuaded to do so.

Initial pilot programs in the hundreds of users are being carried out by several companies in East Africa.

The latest generation of such systems for LPG employ wirelessly Internet-connected "smart valves" with embedded meters and controls which allow users to prepay for small quantities of LPG that are then released by the smart valve until the prepayment amount is used up. This is similar in practice to buying mobile phone minutes on a prepaid basis and then using them.

The cost of such valves is in the range of € 30 to € 50, which potentially doubles the asset intensity (*i.e.*, the CapEx) of an LPG distribution business which utilizes them. Unless and until those costs decline sharply,

128 U.S. Dollars are referenced in this chapter, rather than Euros, because the microloans were underwritten in USD.

pay-as-you-go LPG companies may face significant challenges in generating adequate profits and financial returns compared to traditional LPG marketing and distribution companies serving the same markets, or may have to price significantly higher (per kg on average) to recover their added technology cost, thus reducing the size of the market they can serve.

To recover the added cost of the smart valve over a reasonable time period, there are two main approaches, both of which are being used:

i. Charge the customer more, in some way. This can be through a subscription fee charged in addition to the cost of the LPG consumed, or through a surcharge to the LPG fuel cost, or both. This is more practical to do in an LPG market with unregulated pricing than in a market, such as Ghana's, that has regulated or semi-regulated LPG pricing.

ii. Extract some level of operational savings by using the telemetry and usage data from the smart valves/meters to improve customer service and to optimize logistics. In practice, such operational savings have not risen to a level at which, by themselves, they cost-justify the pay-as-you-go technology.

Pay-as-you-go LPG companies are making two strategic bets. It is too early, as of this writing, to judge whether the bets will prove sound, leading to meaningful scale of adoption and use and to commercial success for at least some competitors. These bets are that:

i. A consumer who starts out as a pay-as-you-go customer of a given company will remain a customer of that company over the long term. That is, will pay-as-you-go technology serve an on-ramp to the national LPG system for new users, who eventually transition to the traditional part of the LPG system (where the price per kg of LPG is lower, but the transaction size is larger), or will they, mostly, remain pay-as-you-go customers for life? For companies that seek to create business value from LPG service, this bet may be hedged by operating a parallel LPG business on the traditional pay-as-you-refill model, so that customers who transition from pay-as-you-go can remain brand loyal. For companies that seek to create business value from selling the pay-as-you-go technology to other LPG companies, the result from this bet will determine whether their market is a narrow, niche market requiring a continual churn of the newest LPG users to survive, or whether it can expand to a meaningful share of the total residential LPG market, country by country.

ii. The cost to acquire, deploy and use the pay-as-you-go technologies applicable to LPG will fall rapidly and significantly with time, increased scale, and growth in smart valve production volumes.

In Ghana to date, the US-based biomass stove manufacturing company Envirofit has prepared to enter the LPG market with a pay-as-you-go LPG offering. Envirofit plans to operate as a marketer of LPG in Ghana once it obtains the necessary governmental licensing. The company intends to experiment with pricing and business models to find an optimal value proposition whose price points and elements are sufficiently attractive to a critical mass of unserved Ghanaian consumers as well as sufficiently attractive to the company and its investors.

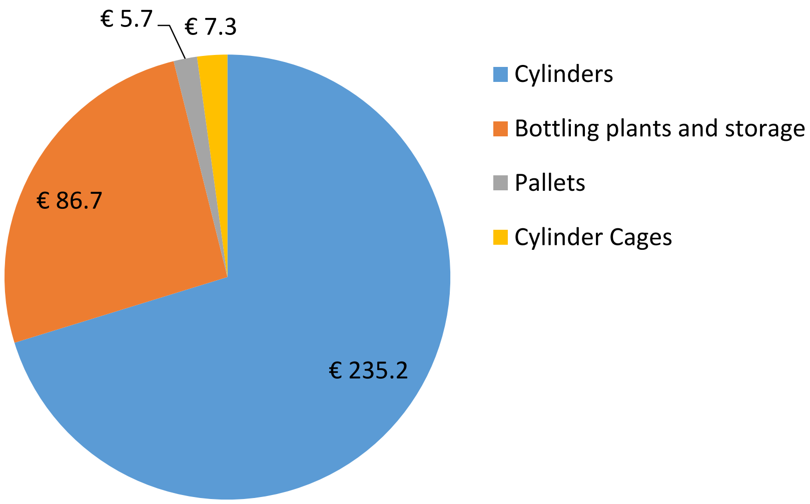
19. Investment Plan Overview

The detailed investment and financing plan is documented in the companion **Ghana LPG Investment and Implementation** report. In this report, this Part summarizes key elements of the companion report.

The GLPGP Clean Cooking for Africa expert team, after discussions with Ghanaian governmental agencies and financial sector entities, identified the following € 335 million of capital expenditures over the 2019-30 period to help achieve such LPG penetration.

Table 63. Capital investment requirements to 2030 for LPG sector scale-up

Category	Capital requirement (mm Euro)	Supply chain node
Cylinders	€ 235.2	Bottler or marketer[129]
Bottling plants and storage	€ 86.7	Bottler
Pallets	€ 5.7	Bottler or marketer[94]
Cylinder Cages	€ 7.3	Retailer
Total	**€ 334.9**	



Summary of financial structuring and arranging approach

To fund these investment projects, it is recommended to create up to four types of financing vehicles: two special purpose vehicles (SPVs), Non-Bank Financial Institutions (NBFIs), or Investment Funds (Funds).

A potential financing role for the Clean Cooking for Africa Program/GLPGP could be to provide the expert resources to act as technical advisor to the SPV managerial companies, the NBFI and/or the Funds, to help establish objective outside management and oversight of comfort to both large foreign and some domestic institutional (debt and equity) providers (Funders), as well as risk mitigation sources.

[129] The final determination by Government of which node shall be required to invest in, brand and deploy cylinders into the market and maintain and ensure their safety has not been completed as of this writing.

The recommended approach for mobilizing funding, guarantees, and risk mitigation options is initially to focus on sizable sources, as "leaders," in building the capital and risk mitigation layers and "crowd in" other Funders. This entails engaging both Ghanaian and non-Ghanaian sources. Ideally the approach will enable GLPGP-related entities in the target markets to mobilize funding to build out the LPG supply chains, and use commercial and concessional capital (Blended Capital) to yield, in hard currency, an overall target debt interest rate of around 9% and a target equity internal rate of return (IRR) of around 20%. These rates are consistent with what capital providers to top-ranked investments are currently realizing in target Sub-Saharan African markets.

Identification of prospective funding sources

To focus efforts efficiently on targeting the largest and most accommodative mix of blended capital from pivotal funding groups like DFIs, IFIs and MDBs as leads, coupled with risk mitigation, the Clean Cooking for Africa/GLPGP team conducted face-to-face discussions and phone calls, and researched comparable activities of the targeted organizations.

Domestically, Ghana provides a broad range of private sector financial resources – approximately US $16.5 billion in banks, and US $5-6 billion in pension funds, mutual funds, and insurance companies. Ghana also has access to sizable external Funders, public securities markets on which new securities can be listed which feature advanced securities regulation and oversight providing investor confidence, national investment promotion agencies with clear roles and reporting mechanisms, and key governmental agency initiatives. There are numerous Ghanaian funding precedents that may be good references for structured LPG investment. GLPGP has chosen two, as discussed below, that are especially important as being instructive on mixing various Funders and risk mitigation mechanisms: Energy Sector Levy Bonds (ESLA Bonds) and the Produce Buying Corporation shelf (PBC Shelf) securities issuances.

Moreover, the present Minister of Finance is a former investment banker and has put in place initiatives to attract both domestic and foreign capital sources for national private and public sector development. The Ministry of Finance (MoF) has created domestic investment vehicles, such as a US $250 million (targeted US $1 billion) Ghana Infrastructure Investment Fund (GIIF). The Ghana Investment Promotion Center (GIPC) has a mandate to attract $10 billion for investment into Ghana in 2018 alone, and is consequently supportive of initiatives like the LPG investments discussed here.

Internationally, MDBs, such as the IBRD, IDA, AfDB, AsDB, EBRD and IADB, committed almost US $84 billion in 2014. European DFIs, such as BIO, CDC, COFIDES, DEG, FINNFUND, FMO, IFU, Norfund, OeEB, PROPARCO, SBI, Sifern, SIMEST, SOFID, and SWEDFUND committed $6.8 billion in 2015, and OPIC a further $4.4 billion. IFIs contributed additional funds. So funding and Funders are available if the targeted recipient is right. These dynamics are discussed in more detail later in this document.

Key financing topics

This Part of the report will discuss:

1. The investment funding needs;
2. Preferred structuring options using Blended Capital;

3. Factors to consider in structuring to access these Funders' capital on optimal terms;

4. Prospective Funders (Ghanaian and foreign); and

5. Risk mitigation options for the Funders.

This is an evolving process, because regulatory and other related frameworks for the new Ghanaian LPG operational paradigm and ecosystem are still being refined locally, and specifications of the investment projects remain subject to change by the Ghanaian authorities.

Critical path of financing steps

Based on the research and analysis of the Clean Cooking for Africa/GLPGP financial expert team (as set forth more fully in the companion *Ghana LPG Investment and Implementation* report), the following steps are recommended to be taken by the Government and its advisors[130]:

1. Confirm the Government's support for the proposed, or some amended version of the, national LPG investment plan (Investment Plan), including confirmation by the NPA, MoF and Ministry of Energy (MoE);

2. Select the appropriate funding structure(s) to optimize access to Funders at the most attractive overall terms for the Government, and for designated private sector champions;

3. Identify the leading Funders which can "crowd in" others.

4. Ensure the domestic execution parties have the cash flow absorption, deployment and generation capacities to support the proposed financing structures and to perform their roles.

5. Strengthen the "bankability" of the financing with sufficiently strong backstops, such as levies, guarantees and risk mitigation tools.

6. Secure operational approval from relevant ministers and agencies (including NPA, MoE and MoF) as to the structuring and financing path chosen.

No set of Funders can ultimately be chosen until an LPG Investment Plan has been approved by the Government, and the specific recipients of the associated funding (that is, public sector or private sector companies or consortia for each major project or expansion of an existing business) identified and qualified.

Summary of assets and projects requiring financing

The financing would cover 9.3 million LPG cylinders of 14.5kg equivalence, 10 bottling plants with appropriate storage capacity, palletization assets for moving the cylinders safely and effectively, and cages for retail cylinder display and management. The cylinders would be funded in three tranches spaced over the 2019-30 period, with interest only the first year and equal principal repayments in the remaining years. The BPs would be built and then enlarged in three tranches starting in 2019, 2023 and 2028. The palletization assets' cost, after an initial $1.3 million in 2020, would be spread over the remaining years.

130 Which may continue to include GLPGP

As detailed in Part VIII (Critical Path LPG Infrastructure Investment Projects to 2030), importation and production facilitates and bulk storage and transportation capacity are adequate to support the expected sector growth through 2030, and therefore do not require financing attention for expansion at this time.

Capital recovery and affordability mechanism

An important element in the proposed Investment Plan is the establishment of a notionally 12-year LPG levy in the LPG price structure, such that the price structure can reduce the initial cost of cylinders to the supply chain (either Bottling Plants or marketers, based on pending final market structure determinations to be made by the Government). This reduction, if employed, is in effect a subsidy that covers a portion of the capital cost of the key, high-risk asset—cylinders—thereby improving the risk profile of the cylinder investment for the BPs (or marketers) and their investors and lenders, increasing substantially the rate at which cylinders can be acquired and deployed without generating negative cashflow, and as a secondary benefit, potentially decreasing significantly the size of the deposit required of consumers to acquire a new LPG cylinder. This mechanism is similar (but in a positive sense) to the ELSA levy used to clean up the balance sheets of Ghanaian banks which were deeply exposed to non-performing petroleum sector loans in recent years.

This mechanism, which (if paid by the consumer) would increase LPG pricing by approximately 3% on average over 12 years, might increase consumer demand, but quantification of that effect was not feasible to calculate with the data available. The countervailing reduction in consumption from such a price increase would be approximately of 1.4%, based on the price sensitivity analysis from Part VI.

As an alternative to charging the consumer, this amount could be deducted from the margins provided to the BPs (assuming the BPs are made responsible for the cylinder investment). This alternative is discussed in Chapter 16 (Investments at the Firm Level), which begins on page 165.

The LPG levy, if adopted as proposed and as discussed to date with the Government, would result in a reduction in the capital cost paid by the Bottlers (or marketers) for cylinders of approximately 40%. This 40% savings would have a ripple effect throughout the supply chain, potentially reducing in proportion the working capital need of the distribution and retailing network and the one-time deposit amount to be paid by consumers for access to their LPG cylinder service under BCRM.

The levy, when combined with an SPV or other similar financing vehicle for pooling of national cylinder acquisition and management, has several purposes:

1. To partially shift the risk associated with cylinder investment from the Bottlers to the LPG market as a whole (that is, recovery of capital is partially shifted to the levy, a state-administered mechanism associated with the total volume of LPG consumed in the country, and not to any one private counterparty);
2. To increase (by approximately the same 40%) the rate at which the entire supply chain, starting with the Bottlers (or marketers)[131], can acquire and deploy cylinders without reducing their free cashflows to unsustainably low levels, or to zero or below;

[131] Each node of the supply chain downstream of the cylinder investor (Bottler or marketer) obtains its cylinder inventory from the node above on deposit, which consumes working capital. The deposit amounts would decrease by 40% in a cascade down the chain, ultimately reducing the deposit paid by the consumer for an individual new cylinder.

3. To provide a layer of improved diligence, transparency, and accountability for cylinder assets to the Funders, in view of many private-sector LPG businesses having non-standard or incomplete accounting (of their LPG operations, where multiproduct), insufficiently strong balance sheets, inadequate credit capacity (such as for obtaining letters of credit affordably), and so on;

4. To increase the focus of the LPG sector on customer acquisition and customer service by reducing the need to focus on cylinder acquisition and financing.

Between the marketers and the Bottlers, the Bottlers may be the best-positioned supply-chain node to buy the cylinders, and around which to design the funding mechanism. This is based on their size and economic scale relative to most marketers, thereby being most likely to generate consistent cash flows and a mix of fixed and mobile (cylinder) assets that can be attractive to Funders. This has been suggested by banks and Ghanaian officials (NPA, MoE, etc.) as well as pension and other potential institutional investors, and is supported by the comparative pro-forma economics of companies at each of these nodes in Chapter 16 (Investments at the Firm Level) beginning on page 165.

Importantly, the structures proposed in this report to back these expenditures benefit from: transparency, liquidity, and potential pricing and returns requirements of Funders as well as regulatory bodies that control local institutions such as banks, pensions, and insurance companies. This set of benefits should make successful funding more likely.

Main structuring options

1. The four options discussed below are the likeliest alternatives on an initial basis, based on the fact that the NPA and Task Force deliberation and decision-making process regarding the investment projects and enabling environment are not yet concluded. The options will be refined based upon further local LPG constituent and Funder discussions. While they are not the only options, they represent the most attractive identified to date based on extensive consultations.

2. The four options all entail prioritizing the blending of local capital with international capital. They differ in that the Investment Funds approach (Option 4) will most likely <u>not</u> attract considerable local funding, because institutional investors have statutory limits of 15% of portfolio (especially, pensions) on how much they can allocate into investment funds. Although this is being reviewed by the National Pensions Regulatory Authority (NPRA) and exceptions can be made, it is a probable limiting factor for the foreseeable future. It might also be the case, as with the GIIF, that MoF could co-invest if MoF determines that doing so meets important national objectives. Investment Funds also involve a longer implementation process, especially in terms of capitalization. However, they are otherwise an attractive option because they offer exposure to many Funders who can only invest in investment funds (sovereign funds, international pensions, some family offices, etc.). They also open up DFIs' fund investment units to participate.

Four Options

1. The following four options are prioritized as follows. They match funding structures with appropriate Funders and risk mitigation sources:

   a) **"SPV-G (Ghana)" Listed.** For example, an LPG sector growth SPV. The SPV would fund the underlying modalities' growth. A dedicated LPG fuel levy could be created and used to cover the portion of the capital costs borne by the SPV that the underlying modalities would not repay. A levy resembling the existing ESLA Bonds levy could be structured and used to back-stop the SPV. DFI and other guarantors could also be brought to support the Investment Plan.

b) **LPG (Vertical) SPVs-listed or Non-listed.** For example, a cylinder-based SPV. As with all the structures, this option would depend on the creation/enhancement of the "bankability" of the underlying entities to be funded and de-risked. This also involves more active outside oversight, such as through an escrow agent and specialist[132], and transparent involvement of capital expenditures entities. The level of official market based oversight – such as through the Ghanaian Securities and Exchange Commission (SEC), if this SPV were listed, will also impact the level of appeal such a structure will have to Funders.

c) **LPG Non-Bank Financial Institution (NBFI).** Create a new NBFI entity which could finance specific LPG developments (and also could be listed). There are specific regulations and requirements GLPGP has researched and discussed for potential partnering with existing local financial institutions leaders such as Adenia, Databank, Injaro, and Petra. Institutions such as Adenia and Injaro also carry the added credibility of having DFIs and IFIs as backers. This should be commenced by targeting logical initial players involved in building out financial inclusion, innovative finance, capital markets and solutions for private/public sector financing. These should include, but not be limited to, AfDB, CDC, DBSA, DEG, FMO (already a financial sector investor in Ghana via Fidelity Bank), IFC, Norfund, OPIC, and Swedfund. These institutions are active in financial institutions/innovations and also infrastructure plays.

d) **Investment Funds (LPG infrastructure Development Fund (LID) and the LPG First Cost Fund (FCF)).** Clean Cooking for Africa/GLPGP could create two Investment Funds that would act as aggregators and managers of DFI and other institutional capital from major Funders. The LID Fund would be for the capital expenditures and growth capital along the LPG supply chain. The concessional-rate FCF Fund would be for the related SME working capital and microfinance needs. GLPGP has been exploring the LID Fund with local fund managers like Injaro and Adenia. Both manage major DFI and other non-Ghanaian capital, so they would be good groups with which to consider building the Investment Fund(s). Because of the FCF Fund's mandate to facilitate accessible and affordable finance for SMEs and consumers, it may be an earlier candidate to design and partner with a local financial institution, such as Stanbic or Databank, which have asset management activities.

2. These funding mechanisms could also be used to reposition the Ghanaian station owners who need funding to migrate to other roles on the value chain. This could be done through the creation of an NBFI with units/shares/debt eventually listed on the GSX. This will appeal to DFIs and IFIs trying to facilitate the broadening of local capital markets in Ghana. Such a listing might

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[132] Such as Clean Cooking for Africa/GLPGP

even go as far as the London Stock Exchange AIM where African growth stocks from Ghana and elsewhere have listed. Ensuring that these entities can be made a "bankable" group may be needed to justify creating an NBFI.

3. In general, the following summarize the main advantages, risks/issues and mitigants for these four options:

Primary Advantages

a) They are potentially appealing to the Government because MoF, GIPC, and BoG are all trying to encourage more domestic and foreign institutional investment into Ghana's infrastructure and critical social and business sector development.

b) They will also appeal to DFIs and IFIs who are trying to promote capital flows into Ghana and emerging markets through innovative financial instruments. AfDB, CDC, FMO, OPIC, and the IFC are active examples of groups to be approached to back these instruments in some capacity. This can be through investment in the SPVs, on-lending or funding the NBFI or parent company, investing as limited partners in an Investment Fund (debt or equity funds), or providing guarantees. These groups have indicated their potential interest once the specifics are established behind how such vehicles might be structured and operated.

c) They can attract a wide range of local institutional investors such as pension funds, mutual funds, insurance companies, private investment houses and foreign investors.

d) Statutory rules governing pensions and insurance companies favor (after Ghana Government securities) corporate debt and listed investments. Private securities have more restrictions.

e) For insurance companies, a listed instrument, and particularly if issuing debt, does not require a 15% discount reserve for performance as would be the case with equity.

f) The precedents for documentation and structuring have been established and accepted for SPV and corporate related securities issuance and shelf registrations of debt and equity, bonds, etc. This means that the primary targets among local market institutional investors and foreign investors are familiar with the concepts involved.

Primary Risks/Issues and Mitigants

a) SPV or NBFIs may at first sound complicated, but Ghanaian investors understand them well, based on established precedents. Ghana has numerous SPVs that have attracted Funders' institutional capital into sector enterprises such as cocoa and the energy sector bond restructurings. Ghana also has numerous NBFIs and Investment Funds.

b) Numerous public listings have taken place. The listing process requires a filing with the Ghana Stock Exchange (GSX) and SEC. It also requires the creation of a more detailed Offering Document which meets all listing standards. This can take about

90 days depending on the focus of the SEC and the GSX, once the issuer of the securities has completed and filed the appropriate documentation.

c) The local market providers of banking advice, accounting, listing, legal, structuring and administration are professional and are appropriately experienced, having created complex vehicles such as the ESLA Bonds and PBC Shelf Registration. Regulators too, are well versed. GLPGP has already engaged with certain service providers (bankers/advisors like Databank, Stanbic, Barclays, and PwC) and senior leadership at GSX, SEC, NPRA, NIC, MoF, GIPC, BoG, and other regulatory bodies, which have shown broad interest in seeing such innovative financial solutions brought to the local capital markets. This goodwill can be a magnet to attract both domestic and foreign capital into developing Ghanaian capital markets further.

Important drivers in choosing among alternatives for financing the investments

Important requisites for choosing financing approaches and sources include:

1. Ghana's targeted LPG-related funding needs should be well defined.
2. The funded entities or modalities in the LPG value chain behind the ultimate repayment responsibilities should be able to demonstrate "bankability".
3. The debt and equity (or other instruments) should reflect the blended capital that is most efficient, to achieve the costs and structural terms most suited for the Investment Plan.
4. The risk and return needs (financial, liability management, etc.) of the Funders have to be factored into the instruments for best success potential to be able to close with the Funders.
5. Attracting the participation of meaningful internal sources is a means to "crowd in" external funding sources by providing a vote of confidence.
6. ESLA and PBC issuances provide good precedents that have appealed to Funders, given their cash flow predictability as well as managerial, operational and financial transparency, and encourage faster responses from Funders.
7. There should be built-in risk mitigation: Escrow accounts, liquidity, governance by outside parties (trustee agents such as banks and industry auditors) to monitor economic flows.
8. Respected, professional, and sector-experienced management for the funding vehicles is necessary.
9. If possible, an "official request" by the Government will facilitate responses from DFI, IFI, and MDB Funders when sound, detailed business plans for the projects and business expansions are in place. The Government has been cautious due to its own IMF-imposed debt ceilings, but its IMF oversight may be easing soon, which will open up the Government's ability to become more directly involved in the financing. For example, the Government through MoF might reach out to the World Bank Group's International Bank for Reconstruction and Development (IBRD) for funds to be arranged to finance the Investment Plan. (Only governments can approach IBRD directly to initiate such discussions.) The Government may also consider approaching climate finance facilities such as the NAMA Facility of GCF.

Funder issues to be addressed in funding the investment plan

1. In building the specific capitalization mix from blended finance sources, one must be aware of the particular characteristics of the targeted Funders, and take these into consideration. These include but are not limited to:

    a) Funders' Own Liability and Fiduciary Requirements: Requirements for repaying or meeting their funds sources' repayment requirements. Pensions and insurance companies need to match the weekly, monthly or other payment requirements of their clientele.

    b) Other Competing Investment Opportunities: The range of structures and the risk-adjusted returns being offered is considerable.

    The opportunity cost of taking on an LPG-related investment versus other investments available must be addressed. LPG-related investments are competing for domestic funds against government securities and also other high-quality fixed income instruments.

2. For the proposed and recommended LPG structures to be attractive, the funding vehicles must at a minimum be able to attract investors with the correct blend of risk-adjusted prices, equity comparable returns (meaning high and predictable cash flow), credit comfort (if debt or debt-like), and maturities at least as attractive as those of comparable opportunities.

3. For the portion of the Ghana LPG sector development funded by such entities, the four options are appropriately suited to take advantage of the structural expectations and realities in Ghana's capital markets.

4. GLPGP determined from its face-to-face discussions and market research with leading Ghanaian investment groups and banks, that:

    - There is a preference for debt or fixed income-linked investment securities over equities (for reasons of predictability of returns, transparency, and current income);

    - The local institutional investors have both more regulatory and investment preference for listed or Government-supported instruments (e.g., ESLA Bonds, PBC Shelf, GoG Bonds and Treasury Securities).

ESLA Bonds, PBC Shelf Registration, and other benchmark financings

ESLA Bonds

This type of analysis is being factored into the team's "structuring/pricing" considerations for the Ghana GLPGP-related vehicle(s). In addition to GoG bonds, there are two relatively recent and good market proxies for local and foreign investor appetites for structures in Ghanaian capital markets.

First are the ESLA Bonds. A distressed situation in the oil and gas sector led to Ghanaian banks with a major exposure (12-15 billion Cedis) to non-performing loans from local companies. A levy (ESLA) was created by the Government to create a support mechanism for the energy sector and used by the MoF as a back-stop for bonds that would be issued on behalf of stranded energy entities, that could not repay their bank debt. ESLA Bonds were swapped mainly to banks and other energy sector debtholders for existing Ghanaian Energy SOEs' debt that was underperforming and hindering the banks' abilities to lend more into the broader economy. An SPV raised 6.5 billion Cedis worth of bonds to pay the banks, turning that portion of the non-performing loans into performing. This was issued in two tranches – 7-year and 10-year initially only to local institutions. The 2017 ESLA Bonds were priced at roughly GHC (Cedis) 19% to 20% with 7 to 10-year maturities for local investors. Investors preferred the 7-year maturities because they were priced closely to the coupon on the 10-years (both 19% to 20%). The MoF and BoG had to encourage bank buyers of the bonds to take more of the 10-year paper as well. What is demonstrative in this example, and helpful for GLPGP-related entities, is that the MoF is actively working to encourage local institutional investors to take longer-term views of their investment securities. This is to build out the yield curve options for funding longer term projects in Ghana.

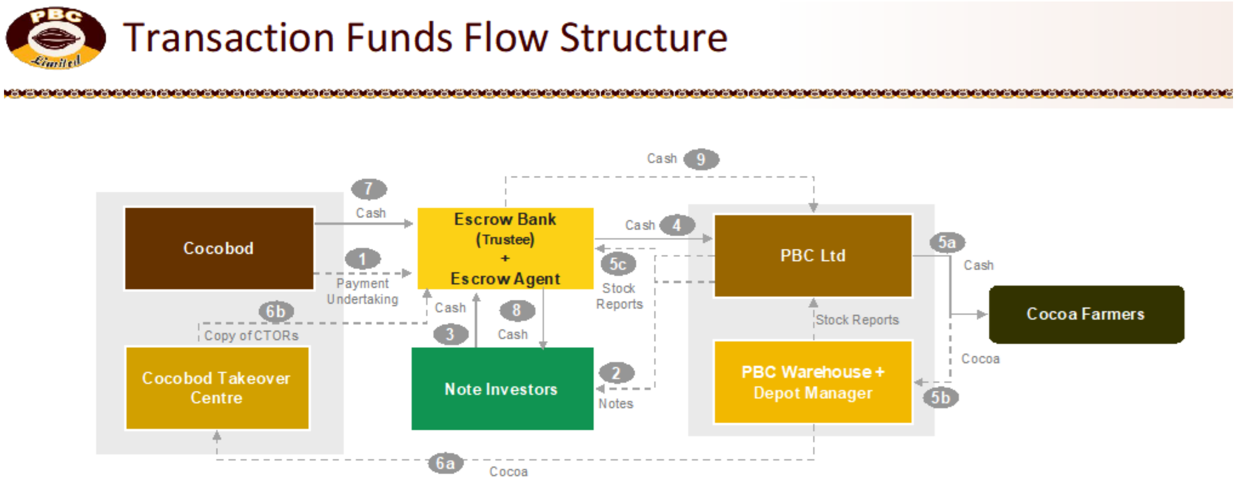
This recent example, and the current experience of levies already embedded in the market price formula of Ghana's LPG, demonstrates there is successful, large-scale experience in Ghana with a levy approach. The public and media understand the levy concept as well. Consequently, the approach of using a levy to back-stop a discounted cylinder acquisition cost to the consumer (as well as to industry) might have broad popular appeal. It directly benefits consumers through a lower initial deposit cost for cylinders instead of what may be seen as their having to pay for the mistakes of others (banks). This may also incentivize technological change, by switching a part of the cost burden for LPG switching from new LPG users to the entire LPG using population, or (under an alternative and broader levy approach), to the general population. For levies, the proceeds go into the Bank of Ghana's Consolidation Fund, unless exempted. MoF should be asked where the Reimbursement Fees' funds would be kept, separate and ring-fenced, to pay off the aggregate cylinder discount.

PBC Shelf Registration

Second is the US $100M PBC Shelf issuance of Notes. Each phase of drawdown issuance is priced (through a standardized pre-approved pricing amendment filed with the GSX and SEC). This enables the pricing on each tranche to be made in a manner to attract the local institutional investors. Each tranche varies on the issuance based on the then-current capital market's conditions.

Figure 45 illustrates the structural flows used by PBC in its 2017 $100M shelf listing and issuance. The GLPGP SPV or NBFI can replicate this structure in the areas that are appropriate to create appeal to local Funders. In this example, see steps 4 to 9. Specifically, the Escrow Agents and Escrow (Trustee) Banks created a level of comfort for investors that their investment/funding would be disbursed based on the PBC's demonstrated need to buy cocoa plus off-take to buyer Cocobod. Bond issuance cash flows are sent to the PBC via an Escrow Bank, which is also responsible for making distributions to investors. The Trustee (it could be GLPGP for the Investment Plan) and Escrow Bank validate relevant business agreements. Clean Cooking for Africa/GLPGP, as an expert in LPG matters, could be considered as potential Trustee/Manager of this process while the SPV, NBFI or Investment Fund could be the equivalent of the PBC Shelf.

Figure 45. PBC shelf issuance transaction funds flow



1. Cocoa Board payment undertaking to PBC in favour of note investors,
2. PBC issues notes listed on GFIM platform of GSE to investors,
3. Investors transfer note proceeds to Escrow Bank for onward transfer to Escrow Agent,
4. Escrow Agent disburses note proceeds to PBC based on proven Cocoa stock available to be purchased from farmers,

5a. PBC pays farmers for Cocoa,
5b. Cocoa Farmers deposit Cocoa Stock to PBC warehouse,
5c. Depot (warehouse) Manager sends monthly Cocoa stock report to Head Office to be sent to Trustee & Escrow Agent,
6a. Depot (warehouse) Manager sends Cocoa stock to Cocobod
6b. Copy of Cocoa Take-Over Receipt sent to Escrow Agent and Trustee as evidence of delivery by PBC against which payment will be made by Cocobod

7. Cocobod pays PBC for Cocoa supplied through Escrow Agent
8. Escrow Agent pays Note investors through the Trustee first and completely before any other party
9. Escrow Agent transfers balance to PBC after investors and transaction costs are paid

Insurance Policies Maintained by PBC	
Policy Type	**Interest Covered**
Fire & Theft	Cocoa beans
Produce Loss	Goods in Transit
Good in Transit	Cocoa beans in transit
Motor Vehicle Insurance	Motor Vehicle
Assets-All-Risk Insurance	Head office

Other Benchmarks

Other helpful precedents emerged from discussions with, and research into, the largest and most accommodative mix of blended capital from pivotal funding groups like DFIs, IFIs and MDBs as leads, coupled with risk mitigation through face-to-face discussions, phone calls, and research. These include identification and discussions of activities in the Ghanaian markets or in other emerging markets that could be instructive. Examples include:

1. FMO's lead funding ~$15 million investment in the $60 million Bangladesh-based LPG company Omera, in the form of debt and equity.

2. Ghana Cenpower: FMO led and mobilized $163 million in additional DFI debt, and facilitated a senior finance facility of $447 million insured by the Export Credit Insurance Corporation.

   This transaction demonstrated that FMO invested in this project along with the Africa Finance Corporation (AFC) – an African-based multilateral finance institution which has committed approximately $3 billion to sectors like infrastructure, power, energy, transportation, and telecommunications. FMO, AFC and the IFC (all Master Cooperation Agreement (MCA) partners) could possibly partner on LPG funding.

3. DFIs such as IFC's role in energy-related entities in Ghana, such as Quantum.

4. CDC, DBSA and Ghana Infrastructure Investment Fund have invested jointly in the multi-hundred million USD building of the extension of the Accra Airport – Kotoka.

The logic for targeting marquee leaders in the blended capital and risk mitigation mix is that they will enable mobilizing scale, and then serve as the catalyst for followers who ideally could lower the overall blended cost of funding, be patient capital, and be well matched to the potential repayment abilities of the LPG supply chain players that underlie the cash flows of the funding mechanisms (SPVs, NBFI, Investment Funds etc.).

This lead Funder approach is similar to typical syndicate and other "book-building efforts" in project finance and other finance efforts. Analysis has led GLPGP to conclude that the financial markets of Ghana have substantial options and a rich history of working with outside capital providers, and are a regional hot spot for attracting such investment.

Potential Funders

The companion *Ghana LPG Investment and Implementation* report describes prospective funders inside and outside Ghana in detail; the pricing ranges, time horizons and investment scales which could be attractive to each; and where applicable the status of LPG financing discussions with each.

Note: DFIs are active in areas that overlap with the LPG investments for Ghana. This makes them likely to be lead Funders and risk mitigation providers for selected initiatives. The sectors such as SMEs and Financial Institutions/Innovations, Infrastructure, and Manufacturing could of appeal to DFIs, especially when coupled with the positive social and environmental impacts from the investments.

If, for example, SPVs, an NBFI, or Investment Funds are created to fund the build-out of the LPG sector and to fund related SMEs and MSEs, this will align well with certain DFI windows, because those are target areas. GLPGP recommends targeting DFIs and IFIs that are already active in Ghana as a start. These include AfDB, CDC, DEG, FMO, IFC, Norfund, OPIC, and Swedfund. To go to the IBRD, the GoG must make the approach and this then creates a semblance of Ghana officially taking on more debt vis-à-vis its debt ceiling restrictions.

Environmental/carbon finance

The potential carbon-market value from implementing what is described in this report is potentially €3-4 million per year, as discussed in Part X (Environmental, Health, Social and Economic Impact Potential) beginning on page 223. However, monetizing that value as an additional financing source faces a significant practical challenge, for which no solution can presently be envisioned. The challenge is that the ownership of the carbon-credit value is attached to the consumers' use of LPG for cooking, through displacement of higher carbon-emitting fuels and technologies. This implies monetizing the carbon value from millions of individual points of use, through an acceptable, practical, and cost-efficient means of measuring and auditing the net carbon benefit from each. The monetized carbon value would also have to be transferrable not to the end-user, but to the service providers along the LPG supply chain which make the investments to be co-funded through that carbon value. The consumer would benefit from a reduced cylinder deposit cost, by way of passthrough from the lower net cost to the service providers. One way this transfer might be accomplished, if carbon monetization were assured, is through utilization of a levy-like mechanism, which would leverage Ghana's ample petroleum levy experience.

The CDM does not allow carbon credits for fossil fuels (since these are defined as non-renewable), and therefore LPG is not eligible for carbon credits under CDM, despite the fact that overall the impact on climate forcing is similar to or less than even the best biomass stoves when all emissions are considered. Recent evaluation studies of CDM-approved, more efficient biomass stoves also demonstrate that there is a substantial risk that these interventions fail to realize the expected fuelwood and associated-carbon reductions under real-life conditions because of technology performance, fuel stacking (the ICS is used together with the traditional stove instead of replacing it) and/or because of extra cooking tasks performed due to previously suppressed demand. In addition, some improved stoves (including rocket and natural draft stoves) have been shown to emit more BC and $PM_{2.5}$ emissions than traditional biomass stoves and open fires.

Gold Standard offers a possible path forward if the issue of end-user scale can be solved, as Gold Standard includes the Kyoto Protocol gases and Black Carbon (BC), although it still does not include CO, SO_2, OC and NMHC.

A number of small-sized LPG projects have been funded through the Gold Standard carbon credit mechanism. One example is the 9,000-stove Darfur Low Smoke Stoves Project implemented by Practical Action and CarbonClear Ltd., which began stove dissemination in 2010. Each LPG stove in that project avoids about 4.6 tons of CO_2 equivalent a year compared to traditional and improved mud wood stoves (15-20% efficiencies) and to traditional and improved metal charcoal stoves (20-25% efficiencies).[133]

Should a practical mechanism arise for monetizing the carbon-credit value created by millions of added users of LPG, and for deploying that value toward the financing of the supply chain expansion that makes the carbon-credit value possible, it could lower both the cost of capital for the expansion and potentially the cost that consumers incur to become new LPG users.

