Norad

Final Report

Study on the Potential of Increased Use of LPG for Cooking in Developing Countries

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Multiconsult

TABLE OF CONTENTS

Executive Summary

The report presents the findings of a study undertaken for Norad regarding the **Potential of Increased Use of LPG for Cooking in Developing Countries** in July-August 2020.

The purpose of the study is to provide Norad with fact-based knowledge regarding