Specific roles for DFIs to increase impact and reduce risk

DFIs are well-positioned to help facilitate the national LPG build-out described in this report and the companion *Ghana LPG Implementation and Investment* report. Through their mandates, experienced teams, and range of tools, they can have a powerful effect on the success of LPG ecosystems and the projects and companies within them. Useful and effective DFI tools include grants, technical assistance, direct or indirect (through investment funds) funding, debt/equity/hybrid funding, guarantees, risk mitigation structures, insurance, syndication with other DFIs and IFIs, SPVs, IFC-led MCA/parallel loans, and political advocacy and influence including linkages (in which governmental undertakings regarding LPG are linked as performance requirements to a larger, broader portfolio of financing and financial cooperation).

The DFIs' critical anchor role as catalyst Funder and accommodative capital provider can be essential for moving the large quantum of capital needed for the country's investments.

DFIs can undertake some of the following key roles:

1. Provide large and diversified capital investment of their own;
2. Catalyze and crowd-in outside non-concessional, more risk-adverse co-funding;
3. Lower the cost of capital for various projects (where it makes sense to do so);

[133] Carbon Clear (2016): *The Gold Standard: Project Design Document for Gold Standard Voluntary Offset projects - Darfur Efficient Cook-Stove Project*. See mer.markit.com/br-reg/public/project.jsp?project_id=103000000002416.

4. Introduce first-loss-protection for other investors (for example, Swedfund with SIDA taking a 50% first loss);

5. Provide risk mitigation tools, such as guarantees (range of DFIs, MIGA) and private bond 144A placement insurance (OPIC);

6. Provide hedging tools to help mitigate LPG price volatility and address currency risk;

7. Use financial influence in the country overall to ensure governmental performance of obligations;

8. Provide technical assistance funding to help the government and the sector develop capacity to suppress black market activities;

9. Provide technical assistance to educate and create awareness of LPG benefits among consumers;

10. Underwrite a country's initial LPG microfinance program on a concessional basis to demonstrate to local financial firms that microfinance can be a legitimate commercial activity for them;

11. Help secure international LPG supply on more favorable terms, through bringing their balance sheets to bear (e.g., AfDB offering letters of credit with concessional terms for use by marketer-bottlers to acquire cylinders *en masse*);

12. Become a Funder to listed or non-local stock exchange listed SPVs and/or provide protections for other investors/Funders; and

13. Support further work by the Clean Cooking for Africa expert team.

The financial modelling of the investment parameters, economic performance, and financial returns of the key firm-level investments described in 16 (Investments at the Firm Level), which begins on page 165, includes co-funding with concessional debt for approximately 40% of the capital stack of the projects sector-wide, both to ensure rates of return to equity investors are possible without risking over-leverage, and to moderate the cost of debt in order to reduce the debt service burden on the LPG sector's firms as they consume capital and defer full profitability for the sake of growth.

The thesis for the DFI role is that DFIs have interest in the large health, environmental, social and development impact that scaling up clean cooking can have on the target countries' populations. To achieve the desired impacts as efficiently as possible, DFIs welcome sizable, scalable, bankable funding opportunities. Although the global LPG sector is over 100 years old, and LPG-for-impact has been the subject of study by UNDP, WHO, and other organizations for many years, it is only recently—such as through the efforts of the Clean Cooking for Africa program—that opportunities for LPG investment and lending at scale are being identified, prepared, and structured for addition to the global flow of projects suitable for DFI support. It is therefore recommended that DFIs include consideration of financial support to LPG initiatives where LPG investment and lending opportunities are demonstrated to be feasible—such as in Ghana, with BCRM well-implemented.

Development of LPG-specific investment funds

A second key role for DFIs is in contributing to indirect investment into such LPG opportunities, by participating in the establishment and funding of an LPG-specific impact-investing fund. Such a fund would aggregate and deploy LPG-focused global capital, including DFI capital, to high-impact, high-need LMICs for prudent and justified LPG expansions and utilize the particular, deep domain expertise of the Clean Cooking for Africa/GLPGP expert team in so doing. GLPGP and KfW have collaborated to design two such funds for future implementation. These funds are the LPG Infrastructure and Distribution (LID) Fund, designed to target LPG supply chain infrastructure as outlined in this report, and the First Costs Financing (FCF) Fund, designed to underwrite microlending at scale to consumers for financing the up-front equipment costs necessary to switch to LPG from charcoal and wood fuel. The first FCF fund and LID fund, at anywhere from € 100 million to € 300 million overall, could be conduits through which interested DFIs could align capital for LPG impact-investing at scale with proven, impartial, dedicated LPG expertise. DFIs can potentially provide General Partnership operating launch capital, as well as provide anchor Limited Partner funding commitments. This can then facilitate additional funding sources joining the fund(s) alongside the DFI sponsors.

20. Summary of Main Project Risks, Mitigations and Mitigation Sources

Main risks and mitigations

Risks may be grouped into several categories, which include:

- Country risks (regulatory, political, other)
- Industry
- Economic
- Consumer demand
- Execution
- Financing / Fund structure and operation
- Investment process

Country risks

Regulatory Risks. The regulatory landscape in Ghana applicable to LPG, for financing, and overall, is a critical consideration. The regulatory scorecard presented in Part V, Chapter 7 (beginning on page 45) is a useful assessment tool regarding the supportiveness of the LPG regulatory environment and gaps to be diligenced and hedged against. As part of investing, legal stabilization clauses will be sought in contracts with Government. Risk mitigation products may also be utilized where justifiable, as described later in this chapter.

Additionally, diligence would be undertaken regarding the regulatory frameworks for business rights protection (including anti-counterfeiting), investment, and/or microlending are adequate. Use of qualified locally-familiar counsel and accountancies will facilitate such diligence.

Investing Environment Risks. Ghana has an overall favorable and improving investment environment, as described earlier in this Part of the report. Country risk premiums may also be priced into the overall cost of blended capital, based on the blend and the needs of the Funder sources.

Nationalization/Expropriation Risks. Standard project and other insurance would be obtained where appropriate through bodies such as OPIC and MIGA; additional sources and products are noted later in this chapter.

Government Nonperformance/Default on Contractual Obligations. As a possible partner in certain levels of the LPG infrastructure and distribution chain, the Government may be contractually committed to funding or other obligations related to projects and consumer access. If the Government were to default, this could have numerous politically sensitive impacts on general voting public, once they are increasingly tied into the expanded LPG market. Performance guarantees by Government and other key partners and counterparties should be provided for project completion and operational finance commitments as conditions precedent to investment.

Political Risks. Sufficient political and business support are integral to scaling up LPG. To reduce political risk, both local official and private sector partners must have a material stake in the success of the local projects. Political support can be developed by project sponsors and Funders, and through linkages by DFIs (for example) to other lending activities in the country. Regarding a shift in future political/policy for LPG investments, various third party insurance products can be considered.

As described in Chapter 11 (National LPG Planning Process from 2017) beginning on page 63, there is risk to smooth BCRM implementation from the potential objection and/or potential non-cooperation of existing microstation operators whose business operations and/or business models could be adversely affected by changes in their roles brought about by new governmental regulations and standards. The Government has already undertaken public relations efforts to attempt to mitigate this risk, and has signaled to the microstation operators the Government's insistence that the proposed and contemplated changes to their businesses are essential for purposes of improved public safety and of effective scale-up of (and associated investment in) the LPG sector. This risk can be further mitigated by ongoing constructive dialogue between Government and concerned microstation operators, potentially combined with assistance measures for transition or repurposing of affected operators' current LPG businesses.

Timing Risks for Governmental Decisions. The actions and investments described in this report are time-sensitive with respect to achieving intended scale and impacts by 2030 at a manageable rate of growth, and delays in governmental decision-making (in particular, in finalization of the parameters and specifications for, and in implementation of, BCRM) can increase the risk of national under-performance against policy goal targets and on the financial parameters of the recommended investments. Timing risk added by such delay can be mitigated through increased utilization of concessional capital, which could permit acceleration of the scale-up of the sector by increasing its economically sustainable growth rate; by use of funding structures and mechanisms such as those described in Chapter 19 (Investment Plan Overview) (beginning on page 199) which could decrease investment lead times and increase the rate of transaction flows through project aggregation and risk-pooling; and by continued or renewed technical assistance support (such as the support funded up through the time of this writing by the Clean Cooking for Africa Program) to the Government to assist it in its analytical and decision-making processes.

Industry risk

LPG Supply, Demand, and Price Movements. As a global commodity, LPG may be subject to price movements based on supply and demand dynamics outside of the internal market conditions of the country. This could impact the availability of product in target markets, if prices rise too high. In Ghana, margins are fixed by regulation, which eliminates margin risk; the remaining market risk is to volume. (This is normal in commodity dependent businesses.) The projects' cost basis, through blended capital sources, will lower overall break-even margin points for infrastructure assets and companies. In addition, underlying companies and projects will be expected to implement appropriate contingency planning in their operations such as hedging of inputs, including LPG supply. Long term supply contracts (such as provided by the Ghana Gas Company) with diverse sources and buffer storage will serve as mitigants to these disequilibriums. MIGA and USAID offer programs to insure commodity price risks and these may also be employed, where justifiable.

Consultancy IHS Markit has forecast that global LPG supply will be in surplus at least through 2030, and potentially to 2050, creating relative price stability during the expected investment horizon. See Annex

Chapter 33 (Note Regarding Long-Term LPG Pricing and Availability) beginning on page 325 for further discussion.

Additionally, commercial quantities of price-competitive bio-LPG have been introduced into the market in 2018; by 2030, such quantities could become a significant hedge against potential LPG supply or price volatility.

Lastly, entering into long-term, price-capped contracts for LPG supply hedges further against LPG volume and price risk. Additionally, the Ghana Gas Company, which already sells domestically produced LPG into the Ghana market under long-term contracts, may (but is not obligated to) choose to sell such LPG domestically on a cost-plus basis should international reference prices rise significantly, as an additional form of hedge.

Energy Alternatives. Price differentials could create a risk regarding substitute fuels at the end of the value chain. Given the level of development of other fuel products, it is expected that the risk of substitution is limited, except among the poorest. While that creates an impacts risk, the likely effect on investment results is expected to be small, based on the modelling performed and presented in this report. In addition, once businesses and consumers have invested in LPG equipment and adapted to them operationally and behaviorally, respectively, a switching barrier (whether economic or psychological or both) is created for abandoning LPG use. That is, LPG use is somewhat sticky, once begun.

Subsidy Challenges. Ghana phased out its general subsidy on LPG fuel, essentially ending subsidy performance risk associated with the Government's ability to make timely subsidy reimbursements to LPG projects and companies. If the Government later decides to institute a targeted LPG subsidy aimed at the poor, the Clean Cooking for Africa/GLPGP advisory team can provide best practice knowledge and guidance to establish the new subsidy in a way which is minimally distortive to the market and minimizes the risk of the subsidy growing beyond the Government's capacity to honor it as LPG volume grows in the target population.

Cylinder Risk Allocation among Bottlers and Marketers. If the NPA determines to allocate cylinder responsibilities (investment, branding, safety, maintenance, liability) to OMCs or LPGMCs rather than to BPs, it is likely to increase overall risk in the sector, for the following reasons:

- The small number of BP companies (8-10 plants owned by no more than 8-10 companies, and probably fewer than eight companies) allows each one (such as the Ghana Oil Company Limited and the Ghana National Gas Company Limited (an SOE)) to operate at a greater economic scale and, therefore, to have a stronger balance sheet, greater longevity/commercial staying power in the face of other risks, and reduced counterparty risk for investors and lenders. With the average market share of OMCs and LPGMCs being 1-2%, they are on average on the opposite end of the spectrum of risk from the BP entities.

- The funding mechanism for cylinders is critical to a scaling-up of LPG usage. Bottlers, with a more physically rooted investment (the bottling plant), compared to the more mobile cylinders, are a more stable and bankable investment from the Funders' point of view, not only as offering better collateral but also more consistent cash flows based on the anticipated LPG pricing structure. (They are the only fillers and earn the fillers' margin, compared to marketers, which are in a more competitive marketplace, and may lose out on revenue due to cross-filling or dynamic pricing by competitors.) Combining cylinder investment into the BPs creates a beneficial portfolio effect on the risks of their assets: the €235 mm of higher-risk cylinder investment is blended with the € 92 mm of lower-risk bottling plant investment, and relatively stable bottling services cashflows hedge potential volatility and risk of cylinder-driven cashflows. (Cylinders are higher-risk than plants because the cylinders are mobile, and therefore more difficult to track, repossess and/or liquidate.) The addition of cylinders to the bottling plants by the JBs then would offer better and more integrated add-on collateral compared to further stand-alone collateral in the case of ownership by marketers.

- In setting up the most efficient LPG supply chain for Ghana, it makes sense to have cost-effectiveness the driver for the portion from importation through storage to filling, being more generic, which then allows the remaining aspects, such as distribution and retail, to the more competitive marketer relationships. Competition among the marketers is best when focused on working toward securing and maintaining end-customers, not potential short-cuts in filling. Thus, BP cylinder ownership and branding potentially improves the overall function and cost-efficiency of the chain, potentially leading to greater LPG adoption and usage over time.

- Cross-filling and cylinder diversions, which represent important operational and safety risks for competing cylinder brand-owners that can reduce profitability and increase liability exposure, would occur far less with regional brands under BPs, because each plant would tend not to be exposed to cylinders from a different plant and brand. Multiple marketers within one region, with multiple brands, would be exposed to much greater cross-filling and cylinder-diversion risk.

- Having the BPs responsible for quality-checking of the cylinders during the refilling process is likelier to happen, and be rigorously done, if the JBs have procured and own their own cylinders.

- With a small number (8-10) of BPs involved in cylinder procurement, it is easier to pool cylinder acquisition for economic advantage, and to supervise cylinder deployment and safety.

- The establishment of a revised LPG price structure gives a unique opportunity for change, such as allocation of the cylinder functions and responsibilities to the BPs, to optimize the supply chain.

For the foregoing reasons, it is advantageous as a risk-mitigant for operations, safety, economics and investment/financing, for the small number of BPs to have the cylinder investment task and the benefits and responsibilities of cylinder ownership, in favor of the large pool of marketers. (Through holding company structures, a marketer that is also a BP can exploit both supply chain nodes from a risk management as well as cost and profit optimization standpoint.)

Economic risks

Interest Rate and Inflation Risks. Currency, interest rates, and inflation changes may impact LPG affordability and also the repayment performance of the LPG projects. Interest rate hedging and other approaches can be utilized to insulate from adversely expanding spreads. Inflation should be priced into contracts as appropriate, so as not to erode SPV/Fund performance. Moreover, Ghana, while having experienced higher than usual inflation (and currency depreciation) in recent years, is not hyperinflationary and is beginning to rein in these trends. Currency hedging will be employed under both project level and SPV/Fund level risk management policies.

Currency and Exchange Rate Risks. The income received by the investment vehicle(s) will typically be denominated in the local currency of the project companies; however, the books and assets, capital contributions, and distributions will be conducted in U.S. Dollars or Euros, as appropriate. Accordingly, changes in currency exchange rates between USD/Euros and the Cedi may adversely affect the U.S. Dollar/Euro value of investment vehicles and the income, interest and dividends or other distributions it receives, gains and losses realized on the sale of investments and the amount of distributions, if any, to be made.

Because imported LPG is priced in Dollars, and project companies' turnover (revenue) is in local currency, there is currency risk for the supply chain. In recent years, the Ghana inflation rate and the rate of currency devaluation against the USD have moved in tandem, causing LPG priced in local currency to avoid dollar-driven real price inflation. (LPG has experienced meaningful nominal price inflation in Cedis, as have all other goods – and wages – in Ghana.)

Currency hedging and derivative products may be employed to mitigate these risks for both investors and operating companies.

Consumer-related risk

Lack of Demand. The amount of projected demand may not come into fruition for a variety of reasons, including lack of awareness by consumers, affordability and accessibility. These potential issues can be mitigated by the work that Clean Cooking for Africa/GLPGP will continue to do in Ghana (subject to availability of resources), including working to create awareness of LPG benefits among consumers. Additionally, the investments are staged over time, and can be accelerated or delayed/reduced based on leading indicators (including those specified in this report) signaling additional pent-up demand or early saturation of the market.

Consumer Repayment Risks (re: Microfinance Loans). Credit risk in large part will depend on both the selection of on-lending partners and consumer repayment behavior. The analysis of the extension of credit will include diligence of the MFIs and their underlying approaches to customer selection, credit policies, and the target market segments. As a practical matter, consumers will not want to be cut off from LPG once they are using LPG for cooking and have acquired the appliances for cooking and heating with LPG. Nevertheless, as a backstop, the use of blended capital that may be required to underwrite or guarantee or partially guarantee MFI lending will lower the costs of lending, and first loss arrangements with DFIs or other impact investors can protect the performance of the underlying lending portfolio.

New MFI lending for LPG adoption will be piloted in carefully expanding phases, applying lessons from each preceding phase to reduce the risks of later phases.

Ultimately, the aim of the Clean Cooking for Africa program is for LPG microlending to transition to an entirely local platform of partners with underwriting from one or more of them for the group's activities, thereby creating the option for early exit and monetization of microlending activities.

Execution risks

Execution Risks. Investment projects must be required to have competent, experienced management. The funding vehicles (e.g., SPVs) must do the same[134]. Local partners that will be required, or are desired, where they are competent and experienced will help address local execution risks at the operational and

[134] The Clean Cooking for Africa/GLPGP LPG expert team may play such a role in the latter.

local co-investment level. Ultimately, a sound governance system with international-standard financial reporting at all levels will be among the most important tools for identifying execution risks and responding quickly and appropriately to eliminate or reduce them.

LPG Distribution Execution Risk. The inability to reach the ultimate end users of LPG will be a gating decision point regarding whether to invest in a particular geographic target area. This will also limit the success of the investment vehicles but will protect from over stretching to serve untenable markets.

Counterfeiting and Issues around Safety. Local LPG industry and the management of the investment vehicle(s) must address these issues to the extent they may arise. Good implementation of the BCRM model (as described in this report) will substantially derisk this issue. Part of the solution may also come from integrating fragmented operators in the distribution chain vertically and horizontally, offering shared benefits from economic scale and market power.

Price and Cost Structure Risks to Firms. If the Government allocates unit margins throughout the supply chain nodes in a way that ends up not adequately covering the costs at a given node, for whatever reason, the risk of viability of the adversely affected firms is increased. This risk can be addressed in two main ways: (i) The Government should carefully match its pricing formula to the costs and financial requirements (of equity-holders and lenders) at each supply chain node, to ensure adequacy at each node and to optimize the overall financial performance of the supply chain (taking into account the analysis of Chapter 16 (Investments at the Firm Level) beginning on page 165, and balancing affordability for consumers against industry profit objectives); (ii) Utilizing the ISLE indicators and consulting with industry and other stakeholders on an ongoing basis, the Government should periodically revise its allocation of unit margins as necessary to ensure the viability and performance of the value chain overall as the sector scales up, and as its conditions change.

Complexity of Coordination of Multiple Investment Projects. The quantity of parallel projects may introduce complexity which could cause delays, overruns in project preparations costs, and execution challenges in excess of projects taken individually. There can be no assurance that management and operation companies can successfully manage such complexity. Conversely, the fact that the projects are all linked through a master investment plan means that no one project will receive and deploy a quantum of growth capital without strong assurance that the linked projects in the supply chain receive proportional, and well-timed, quanta of growth capital, so that all projects are mutual reinforcing.

SPV/Fund/NBFI structural and operational risks and mitigants

No Operating History. These vehicle(s) are likely to be recently-formed entities, with no operating history. This may be mitigated by the operating experience and expertise of the Clean Cooking for Africa/GLPGP team, by experienced LPG operating managers on the ground, and by relevant in-country and international project partners.

Liquidity of Investment. The investments will be illiquid as with all private equity and long term debt investments. The investors will be provided with distributions as appropriate and the critical mass of projects created will make this a potential portfolio for an exchange listing (as discussed earlier in this Part of the report) or potential acquisition. To the extent possible, the investment project agreements will include terms that give options for forced monetizations or exit pathways under appropriate conditions.

Long Term Investment. An investment in the vehicles is a medium- to long-term investment. The aim of facilitating the creation of sustainable LPG platforms dictates a significant length of time between the initial investment and the return of investment or realization of gains, if any. "Patient capital" will therefore have a role to play in the capital stack.

Restrictions on Transfer and Withdrawal. There may be no market for the investment securities, absent an exchange listing. In addition, investments in the SPVs/Funds/NBFIs may not be transferable or withdrawable in the usual course of business.

Asset Valuations. Valuations of the LPG assets will be determined by the management of the investment vehicles working with outside valuation experts. The valuations will be based on audited financial information to the extent possible, complemented by best-practice valuation methods and metrics used in the LPG sector globally.

Investment process-related risks

Finding Investments. The ability to prepare projects and execute the investment strategy in reasonable time frame given possible regulatory and other issues will be a major focus. Continuing diligence will permit walking away from projects which cease to offer the return and risk profile meeting investor requirements before significant amounts of capital have been deployed in them.

Ability to Realize Cash Returns and Exits. As with all investment vehicles, continued listings of the vehicles on liquid exchanges, as well as underlying assets, plus trade sales and dividends, are not certain in time or amount. The strategy of listing or shelf registration can mitigate these risks.

Country Development Risk. Part of the feasibility assessment in this report involved consideration of favorable national developmental trends such as: attractive demographics; rising per capita income; credit reach; urbanization; legal and political stability; progressive governmental policies for healthcare, environment and development; growing foreign investment; development of infrastructure (in particular, road networks), etc.

Environmental Hazards (Other Than LPG Accidents). The investments and projects will be implemented following ADR and other best practices and global regulatory standards. In addition, the funds and projects will take appropriate insurance policies against hazardous accidents and occurrences.

Wrong Investment Thesis. If the findings of, and conclusions from, this report and its companion Ghana LPG investment report are wrong, it will result in overinvestment in infrastructure, but there are nonetheless choices available to address this. For example, a) to run at lower capacity or b) to run at normal capacity but resell surplus LPG acquired into other markets (e.g., to regional traders, or to regional petrochemical producers) at a discount. Also, most LPG infrastructure can be scaled up in steps, rather than built all at once. Management and advisors must continue to conduct detailed studies in advance of major capital deployments to be maximally confident that the investment thesis is correct.

Risk mitigation sources

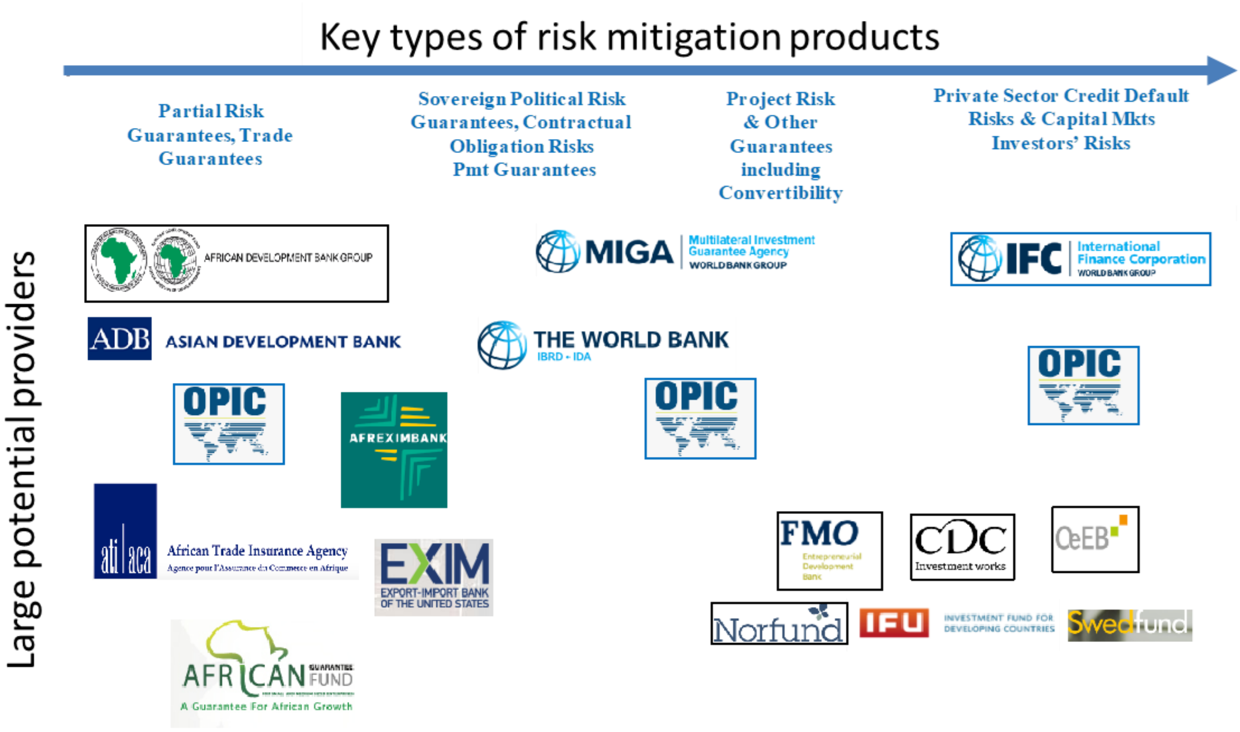
DFIs, MDBs, IFIs, private companies and others provide the risk mitigation tools profiled below.

Risk mitigation tools include guarantees, insurance, and other credit enhancements that are often used in combination with impact or related funding to strengthen the creditworthiness of a funding recipient.

Many providers of capital also provide risk mitigation tools which offer potential efficiency in lining up the right combinations of blended funding and risk mitigation for many products and services.

The following figure[135] provides several examples as points of reference:

Figure 46. Large providers of risk mitigation products, by category



One example of a good source of potential capital and risk products is the U.S. Overseas Private Investment Corporation (OPIC). Its risk/insurance products include enhancing Funders' investment positions by guaranteeing 144A bond placements which can be quite large and attract global pensions, insurance and other investors. This could be used by LPG-related vehicles to issue securities to international investors. This is because the 144A bond insurance essentially converts LPG-related risks into a U.S. Government-mitigated risk. This could also lower the costs of issuance to the backed entity.

IFC and AfDB are investors in, and also offer directly, numerous insurance and risk mitigation products. They are also on the top-tier of potential Funders for the Finance team to approach.

Trade guarantee facilities can be used for the importation of cylinders and other vertical needs.

African-oriented cross-owned institutional financing, credit, and risk mitigation sources should also be leveraged. This could cover trade finance, working capital, capital investment, risk insurance (including re-insurance), and hedging. This cross-ownership is likely to enhance the strategic appeal to various partners, due to their joint focus on doing business in Africa. Examples GLPGP is exploring include the Africa Trade Insurance Agency (ATI), into which AfDB has invested, and the European Investment Bank, which has expressed initial interest.

135 Self-reported institutional data analyzed by GLPGP.

Given that GLPGP and AfDB have established a working relationship through AfDB's grants window for LPG micro-finance, and are exploring larger funding for 2019 and thereafter, AfDB could be a logical partner for risk solutions as well. AfDB and ATI would be logical first partners to approach in terms of larger risk mitigation tools for Ghana.

A two-tiered approach could be used, by accessing AfDB's various risk mitigation tools such as trade guarantees, insurance, and credit enhancements – either directly from AfDB or from proxies. Following one AfDB investment into ATI, a statement from the then Director of Private Sector and Microfinance at AfDB noted that "ATI uses innovative risk mitigation instruments to catalyze private sector financing into a range of critical sectors from core infrastructure to trade finance." This could be useful for GLPGP. Other active groups like Sweden's SIDA partner with USAID, IFC, DFIs and others to actively guarantee risks in development areas that complement Sweden's international development agenda. GLPGP will approach SIDA as appropriate.

Another target might be the heavily DFI-backed AFC. Ghana just became a larger membership-contributing partner for AFC. This entitles Ghana to risk and funding support from AFC, and issuing capital via AFC's enhanced credit rating if appropriate projects are brought forward. AFC is owned by numerous groups including very active DFIs such as AfDB, KfW, DEG, FMO, and PROPARCO. This could be a logical grouping to approach.

In addition, FMO and OeEB have been involved with LPG related activities (FMO in Bangladesh – invested; OeEB in Albania – commissioned studies). OeEB, while smaller among the European DFIs, is quite active across debt, equity, quasi-equity, and grants. In addition, like AfDB, FMO and other DFIs, it could be approached to provide credit lines for an NBFI.

X. Environmental, Health, Social and Economic Impact Potential

This Part[136] provides an evidence base and estimation for use by investors, policymakers, industry and researchers to guide the development of LPG infrastructure and distribution systems in Ghana.

Introduction: impact scenarios

The assessment utilizes the demand forecast scenarios presented in Part VI (LPG Demand Potential to 2030) together with the policy goal investment scenario (Policy Goal Scenario) of Part VIII (Critical Path LPG Infrastructure Investment Projects to 2030) to calculate the potential social, environmental and development impacts through 2030 from each scenario compared to the "business as usual" projection of LPG adoption and use from Part VI.

All of the scenario models take into account that improved biomass cookstoves (ICS) will seek to compete with LPG.

The scenarios are:

- Scenario 1: Base case, where forecasted consumption was derived by extrapolating historical growth trends for residential LPG consumption without market reforms and associated acceleration and scale-up of investment. Total annual LPG consumption for household cooking is projected to grow to 276,060 MT by 2030, resulting in national per capita consumption of 7.12 kg per year.
- Scenario 2: Market reform and expansion scenario, reflecting policy and investment interventions as described in this report. This scenario comprises two sub-scenarios, leading to a range of projected impacts:
  - Scenario 2A: Lower-bound with sufficiency of availability, incorporating demand growth from demographic changes, as well as the impact of expanded LPG availability to serve latent demand. Total annual LPG consumption for household cooking is projected to grow to 404,415 MT by 2030, with 4.47 million households consuming LPG in 2030. This represents an LPG usage penetration of 46% of households (46% of the population), with a national per capita consumption of 10.44 kg per year.
  - Scenario 2B: Upper-bound with sufficiency of availability, incorporating the same demand drivers as Scenario 2A (demographic changes and expanded LPG availability), as well as additional changes in preferences that result in additional households switching to LPG. Total annual LPG consumption for household cooking is projected to grow to 530,420 MT by 2030, with 5.3 million households consuming LPG. This represents an LPG usage penetration of 55% of households (and 55% of the population), with a national per capita LPG consumption of 13.69 kg per year.

  Taking into account a potential price increase of 12.6%, the potential penetration is not forecast to decline materially, but the consumption (due to greater fuel-stacking) would grow to the lesser

[136] The contents of this Part were developed with Dalberg Global Development Advisors under engagement to GLPGP.

amounts of 381,880 MT (lower bound estimate) and 500,870 MT (upper bound estimate). See in Chapter 13 (Demand Assessment through Probit Analysis) the section *Estimating the impact of price on LPG demand* on page 108 for details.

- Scenario 3: Investment recommendations/government Policy Goal Scenario, which gives total projected consumption as per the investments needed to reach the Government's goal of 50% LPG penetration by 2030 (details of which are provided in Part VIII).

Because the Policy Goal Scenario falls between the lower bound (2A) and upper bound (2B) scenarios (including under increased pricing), the ranges of values presented in this Chapter's introduction are based on the lower bound and upper bound cases. Details for all three scenarios are presented in Chapter 21 (Detailed Impact Analysis and Findings) beginning on page 229.

As discussed in the demand forecast chapters, LPG consumption by 2030 may be approximately 5.6% lower than modelled if an anticipated, recommended increase in the LPG end-user price of approximately 12.5% is put into effect under BCRM in order to cover incremental costs of expanding the LPG supply chain, and no offsetting measures are implemented. This level of price increase would apply until 2030, corresponding to the financial horizon of the LPG infrastructure investments. After 2030, when the anticipated capital costs have been fully recovered, the price could be reduced by eliminating the price formula element associated with capital cost recovery. The effect of a 5.6% consumption reduction creates, for some impact measures, a somewhat proportional reduction of the measure. Direct modelling of the exact proportionality was not possible, because of a lack of necessary data. For other impact measures, the proportion of reduction is much less than 5.6%, due to the effects of non-linearity. This is noted hereafter where applicable.

Data sources

The Ghana Living Standards Survey Round 6 2012/2013 (GLSS 6) was the primary data source for the assessment. Where possible, this information was triangulated with the (limited) available aggregated data from the Ghana Living Standards Survey Round 7 2016/2017 (GLSS 7), the data of which had not been publicly released at the time of this writing**.** The data alongside the demand scenarios were used to analyze and model the environmental, health, gender, and macroeconomic impact from serving the potential demand for household cooking in Ghana to 2030, taking into account the primary cooking fuel(s) previously used by new LPG users.

Each cooking fuel has its own characteristics in daily use with respect to health, environment, gender and economic impacts.

It is important to note that the impact assessment presented in this report is calculated for scenarios where LPG is made sufficiently available to serve the projected demand, relative to the base case projections. This approach helps estimate the incremental impact of the investment to be made to cause LPG to be fully available to Ghanaian households that desire it over time, and are located in an area of Ghana where LPG is feasible to be provided and used[137].

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137 For example, areas without good road access, or where most cooking fuel use is and will be from gathered wood, were not deemed to develop new LPG demand.

Environmental impacts

Ghana's greenhouse gas emissions profile is dominated by emissions from land-use change and forestry (53% of total emissions) and energy (25% of total).[138] One of the contributing factors to land-use change and fuel combustion is the use of biomass as fuels. The impact of households changing their primary fuel from charcoal and firewood to LPG can have many positive impacts on the environment and climate. For this study, the environmental impacts from increased LPG use and correspondingly decreased charcoal and firewood use (without major increase to charcoal exports) were calculated as[139]:

- **Averted deforestation**: 11 – 21 million trees saved annually relative to base case projections in 2030 and 127 - 221 million trees saved between 2020 and 2030
- **Carbon dioxide equivalent (CO_2eq) emissions[140] averted:** 0.50 – 0.76 million MT of CO_2eq emissions reduced annually in 2030 and 6.76 – 9.30 million MT of CO_2eq emissions averted cumulatively between 2020 and 2030
- **Black Carbon equivalent (BCeq) emissions[141] averted:** 1.0 – 1.7 million MT of BCeq emissions averted annually in 2030 and 10.4 – 16.6 million MT of BCeq emissions averted cumulatively between 2020 and 2030
- **The economic value of averted CO_2eq emissions in terms of carbon financing:** € 29.6 – € 40.6 million cumulatively between 2020 and 2030, using the 2018 prevailing price of carbon

Health impacts

Quantitative impacts

Transitioning from charcoal and firewood to LPG can have significant health impacts due to reduced exposure to household air pollution (HAP) from burning solid fuels to meet household energy needs. HAP is causally related to ischemic heart disease, stroke, chronic obstructive pulmonary disease, lung cancer in adults, and acute lower respiratory infection in children (based on Global Burden of Disease (GBD) data)[142], plus several other conditions not included in GBD estimates (e.g. blindness in women). All these diseases can result in premature death or a disability. For this study, the health impacts from increased LPG use (and decreased charcoal and firewood use) were estimated by calculating (1) Deaths averted, and (2) Disability-

[138] USAID (2016); FAO (2015)

[139] These values are subject to the effect of a possible 5.6% LPG reduction in the growth of LPG consumption to 2030, if LPG pricing is increased to end-users, without any offset mechanisms, by an anticipated 12.5%.

[140] CO_2eq emissions include carbon dioxide equivalent emissions from carbon dioxide, methane, and nitrous oxide. These were calculated using IPCC conform standards.

[141] BCeq emissions includes black carbon equivalent emissions from black carbon, organic carbon, carbon monoxide, and total non-methane organic compounds.

[142] IMHE (2016)

Adjusted Life Years (DALYs)[143] saved due to reduced exposure to HAP from reparable fine particulate matter ($PM_{2.5}$).[144] Impacts on both adults and children were estimated.

Overall, relative to base case projections, between 11,965 and 19,415 deaths could be averted cumulatively between 2020 and 2030 due to increased LPG usage, based on the scenario. In addition, 423,774 – 688,042 DALYs could be saved depending on the LPG adoption scenario, relative to base case projections[145]. This could result in a total economic value of labour of working age adults (from deaths averted and DALYs saved) of € 198 million – € 321 million, relative to base case projections, based on prevailing wage rates.

Gender impacts

Qualitative impacts

Globally, it is estimated that women spend an average of 4.5 hours a day on unpaid work, more than double the amount of time spent by men.[146] Reducing the number of hours per day women spend on unpaid work could have numerous financial and social benefits including allowing women to find more paid work (including both farming activities and other income-generating labor which would vary by setting), pursue education and/or have more leisure time.[147] LPG offers a significant time saving advantage to charcoal and firewood (and other collected biomass) as it provides storage of LPG in cylinders within the home, and saves cooking and cleaning time.[148] In this analysis, the main gender impacts of transitioning to LPG resulted from time saved from not having to acquire fuel daily as households transition from firewood and charcoal to LPG.

In all the demand projection scenarios (based on primary fuel use only), the firewood using households that were forecasted to transition to LPG were almost exclusively purchasers of firewood, not collectors. Therefore, negligible time savings would be created among firewood-collectors in Ghana. No data were available to estimate the reduction in time previously spent purchasing charcoal daily or nearly daily (to the extent incremental to other shopping time) caused by purchasing LPG on a multi-week cycle instead.

Note that there may be additional time saved when taking into consideration (i) the time saved from cooking with LPG, and (ii) time saved cleaning (as pots, stoves, and the household cooking space are not blackened by LPG). However, these effects were excluded from this analysis due to lack of available data.

While jobs will be created in the LPG sector, including for women, women are likely to experience reduced employment and income opportunities in the informal charcoal sector as charcoal use for cooking is displaced by LPG use. These effects may be significant, but were excluded from this analysis due to lack of available data on employment in the charcoal sector.

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143 The disability-adjusted life year (DALY) is a measure of the overall disease burden, expressed as the number of years lost due to ill-health, disability, or premature death.

144 PM2.5 refers to Particulate Matter, 2.5 micrometers or less. These are air pollutants with a diameter of 2.5 micrometers or less, small enough to invade even the smallest airways and produce respiratory and cardiovascular illness.

145 All scenarios include assumed rates of growth of the adoption of improved biomass cookstoves by charcoal and firewood users, detailed in Annex Chapter 29 (Impact Assessment Data Sources and Values).

146 Gates, Melinda (2016)

147 Oxfam International (2017)

148 Brooks N. et al. (2016); Nautiyal S. (2013)

Consumer household expenditure impacts

Quantitative impacts

Stove and fuel affordability are potential constraints to LPG initial adoption and sustained use, given income and liquidity levels of Ghanaian households.[149] Yet, LPG could save households costs in the long run, because LPG is more cost-efficient at delivering heat to pots than charcoal in Ghana In Ghana, the KITE household survey estimated that spending on fuel comprised 9% (rural) to 16.2% (urban) of average household income in 2015.[150] Since the GLSS 6 does not contain data on household fuel consumption and expenditure, the total fuel cost savings from using LPG was estimated from the KITE (2015) study data. Because this study, while multiregional, was on a small scale, comprising only 200 households, extrapolation from the KITE data should be done with due caution. The average annual cost of cooking per household shows that, on average, LPG provides cost savings for households purchasing charcoal but not for households purchasing firewood.[151]

Under the market reform and expansion demand scenarios (referred to as lower and upper-bound full availability scenarios), the annual cost savings to consumers, assuming no changes in the relative prices of fuels, could increase between GHC 279 million and GHC 460 million in 2030, relative to base case projections. For the households switching from charcoal to LPG, this equates to an annual per household cost saving of GHC 48 (€ 8.6) and GHC 66 (€ 11.9) for urban and rural households, respectively. The absolute savings are greater for rural households due to the higher price of charcoal in rural areas relative to urban areas. For households switching from purchased firewood, this results in an annual per household increased expenditure of GHC 146 (€ 26.3) and GHC 220 (€ 39.6) for urban and rural households, respectively. This increase would amount to 3.2% and 8.2% of urban and rural annual household income in 2015, respectively. These values should be used with caution, because the KITE (2015) survey data are from a relatively small sample size, and some respondents' answers to its income questions were found to be inconsistent with the range of answers to similar questions posed in GLSS 6.

Macroeconomic impacts

Quantitative impacts

Increasing LPG usage within the country could affect the (1) tax revenue, (2) trade balance for the country's economy, and (3) total number of jobs across various fuel value chains. Ghana's LPG supply is imported in part, and LPG is taxed, and these are expected to continue in a reformed LPG market.

LPG, including imported LPG, is VAT-exempt, while charcoal and firewood are subject to 12.5% VAT in Ghana. However, LPG is subject to a set of hydrocarbon-sector taxes that amount to approximately 20% of the current LPG end-user price[152]. Assuming that the VAT rates and status regarding these fuels remain unchanged over time, an increase in LPG consumption, combined with a decline in purchased firewood and charcoal consumption, will impact national tax revenue from VAT. Displacement of charcoal and firewood

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[149] Maxwell et al. (2018); Asante et al. (2018)

[150] KITE (2015)

[151] KITE (2015)

[152] See Chapter 10 (Pricing) beginning on page 50 for details.

consumption by Increased LPG consumption will increase national tax revenue between GHC 76 million (€ 13 million) and GHC 162 million (€ 29 million) in 2030, relative to the base case scenario.

In 2016, Ghana imported 177,900 MT of LPG and produced 114,200 MT domestically. To meet the latent demand of LPG under conditions of full availability, LPG production and/or LPG imports will need to increase. Assuming domestic production capacity of LPG is constant at 2016 production capacity values and charcoal exports do not rise,[153] increased LPG consumption would require an increase in LPG imports, which will impact the national trade balance. Increased LPG consumption could also decrease the national trade balance by between GHC 314 million (€ 56 million) and GHC 732 million (€ 132 million) in 2030 relative to base case projections.

Serving the projected increased LPG consumption could create between 4,680 and 11,748 direct jobs, net, within the LPG value chain by 2030 relative to base case projections, based on Government and industry estimates. Most of these jobs would be in the distribution and retailing of LPG. The shift to LPG for cooking is also likely to lead to job losses in the charcoal and wood value chains. This analysis was unable to quantify potential job losses in the charcoal and wood value chains due to lack of data.

Unquantified impacts

Increasing the volume of LPG in the country will create additional formal economic activity (e.g., growth of LPG businesses, staff of bulk depots, staff of filling plants, and transporters) which could positively affect the tax revenue from corporate tax in the country. This effect was not captured/modelled in the analysis, because of the lack of data on the corporate tax of different levels of the LPG value chain.

Other impact types

It is important to note that the assessment excluded a few potential avenues for impact that, if possible to include, would likely have increased the amounts of the positive findings. One example is the impact of the time saved by cooking with LPG and cleaning the LPG stoves and cookware and cooking space – relative to other fuels and stoves. These types of impact could not be quantified due to a lack of reliable data.

The health analysis was restricted to the five GBD health outcomes while acknowledging that there is good quality and emerging evidence of other health outcomes associated with HAP (e.g. cataracts, adverse pregnancy outcomes, TB, etc.) and burns, which have not been included in this analysis.

Conclusion

The results summarized above demonstrate that successful scaling up LPG use has meaningful positive impacts on four of five socio-economic impacts assessed: environment, health, gender and consumer household expenditure.

[153] Ghana Energy Commission (2017)

21. Detailed Impact Analysis and Findings

Impacts modelled, data used, and overall approach

This assessment estimated five different impacts of increased LPG adoption and use for household cooking under the lower-bound and upper-bound adoption scenarios described above relative to base case projections scenario:

- **Environment and climate impacts –** the averted deforestation, carbon dioxide equivalent emissions (considering carbon dioxide, methane, and nitrous oxide), black carbon equivalent emissions (considering black carbon, organic carbon, carbon monoxide, and total non-methane organic compounds), and the economic value of averted CO_2eq and BCeq emissions in terms of carbon financing.

- **Health impact –** the averted negative health impacts due decreased burning of firewood and charcoal and resultant household air pollution (HAP). This includes the number of deaths averted, the disability-adjusted life years (DALYs) saved, and the potential economic value that these individuals can now realize from the five main GBD outcomes.

- **Gender impacts –** the time that could be saved by women and other family members by no longer needing to buy firewood and charcoal daily for household cooking, and time saved from faster cooking with LPG. These effects are not quantifiable. Health impacts as mentioned above will be particularly important for women. Increases in employment of women in the expanded LPG sector, particularly in LPG retail, but loss of women's jobs in the informal charcoal and firewood sectors.

- **Consumer household expenditure impacts –** the cost savings/increase for the household due to increased LPG adoption and reduced usage of other fuels.

- **Macro-economic impacts –** the impact of increased LPG adoption on Ghana's tax base and trade balance, as well as the total job creation within the LPG value chain.

The assessment excluded certain potential mechanisms for impact, due to the lack of reliable data:

- Under environmental impacts, the assessment does not consider cooling effects.

- The health analysis is restricted to the five GBD health outcomes, while noting that there is good quality and emerging evidence of other health outcomes associated with HAP (e.g. cataracts in women, stillbirth and low birth weight, tuberculosis etc.) as well as burns in adults and children.

- Under gender impacts, this assessment does not consider the impact of the time saved from purchasing charcoal relative to LPG, and the time saved by cooking on LPG stoves and cleaning them (relative to other stoves) after increased LPG uptake.

- Under macro-economic analysis, the assessment does not account for the job losses that may take place in the charcoal and firewood value chains as LPG adoption increases and charcoal and firewood consumption decrease (assuming exports of these woodfuels do not then rise significantly).

In consequence, the total positive impacts of transitioning to LPG may be underestimated.

Data used and overall approach

The Ghana Living Standards Survey Round 6 2012/2013 (GLSS 6) was the primary data source for the assessment. Where possible, this information was triangulated with the (limited) aggregated data from the Ghana Living Standards Survey Round 7 2016/2017 (GLSS 7) available as of this writing. The GLSS 6 was conducted over a 12-month period between October 2012 and October 2013. The GLSS 6 survey sampled 18,000 households across the country. Data were obtained from 16,772 households, representing a response rate of 93.2%.[154]

In order to measure the impact from transition to LPG under the evaluated scenarios, it is important to consider which fuel households would switch from, and how much LPG they would potentially consume in future. Given the nature of the GLSS 6 data, a number of common assumptions were required to be made across the analyses:

- <u>Fuel transition</u>: In 2013, there were 6.6 million households in Ghana and they used three main fuels for cooking: LPG (22.3% of households used this as a primary fuel); charcoal (31.4% of households); and firewood (41.2% of households). Given that only 5.2% of households reported using another fuel for cooking in GLSS 6, only firewood, charcoal, and LPG were considered. Given the absence of secondary fuel use data, only primary fuel use was analysed. It was assumed that as LPG becomes more widely available over time, households will begin using LPG as a primary fuel and will gradually phase out the use of charcoal and firewood. The remaining charcoal and firewood households were projected from estimates of population growth over the specified time-period.[155]

- <u>Fuel consumption</u>: Given the absence of fuel consumption data in the GLSS 6, it was assumed that average LPG consumption per LPG user of 22.6 kg[156] would remain constant over the predicted time period and that when households begin using LPG their LPG consumption would be equivalent to that average consumption, with both groups predicted to gradually increase to 25kg by 2025.[157] It was assumed that the only other change in LPG consumption for these households would be due to beginning to use LPG in a more exclusive way, and no other potential impacts on

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154 GLSS 6 (2013)

155 It is important to note that only the transition to LPG primary use was analysed, as no secondary fuel use data were available in GLSS 6. Households may continue stacking with charcoal and firewood. The consumption per capita per LPG user in Ghana was 22.6 kg in 2013 and is projected to reach 25kg by 2025. The theoretical maximum, based on the heat energy required to cook Ghanaian meals on average (GACC 2016) is 38 kg. It was assumed that this level of stacking would continue with new users, approaching gradually 25kg over time and plateauing at that level. These were necessary simplifications for modelling purposes, given the absence of secondary fuel data.

156 See Part VI(LPG Demand Potential to 2030) for an explanation of how this value was derived.

157 These values were obtained for all fuel users (both primary and secondary use households). For firewood using households (national – 1065 kg/HH using firewood, urban – 986 kg/HH using firewood, rural – 1113 kg/HH using firewood); for charcoal using households (national – 434 kg/HH using charcoal, urban – 431 kg/HH using charcoal, rural – 440 kg/HH using charcoal); and for LPG using households, a national average of 87 kg/HH using LPG (for both primary and secondary fuel users). Source: The Energy Commission Ghana (2017).

their consumption were modelled, including any other changes that may occur within these value chains, such as price variations and changes in the availability of other fuels.

It is important to note that the impact assessment presented in this report is calculated for scenarios where LPG is sufficiently available (lower and upper bound) to serve LPG demand in the areas potentially accessible to LPG, relative to projected base case projections. This approach helps estimate the incremental impact of the investment to make LPG fully accessible to relevant Ghanaian households over time.

Environment and climate impacts

The impact of households changing their primary fuel from charcoal and firewood to LPG can have many positive impacts on the environment and climate. For the purpose of this analysis, the environmental impacts from increased LPG use (and decreased charcoal and firewood use) were estimated by calculating (1) averted deforestation; (2) carbon dioxide equivalent (CO_2eq) emissions[158] averted; (3) Black Carbon equivalent (BCeq) emissions[159] averted; and (4) the potential economic value of averted CO_2eq and BCeq emissions in terms of carbon financing.

The potential utilization of this carbon financing is addressed in the companion *Ghana LPG Investment and Implementation* report.

Table 64. Summary of environment and climate impacts from increased primary LPG consumption relative to base case scenario in 2030

Annual impact	**2030**		
	Lower-bound adoption scenario	**Government Policy Goal scenario**	**Upper-bound adoption scenario**
Averted annual deforestation	11.17 million trees saved annually	16.19 million trees saved annually	21.20 million trees saved annually
Reduction in annual CO_2eq emissions	0.50 million MT reduction in CO_2eq emissions annually	0.63million MT reduction in CO_2eq emissions annually	0.76 million MT reduction in CO_2eq emissions annually
Reduction in annual BCeq emissions	1.0 million MT reduction in BCeq emissions annually	1.35 million MT reduction in BCeq emissions annually	1.70 million MT reduction in BCeq emissions annually
Economic value of annual averted CO_2eq emissions	€ 2.19 million annually	€ 2.8 million annually	€ 3.34 million annually

Cumulative impact	**2020 - 2030**		
	Lower-bound adoption scenario	**Government Policy Goal scenario**	**Upper-bound adoption scenario**
Averted cumulative deforestation	127 million trees saved	174 million trees saved	221 million trees saved

158 CO_2eq emissions includes carbon dioxide equivalent emissions from carbon dioxide, methane, and nitrous oxide.

159 BCeq emissions includes black carbon equivalent emissions from black carbon, organic carbon, carbon monoxide, and total non-methane organic compounds.

Cumulative impact	**2020 - 2030**		
	Lower-bound adoption scenario	**Government Policy Goal scenario**	**Upper-bound adoption scenario**
Cumulative reduction in CO_2eq emissions	6.76 million MT reduction in CO_2eq emissions	8.01 million MT reduction in CO_2eq emissions	9.27 million MT reduction in CO_2eq emissions
Cumulative reduction in annual BCeq emissions	10.43 million MT reduction in BCeq emissions	13.53 million MT reduction in BCeq emissions	16.63 million MT reduction in BCeq emissions
Cumulative economic value of averted CO_2eq emissions	€ 29.64 million	€ 35.14 million	€ 40.65 million

The foregoing impacts could be reduced by an amount in the vicinity of 5.6%, but not presently calculable using available data, based on the actual demand response over time to the anticipated future pricing of LPG under BCRM.

Averted deforestation

Ghana has one of the highest deforestation rates in the world, losing approximately 135,000 hectares, equivalent to 2.7% of forest annually. Although 21.7% (4,940,000 hectares) of Ghana is covered in forest, the country has lost one third – 2,500,000 hectares – of its forest cover between 1990 and 2010.[160] Despite a history of national policy promoting the use of non-wood fuels, as of 2013, 72.7% of Ghanaian households still relied on firewood and charcoal for cooking.

A transition to LPG has the potential to significantly reduce the pace of forest degradation and deforestation in Ghana. To calculate the potential averted deforestation from increased LPG uptake, the study estimated the total number of trees saved due to reduced firewood and charcoal use through displacement by LPG use. The number of trees used in each scenario was calculated from current firewood[161] and charcoal consumption,[162] the proportion of this consumption that is produced unsustainably (using the forest non-renewability factor - a measure of how sustainably fuel is sourced from the forest[163]), and the typical usable mass of a tree.[164] The approach assumes that the same mix of wood type is used nationally and does not change over time, and that charcoal and firewood displaced by LPG use will not then be exported to other countries. If this charcoal is exported, associated deforestation will continue. (Regulatory measures to limit charcoal export growth would ensure full capture of forest-saving benefits caused by increased adoption of LPG.)

160 FAO (2010)

161 For firewood, this is calculated by using the average firewood use per household using firewood (national – 1065 kg/HH using firewood, urban – 986 kg/HH using firewood, rural – 1113 kg/HH using firewood). Source: The Energy Commission Ghana (2017).

162 For charcoal, this was calculated by using the average charcoal use per household using charcoal (National – 434 kg/HH using charcoal, urban – 431 kg/HH using charcoal, rural – 440 kg/HH using charcoal) Source: The Energy Commission Ghana (2017) "National Energy Statistics (2007-2016)". This household charcoal use was converted to equivalent wood consumption, using a ratio of 7 from: Mjumita (2016). This is a global approximation that is commonly used in literature.

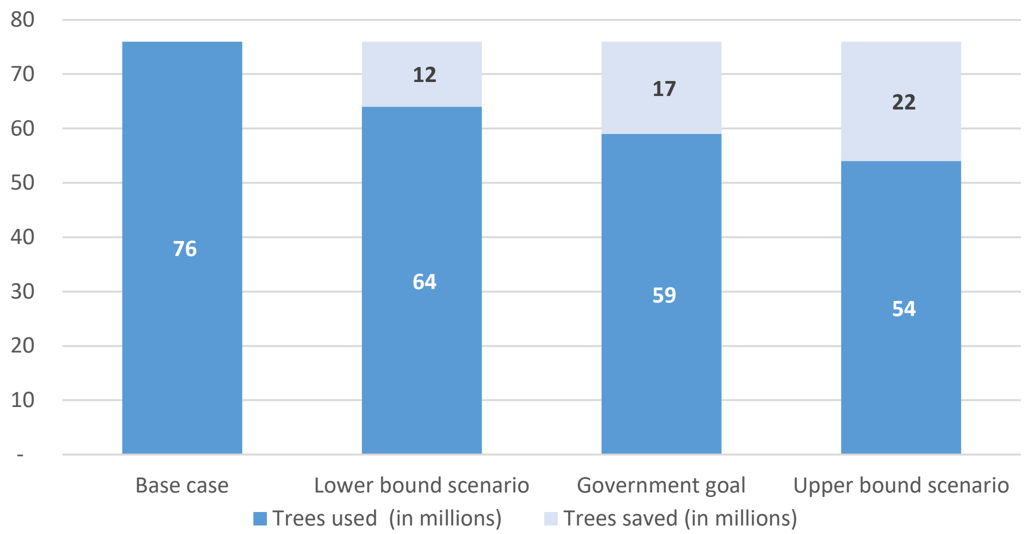
163 In Ghana, 65% of wood is taken from forests in a non-renewable manner (this can be applied to both charcoal and wood). Source: EPA (2016).

164 The global average value is 100 kg which is most commonly used in the literature – from: Penn State University (2016)

Using this approach, it is estimated that 59.5 million trees were used for household cooking in Ghana in 2013. In 2030, between 19 million and 32 million trees, could be saved per year under the lower and upper bound scenarios, respectively, compared to base case projections (see Figure 1). Between 2020 and 2030, this amounts to a cumulative 127 – 221 million trees saved, depending on the LPG adoption scenario, relative to base case projections. Note that this likely represents an underestimation of the total number of trees saved, as the analysis does not consider LPG secondary fuel users.

Forest loss in Ghana is measured in hectares, but reliable data were not available on the tree density of Ghana's forests. If one makes a broad assumption that a hectare contains approximately 500 trees, 11-21 million trees saved represents 22,000 to 42,000 hectares. Ghana loses 135 ha of forests annually (2.7% of total forest). Therefore, based on this density assumption, the LPG transition would avert 16-31% of annual Ghanaian forest loss. However, these values must be used with caution, because of the uncertainty regarding the tree-to-land area ratio in Ghana's main regions of forest loss.

Figure 47. The number of trees used and trees saved per year
under base case, lower bound and upper bound adoption scenarios in 2030



The foregoing impacts could be reduced by an amount in the vicinity of 5.6%, but not presently calculable using available data, based on the actual demand response over time to the anticipated future pricing of LPG under BCRM.

Averted carbon emissions

Ghana's greenhouse gas emissions profile is dominated by emissions from land-use change and forestry (53% of total emissions), and energy (25% of total).[165] Within energy, 29% of emissions are attributable to fuel combustion.[166] In 2011, Ghana emitted 59 million metric tonnes (MT) of total carbon dioxide equivalent emissions (CO_2eq).[167] One of the contributing factors to land-use change and fuel combustion is

165 USAID (2016)

166 USAID (2016)

167 USAID (2016)

the use of biomass as fuel. The transition from charcoal and firewood to LPG for cooking will decrease total and per capita carbon emissions through two mechanisms – decreased carbon emissions from fuel use and decreased fuel production (charcoal and LPG).

The total CO_2eq emissions from fuel use was calculated using the Gold Standard TPDDTEC Guidelines.[168] This methodology estimates total CO_2eq emissions by calculating the carbon dioxide equivalent emissions of three particles – carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) – and including global warming potential (GWP) conversion factors.[169]

The CO_2eq emissions for different fuel use were calculated by multiplying household level fuel consumption[170] by the net calorific value of the fuel and average stove efficiencies using global averages obtained from literature[171]. This results in the energy use per fuel (MJd), which was multiplied by the CO_2eq emissions factor (in g/MJd) to obtain the total CO_2eq emissions (in grams, which were then converted to metric tonnes). This methodology was used to calculate CO_2eq emissions for the base case projections scenarios, and the two full-availability adoption scenarios (lower and upper bound). The CO_2eq tonnage differential was calculated by subtracting the CO_2eq emissions under the full availability scenarios from CO_2eq emissions in the base case projections scenario.

The total CO_2eq emissions from fuel production was estimated using Kyoto Particles Emissions rates calculated for the production of charcoal and LPG.[172] It is important to note that in the case of LPG, given that Ghana imports LPG and may continue to do so to meet the forecasted demand, the emissions from production of LPG may occur outside of Ghana. Since LPG is a by-product of the petroleum industry, the emissions from fuel production would take place regardless of the increase in LPG consumption[173].

Combining the CO_2eq emissions from fuel use and fuel production, in 2013, an estimated 7.5 million MT of CO_2eq emissions were emitted in Ghana from fuel use for cooking. Table 65 shows that in 2030, 0.50 and 0.76 million MT of CO_2eq emissions could be reduced per year under the lower and upper bound scenarios, respectively, compared to the base case projections. Note that this likely represents an underestimation of the total reduction in CO_2eq emissions, as the analysis does not consider secondary fuel users.

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168 Gold Standard Methodology (2017)

169 CO_2 emissions rate was multiplied by the applicable non-renewability factor, CH_2 and N_2O emissions rate were multiplied by the global warming potential 100 factors (25 for CH_4 and 298 for N_2O). See all values in Annex.

170 These values were obtained for all fuel users (both primary and secondary use households). For firewood using households (national – 1065 kg/HH using firewood, urban – 986 kg/HH using firewood, rural – 1113 kg/HH using firewood); for charcoal using households (national – 434 kg/HH using charcoal, urban – 431 kg/HH using charcoal, rural – 440 kg/HH using charcoal); and for LPG using households, a national average of 87 kg/HH using LPG (for both primary and secondary fuel users). Source: The Energy Commission Ghana (2017).

171 Given the paucity of relevant field studies in Ghana, the study relied on global averages obtained from literature. See Annex 9

172 This methodology estimates total CO_2eq emissions by calculating the CO_2eq emissions of three particles – carbon dioxide, methane, and nitrous oxide – and including global warming potential conversion factors. CO_2 emissions rate was multiplied by the applicable non-renewability factor, CH_2 and N_2O emissions rate were multiplied by the global warming potential 100 factors (25 for CH_4 and 298 for N_2O). Source: EPA (2018).

173 Surplus LPG production globally is cleared from the market by the portions of the petrochemical and plastics industry which utilize LPG as a feedstock. Sources: IHS Markit (2018), WLPGA (2018).

Table 65. Reduction in annual and cumulative CO_2eq emissions from increased primary LPG consumption, relative to base case scenario in 2030[174]

Annual impact	2030		
	Lower-bound adoption scenario	Government Policy Goal scenario	Upper-bound adoption scenario
Reduction in annual CO_2eq emissions relative to base case projections (MT)	0.50 million MT	0.63 million MT	0.76 million MT
Reduction in annual CO_2eq emissions per capita relative to base case projections (MT)	0.01 MT	0.02 MT	0.02 MT

Cumulative impact	2020 - 2030		
	Lower-bound adoption scenario	Government Policy Goal scenario	Upper-bound adoption scenario
Reduction in cumulative CO_2eq emissions relative to base case projections (MT)	6.70 million MT	8.01 million MT	9.27 million MT

The foregoing impacts could be reduced by an amount in the vicinity of 5.6%, but not presently calculable using available data, based on the actual demand response over time to the anticipated future pricing of LPG under BCRM.

Averted black carbon emissions

Black carbon (BC) is a key climate-active pollutant with high global-warming effect. Globally, it is estimated that household use of solid fuel contributes 25% of the total BC emissions.[175] In Africa and Asia, where usage of solid fuels is more common, residential usage of biomass can contribute 60 – 80% of total BC emissions.[176] Reducing the usage of biomass for residential cooking will directly reduce global BC emissions.

To estimate the BCeq emissions (i.e., the CO_2 equivalent of BC emissions) due to reduced firewood and charcoal usage and increased LPG adoption, the study calculated the total BCeq emissions for each scenario to 2030. To calculate annual BCeq emissions, a three-step approach was used, according to the Gold Standard Methodology: (i) The BCeq emissions per unit of fuel use was calculated using the formula in Gold Standard TPDDTEC Guidelines black carbon methodology; (ii) BCeq emission per fuel was multiplied by the GWP of black carbon (1140)[177]; (iii) the global warming potential of BCeq emissions per fuel was multiplied by the total consumption per fuel in kg.[178] This calculation estimated the BCeq emissions from

174 In 2013, the CO2eq emissions amounted to 1.71 MT per HH from charcoal, 1.19 MT per HH from firewood, and 0.51 MT per HH from LPG. The CO2eq tonnage differential depicts the difference in MT under the full availability scenario and base case scenario. The results should be interpreted accordingly. If the demand for LPG under BAU is lower than projected, for example, the CO2eq tonnage differential will be higher.

175 Bond TC et al (2013).

176 Bond TC et al (2013).

177 While the IPCC global GWP value = 690, Rypdahl et al (2009) provides an Africa-specific GWP value of 1140, which we have used in this analysis and is used in the impact literature related to clean cooking more broadly.

178 These values were obtained for all fuel users (both primary and secondary use households). For firewood using households (national – 1065 kg/HH using firewood, urban – 986 kg/HH using firewood, rural – 1113 kg/HH using firewood); for charcoal using households (national – 434 kg/HH using charcoal, urban – 431 kg/HH using charcoal, rural – 440 kg/HH using charcoal);

fuel use, calculated for LPG, charcoal, and firewood. In addition, the BCeq emissions for charcoal production were calculated following the approach laid out above but considered the BCeq emissions per fuel production rather than fuel use.[179] Only the production of charcoal was considered, as firewood is often collected (and therefore it is difficult to quantify the BCeq emissions from firewood production) and LPG production produces negligible BCeq emissions.[180]

The total BCeq emissions in 2013 were estimated to be 5.6 million MT. Table 66 shows that in 2030, 1.0 and 1.7 million MT of BCeq emissions could be reduced annually under the lower and upper bound LPG adoption scenarios, respectively, compared to base case projections projected trends.[181] Note that this likely represents an underestimation of the total reduction in BCeq emissions, as the analysis does not consider secondary fuel users.

Table 66. Reduction in annual and cumulative BCeq emissions from increased primary LPG consumption, relative to base case scenario in 2030[182]

Annual impact	**2030**		
	Lower-bound adoption scenario	**Government goal scenario**	**Upper-bound adoption scenario**
Reduction in annual BCeq emissions relative to base case projections (MT)	1.09 million MT	1.35 million MT	1.70 million MT
Reduction in annual BCeq emissions per capita relative to base case projections (MT)	0.03 MT	0.04 MT	0.05 MT

Cumulative impact	**2020 - 2030**		
	Lower-bound adoption scenario	**Government goal scenario**	**Upper-bound adoption scenario**
Reduction in cumulative BCeq emissions relative to base case projections (MT)	10.43 million MT	13.53 million MT	16.63 million MT

The foregoing impacts could be reduced by an amount in the vicinity of 5.6%, but not presently calculable using available data, based on the actual demand response over time to the anticipated future pricing of LPG under BCRM.

Economic value of averted CO_2eq and BCeq emissions via carbon financing

Once emitted, CO_2 lasts about 100 years in the atmosphere, meaning that the benefits of abating CO_2 emissions today will continue to be felt over the next century. Therefore, reducing CO_2eq and BC

and for LPG using households, a national average of 87 kg/HH using LPG (for both primary and secondary fuel users). Source: The Energy Commission Ghana (2017).

179 Given the paucity of relevant field studies in Ghana, the study relied on global averages obtained from literature. See Annex 9.

180 World LP Gas Association and ESMAP (2015).

181 The per capita reduction does increase across the projected years, albeit by a small amount, resulting in the appearance of a consistent per capita emissions reduction.

182 In 2013, the BCeq emissions amounted to 0.97 MT per HH from charcoal, 1.32 MT per HH from firewood, and 0.01 MT per HH from LPG. The BCeq tonnage differential depicts the difference in MT under the full availability scenario and base case scenario. The results should be interpreted accordingly. If the demand for LPG under BAU is lower than projected, for example, the BCeq tonnage differential will be higher.

emissions from clean cooking will have positive environmental benefits. Both the Clean Development Mechanism and Gold Standard Methodologies allow for carbon finance of LPG stoves. The economic value of abated CO_2eq emissions can be estimated by multiplying the total emissions averted through 2030 by the prevailing price of carbon in 2018.

It should be noted that there are currently no examples of carbon markets paying for BCeq abatement. To address this, the Gold Standard has proposed a new BC methodology in 2017 for household cooking and BC emissions should be possible to value under this methodology in due course. For now, the potential value of BC abatement can be calculated by taking the CO_2eq quantities of BC emissions (i.e., BCeq emissions) and multiplying it by the prevailing price of carbon.

For both the estimations, there are two ways to determine the price of carbon:

1. *Price carbon on prevailing carbon values* – A 2017 review of global carbon prices found that clean cookstove offsets from Africa were priced at an average of € 4.4/MT (US $5.1/MT) of CO_2 (carbon prices ranged from € 1.7 – 17.2 (US $2-20)[183]

2. *Use a fair estimate of the price of carbon* – The fair price of carbon in the market is predicted to be € 34 – 69 (US $40-80) per MT of CO_2 by 2020 and € 43 - 86 (US $50-100) per tonne by 2030.[184] However, these carbon prices are not reflected in any market. In fact, 85% of global carbon emissions are currently not priced, and about three quarters of the emissions are priced at below € 8.6/MT (US $10/MT) of CO_2.

Given that real carbon prices are consistently lower than the fair estimate of carbon price, the economic value of reduced carbon was estimated using the observed prevailing carbon price in Africa of US $ 5.1/MT (€ 4.4/MT) of CO_2 and multiplying it by the carbon emissions averted.

The annual economic value of CO_2 emissions and BCeq emissions averted in 2030 range between of € 2.2 – € 3.3 million and € 4.4 – € 7.4 million, respectively, relative to business as usual. The cumulative economic value for CO_2 emissions averted between 2020 and 2030, could range from € 30 million to € 41 million, depending on the adoption scenario, relative to base case projections. The cumulative economic value for BCeq emissions averted between 2020 and 2030, could range from € 45 million to € 73 million, depending on the adoption scenario, relative to base case projections.

The foregoing impacts could be reduced by an amount in the vicinity of 5.6%, but not presently calculable using available data, based on the actual demand response over time to the anticipated future pricing of LPG under BCRM.

Health impacts

Transitioning from charcoal and firewood to LPG can have significant health benefits due to reduced personal exposure to household air pollution (HAP) from burning solid fuels to meet household energy needs. HAP is causally related to ischemic heart disease, stroke, chronic obstructive pulmonary disease

183 World Bank (2017)

184 Stiglitz and Stern (2018)

(COPD), lung cancer in adults, and acute lower respiratory infection in children (ALRI).[185] All of these diseases can result in premature death or a disability that can affect life expectancy. In 2013 in Ghana, exposure to HAP from cooking with solid fuel resulted in 30,017 premature deaths and 736,524 Disability Adjusted Life Years (DALY)s.[186] A "DALY" is a measure of overall disease burden, expressed as the number of years lost due to ill-health, disability or early death.[187]

For the purpose of this study, the health benefits from increased LPG use offsetting charcoal and firewood use was estimated by calculating (1) deaths averted, and (2) Disability-Adjusted Life Years (DALYs) saved due to reduced HAP from fine particulate matter ($PM_{2.5}$) exposure rates based on the five diseases included in the GBD only.[188] $PM_{2.5}$ is one of a number of health-damaging products of incomplete fuel combustion that are emitted at relatively high concentrations when wood, charcoal, and other solid fuels are burned in open fires or cookstoves, but are negligibly emitted by combustion of LPG.

The World Health Organization (WHO) has published safe levels of $PM_{2.5}$ for health, termed "air quality guidelines." The current recommended guideline for annual average $PM_{2.5}$ level is 10 ug/m^3 (annual average). Recognizing the challenge of rapidly achieving such low concentrations of particulates, the WHO has also identified three interim targets for $PM_{2.5}$ concentrations that would offer some health protection to support efforts towards meeting the WHO guidelines. The first (highest) of such targets is the interim-target 1 (IT-1), set at 35 ug/m^3.

Compared with combustion of solid fuels in the home, LPG has a very clean emissions profile at point of use that consistently delivers low emissions independently of the operation, age, or condition of the stove used.[189] As such, and in the absence of other indoor or ambient sources of pollution, it is reasonable to assume that the concentrations of $PM_{2.5}$ in households using LPG exclusively for cooking, will be below the WHO annual average Interim Target 1 (35 ug/m^3). Higher exposure rates reported in certain other studies are likely due to background air pollution, including from neighbouring households that continue to rely on polluting fuels and technologies, and/or from concurrent use of other, more polluting fuels in the homes studied. Given that there are still relatively few field studies conducted in Sub Saharan Africa, which carefully document fuel stacking and levels of ambient air pollution (see Annex Chapter 21 (Detailed Impact Analysis and Findings) beginning on page 229), and that it was beyond the scope of this work to conduct a systematic review of all published studies, the modelling uses the WHO IT-1 annual $PM_{2.5}$ concentration as a basis for assessing the health impacts of increased primary/exclusive LPG consumption in adults and children.

In terms of pre-intervention exposure data, the study relied on published concentrations of $PM_{2.5}$ exposure for firewood and charcoal users taken from a systematic review of field studies conducted by Pope et al (2017) (See Annex Chapter 21). Pre and post-intervention exposure values were inputted into the Household Air Pollution Intervention Tool (HAPIT version 3.1.1)[190], a tool based on established GBD methods that is in widespread use for modelling health impacts of interventions to reduce HAP

185 Smith et al. (2015)

186 Based on outputs from the WHO: HAPIT model, version 3.1.1, using GLSS 6 data.

187 IHME (2016); WHO (2016)

188 $PM_{2.5}$ refers to "Particulate Matter, 2.5 micrometers or less". These are air pollutants with a diameter of 2.5 micrometers or less, small enough to invade even the smallest airways and produce respiratory and cardiovascular illness.

189 Smith K.R., et al. (2000); Zhang et al. (2000); MacCarty et al. (2010); Shen et al. (2018)

190 householdenergy.shinyapps.io/hapit3/

exposure.[191] This tool was used to estimate the deaths averted and DALYs saved in Ghana under each scenario.[192]

The 2014 Demographic and Health Survey shows that that 31% of urban and 43% of rural Ghanaian households cook always or mainly outdoors. Outdoor cooking could result in somewhat lower exposure to $PM_{2.5}$, due to increased ventilation. This analysis does not differentiate indoor vs. outdoor $PM_{2.5}$ exposure concentrations, as there are very few field studies that examine $PM_{2.5}$ concentrations with outdoor cooking, and there is no consensus on the effect on HAP exposure of outdoor cooking.

To account for the effect of fuel stacking, an overall household $PM_{2.5}$ emission level of 35 ug/m^3 (representing LPG emissions plus HAP from non-LPG fuels) was assumed, instead of the actual emission level of pure LPG.

The health impacts of increased LPG adoption can be seen in the table below. Overall, between 11,965 and 19,415 deaths could be averted cumulatively between 2020 and 2030, relative to base case projections, with increased LPG consumption under the different scenarios. In addition, 423,774 – 688,042 DALYs could be saved depending on the scenario. These values lead to a total economic value (based on the prevailing average wage rate times the labour time and productivity gained from the averted deaths and saved DALYs) of approximately € 198 million - € 321 million, relative to base case projections, based on prevailing wage rates. This economic impact does not consider the cost-savings to society from a reduced healthcare burden. It may overestimate the economic value of gained labour productivity, because not all working age adults affected by HAP are economically active.

Table 67. Summary of health benefits
from increased primary LPG consumption relative to base case scenario, 2020-2030 (cumulative)

Cumulative impact (adults and children)	**2020 – 2030**		
	Lower-bound adoption scenario	**Government Policy Goal scenario**	**Upper-bound adoption scenario**
Cumulative deaths averted	11,965	15,690	19,415
Cumulative DALYs saved	423,774	555,908	688,042
Cumulative economic value of deaths averted and DALYs saved	€ 198 million	€ 259 million	€ 321 million

Premature deaths averted and DALYs saved

In 2013, 72% of Ghana's households used solid fuels such as wood or charcoal.[193] Use of solid fuels results in HAP. Data taken from GBD from the main 5 HAP-related diseases in Ghana shows that in 2013, 30,017 people died due to HAP. Women tend to be much more exposed to HAP than men, given that, in Ghana,

191 The HAPIT model uses disease rates and relationships as described in the Institute for Health Metrics and Evaluation's 2013 Global Burden of Disease and Comparative Risk Assessments efforts and estimates potential health changes due to interventions designed to lower household air pollution. See householdenergy.shinyapps.io/hapit3/#

192 A useful intervention lifespan of five years was assumed (with the results divided by five to obtain a per year output), and the default values for Ghana were used, with a counterfactual of 7 ug/m3. This counterfactual is a measure of the ideal exposures, below which there is no risk to health.

193 As calculated from GLSS 6 data.

they are primarily responsible for cooking. The leading cause of these deaths (14,040) was stroke, and the second leading cause was ischemic heart disease (9,143).[194]

In 2013, between 736,524 and 1,320,583 DALYs were lost in Ghana due to ill-health, disability, and early death as a result of HAP. Strokes and ischemic heart disease account for the majority of the years lost, with strokes accounting for an average of 306,415 years lost, and ischemic heart disease accounting for an average of 214,210 years lost.[195]

The total number of deaths that could be averted and DALYs that could be saved per year due to nearly exclusive LPG use (displacing firewood or charcoal use), was estimated under various scenarios (lower bound, upper bound and base case projections) using the HAPIT model[196]. The difference between the upper/lower bound/governmental policy goal scenarios and the base case scenario shows the number of deaths that could be averted and DALYs that could be saved, should adequate LPG availability be achieved. Table 68 shows a summary of the results for each scenario. Between 2020 and 2030, 11,965 – 19,415 deaths could be averted and 423,774 – 688,042 DALYs could be saved depending on the scenario, relative to the base case projections, due to increased LPG usage under conditions of expanded LPG availability.[197]

Table 68. DALYs that can be saved
from increased nearly exclusive LPG consumption relative to base case projections scenario[198]
(annually in 2030 and cumulatively between 2020 and 2030)

Annual impact (adults and children)	**2030**		
	Lower-bound adoption scenario	**Government Goal scenario**	**Upper-bound adoption scenario**
Annual adult deaths averted	925	1,260	1,595
Annual child deaths averted	213	290	367
Annual adult DALYs saved	22,052	30,056	38,060
Annual child DALY's saved	18,211	24,816	31,421

Cumulative impact (adults and children)	**2020 - 2030**		
	Lower-bound adoption scenario	**Government Goal scenario**	**Upper-bound adoption scenario**
Cumulative adult and child deaths averted	11,965	15,690	19,415
Cumulative adults and child DALY's saved	423,774	555,908	688,042

194 Based on outputs from the WHO: HAPIT model, version 3.1.1, using GLSS 6 data.

195 Based on outputs from the WHO: HAPIT model, version 3.1.1, using GLSS 6 data.

196 See Annex Chapter 29 (Impact Assessment Data Sources and Values) beginning on page 306 for details.

197 The analysis does not include secondary LPG users. It is unlikely that secondary fuel users would experience low enough exposure data to elicit impacts on health outcomes.

198 The number of DALYs saved depicts the difference in the number of potential DALYs saved under the enhanced availability scenario and base case scenario. The results should be interpreted accordingly. If the demand for LPG under the base case is lower in future than projected, for example, the number of DALYs saved will be higher.

Figure 48. HAP-related deaths per year and deaths averted per year under base case, lower bound and upper bound adoption scenarios in 2030

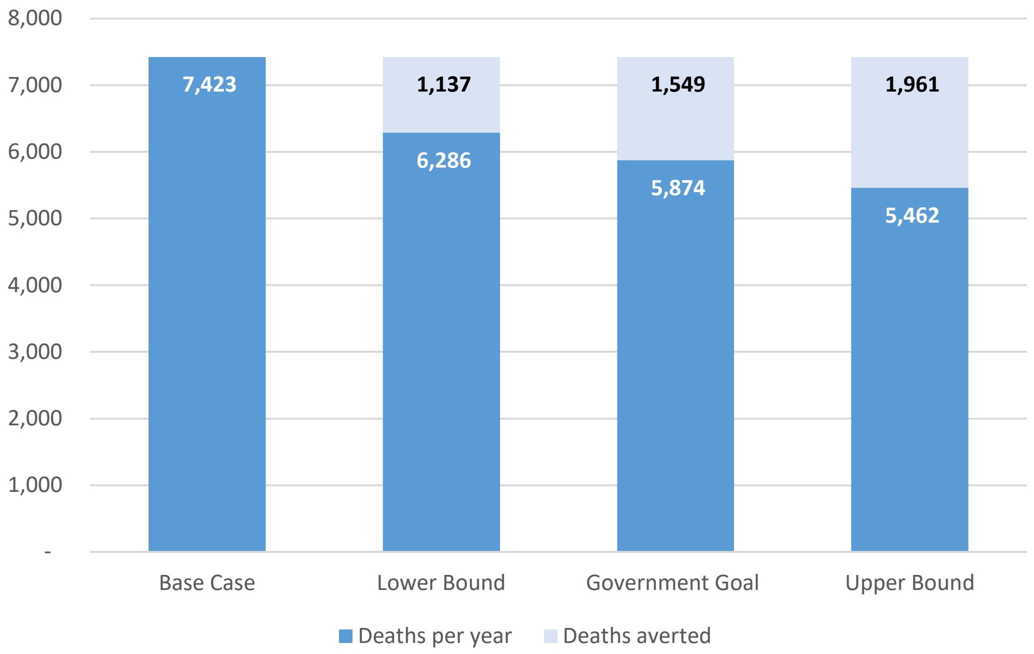
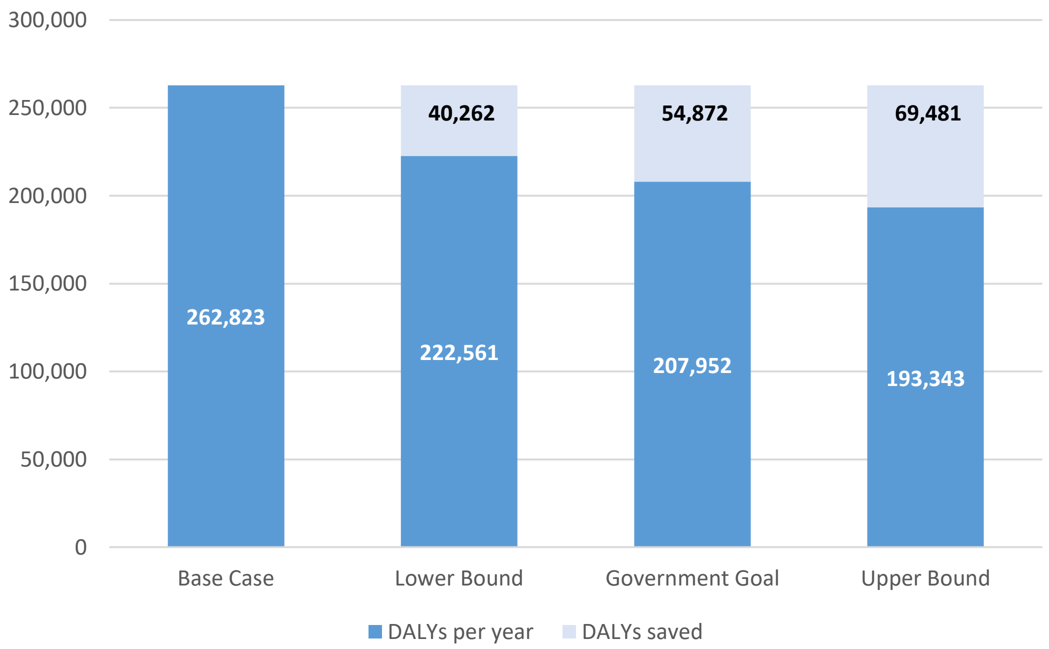


Figure 49. HAP-related DALYs per year and DALYs saved per year under base case, lower bound, and upper bound LPG adoption scenarios in 2030



Economic value of deaths averted and DALYs saved

Economic value of deaths averted: The economic value of the HAP-related deaths averted was estimated by multiplying the annual average GDP per person employed in Ghana[199] by the total number of adult deaths averted (as calculated above) for working age adults (age 15-64).[200]

Economic value of DALYs saved: The economic value of HAP-related DALYs saved was calculated by multiplying the annual average GDP per person employed in Ghana by the number of DALYs saved for working age adults (age 15-64).

The economic value of deaths averted and DALYs saved per year due to increased LPG adoption and nearly exclusive use was estimated under various scenarios (lower bound, governmental goal, upper bound, and base case projections). Table 69 shows that under the upper bound adoption scenario, the annual economic value of the deaths averted and DALYs saved could reach € 32 million per year in 2030, relative to base case projections. The cumulative economic impact could range from € 198 million to € 321 million, depending on the adoption scenarios, relative to base case projections. Note that this likely represents an overestimation of the economic value of deaths averted, as not all working age adults are productive, and because women, who bear the greater burden of HAP exposure, have a lower share of national formal employment income.

It should be noted that the potential cumulative economic impact from LPG for Ghana caused by health effects alone represents from between 59% to 96% of the total investment capital expected to be required to deliver availability of LPG to all households that desire to use it, as detailed in Part VIII (Critical Path LPG Infrastructure Investment Projects to 2030).

Table 69. Economic value of HAP-related deaths averted and DALYs saved from increased exclusive use of LPG relative to base case scenario in 2030[201] (annual and cumulative)

Annual impact (working age adults – age 15-64)	**2030**		
	Lower-bound adoption scenario	**Government Goal scenario**	**Upper-bound adoption scenario**
Annual economic value of adult deaths averted (€)	0.75 million	1.03 million	1.30 million
Annual economic value of adult DALYs saved (€)	18.02 million	24.57 million	31.12 million
Annual total economic value of adult DALYs saved and deaths averted (€)	18.77 million	25.60 million	32.42 million

Cumulative impact (working age adults – age 15-64)	**2020 - 2030**		
	Lower-bound adoption scenario	**Government Goal scenario**	**Upper-bound adoption scenario**

199 A value of EURO 2,985 (USD 3,471)/year was used from: World Bank Data Indicators (2018).

200 This was calculated by adjusting the adult deaths averted by the age dependency ratio for Ghana in 2013 (72.61).

201 The economic value of DALYs saved depicts the difference in the potential economic value of the DALYs saved under the full availability scenario and base case scenario. The results should be interpreted accordingly. If the demand for LPG under BAU is lower than projected, for example, the economic value of the DALYs saved will be higher.

Cumulative impact (working age adults – age 15-64)	2020 - 2030		
	Lower-bound adoption scenario	Government Goal scenario	Upper-bound adoption scenario
Cumulative economic value of adult deaths averted (€)	7.94 million	10.43 million	12.91 million
Cumulative economic value of adult DALYs saved (€)	189.78 million	248.97 million	308.15 million
Cumulative total economic value of adult DALYs saved and deaths averted (€)	197.72 million	259.40 million	321.06 million

Gender impacts

The GLSS 6 indicates that collecting firewood takes an average of 21.9 minutes (round-trip) per household per day in Ghana. Urban households using firewood spend an average of 18.9 minutes per day and rural households spend 22.4 minutes a day collecting fuel. In the demand analysis, none of the households that switched to LPG (as identified through the propensity matching approach) were households that collected firewood. Because charcoal is purchased locally, because LPG is purchased infrequently relative to other fuels, and because LPG under the scenarios of enhanced availability would by definition be locally available to the consumers who switch to LPG, it was assumed that the time taken per day to collect LPG is negligible relative to the time taken to collect charcoal (given the absence of data). Therefore, only the value of time saved for households no longer collecting firewood was estimated. Through the demand analysis, it was possible to identify whether the firewood-using households that could switch to LPG by 2030 collected firewood, or purchased it.

Therefore, there are no time savings from the transition to LPG in the full availability scenarios modelled in this analysis.

Note that there may be additional time saved when taking into consideration (i) the time saved from cooking with LPG, and (ii) time saved cleaning (as pots, stoves, and the household cooking space are not blackened by LPG). However, these effects were excluded from this analysis due to lack of available data.

Long-term potential for gender impact from LPG displacing collected firewood

The impact in Ghana of LPG availability and promotion on firewood-collectors was modelled to be negligible. This is due mainly to their household economics and to the impracticality, or inability, of authorities to restrict firewood collection. However, in principle a switch away from fuelwood collection for household energy purposes could have significant effects, including time savings for women, particularly as inclusive economic development enables more firewood-collecting persons to be able to participate in the cash-based energy economy over time.

Globally, it is estimated that women spend an average of 4.5 hours a day on unpaid work—more than double the amount of time spent by men.[202] The global value of this work is estimated at € 8.8 trillion, equivalent to one-eighth of the entire world's GDP. Reducing the number of hours per day spent by women on unpaid work involving gathering fuel could have numerous benefits, both financial and social, including

[202] Gates, M. (2016)

allowing women to find more paid work, pursue education, or have more time for themselves and their wellbeing.[203] LPG potentially offers a significant time saving advantage to firewood (and other collected biomass) as it provides storage of LPG in cylinders within the home, saving time spent collecting fuel.[204] In addition, LPG stoves can offer time savings from increased speed of cooking, including time saved from having to start the fire, and reduced cleaning time as utensils are not blackened by smoke.[205] Although the number of studies quantifying the time spent on biomass collection activities and speed of cooking and cleaning is limited, some studies from different settings show that households, and women in particular, spend between 1 and 3 hours per day gathering biomass fuel[206,207], and between 1 and 5 hours per day cooking and preparing food in Africa.[208]

Charcoal sector impacts

According to FAO (albeit from a very old study, conducted with the Ghana Energy Commission and Forestry Commission), the Ghana charcoal sector supported 144,000 jobs in 2000[209], with an annual turnover of approximately US $60 million at that time. According to the Ghana Energy Commission (2010), tree resources for charcoal are declining in the main production areas. Exploitation of new species to compensate is causing a reduction in charcoal quality and calorific content, causing charcoal to be less competitive with alternative fuels while accelerating the consumption of wood resources. Nonetheless, charcoal production is a major source of income to rural households in Ghana[210]. Studies addressing which gender dominates charcoal supply in Ghana (production, transport and marketing) present contradictory findings[211].

In 2016, according to press reports, 590 KT of charcoal was produced in Ghana.

The informal charcoal sector represents a source of employment for women, and expansion of LPG use at the expense of charcoal use for cooking can be expected to reduce employment meaningfully in the charcoal sector, as well as motivate charcoal selling (and production) to shift to areas with lower levels of competition from, and availability of, LPG. More recent data on the employment levels in the charcoal sector in Ghana, formal or informal, were not available. Therefore, it was not possible to estimate the potential loss of charcoal sector jobs associated with accelerated LPG adoption and use.

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203 Oxfam International (2017)

204 A study from India showed that the introduction of LPG reduced time spent on fuel collection from 2.2 to 0.2 hours per day. In other studies, the time savings from LPG have been shown to be between 1.5 and 2 hours a day. Sources: Nautiyal S. (2013); Brooks N et al. (2016).

205 Savings on cleaning time estimated as between 15 and 30 minutes in the following study: Chandar M, Tandon V. (2004); Shashni S and Chander M. (2014).

206 Regarding Sri Lanka: Wickramasinghe A. (2011); Nautiyal S. (2013); Brooks N et al (2016); Chandar M, Tandon V. (2004); Shashni S and Chander M. (2014).

207 In many countries children and sometimes men help with fuel collection.

208 ESMAP (2015)

209 www.fao.org/docrep/003/Y3198E/Y3198E05.htm

210 ESMAP (2006)

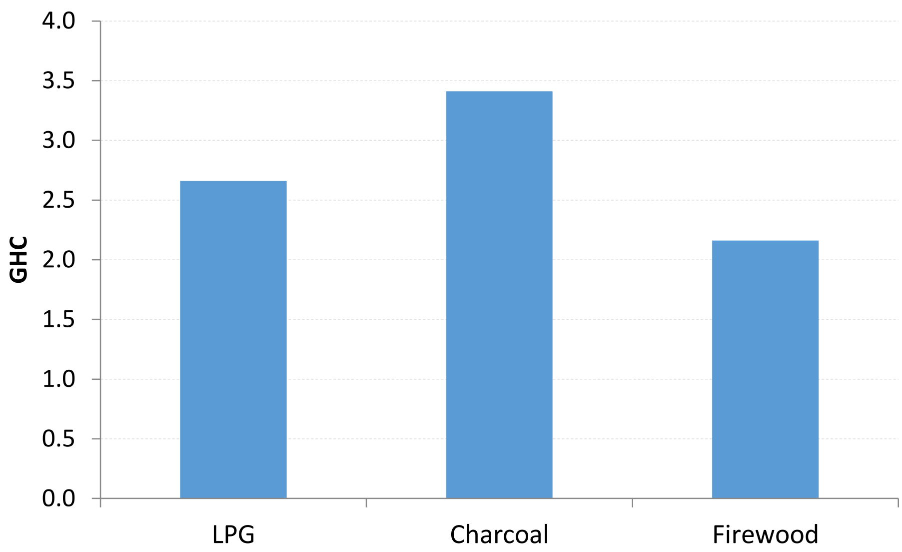
211 Ricerca Cooperazione, *Developing eco-charcoal certification to fight desertification and poverty in Afram Plains, Ghana* (2011). Blay et al., “Charcoal Production as Sustainable Source of Livelihood”, *Discovery and Innovation* vol. 19, pp. 199-204 (2007). Amoh-Anguh, *Socio-economic Analysis of Wood Fuel Production and Utilization Case Study*, KNUST, Kumasi, Ghana (1998).

Consumer household expenditure impacts

Stove and fuel affordability are potential constraints to LPG initial adoption and sustained use, given the income and liquidity levels of Ghanaian households. Yet, LPG could create household cost savings over the long run.

The following chart shows the comparative cost of cooking a meal in Ghana with LPG, charcoal and purchased firewood:

Figure 50. Average household fuel cost per meal cooked with LPG, charcoal and firewood (in GHC)



LPG has a higher initial purchase price (in terms of the cost of the stove and cylinder) and larger, multi-weekly refill transactions relative to daily or weekly woodfuel purchases. Over the lifecycle of the equipment, however, the cost of fuel dominates household cooking economics, as shown in Figure 13 (page 78). Considering only the direct cash cost of cooking (what is paid for the equipment, amortized over its lifetime, plus the fuel), LPG delivers more cooked meals per Cedi or Euro compared with charcoal, and fewer meals compared with purchased firewood. However, other benefits of LPG not captured in a direct cost calculation, such as speed (essentially zero ignition time, zero warm-up time, zero dousing time, cleanliness and clean-up time, negligible smoke/emissions, and others), mean that the cost-benefit comparison of LPG to firewood (considering such benefits) nevertheless favors LPG for a portion of households that use purchased firewood for cooking.

Additional analysis regarding comparative household costs is presented in Part VI.

It is estimated that 7% of a household's income in Africa is spent on energy, and additional incremental spending is often viewed as unaffordable given competing essential household expenses, including food and shelter.[212] In Ghana, the KITE household survey estimated that spending on fuel comprised 9% (rural) to 16.2% (urban) of average household income in 2015. Since the GLSS 6 does not contain data on household fuel consumption and expenditure, the total fuel cost savings from using LPG was estimated from the KITE (2015) study data. Because this study, while multiregional, was on a small scale, comprising

[212] ESMAP (2015)

only 200 households, extrapolating from it should be done with due caution. On average, the total expenditure on fuel does not vary by income, and similar sized households from different income quintiles tend to spend similar amounts of money on fuel. This means that low-income households spend a greater proportion of their income on energy relative to high-income households. The fuel cost savings was calculated using the average cost of fuel per year per household to obtain the total fuel costs under each adoption scenario. The average annual cost of cooking per household shows that, on average, LPG provides cost savings for households using charcoal but not for households using purchased firewood.[213]

In 2013, it was estimated that households in Ghana spent GHC 1.5 billion on residential cooking fuel.[214] The table below shows that under the three LPG adoptions scenarios, the annual cost savings to LPG consumers could increase between GHC 227 – 295 million (€ 41 – 53 million) in 2030, relative to the base case. For the households switching from charcoal to LPG, this equates to an annual per household cost savings of GHC 48 (€ 8.6) and GHC 66 (€ 11.9) for urban and rural households, respectively, based on prevailing prices. The absolute cost savings are higher for rural households than urban households given the higher rural price for charcoal relative to urban areas. For households switching from purchased firewood, this results in an annual increased expenditure per household of GHC 146 (€ 26.3) and GHC 220 (€ 39.6) for urban and rural households respectively, based on prevailing prices. The upper bound adoption scenario shows a lower annual cost savings relative to the lower bound adoption scenario because in the former more firewood-using households start using LPG and therefore begin spending more on fuel than they did in 2013.

Table 70. Cost savings per year from increased LPG consumption relative to base case scenario in 2030

	2030		
	Lower-bound adoption scenario	**Government Policy Goal scenario**	**Upper-bound adoption scenario**
Annual cost savings for all households switching from firewood and charcoal to LPG, relative to base case	GHC 227 million (€ 41 million)	GHC 262 million (€ 47 million)	GHC 295 million (€ 53 million)

When a 12.5% LPG price increased is assumed through 2030, the shift in net savings or net expense increase from switching to LPG from charcoal or from firewood, respectively, is disproportionate to the shift in LPG consumption volume, because the annual costs of cooking from all three purchased fuel types are relatively close together. The annual cost savings shown in Table 70 under this price-increase assumption become GHC 126 million (€ 23 million) for the lower-bound case, GHC 146 million (€ 26 million) for the Policy Goal Scenario, and GHC 164 million (€ 30 million) for the upper-bound case.

Macroeconomic impacts

Increasing LPG usage within the country could affect the (1) tax revenue, (2) trade balance for the country's economy, and (3) total number of jobs across various fuel value chains. Ghana's LPG supply is imported in part, and LPG is taxed, and these are expected to continue in a reformed LPG market.

[213] KITE (2015).

[214] Calculated using the total number of households, the annual cost of using different fuels in Ghana to obtain the total spent.

LPG (including imported LPG) is VAT-exempt in Ghana, and charcoal and firewood are subject to 12.5% VAT. LPG is however subject to approximately 20% of hydrocarbon sector-specific taxes. Assuming that these sales taxes on these fuels remain unchanged over time, an increase in LPG consumption, combined with a decline in purchased firewood and charcoal consumption will impact national tax revenue. Assuming no major increase in the export of these woodfuels, the result will be an increase in annual national tax revenue by between GHC 76 million (€ 13 million) and GHC 162 million (€ 29 million) in 2030.

In 2016, Ghana imported 177,900 MT[215] of LPG and produced 114,200 MT domestically.[216] To meet the latent demand of LPG under conditions of full availability, LPG production and/or LPG imports will need to increase. Assuming domestic production capacity of LPG is constant at 2016 production capacity values,[217] increased LPG consumption would require an increase in LPG imports, which will decrease the national trade balance[218] by between GHC 314 million (€ 56 million) and GHC 732 million (€ 132 million) in 2030 relative to base case projections.

Increased LPG consumption, holding LPG production constant at 2016 capacity, could create between 7,412 and 11,757 net new long-term jobs in 2030, relative to base case projections (short-terms jobs, e.g. for infrastructure construction, and jobs such as sales points that may retail LPG with other goods, are not modelled in this analysis). The NPA estimates that direct job creation due to BCRM will be 9,468 additional jobs including in particular new jobs in distribution (including the effect of displacing and repurposing certain microstation jobs). It is important to note that a wide uptake of LPG will result in job losses in charcoal and firewood value chains, particularly in the informal sector. Detailed methodology and results are described in the sections that follow.

The above results are for a scenario where domestic LPG production capacity in Ghana remains at 2016 capacity. However, according to stakeholder interviews, the largest national producer – Ghana National Gas Company – which has over 50% of current market share as of 2018, intends to double production capacity in the near future. There would be positive macro-economic effects if production capacity increased by 50% from 114,200 MT in 2016 to 171,300 MT in 2020. An increase of the local production capacity of 50% would result in an increase of the national trade balance by a factor of 1.2 – 1.3, relative to base case projections.

Table 71. Summary of annual macro-economic impacts
from increased primary LPG consumption relative to base case scenario in 2030

Annual impact	**2030**		
	Lower-bound adoption scenario	**Government Goal scenario**	**Upper-bound adoption scenario**
Annual decrease in national tax base relative to base case projections	GHC 76 million € 13 million	GHC 119 million € 21 million	GHC 162 million € 29 million
Annual decrease in national trade balance relative to base case projections	GHC 314 million € 72 million	GHC 523 million € 94 million	GHC 732 million € 132 million

215 Ghana Energy Commission (2017)

216 Ghana Energy Commission (2017)

217 Ghana Energy Commission (2017)

218 Ghana ended a decade of a trade deficits in 2017, positing a US $1.5 billion trade surplus in both 2017 and 2018. Source: Statista (2018).

Annual impact	2030		
	Lower-bound adoption scenario	Government Goal scenario	Upper-bound adoption scenario
Net job creation in the LPG value chain relative to base case projections	7,412	11,050	11,747

Tax revenue impact

The impact of increased LPG adoption will be felt on the GHC 3.2 billion[219] tax base (in 2015) through changes in total volume of hydrocarbon sector-specific taxes collected on LPG, and from sales taxes (VAT) collected on purchased firewood and charcoal. LPG is VAT-exempt. The net effect of increased LPG consumption and decreased charcoal and firewood use would be an increase in the combined value of these taxes collected in Ghana. Import tax would be minimally affected: Imported LPG is not subject to import duties, and Ghana does not import charcoal or firewood, which are.[220] Increasing the domestic consumption of LPG will create formal economic activity (e.g., LPG marketers, staff of bulk depots, staff of filling plants, truckers, etc.) which could positively affect the tax revenue from corporate tax in the country. This effect was not captured/modelled in the analysis.

To estimate the impact of fuel sales on the tax base (through 12.5% VAT on charcoal and purchased firewood and the 20% of sector-specific levies and taxes applicable to LPG, including the Special Petroleum Tax),[221] the total quantity of fuel consumed in-country was multiplied by the domestic sales price per kg of fuel[222] and the various taxes applicable to that fuel. Changes to LPG production capacity, sales and import fuel prices would change the tax revenues, but projecting how these might change over time is beyond the scope of this work.

In 2013, the national tax revenue due to cooking fuels was calculated to be GHC 930 million (€ 167 million).[223] The national tax revenue could increase annually by GHC 76-162 million (€ 13-19 million) in 2030, relative to the base case projections scenario.

This impact could be reduced by an amount in the vicinity of 5.6%, but not presently calculable using available data, based on the actual demand response over time to the anticipated future pricing of LPG under BCRM.

Trade balance impact

This study assumed that the production capacity of LPG and charcoal would remain constant over the projected time frame, which kept Ghana as a net importer of LPG and a net exporter of charcoal. Given Ghana's high forest cover, it was assumed that production capacity would meet firewood demand (if demand exceeded capacity in 2016). As a result, Ghana's trade balance, which in 2018 is at a surplus GHC

219 OECD (2015)

220 Import tax rates for both charcoal and firewood are 20%, and LPG is 0%. Source: Republic of Ghana (2007). "The harmonized system and customs tariff schedules, 2007".

221 NPA (2018)

222 This was held constant over time, and was sourced from the market survey data, and The Energy Commission Ghana (2017) A value of GHC 0.65/kg was used for charcoal, GHC 1.93/kg for firewood, and GHC 5.17 for LPG.

223 As calculated from the GLSS 6 data.

8.33 billion (€ 1.5 billion)[224], would decrease over time, as large volumes of LPG would need to be imported to meet demand. Charcoal usage will decrease, however, and could result in increased exports of charcoal. The value of the charcoal exports would remain lower than the value of the LPG imports, making Ghana a net importer of fuel.

To estimate the impact on the trade balance, the study calculated the total impact of importing and exporting different cooking fuels on the national trade balance under various adoption scenarios (lower bound, upper bound, and base case projections). The impact on the country's trade balance was calculated by determining exports of LPG and charcoal and subtracting these from Ghana's imports of LPG and charcoal. The values of future exports and imports were estimated by keeping the price per kg of fuel imported/exported constant over time.[225] The difference between the base case projections scenario and the upper/lower bound scenarios shows the impact to the national trade balance, should investments in LPG availability be made.

In 2013, cooking fuel resulted in a GHC 326 million (€ 58 million) increase to the trade deficit in that year, representing 8.6% of the total trade balance in Ghana. 100,751 MT of LPG was imported for cooking (at GHC 521 million), and a total of 901,336 MT of charcoal and firewood was exported, earning GHC 234 million.[226] The national annual trade balance could decrease between GHC 313 million (€ 56 million) and GHC 732 million (€ 132 million) in 2030, relative to the base case projections.

This impact could be reduced by an amount in the vicinity of 5.6%, but not presently calculable using available data, based on the actual demand response over time to the anticipated future pricing of LPG under BCRM.

Net job creation across fuel value chains

As LPG consumption increases, there will be a corresponding rise in employment in the LPG sector through new jobs for the production and distribution of LPG to meet the increased demand[227]. Simultaneously, jobs in charcoal and firewood will decrease with the declining demand for those two fuels to meet household energy needs. Given the challenges of accurately quantifying direct and indirect jobs (including construction, maintenance, and staff of retail shops) in three fuel value chains, only long-term direct jobs were considered in this analysis. Reliable estimates for the total number of jobs in each value chain could not be found and should be included as specific employment questions in future census and national representative surveys to allow proper quantification. The analysis also does not consider short-term jobs created from constructing the LPG distribution infrastructure (e.g. engineers, constructor workers, suppliers of raw materials *etc*.).

In the absence of national-level estimates, the total employment in the LPG value chain was obtained from an industry expert estimation and estimated at an average of 9,000 jobs, or between 8,000 and 10,000

[224] At the end of Q1 of 2018. Source: Ghana Statistical Service (2018).

[225] Import prices were held constant over time and was calculated from domestic sales prices and sales and import duties. A value of GHC 5.17/kg was used for LPG. The export prices were held constant over time and sourced from FAO Stat (2016) "Wood charcoal exports." A value of GHC 0.23/kg was used for charcoal.

[226] Ghana Energy Commission (2017)

[227] The project net LPG job increases take into account potential reductions in jobs among the up to 80% of LPG microstation sites presently identified by the Government for relocation, business model change, or closure.

dedicated full-time jobs (including staff of bulk depots, filling plants, truckers, marketing companies, and appointed marketers' distributors).[228] Less than 1% of these jobs are within gas processing (production); approximately 45% are in bottling and 54% in distribution.

According to the Ghana National Employment Survey (2016), forestry and logging employs 5,016 people. This category is likely to include other jobs that are not directly related to firewood and charcoal fuel sales but is also likely to exclude jobs in distribution and sales. The Forestry Research Institution of Ghana has indicated that there were 144,000 permanent jobs within charcoal production and marketing in 2015. Data could not be obtained on how these jobs are segmented into production and distribution, and if a decrease in consumption will result in job losses within this category – for example charcoal distributors may distribute other items too.[229] Given the poor quality of this data, estimations of job losses will be inaccurate and have been excluded from the analysis. However, it is important to note that many of the charcoal and firewood jobs are in the informal sector, often held by poor women. Job losses in this sector will therefore have negative impact on their incomes until they obtain alternative sources of earnings.

Given that Ghana imports LPG, an increase in LPG household consumption will increase jobs in LPG distribution rather than production. Given that 99% of all current LPG jobs are in the filling and distribution nodes of the supply chain, the number of non-production jobs per kg of LPG consumed was calculated for 2016. Assuming this ratio remains constant over time, and accounting for distribution job tasks changing from the elimination of some microstations under the transition from CCCM to BCRM, the total number of new jobs was calculated from multiplying the bottling and distribution jobs per MT of LPG by the total domestic LPG consumed under various adoption scenarios.

Across the LPG value chain, an estimated 9,000 jobs existed in 2016. As a result of increased LPG use, between 4,680 and 11,748 new jobs can be created by 2030. The NPA estimates that direct job creation due to implementation of BCRM will be 9,468 additional jobs including new jobs in LPG distribution,[230] which falls within the estimated range. It is not possible to ascertain how many of the additional jobs that NPA estimates would exist in the base case scenario relative to full availability adoption scenarios. It is important to note that a wide uptake of LPG will result in job losses in charcoal and firewood value chains, particularly in the informal sector.

Because job development in the LPG sector is driven more by the number of new consumers than their aggregate tonnage, and because the modelling predicts a lesser effect on adoption than on consumption from a potential price increase to LPG, this impact could be reduced by an amount below 5.6%, but not presently calculable using available data, based on the actual demand response over time to the anticipated future pricing of LPG under BCRM.

[228] This was estimated using industry knowledge of how LPG value chains are structured. Employment in LPG can be divided into (1) Dedicated full-time jobs - staff in bulk depots, filling plants, truckers, marketing companies, appointed marketers' distributors. These jobs can be permanent and non-permanent. As a rule of thumb, experts suggest about 8,000-10,000 direct jobs when the supply chain is running one operational shift per day. (2) Indirect jobs such as retail shops, with or without at home delivery, cylinder maintenance companies, and service companies for the marketing companies, which can amount to 28,000 to 30,000 jobs. The first set of jobs is much easier to assess than the second.

[229] Forestry Research Institution of Ghana (2015)

[230] www.graphic.com.gh/features/features/the-cylinder-recirculation-model-all-you-need-to-know.html

Unquantified impacts

The assessment excluded a few potential avenues for impact, due to the lack of reliable data, which in turn may underestimate the total positive impacts of transitioning to LPG.

- With respect to environmental impacts, the assessment does not consider cooling effects.
- The health analysis is restricted to the five Global Burden of Disease health outcomes, while noting that there is good quality and emerging evidence of other health outcomes associated with HAP (e.g., cataracts in women, stillbirth and low birth weight, tuberculosis) as well as burns in adults and children.
- Under gender impacts, this assessment does not consider the impact of the time saved from purchasing charcoal (to the extent a significant increment to other shopping activity) relative to LPG, and the time saved by cooking on LPG stoves and cleaning them (relative to other stoves) after increased LPG uptake.
- Under macro-economic analysis, the assessment does not account for the job losses that may take place in the charcoal and firewood value chains as LPG adoption increases and charcoal and firewood consumption decrease.

The results reported in this Part demonstrate that scaling up LPG use has clear positive impacts on four of five socio-economic impacts assessed: environment, health, governmental revenues, and consumer household expenditure. Regarding gender, there are multiple positive impacts for millions of women in their roles as cooks, family caretakers and consumers, but potential negative effects for women employed in the charcoal and firewood sectors.

Calculations, methodology, data sources and values

Details of the calculation equations and methodology used in the Part are presented in the Annexes, Chapter 28 (Impact Assessment Calculations and Methodology) beginning on page 305.

Details of the data sources and values are presented in the Annexes, Chapter 29 (Impact Assessment Data Sources and Values) beginning on page 307.

XI. Monitoring and Evaluation Framework

This Part is intended to set the basis for the creation of a monitoring and evaluation (M&E) framework to measure progress and impacts of increased LPG access and use for cooking in Ghana over time to meet the national policy goal. This is a guidance document intended to be further developed through working closely with national organizations and associated partners responsible for program monitoring and evaluation at the country level, and subsequently implemented upon identification of appropriate resources.

In this Part, a set of indicators - the **Indicators of Sustainable LPG Expansion (ISLE)** – is described in order to help the Government of Ghana (and the governments of other relevant countries) to evaluate and report on progress in safely scaling up LPG adoption and sustained use at the household level.

22. M&E Goals and Context

M&E of LPG in an impacts context

LPG has been highlighted by several international organizations, including the World Health Organization (WHO) and the International Energy Agency (IEA), as one of the key fuels to be scaled up rapidly throughout the developing world. This is because LPG is a clean burning and easily transportable fuel that consistently achieves the best performing tier level for indoor emissions (Tier 4) under the International Organization for Standardization, International Workshop Agreement 11 (ISO/IWA-11)[231], in both laboratory and field conditions. Its performance in the field does not normally vary with user operation and equipment condition (which means that it burns cleanly not only initially but also over time). Nevertheless, there may be variations in the levels of personal exposure reductions due to local circumstances (e.g. ambient (outdoor) air pollution, fuel stacking etc.). For example, the benefits of LPG adoption in terms of reduced household air pollution might be reduced due to cross-contamination from neighbouring households' continued use of polluting fuels/stoves, or LPG households not fully switching to using LPG for a sufficient portion of cooking tasks.

Types of evaluations

This proposed M&E framework covers two aspects of an evaluation: process and impact.

1. The *Process/outcome evaluation* is intended to understand better the effectiveness of policies and programs and to assess why particular interventions work or do not work. It measures program effects on the target population by assessing the progress towards the program's outcome objectives and how the program has been implemented;

2. The *Impact evaluation* focuses on the results and ultimate effects of the intervention program/policy in regard to achieving its goals for the target population.

The two types of evaluation go hand in hand. They draw from a mix of regularly collected data on key aspects of an LPG national market, such as consumption, sales, distribution and safety, national population surveys with questions on household energy use, and ad hoc data collection efforts and research activities. The combination of different data gathering efforts is needed in order to quantify impacts in a more robust way. Specifically, without very accurate information on LPG household consumption and sustained use (i.e., primary and secondary fuel use), it is not possible to evaluate and accurately quantify the health, environmental, climate and other impacts of LPG uptake over time.

Population-based household surveys, conducted as part of ad hoc data collection efforts (e.g. research projects or programs), will be a key component in complementing and enhancing the proposed set of monitoring indicators that track LPG scale-up (see Chapters 23 and 24). Surveys and qualitative methods (e.g., in-depth interviews and focus groups discussions) are, indeed, needed to capture the complexity of cooking behavior, including fuel usage patterns and decreased use of traditional cookstoves and fuels. Such

231 Shen, et al. (2018). Evaluating the performance of household liquefied petroleum gas cookstoves. Environmental Science & Technology, 52(2), 904–915.

surveys and methods will also be necessary in capturing gender-related impacts of adoption and sustained use of LPG, which are currently difficult to quantify.

Household energy questions in existing national representative surveys

A number of nationally representative surveys are conducted in Ghana at regular intervals, which are instrumental in tracking national estimates of household energy use and model household air pollution impacts. These include the:

i. Ghana Living Standard Survey (GLSS), conducted every 4-5 years. This survey gathers comprehensive and reliable data to assess the impact of development policies and programs on living conditions. The last round of data collection occurred in 2018 (GLSS 7) and results have not yet been made public at time of writing;

ii. National Population and Housing Census, conducted every 10 years (the last one was completed in 2012);

iii. USAID's Demographic and Health Survey (DHS), conducted every 5-6 years (the last one completed in 2014); and

iv. UNICEF Multiple Indicator Cluster Surveys (MICS), conducted every 6 or more years (the last one completed in 2011).

All the listed surveys include a small set of household energy questions, in most cases only a single question on the main fuel used for household cooking. Often, the listed answer options and fuel categories are different in different surveys, limiting comparability.

Given the importance of tracking progress towards Sustainable Development Goal 7 (SDG7) and specifically, SDG 7.1.2: Proportion of population with primary reliance on clean fuels and technologies, the World Health Organization (WHO) and the World Bank have initiated in recent years a process of survey harmonization to agree on a set of 'harmonized' household energy survey questions to be incorporated in all the main nationally representative surveys. Once the revised and harmonized set of household energy questions has been endorsed by statistical offices and major national surveys, it will be possible to track household fuel use, and specifically LPG uptake more accurately (see later sections for further discussion). For example, in a number of current surveys, LPG data is co-mingled with data about other gases (biogas and natural gas), and no data on secondary fuel use is captured. Asking about primary and secondary fuel use is, indeed, needed (i) to assess the concurrent use of multiple stoves and fuels, known as stove/fuel stacking, and (ii) to quantify impacts better.

Why is an M&E plan needed?

This work is embedded in the implementation of a new Ghanaian national LPG policy and associated market reforms. Adoption of the new policy was announced by the government immediately following the Atomic Junction LPG explosion in October 2017. Ghana is planning a transition to the 'cylinder re-circulation model' (CRM), to take initial effect in 2019, in order to increase the safe delivery, use, and access of LPG in order to meet its national SE4ALL objective of 50% of the population accessing, and using, LPG on an ongoing basis by 2030. The National Petroleum Authority (NPA) has been mandated by the President of Ghana to implement this transition to the CRM, and the Global LGP Partnership (GLPGP) is supporting the NPA in planning the transition and securing the capital required to implement it.

The Government of Ghana recognizes the importance of monitoring and evaluation of its energy initiatives, as demonstrated by the inclusion of an M&E framework in the SE4ALL action plan[232], although technical capacity and resources to implement M&E components is limited.

A properly designed and implemented M&E framework for LPG scaling up will allow national/international stakeholders to:

i. Monitor progress with the implementation of agreed policy against program goals;

ii. Apply evidence-based adjustments to improve program performance and reach;

iii. Contribute (using harmonized survey questions) to the SDG7 and SE4All global tracking; and

iv. Understand, quantify, and interpret the wider societal impacts (health, the environment, climate, gender empowerment and economic development) of scaling up LPG uptake.

Steps in developing and implementing the LPG scale-up M&E plan in Ghana

The process of developing a national M&E plan for LPG scale up should begin during the initial stages of program planning and implementation, in consultation with local stakeholders responsible for program implementation, ministries and agencies with M&E expertise. The framework presented in this document and developed under the EU/KfW-sponsored Clean Cooking for Africa Program should, therefore, be considered as one of the initial steps in the process to help Ghanaian authorities develop and implement a full M&E plan, for which additional funding needs to be sought.

The proposed framework should be discussed and refined through stakeholder consultation and participation by local implementers and M&E authorities, according to the following steps:

i. Conduct stakeholder consultation(s) convened by Ghanaian authorities;

ii. Define processes for stakeholder involvement: identify the key local stakeholder(s) responsible for overseeing and implementing the M&E plan, determine which local capacity is available (and can also be strengthened), and identify which partners can support the process;

iii. Discuss and revise the proposed M&E framework and the ISLE indicators developed under the Clean Cooking for Africa Program to determine elements to be monitored and evaluated;

iv. Identify available resources to implement the plan, including over which timeframe; this is a key limiting factor that may influence how the plan is finalized and implemented;

v. Determine M&E methods for data and information collection: (a) develop a data collection plan (including indicators to be collected, timing for data collection and analysis, tools, resources, training provision for staff, etc.); (b) determine M&E responsibilities (data collection, supervision, analysis, reporting, etc.);

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232 See energycom.gov.gh/files/SE4ALL-GHANA%20ACTION%20PLAN.pdf

vi. Set M&E targets; and

vii. Define a reporting system for dissemination and utilization of results.

Status of the M&E planning process in Ghana

During the course of 2017/2018, Clean Cooking for Africa/GLPGP engaged in discussions about M&E for LPG scale-up in Ghana with a number of international partners including the U.S. Centers for Disease Control and Prevention (CDC), the Clean Cooking Alliance (CCA), and Vital Strategies, an NGO and consultancy focused on global health issues that partners with CDC. An initial working-level meeting and stakeholder consultation with members of the NPA and other relevant institutions is expected to be hosted in the last quarter of 2018/first quarter of 2019 to plan cooperation around, and implementation of, the steps listed above.

In parallel, during July-October 2017, GLPGP supported the University of Liverpool (UoL) on a UK National Institute of Health Research (NIHR) grant application, which successfully resulted in the establishment of the Clean Energy Access for prevention of Non-communicable disease in Africa - *CLEAN-AIR (Africa)* - Research Group in April 2018. The UK NIHR Group will conduct a 3-year research and capacity building program (2018-2020) to support scaled population transition from polluting solid fuels and kerosene for household energy to LPG (as a clean fuel) to address the substantial public health burden from mainly non-communicable diseases due to household air pollution. Focus countries for this work include Ghana, Kenya, and Cameroon. These countries were strategically chosen by UoL and GLPGP to build the research and evaluation components around the *Clean Cooking for Africa Program* and the ongoing national efforts to scale up LPG in these countries.

Research and health-sector capacity building activities under *CLEAN-AIR (Africa)* will begin in the first quarter of 2019, following completion of an initial scoping phase (April – October 2018) required under the NIHR program (see Annex I for project goals and main activities). Ghanaian partners for the Group include Kintampo Health Research Centre and the University of Ghana. The outputs of the *CLEAN-AIR (Africa)* work will contribute directly to the M&E goals for LPG scale-up in Ghana.

23. ISLE Indicators for Monitoring and Evaluation

Indicators for Monitoring and Evaluation of LPG adoption, sustained use and infrastructure expansion over time

The **Indicators of Sustainable LPG Expansion (ISLE)** developed by Clean Cooking for Africa/GLPGP consist of a set of indicators to be routinely collected at the national level in order to inform the monitoring and evaluation of scaling safe adoption and sustained use of LPG as a clean household cooking fuel and the resulting social, environmental and economic impacts.

These indicators are the first step to conducting further, more detailed evaluation on different impact categories with metrics presented in the final section of this chapter. These impact metrics measure the extent and rate of the existing and projected social, health, environmental and economic impacts from increased LPG adoption and use and associated economic activity, including number of jobs created and lost across different fuel value chains. Quantifying impacts would require bespoke expertise and data collection efforts, including monitoring concentrations of and personal exposure to health damaging air pollutants such as fine particulate matter ($PM_{2.5}$), in order to reliably project the health impacts of scaling adoption of LPG over time.

Execution of this M&E plan aims to provide representative data which is sufficiently valid and precise for the purposes of review efforts to achieve desired LPG scale and subsequent improvements to related policies and actions. It is recommended to track the ISLE indicators on an annual basis (or as practical based on availability of national representative surveys), depending on available resources and survey data already being collected.

As described in the section below, the proposed set of M&E indicators can be grouped into distinct categories according to different aspects of LPG scale-up they intend to cover, for which bespoke data collection efforts are required in most cases.

Categories of indicators

There are three main categories of ISLE indicators:

Category 1: LPG adoption and use (ISLE Table 1). This category measures the extent and rate of expansion of LPG adoption and consumption through national consumption data and nationally representative surveys

Category 2: LPG supply chain expansion and indicators of the safety of the LPG market (ISLE Table 2). This category measures the extent and rate of build-out of the LPG supply chain and associated investment, as well as the safety performance of the LPG sector

Category 3: LPG safety for households and occupational settings (ISLE Table 3. This category measures injuries and burn incidents related to LPG fuel use in the population

While the Ghana Energy Commission and the NPA already collect information on key LPG metrics on an annual basis (e.g., LPG national consumption, national LPG production, LPG imports/exports, and several others), other indicators are not tracked as of yet. These include, for example, the exact amount of LPG consumed by households as compared to autogas, the number of cylinders in circulation in the market, the number of scrapped cylinders, and number of existing jobs in the LPG supply chain (short-term and long-term), etc. In addition, key indicators such as the number of LPG-related accidents at the occupational and household level are also not tracked making it difficult to enhance safety measure and plan for better consumer education.

The ability to collect all the proposed ISLE indicators depends on a number of factors: (i) endorsement by national stakeholders following discussion and adaptation, (ii) availability of resources, and (iii) staff capacity of the relevant agency(ies) involved in the implementation and monitoring of the new LPG policy. For example, in order to collect and track the ISLE safety indicators, it may be necessary to establish a national surveillance system to record the LPG and other fuel-related accidents in both occupational and household settings by involving the Health Sector

Methodology used to develop the ISLE indicators

The proposed ISLE indicators have been developed between June 2016 and July 2018 through a stakeholder consultation process with LPG industry experts (LPG policy and regulatory advisors, LPG business developers and industry technical experts, GLPGP country managers in Ghana, Kenya and Cameroon among others, financial experts (planning and investment) and public health experts (academics with expertise in M&E and HAP/household energy use)). Starting with the review of existing literature on indicators to track under SDG 7.1 ‘Ensure universal access to affordable, reliable and modern energy services by 2030’ and indicators of household energy adoption[233], two rounds of international expert consultations have been conducted. The first consultation was hosted in 2016 in Frankfurt with the Clean Cooking for Africa Program scientific advisory board, comprising leading public health and climate experts. This initial set of indicators was then revisited, expanded and discussed during a consultation hosted with the KfW Clean Cooking for Africa Program appointed technical experts and University of Liverpool public health experts in February 2018.

Following the consultations, the indicators were piloted in Kenya, Ghana and Cameroon to test the feasibility and practicality of collecting the required data, to adjust and refine the indicator set. In a later stage of the process, input from public health experts from US CDC was also sought and incorporated into the proposed list, with focus on the safety indicators.

Additional piloting with specifically allocated resources is needed to further refine the ISLE Indicators’ list and finalize a set of “*essential*” vs. “*desirable*” indicators.

Guiding principles

The development of the ISLE Indicators was guided by three key principles: (i) identifying and making the best use of existing routine and annual data collection systems, (ii) collecting new data at minimal or no extra cost and (iii) not excluding metrics that would require full cooperation in data sharing from private sector players, which may result in added costs to conduct stakeholders interviews/surveys.

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233 See cleancookstoves.org/binary-data/RESOURCE/file/000/000/379-1.pdf

In the case of Ghana, data for 2017 presented in this document has been collected with support from the NPA, using existing sources and desk reviews. Some information could not be obtained and supporting explanations are included in the 'source and comments' column of each table. The rationale for the indicator categories, and certain key features of the ISLE indicators, are presented in the next sections.

Category 1: ISLE Indicators of LPG market expansion and household adoption and use

The Indicators proposed in ISLE Table 1 include some of the key performance indicators (KPIs) used by the worldwide LPG industry, and indicators of population access to LPG that can be compiled through existing data collection systems. These indicators should be collected on an annual basis (or as frequently as survey information from nationally representative surveys is available, estimated as every 2-3 years). They would serve to track progress towards the Ghanaian Government's goal of achieving 50% of the population using LPG by 2030.

Selected highlights on the proposed indicators:

- Indicator 1.1 – *Total LPG kg per capita consumption per year* – is the 'gold standard' or preferred LPG industry KPI to track LPG market expansion and uptake. It also allows international comparisons of LPG penetration to be made (see Box 1)[234]. However, this indicator would over-estimate household use of LPG if other sectors (e.g., autogas, such as in the case of Ghana) also make up a substantial proportion of total LPG consumption. For this reason, Indicator 1.2 on residential LPG consumption should also be jointly tracked.

- Indicator 1.2 – *Residential LPG kg per capita consumption per year* – is specific to the residential sector and is based on consumption of LPG in cylinders of 3-15 kg sizes (as compared to larger cylinders, typically of 35-50 kg that are used in institutional and commercial settings), divided by the total population.

Box 1 – LPG market stage according to international industry standards

- **Early stage/growth markets:** Defined as <10 kg per capita per year.
- **Transitioning stage markets**: Defined as around 15 kg and aspiring to increase (e.g., up to 40 kg capita per year or more).
- **Mature/advanced stage markets**: Usually >15 kg/capita but not <u>necessarily</u> defined by high LPG consumption (some are well below this). This market classification is based on sophistication and diversity of the LPG value chain as well as an excellent overall safety record.

In Ghana, current cylinder sizes include 14.5 kg, 6 kg and 3 kg. However, small businesses such as roadside food-street vendors can also make use of cylinders of smaller capacity and their consumption would be captured as part of the total residential consumption (unless a digitized system is put in place for a more accurate tracking and monitoring; see later section in this Part titled *The role of a digital recording system for LPG tracking*. Note that in most Sub-Saharan African markets, the residential use of LPG is for cooking and not for heating purposes with LPG portable heaters so the kg/capita of LPG residential consumption would effectively correspond to the amount of LPG used for

[234] Source: WLPGA (2014). Guidelines for the Development of Sustainable LPG Markets – Transitioning-Stage Markets. Pairs: World LP Gas Association.

cooking. In addition, it is helpful to note that if the national LPG market is primarily for residential use, the correspondent kg/capita value will be close to the Total LPG kg/capita consumption.

- Indicator 2.1 – *Percentage of population cooking primarily with LPG in a given year* – and its sub indicators (urban / rural primary usage), rely on nationally representative population-based surveys that are used to monitor household energy use, including for SDG 7 reporting. Large-scale nationally representative surveys (e.g., GLSS, DHS, MICS, etc.), take place every 5 to 10 years. However, due to their different frequency, it may be possible to track primary LPG use in a range of 2-3 years. This interval is appropriate for tracking purposes, as extremely large changes in percentage of LPG use are unlikely to occur in periods of less than 2-3 years. These data, complemented by indicator 2.2 below, provide the best means of tracking progress on LPG uptake based on existing routine information. The suggested new question under the WHO-World Bank survey harmonization process is designed to capture primary, secondary and tertiary fuel/stove use as three answers are allowed. The proposed question is: '*What does this household use for cooking most of the time, including cooking food, making tea/coffee, boiling drinking water? Please tell me the cookstove or device that is used for the most time, followed by the other cookstove(s) or device(s) used most often, if applicable'.*

- Indicator 2.2 – *Percentage of population using LPG for cooking (any use) per year* – intends to capture primary and secondary use of LPG for household cooking and boiling water. Secondary use of LPG is common, particularly for households that have recently adopted LPG but do not yet use it for all their cooking/boiling water needs. Lack of such secondary use recording may underestimate total LPG household usage figures. By endorsing the full set of household energy questions, countries will be able to track this indicator.

- Indicator 2.3 – *LPG consumption per LPG user (kg/capita among LPG using households) per year* is calculated as the total LPG consumption in the residential sector in a giving year, divided by the percentage of households using LPG in the same year multiplied by the mean household average size for the country. The accuracy for tracking this number depends on the accuracy of the residential LPG consumption estimates (that may be a slight overestimate if it includes LPG use for cooking by small commercial entities) and the number of households using LPG (whether primary or secondary users, and the year the number of households is estimated for). Without a digitised system that would allow to exactly know how many households are making use of LPG (and their refilling patterns), national representative surveys should be used as an alternative source to estimate household LPG consumption.

Indicators of LPG supply chain expansion and safety of the LPG market

The set of indicators presented in ISLE Table 2 is a selection of key metrics for tracking and recording LPG infrastructure expansion, as well as detecting and responding to market dysfunctions (e.g. cross-filling of cylinders of different brands, interchangeability of cylinders etc., that are detrimental for LPG marketers). It also contains a section on indicators for tracking economic development, including the quantity of direct jobs created as a result of LPG market expansion.

Obtaining the information needed to compile this set of indicators may present challenges as most of the data is not routinely collected and would need some bespoke data collection efforts. Challenges may include: (i) obtaining information on cylinders in circulation from each private sector player (e.g. LPG marketers operating under the CRM) for pooling into national estimates, due to private firms' possible concerns about this information being proprietary (e.g. see indicators 3.2 and 3.3); (ii) procuring the data, if the information is scarce (e.g. on safety) and/or not currently compiled (e.g. indicator 5.2); and (iii) sourcing the number of LPG-related jobs created under the different categories without asking each individual company on a bespoke basis (e.g. indicators 5.3 and 5.4). It is anticipated that obtaining some of these data will be labour intensive and require special data collection efforts and resources along with good technical knowledge of the LPG sector. It is, therefore, strongly recommended that collection and compilation tasks are assigned, in the first instance, to technical experts with a thorough understanding of the LPG system and the private sector rules in the country.

The government/NPA may need to consider legislation on mandatory data reporting from all LPG marketing companies and private sector players, especially on safety aspects.

Selected highlights:

- ISLE Table 2, Section 3 – LPG supply infrastructure development: cylinders and bulk infrastructure, includes a number of indicators and sub-indicators to track the number of cylinder assets added and taken out from circulation and bulk infrastructure expansion. All the information regarding cylinders is critical in terms of measuring both supply and demand (and safety). For example, with regards to indicators 3.2 - 3.4, the best way to collect the total numbers of cylinder deployed, scrapped and circulating into the market is to have numbers submitted by the individual LPG marketers to an appointed body (e.g. NPA or others) on a mandatory basis. Information about cylinders which are imported should also be made available from customs duties, as a cross-check.

- ISLE Table 2, Section 4 – LPG industry safety metrics: presents a recommended set of indicators for tracking safety in relation to LPG use at all nodes in the value chain. The indicators are tailored for countries operating under the CRM, relevant to Ghana as it transitions to CRM. Cylinder scrapping, testing and recertification are examples of standard industry practices for ensuring safety, but national level monitoring or compilation of information is rarely implemented in Sub-Saharan African settings. Stakeholder consultation will be key in this area to determine what is possible to monitor and consider for inclusion, as the data is currently very sparse. Strengthening safety monitoring and the use of good practices throughout the LPG value chain is vital to protecting both LPG consumers and LPG operators and can help address the root causes of LPG incidents and injuries.

- ISLE Table 2, Section 5 – Economic aspects in relation to LPG expansion, include a selection of indicators to capture the amount of investment in LPG infrastructure and the jobs created and lost as a consequence of market expansion. While these data are critical to monitor contributions to national economic growth and mobilization of international capital, these are not currently compiled and sourcing may pose challenges. Other indicators, such as the indirect jobs created by LPG infrastructure expansion, are useful to include in the list, recognizing that obtaining reliable information will be difficult; the wider impacts of LPG expansion on the macroeconomics should not be underestimated or ignored. Similarly, systems to track the number of jobs in the charcoal and firewood sectors over time should be put in place to monitor overall impacts on job loss/creation at the national level. This requires an expanded set of indicators and information sources, going beyond the focus of the ISLE indicators on LPG-related metrics.

The ISLE LPG supply chain expansion and safety indicators should be ideally compiled on an annual basis to measure progress over time. Tracking of this information is valuable and necessary also for making international comparisons about market expansion, especially for countries starting with similar LPG market conditions and LPG consumption rates to Ghana.

Safety indicators in relation to LPG

ISLE Table 3 is specifically designed to track LPG-related explosions and accidents (burns and injuries) in both home and occupational/institutions settings. Being able to track, monitor and report on safety-related indicators is the first step to help prevent and intervene when such events occur.

Notwithstanding the importance of safety, recording, compiling and acting on the results of such data poses certain challenges. Often, these actions are not possible to implement unless a specific surveillance system coordinated by the health sector is put in place (e.g. at hospital's level). It is therefore recommended that national stakeholders in Ghana consider establishing such a mechanism for data gathering and reporting in order to monitor safety accidents closely and put in place measures to address the root causes of LPG-related safety accidents. The Ministry of Health/Ghana Health Services, working together with fire services, may lead this process.

In Accra, the Korle Bu teaching hospital has been identified as having a burns surveillance system in place, and their model could be replicated elsewhere. Note also that WHO has made available a Global Burn Registry (GBR) for health facilities, which collects information on main risk factors, mechanisms, and risk groups for burn injuries requiring a hospital stay (see www.who.int/violence_injury_prevention/burns/gbr/en/). Participation in the GBR would allow standardized data collection from burn victims, help prioritizing prevention programs in Ghana and allow global tracking of burn victims and their causes, including LPG-related burns and injuries.

The potential role of a digital recording system for LPG tracking

The advantages of setting up digital recording for LPG adopting households and businesses are multiple and are summarized below. A prerequisite for such recording at the retail and consumer level is a digitized LPG and/or payments system, such as already developed and in near-universal use in India, or such as are in pilot phases by pay-as-you-go LPG providers in certain Sub-Saharan countries.

Several high-income and middle-income countries have been making use of digital databases over the years for taxation and other purposes, and have been able to digitize LPG consumers' data successfully. India, Brazil, and El Salvador are just a few examples. This section presents the case of LPG data tracking in India, one of the countries that most recently have embraced such digitalization (see https://socialcops.com/case-studies/tracking-pmuy-beneficiaries-using-data-intelligence/).

Under Indian law, LPG distributors must maintain an electronic register with names and addresses of persons registered to obtain their first LPG cylinder and equipment (LPG connection) and subsequent refills. Each household is registered with a unique identification number.

The advantages of such a digital recording system of LPG customers are multifold, and include:

i. Accurately tracking LPG household consumption as compared to LPG use by other sectors (e.g. autogas, power generation, etc.) and by small and medium enterprises (e.g. food street vendors). Monitoring refill patterns across consumers and over time is needed to understand factors influencing refill rates and contribute to better delivery planning;

ii. Recording precisely the number and location of households using LPG – which is important for both creating new distribution centres (sales outlets under the CRM) and creating potential for booking of cylinder refills online or through mobile phone apps for home delivery;

iii. Tracking seasonal and other cyclical demand variations (e.g. tied to agricultural production) for planning of distribution;

iv. Identifying gaps between refill requests and actual refills to identify bottlenecks in supply or under-performing distributors;

v. Providing a tracking system for cylinders that LPG marketers and distributors can rely on to control their cylinder assets;

vi. Tracking households that receive subsidized equipment/fuel as part of pro-poor initiatives (e.g. PMUY program in India that provides free initial LPG equipment to below-poverty line women); and

vii. Avoiding abuse of LPG subsidies as registered households are tracked and only one household member is allowed to receive the subsidized equipment and LPG refills.

Overall, such a digital system provides a platform for benefit transfer to the right people at the right time, and identify where processes are failing to deliver and need to be improved.

Regardless of specific hardware/software specifications, which go beyond the scope of this document, a number of principles would need to be considered:

- Security of the system for ensuring confidentiality of records;
- Creation of unique ID systems tied to individual customers;
- Ensuring standardization in data entry – for example, having village names spelled differently, or addresses entered using more than one convention (e.g. village name + district name in one field versus in two separate fields) would create problems later in ensuring households are assigned to the right village in analysis;
- Ability to easily export data into one or more widely used file formats and ability to select subsets of data for export; and
- Data fields to distinguish different classes of customers (e.g. those benefiting from LPG subsidy / subsidized equipment versus those who do not).

Ghana would have much to gain in embracing the digital revolution for the LPG sector and other sectors. In addition, considering how ubiquitous mobile phones are in Ghana and how mobile banking is becoming popular (with over 11 million active mobile money accounts in 2018)[235], one could see the potential for using mobile phone systems for booking, tracking and paying for LPG refills. The mobile phone infrastructure could support digitization of cylinder tracking by SMS and bar-coding applications, eliminating some of the paperwork needs.

235 bog.gov.gh/privatecontent/Payment%20Systems/PAYMENT%20SYSTEM%20STATISTICS%20-%20Half%20Year%20June%20%202018.pdf

Potential for additional indicators based on digital LPG records

Additional key indicators could be added to the current ISLE list if a certain condition, such as a unified system for digital recording of LPG adopting households and businesses, is put in place. A couple of examples are reported below:

- *Average number of LPG 14.5kg cylinder refills-equivalent per year by household using LPG*. This indicator and potential sub-indicators (urban, rural and regional averages) would help to measure primary and secondary LPG usage accurately across the national territory. This value could then be compared to the number of refills that is needed as an indicator of primary use in the country to ensure that the public health and other benefits from transition to LPG are achieved.

- *Percentage of calls to emergency service helpline for LPG leakage complaints per year.* This indicator would contribute to the safety and prompt intervention tracking. It could be considered only if LPG marketing companies under the CRM operate an emergency service helpline as most middle and high-income countries do.

Final considerations

The proposed ISLE indicators are intended as a resource to be used in all countries that promote LPG as a household fuel. They are particularly important to be adopted in low and middle-income settings that are trying to create a robust monitoring system for LPG sustainable scale-up.

24. ISLE Indicators Compiled

For Ghana, 2017 data have been collected and presented by the GLPGP Clean Cooking for Africa Ghana team in Tables 1-3, using a wide range of sources. Existing gaps in the available data result from either a lack of systematic tracking (e.g. number of jobs in the LPG supply chain), or because the indicator in question will not apply until the CRM is implemented.

The recommended set of ISLE indicators for Ghana should be considered provisional until endorsed by the relevant authorities following appropriate national stakeholder consultation. As much as they have been designed as a flexible tool to incorporate in-country variations, their added value is also as a harmonized set of indicators for international comparison, and for reviewing trends over time at the country level.

Among the whole set of proposed indicators, an 'essential' set of indicators could be also prioritized for regular annual updating and public reporting. The essential set should include a mix of indicators from the three listed categories (including safety, if a national surveillance system can be successfully established).

<table>
<tr><th colspan="6">ISLE TABLE 1: ISLE Indicators of LPG adoption and use</th></tr>
<tr><th>Domain</th><th>Indicator</th><th>Sub-indicator / Component needed for main indicator and rationale</th><th>Indicator measured or calculated[236]</th><th>Results</th><th>Sources and comments</th></tr>
<tr><td colspan="6">1. LPG consumption</td></tr>
<tr><td rowspan="2">1.1</td><td rowspan="2"><u>Total</u> LPG kg/capita consumption per year</td><td rowspan="2">This indicator is the standard and universally accepted <u>key performance indicator</u> (kpi) to describe the degree of development of the LPG market in a country (all sectors).

To be measured using:

(i) The total national LPG consumption in a given year divided by (ii) the population amount in the same year.</td><td rowspan="2">Calculated</td><td>National LPG per capita consumption in 2017 = 12.4 kg/capita</td><td>Calculated as LPG quantity consumed divided by the national population</td></tr>
<tr><td>(i) Total LPG consumption in 2017 (all sectors): 358,931 metric tonnes (MT) (27% higher than in 2016)
<table><tr><th colspan="2">GHANA LPG SALES 2017</th></tr><tr><th>Source</th><th>Qty Sold (MT)</th></tr><tr><td>Import</td><td>202,400</td></tr><tr><td>Local Production</td><td>114,000</td></tr><tr><td>Re-export</td><td>40,300</td></tr><tr><td>Loss / Gain</td><td>2,231</td></tr><tr><td>Grand Total</td><td>358,931</td></tr></table>(ii) Population 2017: 28,833,629</td><td>(i) Consumption Source: Energy Commission, 2018. National Energy statistics. See: http://www.energycom.gov.gh/planning/data-center/energy-outlook-for-ghana#
File: ENERGY COMMISSION_2018 Energy Outlook_2018
(ii) Population source: https://data.worldbank.org/country/ghana</td></tr>
<tr><td>1.2</td><td>LPG kg/capita consumption for the residential sector per year</td><td>This is a specific indicator to measure the degree of development of the residential LPG sector. In Sub-Saharan Africa, the residential use of LPG is almost exclusively for</td><td>Calculated</td><td>Estimated LPG consumption for the residential sector in 2017: 4.3 kg/capita in 2017</td><td>Calculated as LPG residential consumption divided by the national population.
Comment: There is no differentiated taxation system in Ghana for LPG for households and LPG for transport (autogas). Both are dispensed through the same dispensing units.
LPG Marketing companies' monthly reports</td></tr>
</table>

236 'Measured' indicator = data have to be gathered. 'Calaculated' indicator = it can be calculated using already measured and available data.

ISLE TABLE 1: ISLE Indicators of LPG adoption and use					
Domain	**Indicator**	**Sub-indicator / Component needed for main indicator and rationale**	**Indicator measured or calculated[236]**	**Results**	**Sources and comments**
		cooking/water boiling and not for heating purposes. To be measured using: (i) the total LPG consumption in the Residential sector in a given year (as compared to other sectors such as Industry; Transport; Refinery; Chemical and Agriculture), divided by (ii) the population amount in the same year.			to NPA only show the aggregated sales figures of LPG sold which is not disaggregated into autogas and LPG cylinder refills. NPA records combine these figures as 'Domestic LPG'. The percentage attributed to the residential sector is based on LPG marketing companies' figures.
				(1) Residential sector: between 152,187 MT and 165,752 MT in 2017	Sources: According to estimates from the LPG Marketing Companies, LPG cylinder refills accounted for 55% of total LPG filling station throughput in 2017 (152,187 MT). Based on GLSS 7 data on the population using LPG (7.1 million), the amount of LPG used by the residential sector is estimated at 165,752 MT.
				(2) Transport/Autogas: between 116,577 MT and 124,516 MT	Sources: According to estimates from the LPG Marketing Companies, the autogas refills accounted for 45% of total LPG filling station throughput in 2017 (124,516 MT). Based on the residential sector amount calculated through GLSS 7 data, the autogas market is estimated at 116,577 MT for 2017.
				(3) Commercial & Industrial: N/A	No separate figures available. Bulk quantities included in autogas consumption figures and cylinders used for commercial activities (street vendors. etc.) included in the residential figures.

<table>
<tr><th colspan="6">ISLE TABLE 1: ISLE Indicators of LPG adoption and use</th></tr>
<tr><th>Domain</th><th>Indicator</th><th>Sub-indicator / Component needed for main indicator and rationale</th><th>Indicator measured or calculated[236]</th><th>Results</th><th>Sources and comments</th></tr>
<tr><td></td><td></td><td></td><td></td><td>(4) Power Generation: 82,228 MT</td><td>Source: National Petroleum Authority (NPA): http://www.npa.gov.gh/downloads
File: National consumption data (Jan-Dec 2017)</td></tr>
<tr><td colspan="6">2. Population cooking with LPG</td></tr>
<tr><td>2.1</td><td>Percentage of population cooking primarily on LPG in a given year</td><td>The source for this indicator and its sub-indicators are nationally representative surveys such as census, DHS, MICS, World Bank Multi-Tier Tracking Framework and others national surveys that are usually conducted every 5 to 10 years.</td><td>Measured</td><td>Last publicly available data point from national representative surveys (GLSS 6): 22.3% as of 2013.
New data on primary LPG usage to be released by GLSS 7 for 2016/2017. Pre-published figures show increase of LPG primary use to 24.5%.</td><td>Source: Ghana Living Standards Survey 6 (GLSS 6).
Historical GLSS data provided below.
<table>
<tr><th>GLSS#</th><th>Survey Dates</th><th>All (%)</th></tr>
<tr><td>GLSS3</td><td>1991 – 1992</td><td>2.20</td></tr>
<tr><td>GLSS4</td><td>1998 – 1999</td><td>4.10</td></tr>
<tr><td>GLSS5</td><td>2005 – 2006</td><td>9.50</td></tr>
<tr><td>GLSS 6</td><td>2012 – 2013</td><td>22.30</td></tr>
</table></td></tr>
<tr><td>2.1.1</td><td></td><td>Percentage of URBAN population cooking primarily on LPG in a given year</td><td>Measured</td><td>Last publicly available data point from GLSS 6: 35.8% as of 2013.
New data on primary LPG usage to be released by GLSS 7 for 2016/2017.</td><td>Source: GLSS 6
<table>
<tr><th>GLSS#</th><th>Survey Dates</th><th>Urban (%)</th></tr>
<tr><td>GLSS3</td><td>1991 – 1992</td><td>5.70</td></tr>
<tr><td>GLSS4</td><td>1998 – 1999</td><td>10.10</td></tr>
<tr><td>GLSS5</td><td>2005 – 2006</td><td>20.00</td></tr>
<tr><td>GLSS 6</td><td>2012 – 2013</td><td>35.80</td></tr>
</table></td></tr>
<tr><td>2.1.2</td><td></td><td>Percentage of RURAL population cooking primarily</td><td>Measured</td><td>Last publicly available data point (GLSS 6): 5.5% as of 2013.</td><td>Source: GLSS 6</td></tr>
</table>

<table>
<tr><th colspan="6">ISLE TABLE 1: ISLE Indicators of LPG adoption and use</th></tr>
<tr><th>Domain</th><th>Indicator</th><th>Sub-indicator / Component needed for main indicator and rationale</th><th>Indicator measured or calculated[236]</th><th>Results</th><th>Sources and comments</th></tr>
<tr><td></td><td></td><td>on LPG in a given year</td><td></td><td>New data on primary LPG usage to be released by GLSS 7 for 2016/2017.</td><td><table><tr><th>GLSS#</th><th>Survey Dates</th><th>Rural (%)</th></tr><tr><td>GLSS3</td><td>1991 – 1992</td><td>0.30</td></tr><tr><td>GLSS4</td><td>1998 – 1999</td><td>0.60</td></tr><tr><td>GLSS5</td><td>2005 – 2006</td><td>1.50</td></tr><tr><td>GLSS6</td><td>2012 – 2013</td><td>5.50</td></tr></table></td></tr>
<tr><td>2.2</td><td>Percentage of population using LPG for cooking (<u>any use</u>) in a given year</td><td>The source for this indicator and its sub-indicators would be nationally representative surveys that include question on secondary cookfuels (up to 2018, this was not included in DHS, MICS and other global surveys).</td><td>Measured</td><td>No survey data reporting on this at present.</td><td rowspan="3">Secondary cooking fuels are not captured in GLSS surveys, or in DHS, etc.
It may be possible to capture this information in the future from the Multi-Tier Tracking Framework.</td></tr>
<tr><td>2.2.1</td><td></td><td>Percentage of URBAN population using LPG for cooking (any use) in a given year</td><td>Measured</td><td>No survey data reporting on this at present.</td></tr>
<tr><td>2.2.2</td><td></td><td>Percentage of RURAL population using LPG for cooking (any use) in a given year</td><td>Measured</td><td>No survey data reporting on this at present.</td></tr>
<tr><td>2.3</td><td>LPG consumption</td><td>This is the recommended indicator to be used to</td><td>Calculated</td><td>LPG consumption per LPG user in 2017: 22.4 kg/capita (or 85 kg per</td><td>Sources used for calculations:
• Residential consumption for 2017 =</td></tr>
</table>

ISLE TABLE 1: ISLE Indicators of LPG adoption and use					
Domain	**Indicator**	**Sub-indicator / Component needed for main indicator and rationale**	**Indicator measured or calculated**[236]	**Results**	**Sources and comments**
	per LPG user (kg/capita) per year	monitor LPG adoption and sustained use at the household level. To be measured using: (i) the total LPG consumption in the Residential sector in a giving year, divided by the (ii) percentage of households using LPG in the same year multiplied by the (iii) mean household average size for the country.		household per year)	152,187,000 kg (see Indicator 1.2) • Total number of households = 7,299,925 (GLSS 7) • Percentage of households using LPG in 2016/2017 = 24.5% (GLSS 7) • Average household size = 3.8 (GLSS 7) *Note:* the GLSS 7 data has not yet been publicly released at time of writing and the information has been accessed through the NPA.

ISLE TABLE 2: ISLE Indicators of LPG supply chain expansion and safety of the LPG market					
Domain	**Indicator**	**Sub-indicator / component needed for main indicator and rationale**	**Indicator measured or calculated**	**Results**	**Sources used and comments**
3. LPG infrastructure development: cylinders and bulk infrastructure					
3.1	Amount and percentage of LPG produced and/or imported per year	1.3.1 Production	Measured	114,000 MT in 2017 (44% of total supply)	Energy Commission Data *http://www.energycom.gov.gh/planning* File: ENERGY_STATISTICS_2018_FINAL.xlxs
		1.3.2 Import	Measured	202,400 MT in 2017 (56% of total supply)	Energy Commission Data *http://www.energycom.gov.gh/planning* File: ENERGY_STATISTICS_2018_FINAL.xlxs
3.2	Number of new cylinders deployed into the market per year (by cylinder size)	This indicator helps to understand the level of LPG market expansion. The more cylinders are injected into the market (i.e. new cylinders), the more the market is in expansion. This indicator includes both imported and locally manufactured cylinders, by cylinder size.	Measured	Approximately 200,000 assorted cylinders were injected into the market in 2017 (note that Ghana currently operates under the Customer Owned Cylinder Model).	Comments: No national statistics currently available. Data sourced through cylinder manufacturing companies. With the rolling out of the CRM, an estimated 3 to 4 million cylinders will need to be injected into the market (mostly through importation at an initial stage). NPA intends to adopt the Indian LPG regulation *(Liquefied petroleum gas (regulation of supply and distribution) order 2000)*. All LPG users will be registered by the LPG Marketing Companies and serial numbers of cylinders issued to customers will be captured and tracked.
3.3	Total number and percentage of cylinders	This is an indicator of the end of a cylinder 'lifecycle'; cylinders that are beyond	Measured	No data available As of 2017-2018, scrapping only	Comment: Under standard practice for the CRM, responsible national authorities would be expected to put in place procedure for

ISLE TABLE 2: ISLE Indicators of LPG supply chain expansion and safety of the LPG market

Domain	Indicator	Sub-indicator / component needed for main indicator and rationale	Indicator measured or calculated	Results	Sources used and comments
	being scrapped per year (by cylinder size)	repair needs to be scrapped. If a maximum shelf life for a cylinder is prescribed, a healthy range would be NIL reported cases of LPG returned for refilling beyond the permitted shelf life.		happens when the cylinder is involved in an accident.	disposal / scrapping of condemned cylinders to avoid them entering the supply chain.
3.4	Total number of 14.5 kg[237] cylinders-equivalent in circulation per capita	This is an indicator used by the worldwide LPG industry to measure and compare LPG market development[238]. To be measured using: (i) the total number cylinder imported/manufactured equivalent to a 14.5 kg cylinder (where a 6 kg cylinder would count as 0.41), less (ii) those scrapped and (iii) those	Measured	As of 2017-2018, there is no formal cylinder management system in place in Ghana currently as cylinders are owned by the end-users. NPA estimates report between 4 and 5 million cylinders of the two most popular sizes (14,5 kg and 6 kg). Considering that approximately 65% of total cylinders are of 14,5kg, and 35% are of 6 kg, it roughly estimated that around 4 million 14.5 kg-equivalent are in circulation in Ghana.	Comment: under the implementation of the CRM, this number will be accurately tracked

237 The chosen cylinder size to calculate the kg-equivalents can ben adapted depending on what the most popular cylinder size is a country.

238 In mature/developed LPG markets this measure falls in the range of to 3-4 cylinders every 10 people. In Morocco, one of the most developed LPG household markets, the ratio is almost 1 to 1.

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Domain	**Indicator**	**Sub-indicator / component needed for main indicator and rationale**	**Indicator measured or calculated**	**Results**	**Sources used and comments**
		exported to other affiliates, divided by (iv) the total national population			
3.5	Cylinder rotation rate per year	This is a KPI used by the LPG industry as an indirect measure of LPG sustained use; the higher is the rotation rate in a country, the more households are refilling their cylinders and using LPG for most of their cooking. To be measured using (i) Quantity of LPG sold in a given year, (ii) divided by the number of. 14.5 kg cylinder-equivalents	Calculated	Calculated as about 2.8 cylinders	*Note:* Based on industry data, the minimum rotation rate to help achieve efficient recirculation is 3. In low and middle-income countries, households tend to have more than one cylinder at home, which reduces the overall rotation rate and affects the profitability of private sector investment in additional cylinders.
3.6	Total national LPG infrastructure capacity by type	3.6.1 Bulk transport – Bulk Road Vehicle (BRV)	Measured	193 BRVs in 2017	Source: Data provided by NPA
		3.6.2 Bulk storage capacity in MT	Measured	22,859 MT in 2017	Source: Data provided by NPA

<table>
<tr><th colspan="6">ISLE TABLE 2: ISLE Indicators of LPG supply chain expansion and safety of the LPG market</th></tr>
<tr><th>Domain</th><th>Indicator</th><th>Sub-indicator / component needed for main indicator and rationale</th><th>Indicator measured or calculated</th><th>Results</th><th>Sources used and comments</th></tr>
<tr><td rowspan="2"></td><td rowspan="2">per year</td><td></td><td></td><td></td><td>
<table>
<tr><th colspan="3">LPG STORAGE FACILITIES</th></tr>
<tr><th>FACILITY</th><th>Location</th><th>STORAGE CAP. (MT)</th></tr>
<tr><td>GHANA GAS</td><td>Atuabo</td><td>4,320</td></tr>
<tr><td>QUANTUM STORAGE & TRUCK LOADING</td><td>Atuabo</td><td>750</td></tr>
<tr><td>Sub-Total</td><td></td><td>5,070</td></tr>
<tr><td>TEMA OIL REFINERIES</td><td>Tema</td><td>9,469</td></tr>
<tr><td>FUEL TRADE</td><td>Tema</td><td>4,000</td></tr>
<tr><td>BLUE OCEAN (PUMA)</td><td>Tema</td><td>4,320</td></tr>
<tr><td>SUB-TOTAL</td><td></td><td>17,789</td></tr>
<tr><td>Grand Total</td><td></td><td>22,859</td></tr>
</table>
</td></tr>
<tr><td>3.6.3 Refilling capacity and number of bottling plants (or refilling stations) over the national territory

Rationale: the number of filling plants should be tracked to check progress against the country's plant for LPG expansions. However, it is the refilling capacity represented by the bottling plants that is more important to measure.</td><td>Measured</td><td>645 LPG refilling stations (or micro-filling centers) in 2017.

Note that the LPG refilling stations are operational under the <u>Customer Controlled Cylinder Model only</u>. They will be replaced by 8-10 automated bottling plants with a minimum filling capacity of 1000 cylinders/hour.</td><td>Source: Data provided by NPA

Comment: Proposed Cylinder Recirculation Model Distribution Infrastructure
<table>
<tr><th>Line #</th><th>Facility</th><th>No</th><th>Comments</th></tr>
<tr><td></td><td>Bottling Plants</td><td>8</td><td>250 MT Minimum Stora
Minimum Filling Capaci
Cylinders / Hr</td></tr>
<tr><td>1</td><td>Cylinder Transport Trucks</td><td>150</td><td>Special Designed trucks
Cylinder Transportation</td></tr>
<tr><td>2</td><td>Cylinder Distribution Centres</td><td>2000</td><td>Will also serve as cylind
exchange points</td></tr>
<tr><td>3</td><td>Autogas service stations</td><td>100 - 150</td><td>Low Risk filling stations</td></tr>
<tr><td>4</td><td>Cylinder Manufacturing /
Revalidation plants</td><td>2</td><td>To provide Cylinder rep
maintenance facilities</td></tr>
</table>
Note: automated bottling plants (i.e., with carousel) can reach very high performance rates when compared with non-automated or semi-automated bottling plants. For example, for filling 14.5 kg cylinders, an automated plant with 18 scales would fill up to 800 cylinders per hour, as compared to a stationary scale whose performance is 60</td></tr>
</table>

ISLE TABLE 2: ISLE Indicators of LPG supply chain expansion and safety of the LPG market

Domain	Indicator	Sub-indicator / component needed for main indicator and rationale	Indicator measured or calculated	Results	Sources used and comments
					cylinders per hour.
		3.6.4 Cylinder manufacturing capacity (if applicable)	Measured	Two entities are already established in Ghana: (i) Sigma Gas; (2) Ghana Cylinder Manufacturing Company (GCMC). Their combined production capacity is estimated at 2.2 million cylinders per annum (6kg and 14.5 kg, no breakdown by size available)	Source: GLPGP – Greater Accra LPG Demand Assessment (2014)
		3.6.5 Number of construction permits for building filling plants / or plant built per year	Measured	8 bottling plants with capacity of filling 1000 cylinders per hour expected to be constructed in Ghana (to 8 construction licenses) to implement the CRM. Plants expected with minimum storage capacity of 250 MT on commencement; ultimately reaching 750 MT.	All LPG construction permits have been on hold since October 2017 after the Atomic Junction accident. New license window opens in August 2018 under the new licensing framework for CRM. See: https://www.thefinderonline.com/news/item/13024-8-bottling-plants-for-cylinder-recirculation-model-npa
		3.6.6 Number of construction permits for building or expanding import terminals, including storage capacity, per year	Measured	2 construction permits identified	Source: http://cbodghana.com/downloads/ • File: CBOD-2017-INDUSTRY-REPORT.pdf

<table>
<tr><th colspan="6">ISLE TABLE 2: ISLE Indicators of LPG supply chain expansion and safety of the LPG market</th></tr>
<tr><th>Domain</th><th>Indicator</th><th>Sub-indicator / component needed for main indicator and rationale</th><th>Indicator measured or calculated</th><th>Results</th><th>Sources used and comments</th></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td>
<table>
<tr><th colspan="6">LPG Storage investments 2017 / 2018</th></tr>
<tr><th rowspan="2">L #</th><th rowspan="2">Installation</th><th colspan="2">Storage Capacity (MT)</th><th rowspan="2">Year</th><th rowspan="2">Port</th></tr>
<tr><th>Butane</th><th>Propane</th></tr>
<tr><td>1</td><td>Blue Ocean</td><td>4,320</td><td></td><td>2017</td><td>Tema</td></tr>
<tr><td>2</td><td>Quantum</td><td>600</td><td>15,800</td><td>2018</td><td>Tema</td></tr>
<tr><td></td><td>Grand Totals</td><td>4,920</td><td>15,800</td><td></td><td></td></tr>
</table>
</td></tr>
<tr><td>3.7</td><td>Number of licensed marketers/cylinder brand owners per year</td><td>This indicator is a proxy for LPG industry consolidation/ fragmentation</td><td>Measured</td><td>41 licensed LPG Marketing Companies (LPMC) as of 2017
NPA expects there will be consolidations bringing down the number of LPG Marketing Companies and cylinder brands to 15.</td><td>Source: NPA</td></tr>
<tr><td>3.8</td><td>Total number of authorized retail outlets per year</td><td>This indicator and its sub-indicator is an important measure to track LPG market expansion over the national territory and harder to reach regions. The more retail outlets are available, the more households can access LPG at relatively short distances.</td><td>Measured</td><td>Currently the LPG reaches the household end-user (last mile distribution) through 645 refilling stations that are contracted by the LPG Marketing Companies (LPMC) and the Oil Marketing Companies (OMC) to fill customer owned cylinders under the <u>Customer Owned Cylinder Model.</u>
NPA projects to have 2000 cylinder distribution centers under the CRM.</td><td>Comment: In the proposed CRM, the cylinders will be owned by the LPMC who will be required to contract bottling plants for LPG filling services. The LPMC will establish distribution networks involving distributors and retailers who will be responsible for establishing distribution depots and retail points through which customers will exchange their empty cylinders for filled ones. Customers will only pay for the LPG refill.</td></tr>
<tr><td>3.8.1</td><td></td><td>Total number of authorized retail outlets by region/province in a given</td><td>Measured</td><td>Data on refilling stations (micro-filling centres) by region for 2017:</td><td>Source: NPA data</td></tr>
</table>

ISLE TABLE 2: ISLE Indicators of LPG supply chain expansion and safety of the LPG market					
Domain	**Indicator**	**Sub-indicator / component needed for main indicator and rationale**	**Indicator measured or calculated**	**Results**	**Sources used and comments**
		year		Row Labels / Count of REGION Ashanti 97 Brong Ahafo 71 Central 76 Eastern 67 Greater Accra 179 Northern 13 Upper East 12 Upper West 8 Volta 56 Western 66 **Grand Total 645**	
4. LPG Industry safety metrics					
4.1	Percentage of LPG facilities (by type) audited by year	This indicator serves and its sub-indicators measure how compliant is the LPG system with safety norms and regulations	Measured	As of November 2017, out of the 636 registered refilling plants, 276 (43%) were inspected.	Source: NPA. See: http://www.npa.gov.gh/news/108-lpg-stations-fail-npa-test Results as at November 2, 2017
4.1.1		Percentage of LPG facilities (by type) in non-compliance	Measured	In 2017, the number of closed refilling plants for failure to comply with safety rules (out of the inspected ones) was 54 (19.5%).	Source: NPA. See: http://www.npa.gov.gh/news/108-lpg-stations-fail-npa-test
4.1.2		Percentage of LPG facilities (by type) in full compliance	Measured	In 2017, the number of refilling plants fully compliant (out of the inspected ones) was 114 (41%).	Source: NPA. See: http://www.npa.gov.gh/news/108-lpg-stations-fail-npa-test

ISLE TABLE 2: ISLE Indicators of LPG supply chain expansion and safety of the LPG market					
Domain	**Indicator**	**Sub-indicator / component needed for main indicator and rationale**	**Indicator measured or calculated**	**Results**	**Sources used and comments**
4.2	Percentage of total cylinders being hydro tested per year	This is a measure for LPG safety in a market and regulatory compliance with safety norms. During hydro testing a cylinder is examined to ensure it can safely hold its rated pressure.	Measured	N/A under the Customer Owned Cylinder Model.	Comment: Under standard practice for the CRM, responsible national authorities would be expected to put in place a procedure for regular hydro-testing of cylinders. This practice is usually done on cylinders that are at least 5 years old. Defective cylinders need to be scrapped if beyond repair.
4.3	Percentage of total cylinders being refurbished/ recertified per year	This is a measure for LPG safety in a market and regulatory compliance with safety norms.	Measured	N/A under the Customer Owned Cylinder Model.	Comment: Under standard practice for the CRM, responsible national authorities would be expected to put in place a procedure for recertification of cylinders (recommended every 10 years).
4.4	Percentage of cylinders with valve being replaced per year	This is a measure for LPG safety in a market and regulatory compliance with safety norms.	Measured	N/A under the Customer Owned Cylinder Model.	Comment: Under standard practice for the CRM, responsible national authorities would be expected to check this regularly. Note that high replacement of valves occurs when cylinders are not well transported and maintained.
4.5	Percentage of trucks presented for loading turned away (rejected)	This is an indicator of compliance with safety rules and practices. To be collected by individual filling plants where trucks	Measured	N/A under the Customer Owned Cylinder Model.	Comment: all LPG filling plants must have a system in place to check trucks entering the plants. The 'cylinder safe to load' checks per truck should be compiled and passed to the marketer and responsible authority (e.g.

ISLE TABLE 2: ISLE Indicators of LPG supply chain expansion and safety of the LPG market					
Domain	**Indicator**	**Sub-indicator / component needed for main indicator and rationale**	**Indicator measured or calculated**	**Results**	**Sources used and comments**
	for non-compliance with Safety, Health, Environmental and Quality requirements	discharge empty cylinders and upload filled cylinders.			NPA), including fire department, for monitoring purposes.
4.6	Percentage of drivers that have attended refresher courses in defensive driving / LPG truck driving within the stipulated refresher training requirement.	This is an indicator of compliance with safety rules and practices.	Measured	Not known	Comment: All LPG truck drivers are required to have certificate of competence in LPG truck driving and to have a certificate in defensive driving as a minimum. Refresher training courses can occur at different intervals.
5. Economic aspects in relation to LPG					
5.1	Amount and percentage of LPG price	This indicator is useful in a market where there are no price controls in the LPG	Calculated	In Ghana, LPG Prices in Ghana are uniform throughout the country and are reviewed fortnightly (every two	Source: All costs are made available to the customer on the NPA website, see: http://www.npa.gov.gh/downloads

ISLE TABLE 2: ISLE Indicators of LPG supply chain expansion and safety of the LPG market					
Domain	**Indicator**	**Sub-indicator / component needed for main indicator and rationale**	**Indicator measured or calculated**	**Results**	**Sources used and comments**
	volatility in a given year	market allowing for full cost pass through to the end user. Components: maximum and minimum LPG retail price across the national territory and impact on LPG cylinder refill sales.		weeks) and adjusted for fluctuations in: (i) Ex-Refinery Price, (ii) Government Taxes; (iii) Distribution Expenses / Margins.	http://www.npa.gov.gh/images/npa/documents/template/Ex-Pump_Prices_Computation_Template_Effective_16th_July_2018.xlsx Comment: LPG price controls (i.e., fuel subsidy and price regulation/stabilization) have been removed in 2016. NPA however tracks the ex-refinery price based on Import Parity Price and the indicative pump prices. Transport differentials are accommodated by the Unified Petroleum Price Fund (UPPF), which means that transport to distant locations is subsidized by nearer locations.
5.2	Net amount of new investment in LPG infrastructure, per capita, per year	This is an indicator of impact on society and macro-economics.	Measured	No data on existing investment for 2017 identified. Based on GLPGP estimates, the potential new investment required for 2019-2030 to expand appropriately the LPG infrastructure in Ghana is up to € 335mm, at current prices (€235mm for cylinders, €87mm for filling plants/storage expansion; €13mm for pallets and cylinder cages). This corresponds to an average of about € 1 per person per year, given expected population growth.	GLPGP investment plan for Ghana, 2018 Note: a significant portion of the investment spending is expected to occur in the first years as a sizable number of cylinders is needed to meet consumer demand, to fill the supply chain with a buffer stock to accommodate CRM, and to cover the replacement of cylinders which need to be scrapped. Filling plants are also expected to be constructed starting in 2019.

ISLE TABLE 2: ISLE Indicators of LPG supply chain expansion and safety of the LPG market					
Domain	**Indicator**	**Sub-indicator / component needed for main indicator and rationale**	**Indicator measured or calculated**	**Results**	**Sources used and comments**
5.3	Direct number of new short-term jobs created during construction of LPG-infrastructure per year	This is an indicator of impact on society and macro-economics.	Measured	To be collected in association with the CRM implementation.	Source(s) to collect this information to be identified.
5.4	Direct number of new long-term job created in the LPG sector during operations per year	This is an indicator of impact on society and macroeconomics. To be calculated using the following sub-categories: 5.4.1 Importation operations 5.4.2 LPG Bulk Transporters 5.4.3 LPG Storage Companies 5.4.4 Cylinder manufacturing companies 5.4.5 Filling plant operators 5.4.6 Safety inspectors 5.4.7 Cylinder revalidation/recertific	Measured	To be collected in association with the CRM implementation. Anticipated cumulative number jobs from CRM implementation: Direct job creation in relation is estimated to be 9,468 in relation to new jobs under the LMCs, LBPs, LCTs and door-to-door delivery. This does not affect current jobs of LPG Bulk Transporters, LPG Bulk Distribution Companies, and LPG Bulk Storage companies as well as the retail outlets that would transition into distribution centers, which is estimated to be around 3,355. In addition, NPA will recruit a little over 200 safety auditors throughout the country, as well as resource its newly established Health Safety Security and Environment department. There will	Source: https://www.graphic.com.gh/features/features/the-cylinder-recirculation-model-all-you-need-to-know.html

ISLE TABLE 2: ISLE Indicators of LPG supply chain expansion and safety of the LPG market					
Domain	**Indicator**	**Sub-indicator / component needed for main indicator and rationale**	**Indicator measured or calculated**	**Results**	**Sources used and comments**
		ation personnel 5.4.8 LPG Distribution companies 5.4.9 LPG retailers 5.4.10 Consumer education/marketing.		also be a number of indirect jobs created for installations, maintenance, fabrication and other services.	

ISLE TABLE 3: ISLE Safety indicators (occupational and household settings)					
Domain	**Indicator**	**Sub-indicator / component needed for main indicator**	**Indicator measured or calculated**	**Results**	**Sources used and comments**
6. LPG-related Incidents and burns					
6.1	Number of LPG-related incidents (fires or explosions) in occupational and institutional settings per year	Occupation settings: 6.1.1 LPG Primary Distribution operations (bulk importation and bulk transportation to bottling plants) incidents. 6.1.2 LPG Secondary Distribution Operations (bulk delivery to bulk consumers for primary storage and transportation / distribution of bottled LPG) incidents. Institutional settings: 6.1.3 Hotel, restaurants, hospitals, schools, prisons, street vendors, etc. LPG-related incidents.	Measured	3 cases reported in the media in 2017 (Takoradi, Tulip Inn Hotel and Atomic Junction), all in the Greater Accra Area.	Press Article: http://citifmonline.com/2017/10/08/ghana-records-8-gas-explosions-within-3-years-infographic/ Comment: Definition of each sub-indicator 1. Primary Distribution - refers to transportation in the first step of the distribution chain, i.e., from source of supply to major customers (power plants, mining, manufacturing), bulk storage plants and bottling plants. 2. Secondary Distribution - refers to the movement of LPG onward along the distribution chain from a bulk storage facility or bottling plant to the end users.

ISLE TABLE 3: ISLE Safety indicators (occupational and household settings)

Domain	Indicator	Sub-indicator / component needed for main indicator	Indicator measured or calculated	Results	Sources used and comments
6.2	Number of LPG-related incidents (fires of explosions) in homes per year		Measured	Overall, data on LPG related fires in homes is scarce. Only one incident captured in the press in 2017. The fire reached a gas station. No fatalities reported.	Press article source: http://citifmonline.com/2017/10/12/fire-guts-house-near-gas-station-at-mankessim/ Firefighters may keep records of LPG-related fires. There is no formal system to capture such data in Ghana as cylinders are owned by the customers who often have no insurance cover.
6.3	Number of reported LPG burns (injuries and deaths) per year	6.3.1 LPG-reported non-fatal burn injuries 6.3.2 LPG-related burns deaths 6.3.3 Percentage of cases attending hospital	Measured	Press articles reporting 35% of all burns cases in one teaching hospital (Reconstructive Plastic Surgery and Burns Centre, Korle Bu, Accra) were LPG-related, with 51% of the victims being children.	Press articles sources: http://citifmonline.com/2017/06/14/korle-bu-records-300-burn-cases-in-2017-35-are-from-gas-explosions/ https://www.graphic.com.gh/news/general-news/reconstructive-plastic-surgery-and-burns-centre-records-increase-in-cases.html https://www.ghanaweb.com/GhanaHomePage/NewsArchive/LPG-explosions-account-for-33-of-burns-victims-in-Ghana-334491 Comments: additional data may be found at individual burns registry at health facilities. Data collection would occur by contacting each individual health facility until a national surveillance process is in place.

25. Impact Evaluation of LPG Uptake for Household Cooking

Evaluation of impacts related to LPG adoption and sustained use for household cooking is recommended to establish the effects of LPG uptake on individuals and society. Such evaluation is only possible when accurate LPG household consumption figures and associated data are available at baseline and over time as households make the transition to the adoption of LPG and/or more exclusively use. Designing and implementing a systematic and rigorous tracking system through the ISLE indicators described earlier in this document is the first key step needed in this process, although additional data collection and interpretation are required to understand the impacts of expanding the LPG market.

In terms of impacts, LPG uptake for cooking by households has the potential to deliver a wide range of benefits, chiefly on health, the environment and time saving. This is because LPG is a highly efficient and clean-burning fuel at point of use, and it avoids depletion of forest resources where these are at risk from household fuel demand.

For a comprehensive evaluation of key impacts, six categories of impacts can be considered and assessed over time: (i) health, (ii) environment, (iii) climate, (iv) gender, (v) employment and (vi) macro-economic. The table below provides an overview of the key metrics and methods for these six dimensions of impact assessment. It is important to note that impacts are assessed by comparing the population transitioning to LPG with those continuing to rely on traditional polluting fuels (e.g. charcoal, firewood, agricultural residues, kerosene etc.).

Table 72. Outline of impact categories for population projected to transition to LPG

Categories of Impacts	Metric	Comments and methodology
I. Health	Deaths averted per year (estimates)	Household air pollution (HAP) is associated with several adverse health effects on both adults and children due to exposure to products of incomplete combustion, chiefly fine particulate matter ($PM_{2.5}$) and carbon monoxide (CO). In the Global Burden of Disease (GBD) assessments, HAP is causally related to six important diseases: ischemic heart disease, stroke, chronic obstructive pulmonary disease, lung cancer, acute lower respiratory infection in children, and cataract (women only). Current estimates by the Institute of Health Metrics Evaluation (IHME) show that HAP is responsible for around 2.6 million premature deaths from the first five of these conditions each year[239]. There is also evidence that HAP is associated with adverse pregnancy outcomes such as low birth weight, tuberculosis, and other conditions that are also seen with tobacco smoking, all of which can result in premature death or a disability that can affect quality of life and /or life expectancy.

239 www.healthdata.org

Categories of Impacts	Metric	Comments and methodology
		Impacts of the transition to LPG as compared to continued reliance on polluting fuels for household energy needs can be modeled using the established GBD methods for HAP-associated health outcomes (the HAPIT model)[240]. This model yields estimates of premature deaths and Disability-adjusted Life Years (DALYs) averted. Input data: Ideally, use nationally representative measured personal exposures to $PM_{2.5}$ collected in the field for both traditional fuels/stoves users and LPG-using homes (for primary cooks and children using personal exposure monitors). Alternatively, personal exposure rates to $PM_{2.5}$ can be estimated by measuring kitchen area concentrations and published GBD/Comparative Risk Assessment (CRA) conversion ratios[241]. Measuring kitchen $PM_{2.5}$ concentrations, and especially personal exposure levels, requires intensive field work and is resource intensive. Note: Directly measuring impacts on disease rates requires more complex, longer study designs (multi-years), and is very expensive. It is not expected that this will be possible for more routine evaluation in most countries and settings, but where suitable research infrastructure is available, this can be considered.
	DALYs saved per year (estimates)	Disability Adjusted Life Years (DALYs) is a standard measure used to estimate disease burden. Adoption and sustained use of LPG can result in DALYs saved due to reduced HAP exposure to $PM_{2.5}$ for the same five disease outcomes stated above as part of GBD. Input data: Impacts of the transition to LPG on DALYs can be modeled using the same approach and input data described above.
	Cooking-related burns (injuries and deaths) per year	Traditional household energy practices (i.e. use of open fires, simple stoves, kerosene stoves, etc.) are linked to a high risk of burns (e.g. from children falling into fires, spilled fuel, etc.). In general, use of LPG is safer, but poor industry, retailer, or home practices in terms of checking, replacing and using LPG can results in fires and explosions with serious consequences. Data needed: Information on fires, explosion and resulting burn deaths and injuries at the country level may be obtained from a range of sources, including the press/media, occupational accident

[240] householdenergy.shinyapps.io/hapit3/

[241] Smith et al. (2014). Millions dead: how do we know and what does it mean? Methods used in the comparative risk assessment of household air pollution." Annu. Rev. Public Health 35: 185–206.

Categories of Impacts	Metric	Comments and methodology
		reporting, and the health system. Thorough assessment of burns injuries and death resulting from LPG use (and other causes) will require the establishment of a burns surveillance system, located within health facilities. Most commonly this is done in a sub-sample of hospitals representing various settings, as instituting nation-wide surveillance would be prohibitively resource intensive. Cases of LPG-related burns should be tracked using the proposed safety ISLE indicators (Table 3) on both households and occupational settings.
	Economic value of deaths averted and DALYs saved	There is no single standardized method to calculate the economic value of the deaths and DALYs averted due to transition to clean fuels for household cooking in developing countries. An approach would be to stratify the population by 10-year age bands and weight the GDP per capita for each age band by the productive index for the age bands.
II. Environment	Averted deforestation (number of trees or total fuelwood displaced)	Transition to cooking with LPG has the potential to significantly reduce the pace of forest degradation and deforestation in countries (or sub-regions) where household use of fuelwood and charcoal for cooking is known to contribute to forest degradation. The number of trees saved can be calculated based on avoided fuelwood and charcoal use, considering the proportion of biomass consumed that is produced unsustainably. Input data include: firewood and charcoal consumption and export data, fraction of nonrenewable biomass (fNRB) and typical mass of a tree.
III. Climate	Averted carbon dioxide emissions and co-emitted species	LPG combustion leads to some net CO_2 emission but in most situations this contribution is effectively offset by the avoidance of net CO_2 emissions from burning of non-renewable biomass fuel. Carbon dioxide equivalents (CO_2eq) include emissions from the three main greengases – CO_2, methane (CH_4), and nitrous oxide (N_2O). CO_2eq should be calculated based on fuelwood and charcoal displaced from increased access to LPG, under different biomass renewability scenarios. It is known that not all harvested fuelwood is renewable, and the fraction of nonrenewable biomass (fNRB) extracted is typically in the range of 27–34% on a global scale, with large geographical variations. In East Africa for example, the fNRB exceeds 50%[242]. A higher fNRB would ascribe correspondingly higher emissions to biomass fuels and a greater benefit of a switch to LPG.

242 Bailis et al. 2015. The carbon footprint of traditional woodfuels Nat. Clim. Change. 5 266–72

Categories of Impacts	Metric	Comments and methodology
		Input data: Emission factors for technology/fuel combinations. LPG consumption data to be obtained through the ISLE indicators presented earlier in this document. Fuelwood and charcoal consumption data to be obtained by census and nationally representative surveys. Renewability data to be obtained from published and widely accepted data sources such as the Geospatial Analysis and Modelling of Non-Renewable Biomass (WISDOM) model or others.
	Averted black carbon emissions and co-emitted species	Burning of biomass contributes to the emissions of short-lived climate forcing products of incomplete combustion, such as black carbon (BC) and other co-emitted species. Transition to fuels such as LPG, which burn the fuel-carbon much more completely, can therefore reduce emissions of these climate pollutants, which have a warming impact in the short term. The other chemical species emitted through incomplete combustion of carbon fuels beyond BC include: carbon monoxide (CO), organic carbon (OC) - a cooling agent, nitrogen oxides (NOx), non-methane volatile organic compounds (NMVOCs), and others. Calculations are based on emissions at point of use. Input data: fuelwood and charcoal consumption data to be obtained by census and nationally representative surveys. Stove emissions data to be obtained by latest available literature. Renewability data to be obtained from the Geospatial Analysis and Modelling of Non-Renewable Biomass (WISDOM) model or other published and widely accepted data sources. Using the Gold Standard BC methodology[243], climate-related emission reductions are accounted for by comparing fuel consumption in the intervention scenario (i.e. after adoption of LPG for clean cooking) to the applicable baseline scenario (e.g. biomass burnt in traditional low efficiency stoves or open fires).
	Effects on global temperature	Quantification of CO_2eq and BCeq differentials from switching to LPG, as compared to relying on traditional polluting fuels, can be used to estimate the overall effect on the global temperature over

243 Gold Standard Quantification of Climate Related Emission Reductions of Black Carbon and Co-emitted Species due to the Replacement of Less Efficient Cookstoves with Improved Efficiency Cookstoves.

Categories of Impacts	Metric	Comments and methodology
		time (short-term and long-term). An overall cooling effect due to LPG adoption for clean cooking is expected in countries where the fraction of renewable biomass is relatively low, as indicated by studies in India and Cameroon[244,245].
IV. Gender	Time savings from cooking with LPG per day	Use of LPG is expected to save time through faster cooking, reheating of food and pot cleaning, if households primarily use LPG for their daily cooking activities. Input data: There is a need for population-based surveys in countries—including Ghana—to track this impact as part of bespoke data collection efforts. The Multi-Tier Tracking Framework contains suitable survey questions that could be used across countries for making the results comparable.
	Time savings from avoided fuel purchasing per day	Use of LPG is expected to reduce the need to purchase firewood and charcoal daily, once households use LPG as their primary fuel for their daily cooking activities. (According to the findings presented in Parts VI (LPG Demand Potential to 2030) and X (Environmental, Health, Social and Economic Impact Potential), a negligible quantity of firewood-gathering households are expected to switch to LPG in Ghana by 2030.) Input data: There is a need for population-based surveys in countries to track this impact as part of bespoke data collection efforts. The Multi-Tier Tracking contains suitable survey questions that could be used across countries for making the results comparable.
	Economic value of time saved	The time gained from faster cooking with LPG (including preparation and clean-up), and, where applicable, from reduced fuel gathering, can result in a number of benefits, including allowing women to find more paid work[246], or pursue education, or have more time for themselves and their well-being. It should be noted, however, that increased economic activity for women (in any sector) from savings in cooking-related time will be countered at a macro level by a potentially significant loss of jobs in the charcoal and firewood informal sectors (for which specific,

244 Singh et al. (2017). Environmental payoffs of LPG cooking in India. Environ. Res. Lett. https://doi.org/10.1088/1748-9326/aa909d

245 Pope et al. (2018). Climate and health impacts of scaling adoption of LPG for clean cooking through the Cameroon LPG Master Plan. Policy brief.

246 Countries like India have encouraged LPG business operations by families (husband and wife) operating in rural areas. An example of such schemes is Rajiv Gandhi Gramin LPG Vitaran (RGGLV), launched by India in 2009.

Categories of Impacts	Metric	Comments and methodology
		complementary metrics should be designed). The economic value of time can be calculated as a proportion of the time saved likely to be used for economic activity (which is expected to be very low in some settings) multiplied by the average hourly minimum wage in the country.
IV. Employment	Job creation/loss across the LPG value chain (and indirect jobs)	Scaling up of LPG means new job opportunities in construction and long-term in LPG operations, including last-mile distribution, at a relatively large scale. Some specific LPG jobs will be lost, on a comparatively small scale, from increasing use of automation in the bottling node of the supply chain. Data input: Direct LPG-related net job creation (short-term and long-term jobs) to be calculated using the ISLE indicators. Indirect jobs include maintenance, staff of retail shops, *etc*., and these may be more difficult to measure.
	Job-losses across non-LPG value chains	Scaling up of LPG may result in a reduction of jobs in relation to firewood and charcoal production and supply, especially in the informal sector. Such reduction might be offset, in part, by increased production for export purposes, assuming the Government permits increased export of woodfuel products. Data input: Direct jobs in the firewood, charcoal, etc. supply chains to be based on the best available sources. It should be noted that rreliable estimates for the total number of jobs in the different fuel value chains are generally difficult to obtain in low and middle income settings, as there is an overall scarcity of data, and employment surveys do not always adequately capture the different employment categories.
VI. Macro-economics	Tax revenue	The impact on taxes is comprised by changes to the volume of LPG and non-LPG fuels subject to sales taxes that are actually collected (e.g., VAT and, for LPG, which in Ghana is VAT-exempt but subject to various hydrocarbon sector-specific levies and taxes), and to corporate (income) taxes in the LPG and non-LPG fuel sectors that are actually collected. In the case of Ghana, a lack of data regarding corporate profitability across the supply chains of the various cooking fuel alternatives did not allow evaluation of corporate tax effects. In most SSA countries, firewood and charcoal are informal businesses. Therefore, the tax effects depend mainly on how, and how much, LPG fuel and LPG businesses are taxed, and partially on how, and how much, word and charcoal products and businesses and are taxed. The increasing replacement of wood and charcoal by LPG is

Categories of Impacts	Metric	Comments and methodology
		expected to lead to an increase in national tax revenues, based on the increased hydrocarbon sector-specific taxes and levies collected on increased LPG volumes more than exceeding the reduction in taxes collected on reduced sales by the tax-paying wood and charcoal industries. Increased use of LPG would create a larger corporate tax stream from increased formal economic activity (LPG marketers, staff of filling plants and bulk depots, *etc.*) and lead to higher corporate taxes. The net impact on tax revenues would depend on the foregoing factors and the relative LPG and firewood/charcoal use. Input data: To estimate the impact of fuel sales on the tax base (including VAT and any additional levies), the total quantity of fuel consumed in-country should be multiplied by the fixed-amount-per-unit taxes and levies (applicable to LPG), and multiplied by the domestic sales price and VAT per kg of fuel (applicable to biomass fuels). To calculate the import tax contribution, the total quantity of fuel imported (that is generally only LPG and kerosene in SSA) should be multiplied by the price per kg of fuel imported and the import duties per kg of fuel. (In Ghana, this aspect can be disregarded for so long as LPG imports remain not subject to import duties and woodfuels are not imported.) The total imports and sales taxes and increased LPG production would be added to obtain the total impact on the tax base. Measuring the increased use of LPG would depend on the ability to isolate and calculate the commercial benefits of the different effects mentioned above.
	Trade balance	In countries that import LPG, greater use of LPG may worsen the trade balance. This might be partially offset by reduced usage of charcoal for the domestic market and therefore its increased availability for export. However, charcoal production for export should not be encouraged as this contributes to forest degradation and deforestation and has net climate warming impacts. Approach: To measure the effect on trade balance, fuel imports for LPG and charcoal (or other fuels as applicable) should be subtracted from the fuel exports for the same fuels.

Considerations on data needs and methods

Conducting a comprehensive impact evaluation of a national LPG scale-up program, while important and valuable, is a substantial undertaking. A key aspect of this is the collection and analysis of a wide range of data. Some of the main considerations with respect to these data requirements are discussed below.

Health data

- To calculate the health benefits from a transition to sustained use of LPG for the population, there is need to collect personal exposure data to health-damaging pollutants such as $PM_{2.5}$ in the field during daily cooking operations. As an alternative, kitchen area concentrations can be measured, and personal exposure rates can be estimated using published GBD/CRA conversion ratios. These data are unlikely to be readily available, and therefore need to be obtained using exposure monitors in suitable samples of homes and their occupants. Research groups which have carried out studies in Ghana may be able to provide useful data on exposure (e.g. from the GRAPHS study[247], whose results have not been published at time of writing) but this may not be nationally representative. Measurement of personal exposure is time-consuming, and requires access to instruments, analysis facilities and staff trained in the necessary skills, all of which carry significant resource implications.

- Interpreting the personal exposure data is also important and care must be taken in generalizing from a specific context where a field evaluation is conducted. High recorded $PM_{2.5}$ exposure levels (i.e. above WHO recommended safe levels for health) in LPG-using homes may occur for a number of reasons including: (i) high background levels of ambient pollution (e.g. in urban areas, where other sources of pollution contribute to poor air quality; in rural areas, where the practice of trash burning or wood burning for agricultural purposes may be common); (ii) community effect, where neighboring households continue to rely on polluting fuels and technologies impacting the air quality of neighbours who have transitioned to LPG for cooking; and (iii) fuel stacking, when those who have transitioned to LPG have not fully abandoned their traditional stoves and therefore experience residual exposure to health-damaging pollutants. In addition, the continued use of traditional or other solid fuel stoves for heating purposes, or other combustion sources such as kerosene lamps, can contribute substantially to HAP and personal exposure.

- Despite the importance of household fuels in causing burn deaths and injuries through contact with fuel (e.g. solid fuels, kerosene and LPG), reliable data on such events and injuries are scarce. It is therefore important that more effort, including by the Ministry of Health and Health System, is made to collect and report such data.

Environmental and climate data

The ability to accurately project net emissions reductions associated with fuelwood and charcoal displacement by LPG for cooking greatly depends on the input sources and biomass renewability scenarios.

Climate impacts from LPG adoption should consider both Kyoto (e.g. CO_2, CH_4) and non-Kyoto climate pollutants (e.g., BC, OC, etc.). LPG use is associated with lower emissions of BC and other co-emitted species, as well as almost no methane emissions. This is due to the fuel composition (LPG is made of butane and propane) and higher efficiency of LPG stoves compared to traditional or simply manufactured

247 Jack et al. (2015). Ghana randomized air pollution and health study (GRAPHS): study protocol for a randomized controlled trial. Trials, 16:420.

stoves. Conversely, biomass burning leads to CH_4, BC and other non-Kyoto climate pollutant emissions, which warm the climate in the short-term.

The input needed for the modeling would include:

- Baseline emissions data of Kyoto gases and short-lived climate pollutants for the household sector
- Emission factors (i.e., the mass of pollutant emitted for a given task)
- Fuel use data for biomass consumption (renewable and non-renewable fractions). The literature estimates reveal large uncertainties when it comes to the fNRB, particularly in low and middle-income countries.

Gender, employment and macroeconomics

For these categories of impact, the necessary data are generally not readily available (e.g. for sections of the fuel market operating informally, for the amount of time spent in collecting fuels etc.). This means new data collection work is required (i.e., through special surveys if routine ones such as the DHS, GLSS do not include the topics), or assumptions must be made. An example would be impacts on employment, data for which might be included in routine national surveys. These would need to cover all of the relevant fuel value chains. In some cases, it may be possible to rely on research studies to measure some of the impacts on a small scale (e.g. for gender) and extrapolate on a national scale.

Resources needed to conduct an impact evaluation

Adequate funding is critical to ensure appropriate evaluation. The greater the need for primary data collection (i.e. household surveys, stakeholder surveys to obtain accurate figures on number of jobs, personal exposure monitoring etc.), the more resource-intense the evaluation will be. Selecting representative study areas, applying rigorous study design methods and having access to digitized data are the first ways to optimize costs. In addition, the evaluation team needs to include personnel with the technical competence to implement the evaluation methods and amenability to training.

Governments and project implementers need to prioritize the information to be collected and what impacts are to be assessed. It is beyond the scope of this document to make suggestions for prioritization.

Conclusions

A properly designed impact evaluation can answer the question of whether a national LPG scale-up program is achieving the program goals and the wider societal benefits. This would assist in decision-making with regards to LPG market expansion. It would also inform the steps to reduce fuel/stove stacking, to encourage safer practices in the home, and to retrain traditional fuel workers so they can contribute to the clean fuel market.

For a national evaluation, a robust monitoring program that includes the collection of primary and secondary data is an efficient way to help with impact assessment. A key consideration when designing, planning and implementing an impact evaluation is to focus on what the program should achieve, and concentrate the resources available on ensuring that the most relevant information is collected as accurately as possible.

Annex

Please refer to Annex Chapter 31 on page 323 for further information about the CLEAN-AIR (Africa) Group.

XII. Recommendations for Further Technical Assistance and Research

This Part summarizes recommendations for further technical assistance or research which arose during the national assessment process.

Recommendations for further technical assistance

1. Because many decisions affecting the design and rules of the LPG sector under BCRM were not yet taken by the Government as of this writing, this assessment, together with the companion *Ghana LPG Investment and Implementation* report, should be refreshed once these decisions have been taken. In particular, the decisions regarding:

    - Whether the Bottling Plants (BPs) or the marketers will have cylinder investment and branding responsibility, together with liability for cylinder safety;
    - The national LPG price formula, especially with respect to the allocation of margin throughout the supply chain;
    - Resolution of the ongoing debate with the smaller microstation operators regarding their pathway forward as LPG distributors/retailers or as autogas dispensers;
    - Final licensing terms for the new and revised main supply chain nodes (BPs, OMCs/LPGMCs)[248];
    - Whether the Rural LPG Program will be retooled and restarted, and with what objectives and parameters, and at what scale;
    - Agreement by the partner entities to proceed with an LPG microfinance pilot, as described in this report;
    - What companies will ultimately be permitted to obtain BP licenses;
    - The licensing / permitting / registration rules for distributors and retailers, and how they must interact with OMCs/LPGMCs;
    - The sequencing of the BPs across regions;
    - The scale and scope of any governmentally-backed public education and awareness campaigns; and
    - Other promotional or incentivizing measures as the Government may determine (which may include relative changes to taxation of LPG *vs*. alternative fuels).

[248] While the NPA published licenses applicable to both nodes during 2018, the license language contains a clause that allows NPA to revise the terms in future.

2. Within the scope and resources for this stage of the Clean Cooking for Africa Program in Ghana, deep assessments and recommendations were not developed with respect to certain aspects of the LPG sector, with priority given to the aspects that were reported herein. The aspects which received a lesser level of attention to date should be assessed and recommendations developed (assuming events do not outpace the assessing) in a later stage of the program. They include:
   - Bulk Road Vehicles;
   - Alternatives for increasing domestic LPG production for the Ghana Gas Company;
   - Autogas;
   - Importation strategies and opportunities for regional coordination, sourcing and international transport optimization, and infrastructure planning, in order to reduce costs and improve volatility;
   - Opportunities to reduce costs through bulk transport of LPG by rail;
   - The LPG-to-power subsector and coordination of infrastructure planning across this subsector and the household, bulk and autogas subsectors;
   - Pay-as-you-go business models in context of Ghanaian LPG pricing regulations (and potential exceptions to those regulations);
   - Targeting of cylinder exchange points and depots; and
   - Segmentation of LPG standards (propane-butane mix) for different user and usage types (residential, autogas, industrial) and any corresponding implications for infrastructure.
3. Support and underwriting for LPG microfinance program execution.
4. The potential role of bio-LPG in the Ghanaian market for the long term.
5. With investment funding prearranged (as a precondition of Ghanaian business cooperation in sharing proprietary information), evaluation of financial statements and business plans from a critical mass of companies in the bottling and marketing nodes of the supply chain, to refine the projections of scale and impact from this report, and to develop firm-specific investment cases for actual counterparties.
6. Assessing the impact potential of targeted interventional mechanisms for increasing availability (on a commercially viable basis) and affordability of LPG for the rural poor.

Recommendations for further research

1. Household surveying to address GLSS 6 and 7 gaps with respect to comparative fuel economics, and other drivers of fuel-switching and fuel-stacking.
2. Assessing demand elasticity with respect to specific consumer offers—both price and non-price—deemed feasible by LPG marketing and distribution companies. (Such offers may include both traditionally distributed LPG and pay-as-you-go LPG.)

3. Evaluating fuel-stacking behavior longitudinally, including drivers which motivate more or less stacking among different consumer segments.
4. The potential impacts of LPG expansion on the charcoal sector.
5. The potential effects and practicality of imposing limitations on charcoal activity, such as logging bans, charcoal export taxes, etc.
6. Assessing the effectiveness of educational and promotional campaigns to consumers regarding their preferences for LPG.

XIII. Annexes

26. Detailed Methodology – Demographic Matching Demand Analysis

Group 1– Households that do not currently use any LPG

The probability of households transitioning to LPG was modelled on the basis that there would be no LPG availability constraint.

The modelling followed a two-step approach that follows a tailored propensity score matching approach.

1. Segment the households according to their perception of LPG availability, to identify which households may start consuming LPG under conditions of full LPG availability: The 6.6 million households were separated into areas where LPG is available, and areas where it is not available to better understand consumer behaviour. Availability was defined at a household level, according to the households' reported perception of LPG availability. LPG was considered to be available for a household if they reported LPG as always or often available, as compared to areas with no LPG availability, that report LPG is rarely or seldom available. Therefore, there are two groups:

- Group 1A: Households that report no or rare LPG availability. 4.71 million households (71% of households) are in this group
- Group 1B+2: Households that report that LPG is always or often available. 1.89 million households (29% of households) are in this group

  a. It was assumed that Group B can reveal preferences of households when LPG is available. This understanding of preferences was applied to equivalent households in Group A to identify which households are likely to transition to LPG under improved availability (details outlined below). It was assumed that only households in Group A are likely to transition to LPG under the condition of improved availability, as households in Group B have improved availability.

  b. For Group B, a logit regression was run considering income quintile; education level of household head (secondary or above); and age of household head. An earlier analysis also considered gender of household head and total household members, but these coefficients were found to be insignificant. Results are displayed in Figure 51 below.

Figure 51. Stata output for logit regression in Group 1

```
Logistic regression                             Number of obs     =      3,778
                                                LR chi2(3)        =    1016.01
                                                Prob > chi2       =     0.0000
Log likelihood =  -2097.973                     Pseudo R2         =     0.1949

------------------------------------------------------------------------------
   LPG_usage |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
   HHheadedu |   1.311523   .0966868    13.56   0.000      1.12202    1.501026
      HHAGEY |   -.011221   .0027413    -4.09   0.000    -.0165939   -.0058482
  QUINTILE_N |   .7916452   .0395528    20.01   0.000     .7141231    .8691673
       _cons |   -3.89737   .2209377   -17.64   0.000      -4.3304    -3.46434
------------------------------------------------------------------------------
```

c. The coefficients outlined above were used to calculate the probability of using LPG for each household in Group B, using a standard logit regression probability methodology, as shown by the following two equations:

$$L = \beta_C + \sum_{i=1}^{n} \beta_i X_i \qquad (1)$$

$$P(s) = \frac{1}{1 + e^{-L}} \qquad (2)$$

In equation 1, β represents the coefficients, where the subscript (C) represents the constant, and (i) represents each of 8 variables considered. X(i) represents these variables. The output of equation 1 was then used to obtain the probability of transitioning to LPG in equation 2, through an anti-log equation.

d. The probabilities calculated for Group B (as seen above) were then used to allocate households within Group B into 10 fixed deciles. The percentage of LPG users per decile in Group B was then calculated.

Table 73. Probability of using LPG and average LPG consumption for Group B (where there is existing LPG availability)

Decile	Number of households	Number of households using LPG	% Households using LPG
10 (Probability >0.9)	-	-	0,0%
9 (Probability >0.8 and <0.9)	-	-	0,0%
8 (Probability >0.7 and <0.8)	533,280	396,091	74,3%
7 (Probability >0.6 and <0.7)	222,545	151,612	68,1%
6 (Probability >0.5 and <0.6)	286,861	164,959	57,5%
5 (Probability >0.4 and <0.5)	145,635	67,751	46,5%
4 (Probability >0.3 and <0.4)	207,191	78,466	37,9%
3 (Probability >0.2 and <0.3)	144,241	43,222	30,0%

2 (Probability >0.1 and <0.2)	172,423	24,447	14,2%
1 (Probability <0.1)	180,187	4,143	2,3%

Determine the percentage of households in each segment that may start using LPG under conditions of improved availability

a. It was assumed that the same consumer behaviour that drives Group B, drives Group A. Therefore, the regression coefficients from Group B (see Figure 51) were used to calculate the probability of using LPG in Group A. These coefficients were used to calculate the probability that each household in Group A will use LPG. The distribution of households in Group A (across the deciles) was inferred from the distribution of households in Group B.

Table 74. Probability of using LPG and total LPG consumption for Group A

Decile	Number of households	Number of households using LPG	% Households using LPG (as in Group B)
10 (Probability >0.9)	-	-	0.0%
9 (Probability >0.8 and <0.9)	-	-	0.0%
8 (Probability >0.7 and <0.8)	527,525	290,776	74.3%
7 (Probability >0.6 and <0.7)	221,992	142,449	68.1%
6 (Probability >0.5 and <0.6)	410,249	90,485	57.5%
5 (Probability >0.4 and <0.5)	264,931	123,744	46.5%
4 (Probability >0.3 and <0.4)	475,929	181,831	37.9%
3 (Probability >0.2 and <0.3)	436,786	127,550	30.0%
2 (Probability >0.1 and <0.2)	772,982	116,212	14.2%
1 (Probability <0.1)	1,598,727	46,774	2.3%

Through this, it is estimated that an additional 1,119,822 households could use LPG under conditions of sufficient availability. This would increase national annual LPG consumption by 97,425 MT.

Seven assumptions were tested for the logit regression

1. *One dependent variable is nominal*. This is true, as a household either does or does not using LPG.
2. *One or more independent variables are either continuous or nominal.* This is true, as gender of household head is nominal, and age of household head, income quintile, education level of household head, and total household members are continuous.
3. *Observations are independent, and independent variables are mutually exclusive and exhaustive.* This is true, as there are no relationships between the observations in each category (as they are separate households), and each variable is independent.
4. *There is a minimum of 50 cases per independent variable.* This is true, as there are 3,778 observations per variable.
5. *There is a linear relationship between the continuous independent variables and the logit transformation of the dependent variable*. This was observed through the Box-Tidwell test, as seen in Figure 52 below:

Figure 52. Stata output for the Box-Tidwell test to analyze assumption 5 for the logit regression

```
Logistic regression                             Number of obs     =      3,778
                                                LR chi2(5)        =    1042.82
                                                Prob > chi2       =     0.0000
Log likelihood = -2084.5667                     Pseudo R2         =     0.2001
```

LPG_usage	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
HHheadedu	1.284421	.0969921	13.24	0.000	1.09432	1.474522
HHAGEY	.2943013	.0744971	3.95	0.000	.1482896	.4403129
QUINTILE_N	2.372047	.5773834	4.11	0.000	1.240396	3.503698
ln_age	-.0635319	.0154972	-4.10	0.000	-.0939058	-.0331579
ln_quin	-.6920446	.2507379	-2.76	0.006	-1.183482	-.2006073
_cons	-8.986707	1.10819	-8.11	0.000	-11.15872	-6.814693

The last three terms are a product of the natural logarithms of each of the continuous variables with the continuous variables. The continuous independent variable is not linearly related to the logit of the dependent variable (it has failed the assumption of linearity). This proves the assumption.

6. *There should be no multicollinearity.* This can be seen through the variance inflation factor (VIF). A VIF of greater than 10 is often considered to indicate multicollinearity (or a tolerance of less than 0.1). As can be seen in Figure 53 below, this is not true for the variables considered, validating the assumption.

Figure 53. Stata output for the VIF test to analyze assumption 6 for the logit regression

Variable	VIF	1/VIF
QUINTILE_N	7.83	0.127658
HHAGEY	4.82	0.207426
HHheadedu	4.07	0.245849
Mean VIF	5.57	

7. *There should be no significant outliers.* A stem and leaf plot of the predict value was generated.

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27. Probit Analysis – Potential Limitations

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 the Probit analysis, this issue was worked around 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.

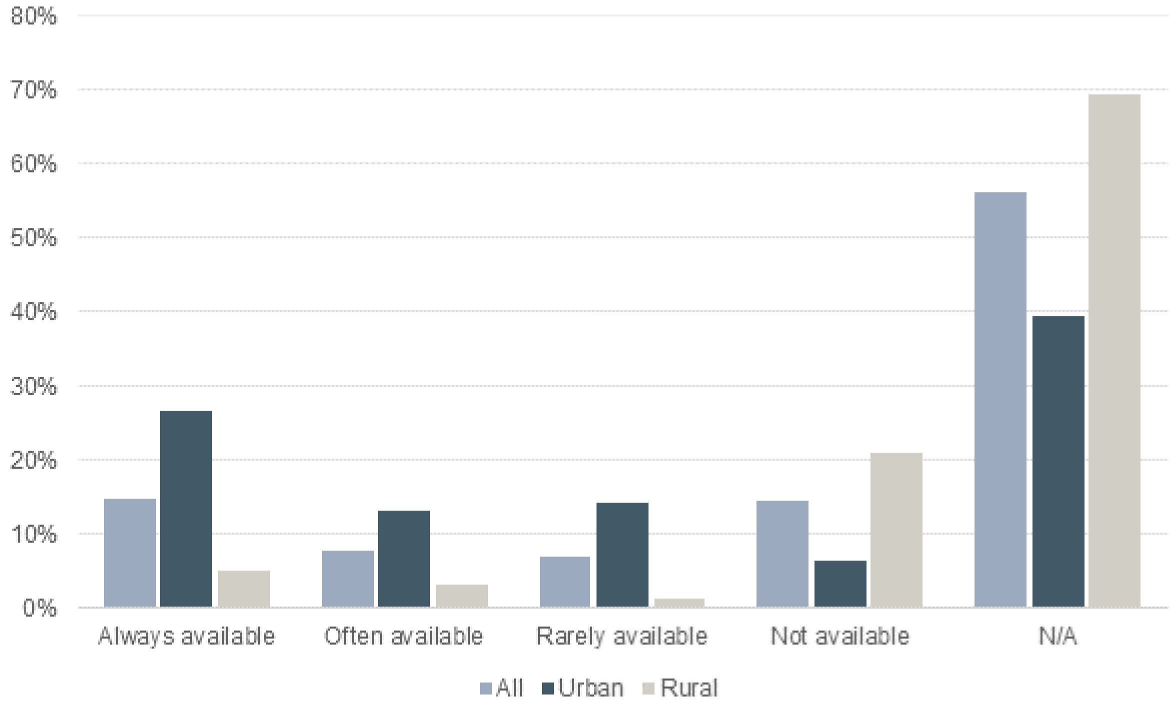
The data will also be biased by each respondent's personal perception. A household may regularly be able to use LPG, but users may have complaints about the service of their local gas vendor/filling station that go beyond the basic question of whether gas is available. One household may be too poor to 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 54 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.

However, this is not a critical issue for the Probit estimate of the potential change in market share should LPG become fully 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 54. Perception of gas (LPG) availability, rural vs. urban households



Source: GLSS 6

28. Impact Assessment Calculations and Methodology

Environment and climate assessment

Averted deforestation

Averted deforestation was calculated as the difference between the number of trees used per year before and after households begin using LPG as their primary fuel (i.e., the difference between the baseline and a scenario). This was calculated as the sum of the number of trees necessary for firewood use and the number of trees necessary for charcoal use.

The equivalent number of trees for firewood use and charcoal use was calculated using the equations below.

$$Trees(Firewood) = (Forest\ non\ renewability)\left(\frac{Firewood\ consumption}{Mass\ per\ tree}\right) = (82\%)\left(\frac{Firewood\ consumption}{100\ kg/tree}\right) \quad (1)$$

$$Trees(Charcoal) = (Forest\ non\ renewability)(Ratio\ charcoal: wood)\left(\frac{Charcoal\ consumption}{Mass\ per\ tree}\right) = (82\%)(7)\left(\frac{Charcoal\ consumption}{100\ kg/tree}\right) \quad (2)$$

The forest non-renewability factor indicates what proportion of wood for fuel was unsustainably harvested.

Carbon emissions

The mass method considers the grams of particles per kilograms of fuel and stove.

In this method, the following equation was used to calculate the metric tonnes of carbon emissions per household.

$$CO_2(eq) = 10^{-6}\left[\frac{Fuel\ consumption}{Number\ of\ households}\right][(CO_2\ emissions\ factor)(Non\ renewability) + (N_2O\ emissions\ factor)(GWPN_2O) + (CH_4\ emissions\ factor)(GWPCH_4)] \quad (3)$$

The emissions factors used vary depending on both fuel and stove, and the non-renewability factor was dependent on the fuel used. All values used can be found in the annex. The global warming potential of nitrous oxide and methane was 298 and 25, respectively[249].

The energy method considers the emissions rate of particles as grams per mega-Joule.

In this method, the following equation was used to calculate the metric tonnes of carbon emissions per household.

$$CO_2(eq) = 10^{-6}\left[\frac{Fuel\ consumption}{Number\ of\ households}\right][(CO_2\ emissions\ rate)(Non\ renewability) + (N_2O\ emissions\ rate)(GWPN_2O) + (CH_4\ emissions\ rate)(GWPCH_4)](NCV)(Thermal\ efficiency) \quad (4)$$

The net calorific value of the fuel (NCV), thermal efficiency of the stove, and the emissions rates for carbon dioxide, nitrous oxide, and methane can be seen in the annex.

The tonnage differential of black carbon emissions is calculated as the difference between the CO_2 equivalent tonnage emitted in the baseline analysis and both the upper and lower bound scenarios.

$$Black\ carbon = 10^{-6}(Fuel\ consumption)[BC\ emissions\ factor - 0.1(OC\ emissions\ factor) + 0.002(CO\ emissions\ factor) + 0.006(TNMOC\ emissions\ factor)] \quad (5)$$

The values for the emissions factors can be found in the following Chapter in the Annexes.

[249] EPA: "Emissions Factors for Greenhouse Gas Inventories", 2018

29. Impact Assessment Data Sources and Values

Environment and climate data

Table 75. Average stove emissions factors for laboratory or simulated kitchen measurements compiled from various sources (when two values were available, the higher value was used)

Stove type (as in survey)	Emissions factor - CO_2 (g/kg)[250]	Emissions factor - CH_4 (g/kg)[250]	Emissions factor - N_2O (g/kg)[251]	CO_2 emissions rate (g/MJd)[250]	CH_4 emissions rate (g/MJd)[250]	N_2O emissions rate (g/MJd)[251, 252]	Emissions factor - BC (g/kg)	Emissions factor - OC (g/kg)	Emissions factor - CO (g/kg)[250]	Emissions factor - TNMOC (g/kg)[250]
FIREWOOD										
Traditional Stone Fire	1610	8.9	0.28	577	3.4	0.0713	0.70[250] 0.70[253]	0.44[254] 0.41[255]	52.8	8.5
Improved stove (unvented)	1580	8.8	0.17	398	2.6	0.0391	1.4[250] 1.16[252]	0.55[251] 0.51[250]	42.4	9
CHARCOAL										
Ordinary Jiko	2559	6.9	0.16	382	1.2	0.0609	0.24[251] 0.22[256]	1.71[251] 4.77[256]	162.3	10.3
Improved Jiko	2622	6.6	0.24	245	0.8	0.0535	0.20[251] 0.19[253]	1.43[251] 2.92[254]	198.5	8.6
KEROSENE										
Kerosene Stove	3180	0.48	0.08	137	0.02	0.0037	0.10[253] 90[257]	0.03[249] 0.4[255]	27.2	0.34
LPG										
Gas Cooker	2532	0.04	0.15	121.025	0.02525	0.006	0.10[253] 0.011[258]	0.02[253] 0.029[258]	14.2	3.7

250 Edwards et al. (2014). Review 2 in: WHO Indoor Air Quality Guidelines: Household fuel combustion
251 Mercy Corps Database (2018) with data from IPCC (2001 and 2006)
252 USAID (2010)
253 Jeuland (2016)
254 Obeng et al. (2017)
255 IEA Bioenergy (2015)
256 Climate Solutions Consulting (2016)
257 Lam et al. (2012)
258 Shen et al. (2018)

Data used for the health analysis

To estimate the health impacts of transitioning from charcoal and firewood to LPG using the HAPIT tool, we used the following set of assumptions for $PM_{2.5}$ exposure data as summarized in Table 11.

Firewood and charcoal exposure data

Due to lack of nationally representative exposure data in Ghana, the $PM_{2.5}$ concentrations for firewood and charcoal using homes at baseline and in 2030 were derived from the Pope et al. (2017) systematic review and meta-analysis of real-life effectiveness of cooking interventions on a global scale. The review covers 42 studies (112 estimates) of solid fuel stoves (kitchen concentrations or exposure levels measured in the field, including Ghana and other SSA countries), with the majority of the studies identified for firewood burning stoves. The following assumptions were held constant at baseline and in 2030 for each scenario, using typical fuel/stoves combinations for Ghana (i.e., improved stoves without a chimney):

- Exposures levels for firewood users:
  - 578 ug/m^3 for traditional stoves (derived from kitchen concentrations of 780 ug/m^3 applying the published conversion factor of 0.742 for women by Smith et al. 2014)
  - 304 ug/m^3 for improved stoves without chimney (derived from kitchen concentrations of 410 ug/m^3 applying the published conversion factor of 0.742 for women by Smith et al. 2014)
- Exposures levels for charcoal users:
  - 519 ug/m^3 for traditional stoves (derived from kitchen concentrations of 700 ug/m^3 applying the published conversion factor of 0.742 for women by Smith et al. 2014)
  - 245 ug/m^3 for improved stoves without chimney (derived from kitchen concentrations of 340 ug/m^3 applying the published conversion factor of 0.742 for women by Smith et al. 2014).

LPG exposure data

Literature review and expert consultation identified six field studies that measure $PM_{2.5}$ exposure data and/or kitchen concentration for LPG using homes in Sub-Saharan Africa (see Table 12), including a study from Greater Accra, in Ghana. It is important to note that the table below is not a systematic review, and as such a review was beyond the scope of this engagement. Results from the GRAPHS randomized controlled study of LPG and advanced biomass stoves conducted in Ghana are yet to be published and couldn't be included for the modelling assumptions.

Based on the identified studies, $PM_{2.5}$ personal exposure measured in the field ranges between 14 ug/m^3 to 43.9 ug/m^3 (average 24.9 ug/m^3) with the exception of one study from Sudan. In this study, conducted in the outskirts of Kassala city, kitchen concentration data of the respirable fraction of particulate matter (which includes particulates up to PM 10um, not just $PM_{2.5}$) spanned a range of 280 ug/m^3 across wet and dry season from baseline average concentrations values of 900 ug/m^3 (pre-LPG intervention). 280 ug/m^3 corresponds to personal exposure levels of 207.8 ug/m^3 applying the published conversion factor of 0.742 for women by Smith et al. 2014. Background levels of ambient air pollution were not measured in the study. Given that there are still relatively few field studies conducted in Sub-Saharan Africa, which carefully document levels of ambient air pollution and stacking with other fuels/stoves combinations, and that LPG burns with minimal $PM_{2.5}$ formation, the WHO annual average Interim Target 1 (35 ug/m^3) was used as a basis for assessing the health impacts of increased primary/exclusive LPG consumption.

Scenarios assumptions

It was beyond the scope of this study to model how firewood and charcoal using households might start using improved firewood and improved charcoal stoves over time (if they did not transition to LPG). GACC (2012) estimated that, in 2012, <5% of households that consumed firewood used an improved cookstove in Ghana. In 2018, according to industry experts, 25-35% of households that primarily use charcoal used improved Gyapa firewood stoves.

Given the lack of stove data in GLSS 6 and no published forecasts predicting the percentage of firewood and charcoal using households that will use improved cookstoves in 2030, we considered some optimistic assumptions of improved access and adoption of improved firewood and charcoal stoves in 2030, in each of the three scenarios (see Table 11 for the projected number of households in each scenario). For charcoal, we used the Kenya experience as a guidance for the potential trend in adoption of improved charcoal stoves. These include:

- Firewood
  - 2020 – 0% of households using improved stoves
  - 2030 – 25% of households using improved stoves (of the projected % of households under each scenario)
- Charcoal
  - 2020 – 35% of households using improved stoves (of the projected % of households under each scenario)
  - 2030 – 80% of households use improved stoves (of the projected % of households under each scenario)

In addition, as it was not possible to predict how many biomass users will switch to LPG from traditional or improved firewood/charcoal stoves, we assumed an equal split:

- Firewood
  - 2020 – 0% of households that switch to LPG use improved stoves (of the projected % of households under each scenario)
  - 2030 – 50% of households that switch to LPG use improved stoves (of the projected % of households under each scenario)
- Charcoal
  - 2020 – 50% of households that switch to LPG use improved stoves (of the projected % of households under each scenario)
  - 2030 – 50% of households that switch to LPG use improved stoves (of the projected % of households under each scenario)

Table 76. National breakdown of LPG adoption scenarios and stove/fuel use, $PM_{2.5}$ exposure level at 2020 (baseline) with projection to 2030

Fuel and scenarios of LPG adoption	% of households (2020) (projected baseline)	% of households using traditional vs improved stoves in 2020 and $PM_{2.5}$ exposure levels	% of households using the different fuels (primary use) (2030)	% of households using traditional vs improved stoves in 2030 and $PM_{2.5}$ exposure levels
FIREWOOD				
Base case scenario	38.5%	For each scenario, assumed 100% of HH use traditional stoves without chimney $PM_{2.5}$= 578 ug/m^3 (Pope et al. (2017))	34.0%	For each scenario, assumed 25% of HH use improved stoves $PM_{2.5}$ = 304.2 ug/m^3 75% of HH use traditional stoves without chimney = 578 ug/m^3 (Pope et al. (2017))
Lower bound scenario	35.8%		31.5%	
Upper bound scenario	32.1%		23.1%	
CHARCOAL				
Base case scenario	28.8%	For each scenario, assumed 35% of HH use improved stoves $PM_{2.5}$= 244.8 ug/m^3 65% of HH use traditional stoves $PM_{2.5}$= 519.4 ug/m^3 (Pope et al. (2017))	24.2%	For each scenario, assumed 80% of HH use improved stoves $PM_{2.5}$= 244.8 ug/m 20% of HH use traditional stoves $PM_{2.5}$= 519.4 ug/m^3 (Pope et al. (2017))
Lower bound scenario	22.0%		15.0%	
Upper bound scenario	12.8%		4.0%	
LPG				
Base case scenario	27.6%	For each scenario, assumed use of standard LPG burner $PM_{2.5}$ =35 ug/m^3 (WHO IT-1)	36.6%	For each scenario, assumed use of standard LPG burner $PM_{2.5}$=35 ug/m^3 (WHO IT-1)
Lower bound scenario	37.0%		46.2%	
Upper bound scenario	50.0%		63.3%	

Table 77. Identified studies measuring LPG exposure or kitchen concentration in Sub-Saharan Africa

Study No.	1
Study Name	**Bruce, et al. (2018). "The Government-led initiative for LPG scale-up in Cameroon: Programme development and initial evaluation". Energy for Sus. Dev. 46:103-110 supplemented by personal communication**
Country/setting	Cameroon, Southwest region (peri-urban and rural)
Kitchen or personal exposure	Both kitchen and personal exposure measurements
Measurement duration	48 hours
Sample size	Total sample for both kitchen and women: exclusive wood fuel (n=61) and primary LPG fuel (n=67)
Methodology	This study reports some of the findings from the LPG Adoption in Cameroon Evaluation (LACE-1), including $PM_{2.5}$ exposure measurements in different fuel users groups: wood (exclusive use) and LPG (primary use) for kitchen, women, and children. RTI MicroPEMs were used for the assessment.
Evidence of stacking/ community level exposures	LPG used in combination with other fuels (stacking) for some cooking tasks
$PM_{2.5}$ exposure measurements ± standard deviations (where available)	Personal: wood (52.3 ug/m^3) and LPG users (14.5 ug/m^3) Kitchen: wood users (319.5 ug/m^3) and LPG users (23.7 ug/m^3)

Study No.	2
Study Name	**Bates, et al. (2005). "Smoke, health and household energy Volume 1. Participatory methods for design, installation, monitoring and assessment of smoke alleviation technologies". Final Technical Report.**
Country/setting	Sudan, Kassala outskirts (peri-urban) (Nepal and Kenya – not relevant for LPG kitchen concentrations data)
Kitchen or personal exposure	Kitchen concentrations
Measurement duration	24 hours
Sample size	Total of 30 households
Methodology	Levels of particulates (PM respirable fraction, including particulates up to PM 10µm particle size) and Carbon Monoxide (CO) were measured in a total of four times for each household which was offered the LPG intervention (before-and after invention).
Evidence of stacking/ community level exposures	By the last measurement in round 4, there is an almost complete switch to LPG. High levels of ambient air pollution
$PM_{2.5}$ exposure measurements ± standard deviations (where available)	Kitchen concentrations (PMresp): Before LPG intervention (wood) = 1180 ug/m^3; after LPG intervention = 250 ug/m^3 (weighted mean across wet and dry season). Value converted to personal exposure using the published conversion factor for women (0.742 from Smith et al. 2014): 185 ug/m^3 across wet and dry season

Study No.	3
Study Name	**Delapena, S., et al. (2018). "Using personal exposure measurements of particulate matter to estimate health impacts associated with cooking in peri-Urban Accra, Ghana". Energy for Sus Dev. 45:190-197**
Country/setting	Ghana, peri-urban Accra
Kitchen or personal exposure	Personal
Measurement duration	48 hours
Sample size	Total sample size of 45 households, with: (i) LPG only group (n=7), (ii) LPG and charcoal (n=18), charcoal only (n=11), wood only (n=9)
Methodology	This study assessed personal exposure for four fuel user groups: LPG-only, LPG and charcoal, charcoal only, and wood use alone or in combination with any other fuel. Over the duration of the monitoring period, the study conducted three consecutive daily household visits to measure: continuous measurements of personal exposure to $PM_{2.5}$ using gravimetric equipment (UPAS); real-time measurements of personal exposure to $PM_{2.5}$ collected using light scattering monitors (only for 50% of households), and stove usage of the two most commonly used stoves.
Evidence of stacking/ community level exposures	Ambient air pollution recognized as a factor driving the majority of $PM_{2.5}$ exposures in LPG and charcoal using homes. Measurements taken in fuel stacking homes.
$PM_{2.5}$ exposure measurements ± standard deviations (where available)	Personal exposure: • LPG only using households: 24 ± 13 ug/m^3 • LPG and charcoal: 31 ± 44 ug/m^3 • Charcoal only: 30 ± 24 ug/m^3 • Wood only: 79 ± 46 ug/m^3

Study No.	4
Study Name	**Kanyiva, et al. (2016). "Household Air Pollution: sources and exposure levels to fine particulate matter in Nairobi slums". Toxics. Jul 13;4(3)**
Country/setting	Kenya, Nairobi slums (urban)
Kitchen or personal exposure	Kitchen concentrations
Measurement duration	<24 hr (between 10.4 and 11.8 hours)
Sample size	72 households from two slums in Nairobi; 69.7% of households used kerosene
Methodology	The $PM_{2.5}$ level data was collected using the DustTrak II Model 8532 monitor Measurements were taken during daytime
Evidence of stacking/ community level exposures	The study mentions that measurements were taken in LPG households using also electricity. No direct mention that community level exposure was high due to ambient air pollution in the urban setting
$PM_{2.5}$ exposure measurements ± standard deviations (where available)	Kitchen concentrations on LPG/electricity using homes: 59.1 ug/m^3 Converted to personal exposure using the published conversion factor for women (0.742 from Smith et al. 2014): 43.9 ug/m^3

Study No.	5
Study Name	**Pope et al. (2018) "The Bottled Gas for Better Life Pilot: An Evaluation of the First Microfinance Initiative in Cameroon to Support Households Switch from Solid Fuel to LPG for Cooking". 2018 Abstract Book. ISEE, Ottawa and personal communication**
Country/setting	Cameroon, Southwest region (peri-urban)

Kitchen or personal exposure	Both kitchen and personal, before and after the LPG cooking equipment was introduced
Measurement duration	48 hours
Sample size	35 households using firewood at baseline and LPG at follow up (same households)
Methodology	This study assessed the impacts on exposure of a microfinance scheme (paid back over 6 months) for LPG start-up equipment (stove, equipment and gas; US$95). A subsample (n=35) of the total households who took up the loan (n=150) took part in exposure measurements at two data points: (i) before they start cooking on LPG, (ii) and around 6 months after they received their equipment through the microloan. RTI microPEMs used
Evidence of stacking/ community level exposures	Households used LPG as primary fuel after they bought the LPG equipment (no exclusivity of use)
$PM_{2.5}$ exposure measurements ± standard deviations (where available)	• Personal: Before LPG intervention (wood) = 73.8 μg/m^3; after LPG intervention = 29.4 μg/m^3 • Kitchen: Before LPG intervention (wood) = 314.0 μg/m^3 geo mean; after LPG intervention = 33.5 μg/m^3

Study No.	6
Study Name	**Titcombe, et al. (2011). "Personal and indoor exposure to $PM_{2.5}$ and polycyclic aromatic hydrocarbons in the southern highlands of Tanzania: a pilot-scale study". Environmental Monitor and Assess., 180:461-476**
Country/setting	Tanzania, Njombe district (rural)
Kitchen or personal exposure	Personal
Measurement duration	7-8 hours
Sample size	72 households from two slums in Nairobi. Sample size: four households and one school for each fuel or fuel mix. Measurements repeated three times.
Methodology	Data were collected in Njombe district where cooking is conducted indoors due to cool climate, and heavy seasonal rainfall. Kitchens are often poorly ventilated. Sampling sites were selected to represent typical cooking practices for different income groups, including stacking with other fuels. Measurements were collected using gravimetric Personal Microenvironment Aerosol Speciation Samplers (PMASS; MSP Corporation, Model 240 PMASS)
Evidence of stacking/ community level exposures	Discussion on stacking or community level exposures not reported
$PM_{2.5}$ exposure measurements ± standard deviations (where available)	• LPG only using: 14 ± 3 ug/m^3 • Kerosene/charcoal: 88 ± 42 ug/m^3 • Charcoal: 588 ± 347 ug/m^3 • Open wood fire: 1574 ± 287 ug/m^3

30. Profiles and Statistics of LPG Sector Actors in Ghana

Licensed LPG companies in Ghana

Table 78. Ghanaian LPG companies

Company	LPG Sales Volume in 2017 (MT)	LPG Market Share	LPG as % of Total Sales Volume
Ghana Oil Company Ltd	22,298.9	8.1%	3.6%
Hills Oil Marketing Company Ltd	19,939.1	7.2%	100.0%
Xpress Gas Ltd	15,696.8	5.7%	100.0%
Manbah Gas Company Ltd	14,303.2	5.2%	100.0%
Trinity Oil Company Ltd	13,341.6	4.8%	100.0%
Andev Company Ltd	12,713.7	4.6%	100.0%
Virgin Petroleum Ltd	9,216.4	3.3%	100.0%
Midas Oil & Gas Ltd	6,403.8	2.3%	100.0%
Mighty Gas Company Ltd	5,978.8	2.2%	100.0%
Rootsenaf Gas Company Ltd	5,936.6	2.1%	100.0%
World Gas Company Ltd	5,637.3	2.0%	100.0%
Lonestar Gas Company Ltd	5,409.7	2.0%	100.0%
Royal Energy Company Ltd	5,366.6	1.9%	100.0%
Joekona Company Ltd	5,099.2	1.8%	100.0%
Lucky Oil Co. Ltd	4,935.2	1.8%	43.7%
Yokwa Gas Ltd	4,628.9	1.7%	100.0%
Anasset Company Ltd	4,546.9	1.6%	100.0%
Trade Cross Ltd	4,481.3	1.6%	100.0%
Annandale Ghana Ltd	4,317.9	1.6%	100.0%
Total Petroleum Ghana Ltd	4,283.3	1.5%	1.3%
Dukes Petroleum Company Ltd	4,168.9	1.5%	12.4%
Radiance Petroleum Ltd	4,041.9	1.5%	9.4%
Superior Oil Company Ltd	3,975.5	1.4%	53.7%
Coegan Ghana Ltd	3,883.7	1.4%	100.0%
Louis Gas Company Ltd	3,545.4	1.3%	100.0%
Quantum Petroleum Ltd	3,518.8	1.3%	11.6%
Shakainah Ventures Ltd	3,454.4	1.2%	100.0%
Gaso Petroleum Ltd	3,436.8	1.2%	26.5%
Seam Oil Company Ltd	3,405.1	1.2%	26.5%
Maxx Energy Ltd	3,355.8	1.2%	26.5%
Lambark Gas Company Ltd	3,218.2	1.2%	100.0%
Patrick K.A Bonney & Co. Ltd	3,158.7	1.1%	100.0%
Nextbons Gas Ltd	3,119.6	1.1%	89.9%
Engen Ghana Ltd	2,968.8	1.1%	8.7%
Kaysens Gas Company	2,943.8	1.1%	100.0%
Alive Gas	2,825.2	1.0%	100.0%
Top Oil Company Ltd	2,700.0	1.0%	4.2%
Star Oil Co. Ltd	2,645.4	1.0%	3.0%
Kan Royal Service Station & Trading Ltd	2,585.6	0.9%	13.9%
Frimps Oil Co. Ltd	2,517.8	0.9%	3.9%
Glory Oil Co. Ltd	2,176.2	0.8%	5.1%

Company	LPG Sales Volume in 2017 (MT)	LPG Market Share	LPG as % of Total Sales Volume
Laminin Bee Ventures Ltd	2,161.5	0.8%	100.0%
Go-Gas Ventures Ltd	1,823.7	0.7%	100.0%
Ki Energy Ltd	1,808.9	0.7%	100.0%
Shelleyco Petroleum Ltd	1,727.6	0.6%	100.0%
Agapet Ltd	1,685.4	0.6%	5.2%
Pacific Oil Ghana Ltd	1,603.3	0.6%	6.0%
Triple A Lp Gas Ltd	1,599.1	0.6%	100.0%
Central Brent Petroleum Ltd	1,565.8	0.6%	100.0%
T- Tekpor Energy	1,527.3	0.6%	100.0%
Baffour Gas Company Ltd	1,524.0	0.6%	100.0%
Ap Oil & Gas Ghana Ltd	1,307.2	0.5%	8.5%
Cent Eastern Gas Ltd	1,144.4	0.4%	100.0%
Riema Company Ltd	1,098.2	0.4%	100.0%
Oando Ghana Ltd	1,061.5	0.4%	17.3%
So Energy Gh Ltd	1,051.9	0.4%	4.2%
Dabemens Gas Co.	1,035.8	0.4%	100.0%
Rural Energy Resources Ltd (Runel)	1,020.0	0.4%	20.5%
Thomcof Energy Ltd	943.5	0.3%	25.6%
Champion Oil Co. Ltd	888.2	0.3%	2.9%
First Gas Company Ltd	856.7	0.3%	100.0%
Maxx Gas Ltd	833.0	0.3%	100.0%
Norgaz Petroleum Ltd	705.5	0.3%	100.0%
Benab Oil Company Ltd	675.4	0.2%	4.7%
Orient Energy Ltd	666.7	0.2%	14.4%
Da Oil Co. Ltd	622.1	0.2%	100.0%
Petroleum Solutions Ltd	553.5	0.2%	1.1%
Puma Energy Ghana Ltd	417.3	0.2%	0.2%
Jusbro Petroleum Co. Ltd	413.7	0.1%	3.7%
Crown Petroleum Gh. Ltd	380.9	0.1%	3.7%
Rich Oil Company Ltd	315.7	0.1%	2.7%
Fraga Oil Gh. Ltd	282.7	0.1%	3.1%
Cash Oil Company Ltd	246.3	0.1%	1.3%
Union Oil Ghana Ltd	231.8	0.1%	0.7%
Plus Energy	212.6	0.1%	2.9%
Ev. Oil Co. Ltd	201.0	0.1%	1.9%
Petrobay Oil Ltd	191.2	0.1%	1.1%
Venus Oil Company Ltd	61.1	0.0%	0.8%
Unique Oil Company Ltd	32.3	0.0%	1.5%
Kings Energy Ltd	23.3	0.0%	0.3%
Zen Petroleum Ltd	22.5	0.0%	0.0%
TOTAL	276,702.8	100.0%	

Highlighting indicates a company reporting only LPG sales during 2017.

Profiles of key LPG sector players

Producers

Tema Oil Refineries Limited

Tema Oil Refineries (TOR) is the only petroleum refining company in Ghana currently producing LPG from crude oil refining.

The refinery itself is situated in Tema, approximately 24 kilometers east of the capital, Accra.

TOR was originally named the Ghanaian Italian Petroleum (GHAIP) Company and incorporated as a Private Limited Liability Company under the Companies Ordinance (Cap 193) on December 12, 1960. It was wholly owned by Italy's ENI Group (Ente Nationalie Indrocarburi). The Government of Ghana bought all the shares of GHAIP in April 1977 and became sole shareholder. In 1990 the name was changed to Tema Oil Refinery.

TOR procures crude oil, which it refines into petroleum products, a by-product of which is LPG. TOR has a nominal LPG storage capacity of 10,560 MT which is used to store TOR's own production and to store imports by BDCs (for a fee) subject to the availability of storage space.

A nine-member Board of Directors oversees the company. Eight of the members are non-executive members and are appointed by the sole shareholder, the Government of Ghana. The Board then appoints the Managing Director. The management is made up of the Managing Director, nine General Managers, and additional layers of managers and supervisors. TOR has a total staff strength of 800.

Ghana Gas Company

The Ghana Gas Company (GGC) was formed at the direction of the President of Ghana in 2011 under the Ministry of Energy to build, own and operate infrastructure for gathering, processing, transporting (such as by pipeline) and marketing of natural gas resources in the country.

Since its incorporation, GGC executed the Western Corridor Gas Infrastructure Development Project (WCGIDP). The WCGIDP is the first phase of a gas infrastructure development program to monetize natural gas from Ghana's offshore fields. The GGC first phase, currently in operation, comprised an offshore raw natural gas pipeline, an onshore natural gas pipeline, a gas processing plant at Atuabo, a processed (lean) natural gas pipeline, and an office complex. The gas processing plant is designed for a capacity of 150 million standard cubic feet a day (mmscfd) of natural gas and is projected to produce 500 – 800 MT of LPG per day at full capability. A second phase is currently being developed (i) to enable the export of natural gas liquids (NGLs) and condensates using offshore facilities, providing a safer alternative to the current use of road tankers and (ii) to expand the capacity of the natural gas processing plant to 350 mmscfd.

While the initial LPG production rate at the Ghana Gas Atuabo Gas Processing Plant (GPP) was projected to be up to 800 MT per day, based on receiving 120 mmscfd of raw natural gas from the Jubilee field, actual production has been in the range of 350-500 MT. This is due to lower than anticipated deliveries of raw gas from the Jubilee field.

GGC's production of LPG is proportional to its processing of raw natural gas. The LPG production yield is expected to increase with the addition of a turbo-expander to the plant's facilities, notionally in 2019.

GGC owns and operates a 4,320 MT LPG Storage facility at Atuabo comprising 4 x 1,000 MT Horton Spheres. Evacuation of LPG from the facility to end users is through the Quantum Terminals LPG storage and truck loading facility located 2.2 Km to the southeast.

GGC is governed by a nine-member Board of Directors and managed by a Chief Executive.

Bulk Distribution Companies

Sage Petroleum (Quantum Group)

Sage Petroleum is the leading BDC in Ghana, with bulk sales for 2017 of 110,902 MT, accounting for 30.9% of the LPG supplied into the Ghana domestic market. Sage, founded in 2009, is a wholly-owned subsidiary of the Quantum Group Limited. Sage Petroleum Ghana is headquartered in Dubai and administers its West Africa activities from its Ghanaian office.

According to the Africa Centre for Energy Policy, Quantum Terminals has a 25 year exclusive right to build and operate an LPG holding facility for the LPG from the Ghana Gas processing plant at Atuabo, through a memorandum of understanding (MOU) signed between Ghana Gas and Quantum Terminals in which Quantum and Sage are designated as the sole off-takers

The Quantum Group is active along the entire LPG value chain through its subsidiaries as follows:

Bulk storage	Quantum Terminals
BDC	Sage Petroleum
OMCs	Cardinal Petroleum Glory Oil Havilah Oil Sky Petroleum Petrobay

Financial information on the Quantum Group is not publicly available.

Fueltrade

Fueltrade is the second-largest LPG BDC in Ghana by 2017 market share, with 92,758 MT of LPG sold, accounting for 25.8% of the LPG volume that year. Fueltrade was incorporated in 2007 in response to the establishment of the BFC license category.

Fueltrade built and owns jointly with Glencore UK, a major international energy trader, a 4,000 MT LPG facility called the Tema Tank Farm. It provides storage and truck loading facilities to Ghana's OMCs. Fueltrade's stated long-term aspiration is to become the leading integrated oil and gas company in Africa. It has contemplated moving downstream into oil and gas marketing and distribution in Ghana, through a new affiliate or subsidiary, as BCRM is implemented.

Fueltrade is affiliated with Bulk Ship & Trade Limited, which was registered in Ghana in 2002 as an oil trading company and was granted, in partnership with Mercuria Energy Trading S.A (METSA), an oil trading license by the NPA.

Bulk Ship and Fueltrade have joint ventures with METSA and with Geogas S.A., the world's largest international independent LPG trader.

Fueltrade imports LPG through its partnership agreement with its international partners and suppliers. The key customers of the company are OMCs, LPGMCs, and bulk fuel customers.

Fueltrade is governed by a Board of Management. Mr. Chris Chinebuah is the Executive Chairman of the company, responsible for executing the overall operational and commercial strategy, reporting to the Board. Mr. Yaw Koduah-Sarpong is the Chief Finance Officer, in charge of the financial strategy of the company.

Financial information on Fueltrade is not publicly available.

Dome Energy Resources

Dome Energy Resources handles the procurement of propane for Genser Power, imported through the Port of Takoradi for use in power generation. 82,228 MT of propane and 7,690 MT of butane were imported through the Takoradi Genser Power importation facilities.

Dome Energy Resource is registered as a wholly Ghanaian owned business entity and licensed by NPA as a BDC. Information about its governance and finances is not available.

Leading OMCs and LPGMCs

Ghana Oil Company Limited

The Ghana Oil Company (GOIL) is listed on the Ghana Stock Exchange. It is owned by

Government of Ghana	34.2%
Social Security and National Insurance Trust of Ghana	25.0%
Bulk Oil Storage and Transport (a state-owned company)	20.0%
Starmount Development Company Ltd.	5.8%
Other parties	15.0%

GOIL was originally incorporated in 1960 as AGIP Ghana as an affiliate of AGIP SPA and SNAM SPA of Italy. A third investor, Hydrocarbons International Holdings of Switzerland, acquired a 10% share in 1968. The Government of Ghana acquired all of the foreign shares in 1974 and changed the corporate name in 1976. The company was converted into a public, listed company in 2007. GOIL's primary products are petrol and diesel fuel.

GOIL has the largest retail network across the country. The company also has numerous consumer outlets throughout Ghana. The consumer outlets include companies, schools, hospitals, factories, hotels, banks and major parastatals.

In addition, there are a number of other retail outlets established to market premix fuel and kerosene to rural areas. LPG filling facilities have also been installed at some GOIL service stations and at other locations in the country.

GOIL is governed by a nine-member board, including two former Members of Parliament, and is managed by Group CEO & Managing Director Patrick Akpe Kwame Akorli, supported by a twelve-member management team. Dual Chief Operating Officers run, respectively, GoEnergy and GOIL.

The company has seen significant year-on-year growth in assets and profits. Gross turnover in 2017 for the Group was GHC 4.7 billion (approximately € 840 million at current exchange rates) with net profit after tax of GHC 65 million (€ 12 million). The company's annual reports are available at goil.com.gh/investor-relation/annual-reports.

Hills Oil Marketing Company Limited

Hills Oil was established in June 2010 as an OMC with a head office in Accra, although it focuses on LPG. It is the second largest LPG marketing company in Ghana by volume. It has a staff of about 250 people under direct and indirect employment.

Hills Oil has two affiliates:

- CEO Oil & Gas, an LPG haulage company with a fleet of 35 Bulk Road Vehicles (BRVs) and a staff of 46;
- Globex Energy, a multifuel BDC.

Hills Oil was awarded LPG Marketing Company of the Year for 2015 and 2016 at the Ghana Oil and Gas Awards. The company has a stated aspiration to become a leading oil marketing company throughout West Africa.

The company's operating strategy is franchising to independent LPG microstation operators, leveraging its transportation fleet. Hill Oil owns only three microstations of its own.

The company is managed by its owner and CEO, Mrs Ivy Manly-Spain. Her prior work experience included 17 years in America in travel, tourism and shipping. She also serves as CEO of Globex and as Managing Director of Servistar Minwax (West Africa) Limited, an importing and trading company.

Financial information about Hill Oil was not disclosed.

XpressGas Limited

XpressGas Ghana Limited is a Ghanaian-owned LPG Marketing Company (LPGMC) which began operations in 2010. XpressGas is the third largest LPGMC by volume, with a customer base of over 52,000 households and 87 food vendors.

XpressGas was established with the objective of making LPG available, accessible and affordable to all Ghanaians, wherever located, with the aspiration of eventually serving one million households.

Accordingly, XpressGas operates in all ten regions of Ghana in both urban and under-served rural areas.

The company additionally provides operational management services to microstations and bulk hauling and transportation services for OMCs, LPGMCs, institutions, and commercial consumers. In addition, it owns and operates a fleet of bulk haulage trucks, including bobtails and semi-trailers.

The firm's LPG business lines are:

- "Swap & Go". Swap & Go is a last mile distribution and consumer-financing service business unit of XpressGas. It provides branded cylinders to consumers as a precursor to the national BCRM system, going one step further by delivering its filled cylinders to customers' doors using vans and motorized tricycles and picking up the empty cylinders. It also offers stoves on a 6-12 month installment payment model for new LPG users. Cylinders requiring refurbishment are handled under contract with the Ghana Cylinder Manufacturing Company.

- Autogas. Autogas is provided to the vehicular market under the existing Ghanaian model.
- Logistics. The company has a fleet of GPS-enabled BRVs that provide LPG transportation services to other OMCs and LPGMCs and their microstation networks and bulk customers.
- Bulk LPG customers. The company also sells LPG to registered bulk users.
- Microstation operational outsourcing. The company provides management services to microstation owners who wish to outsource the operation of their facilities.

XpressGas was founded by Mr Kofi Nketsia-Tabiri, who previously served as African regional director for E+Co, a US $200 million energy investment fund focused on developing countries. The company is governed by a board of directors and managed by a General Manager, Ms Ama Brobey-Williams. It has 272 staff. Its head office is in Accra.

Financial information about the company was not disclosed.

More information is available at xpressgas.com/about-us.

Cylinder manufacturers

Two companies currently perform LPG cylinder manufacturing in Ghana. Both are Ghana-based, located in Accra. Due to high power costs, both companies import semi-finished cylinders which they finish at their facilities.

- Ghana Cylinder Manufacturing (state-owned)
- Sojafric Industries Limited

Ghana Cylinder Manufacturing Company Limited

The Ghana Cylinder Manufacturing Company (GCMC) was incorporated in 1998 to produce LPG cylinders of all sizes for the domestic and export markets. The company is state-owned. Its establishment was part of the Government’s initiatives to promote wider use of LPG as an alternative to charcoal and firewood.

The company experienced severe performance and financial problems in the mid-2010s, resulting in multiple management changes. A $500,000 capital infusion was provided in 2016 as a grant by the Clean Cooking Alliance to partially recapitalize the company.

GCMC’s capacity is 500,000 cylinders per year, albeit with limitations to the manufacturing steps it can perform due to the state of its plant and equipment. It has been operating at only about 20% of its rated capacity. The company currently imports unfinished cylinders as a raw material and performs painting and valve installation at the plant.

The Government has expressed interest to attract additional capital and, potentially, an international operating partner to assist GCMC in realizing its purpose at scale, with adequate quality, at affordable price points, and at an adequate level of profit.

The company invested in a new, fully automated line to manufacture cylinders. The new line is designed to take precut steel plates as raw material, converting these into LPG cylinders through forming, joggling, automatic welding, heat treatment, shot blasting, zinc coating and powder coating. The line is expected to be operational and debugged during 2019.

The capacity of the new line will be 1,300 cylinders manufactured per day per shift, likely beginning with one shift. At two shifts, it could reach an output level of nearly one million cylinders per year.

The company also produces table-top LPG stoves and sells LPG accessories (regulators, clips, hoses, *etc*.) for the domestic market.

The company has the stated intention of establishing an LPG refurbishment plant at Kumasi to perform repair, recertification and revalidation of (aged) LPG cylinders, all required at large scale with the transition to BCRM.

GCMC is governed by a nine-member Board of Directors and managed by a CEO.

Sojafric Industries Limited (Platinum Impex)

Sojafric is a cylinder manufacturer which sells throughout West Africa. It is one of three facilities owned internationally by Sigma Group; the others are in Lebanon and Iraq.

The company was incorporated and authorized to operate in 1997.

Its plant has the capacity to produce over 200,000 cylinders annually.

The company produces assorted sizes of LPG cylinders and table-top LPG stoves for the Ghanaian market. The company also sells LPG accessories.

The National Petroleum Authority (NPA)

The NPA is the downstream petroleum sector regulator in Ghana. LPG is included in NPA's remit. The authority of NPA is established in parliamentary Act 691, as summarized below:

The object of the Authority is to regulate, oversee and monitor activities in the petroleum downstream industry and where applicable do so in pursuance of the prescribed petroleum pricing formula.

To achieve the object, the Authority shall:

a) Monitor ceilings on the price of petroleum products in accordance with the prescribed petroleum pricing formula;

b) Grant licenses to applicants under this Act;

c) Maintain a register and keep records and data on licenses, petroleum products and petroleum marketing service providers;

d) Provide guidelines for petroleum marketing operations;

e) Protect the interests of consumers and petroleum service providers;

f) Monitor standards of performance and quality of the provision of petroleum services;

g) Initiate and conduct investigations into standards of quality of petroleum products offered to consumers;

h) Investigate on a regular basis the operation of petroleum service providers to ensure conformity with best practice and protocols in the petroleum downstream industry;

i) Promote fair competition amongst petroleum service providers;

j) Conduct studies relating to the economy, efficiency and effectiveness of the downstream industry

k) Collect and compile data on: (i) international and domestic petroleum production, supply and demand, (ii) inventory of petroleum products, and (iii) pricing of petroleum products for the information of the public which the Board considers necessary for the performance of its functions;

l) Periodically review in consultation with petroleum service providers the prescribed petroleum pricing formula and publish in the Gazette the respective formula;

m) Publish in the Gazette the ex-refinery prices and ex-pump prices of petroleum products based on the prescribed petroleum pricing formula;

n) Monitor daily the import parity price of refined petroleum products and publish the price periodically in the Gazette;

o) Collaborate with relevant institutions for purposes of this Act;

p) Oversee open and transparent international competitive bidding for the procurement of petroleum products and crude oil;

q) Approve charges for the provision of petroleum services within the downstream industry;

r) Monitor and evaluate operations of the UPP Fund established under section 62 to ensure the achievement of the object of the Fund;

s) Approve expenditure charge on the fund under this Act;

t) Publish in the Gazette user fees for monopoly infrastructure, and;

u) Perform any other function that is ancillary to the object of the Authority and assigned to it under this Act.

The NPA was also assigned in October 2017 by Presidential mandate the responsibility for implementing BCRM nationally, which includes defining the regulations for, and the structure of, the reformed LPG sector under BCRM.

31. LPG for Power

The US $1 billion Bridge Power Project at Tema, being developed by Early Power Limited, a venture of Endeavor Energy, General Electric (of the U.S.) and Safe Trading Group, will provide an anticipated 400 MW of electric generating capacity. The project will be fueled primarily by LPG during its first five years of operation. After that period, the fuel is to be switched to natural gas supplied from Ghana's natural gas fields and/or from LNG importation. The project commenced construction during the fourth quarter of 2018.

Its baseload fuel requirement is planned for 795 tonnes per day (290,000 MT per year) during its first stage of operation and 1,647 tonnes per day (600,000 MT per year) during its second stage. The input mix required is approximately 90% propane, 10% butane. Because this mix is the inverse of the existing Ghanaian LPG mix (approximately 20% propane, 80% butane), the LPG infrastructure and fuel sourcing for Bridge Power are largely complementary to the infrastructure and fuel sourcing for the residential LPG sector.

It was beyond the scope of this study to consider the long-term opportunities and issues for the Ghana LPG household market that could be created by the Bridge Power Project, except as a positive example of how international capital could be deployed for LPG-related infrastructure in Ghana at scale.

In simplistic terms, the Bridge Power Project will create dedicated LPG infrastructure which, to an extent, might be repurposed to serve other parts of the Ghana LPG market after the power project converts to natural gas as its primary fuel in approximately year six of operations. If this were to come about, certain of the importation- and storage-related LPG investment requirements detailed in this report, whose timing occurs during approximately 2025-2030, might be reduced or altered.

During the initial five-year LPG phase of the Bridge Power Project, the level of national importation of propane could notionally increase to such a level that, if national LPG import sourcing activities were pooled, economies of scale and benefits of improved negotiation power could potentially be realized during that period for both propane and (to a lesser extent) butane, benefitting both the power sector and the residential LPG market. While temporary in effect, such benefits could potentially mitigate the possible need for Government to increase end-user LPG prices to cover costs of new LPG infrastructure and distribution, as outlined in Chapter 10 (Pricing).

Ghana Gas Company bulk LPG sales that would be directed to the Bridge Power Project during its initial five-year LPG operating phase could potentially shift to domestic residential and commercial uses thereafter, reducing the required level of national LPG importation in the long term. That reduction, in turn, would reduce the effects of LPG household market expansion on the trade balance described in Part X (Environmental, Health, Social and Economic Impact Potential).

32. LPG-Related Laws and Regulations

The National Petroleum Authority (NPA) regulates the LPG market in Ghana pursuant to the following statutes, regulations and standards:

Petroleum Pricing Formula Regulations (LI 2186)

Govern the pricing of petroleum products including LPG and is enforced by the National Petroleum Authority (NPA)

Road Traffic (Use of LPG) Regulation, 1994 (LI 1592)

Regulates the use of LPG in vehicles and requires for examination (i) issued certificate and registration in respect of suitability of LPG fitting in vehicles; (ii) a sticker, renewable every six months

Local Government Act, 1993 (Act 462), Section 49

Requires permits for the siting of LPG facilities in a district, which are granted by the relevant District Planning Authority

Environmental Assessment Regulations, 1999 (LI 1652)

Stipulate that undertakings involving refined petroleum products, construction relating to products, and storage facilities be registered with the Environmental Protection Agency (EPA) and an Environmental Impact Assessment (EIA) be provided in respect of such undertakings

Export and Import (Prohibition of Importation of Used LPG Cylinders) Instrument, 2001 (LI 1693)

Prohibits the importation of used LPG cylinders into Ghana

Fire Precaution (Premises) Regulations, 2003 (LI 1724)

Require that a Fire Certificate be obtained for the establishment and use of LPG facilities; provide for setting guidelines for classification and registration of fire protection service contractors; authorize the Ghana Fire Service to enforce the code of practice regarding means of escape, firefighting and fire warning systems, as determined by the Fire Service Council

Code of Standards on LPG

Provides guidance regarding the safe construction and operation of LPG filling facilities

ISO 22991 Gas cylinders — Transportable refillable welded steel cylinders for liquefied petroleum gas (LPG) — Design and construction

This international standard specifies minimum requirements concerning material, design, construction and workmanship, procedure and test at manufacture of transportable refillable welded steel LPG cylinders of water capacity up to and including 150L, exposed to ambient temperatures

Ghana Standard ISO 13341:2010 — Transportable gas cylinders — Fitting of valves

Specifies the procedures to be followed when connecting cylinder valves to cylinders

33. Note Regarding Long-Term LPG Pricing and Availability

LPG pricing trends over spans of 12 years and beyond are not feasible to predict. Historically, global and regional LPG prices tracked directionally with the long-term movements in global and regionally-applicable crude oil price indices. Thus, price spikes of intermediate durations are possible. (The governments of some LPG-using countries protect their populations from such spikes through price-stabilization mechanisms.)

From the 2010s, LPG has increasingly tracked directionally with regional natural gas and LNG prices as natural gas / LNG pricing decoupled from crude oil pricing in international markets.

It should be noted that the LPG market clearing function performed by the petrochemical / plastics sector currently represents approximately 30-35% of total LPG global consumption. This segment is the most price-sensitive of all consuming segments. Therefore, petrochemicals/plastics consumption may provide a buffer that insulates LPG pricing to some degree for the other consuming sectors (residential, industrial, etc.), if global LPG supply tightens after 2030.

This document assumes that LPG source pricing applicable to Ghana will remain relatively stable through 2030. To estimate the effect of significant LPG price change on adoption and consumption on an absolute basis, a sensitivity analysis has been included in the demand and impacts Parts of this report.

Across a 10+ year time scale, it was beyond the practical scope of the study and analysis presented in this report to attempt to assess how relative price changes among LPG and the main Ghanaian cooking energy and technology alternatives might affect adoption and consumption beyond 2030.

34. About the NIHR CLEAN-AIR (Africa) Global Health Research Group

Goals and outline of main activities

The CLEAN-AIR (Africa) National Institute of Health Research Group has four main objectives:

1. Inform strategies to support scaled equitable uptake (and sustained use) of clean fuels across the population;
2. Quantify the impacts of scaled LPG adoption in line with governmental targets on health and climate;
3. Develop capacity through strengthening health systems to address the burden of disease from household air pollution in the partner countries; and
4. Facilitate engagement between the general public and policymakers as research is undertaken to maximize the likelihood for success in national policies to scale LPG adoption and use.

Main research and capacity building activities under CLEAN-AIR (Africa) will include:

1. Understanding current fuel use patterns, drivers for fuel choice and associations with health in rural and peri-urban communities (using surveys and qualitative methods);
2. Quantifying concentrations of, and exposure to, household air pollution (HAP) in households that use LPG and those that do not, to model impacts on both health and climate;
3. Evaluating interventions to assist communities both to adopt LPG and to use it in a sustained way (for example, using microfinance to support purchase of LPG equipment for cooking);
4. Promoting health sector capacity building activities around HAP for health professionals, in collaboration with the World Health Organization (WHO) to inform the Clean Household Energy Solutions Toolkit (CHEST); and
5. Using mixed-methods research methods, evaluate the proposed capacity building activities to bring HAP to the health training agenda in order to help practitioners sensitize communities to change their cooking fuels/ practices for prevention.

35. About the Global LPG Partnership

The Global LPG Partnership (GLPGP) is a United Nations (UN)-backed, non-profit Public-Private Partnership formed in 2012, under the UN Sustainable Energy for All initiative, to aggregate and deploy needed global resources to help developing countries transition large populations rapidly and sustainably to liquefied petroleum gas (LPG) for cooking.

GLPGP is evidenced-based and competition-neutral in its work.

GLPGP partners with host country governments at their invitation, and other relevant stakeholders, to create national plans for rapid, sustainable scale-up of LPG infrastructure, distribution and demand. GLPGP then assists with financing and implementation of key plan elements to transition the maximum viable population to LPG for cooking.

Developing countries request GLPGP's assistance to achieve the three main prerequisites for making LPG widely available and affordable:

- Plan and implement enhancements to government policies, regulations and regulatory enforcement to create the enabling environment for a viable, scalable, sustainable LPG sector;
- Provide knowledge and expansion capital to achieve critical mass of LPG supply, infrastructure and distribution systems quickly and sustainably; and
- Empower consumers, who can otherwise afford LPG fuel, to pay the upfront cost of appliances to use LPG and thereby unlock additional demand.

More information is available at www.glpgp.org.

36. Disclaimer and Safe-Harbor Statement

This document is not an investment prospectus nor a solicitation to buy or sell securities.

Certain portions of this document contain forward-looking statements that are based on expectations, estimates, projections and assumptions. Words such as “expect,” “anticipate,” “plan,” “believe,” “scheduled,” “estimate” and variations of these words and similar expressions are intended to identify forward-looking statements, which include, but are not limited to, projections of supply, demand, consumption, prices, policies, regulations, investment activity, economic and financial performance, business performance, cash flows, contracts and tenders, and other projections. These statements are not guarantees of future performance with respect to the parties associated with, or referred to in, such statements. These statements involve certain risks and uncertainties, which are difficult to predict. Therefore, actual future results and trends may differ materially from what is forecast in forward-looking statements due to a variety of factors, which include, but are not limited to, changes in (i) government policies and regulations, (ii) pricing, (iii) business strategies, (iv) the national and/or global economy, (v) exchange rates, (vi) project costs, (vii) consumer demand or preferences for energy products and services, (viii) competition conditions, (ix) market structures, (x) outcomes of litigations, (xi) outcomes of political and legislative processes, and others.

All forward-looking statements speak only as of the date shown on the front page of this document, or, in the case of any document incorporated by reference, the date of that document. The Clean Cooking for African Project and GLPGP do not undertake any obligation to update or publicly release any revisions to forward-looking statements to reflect events, circumstances or changes in expectations after the date of this report.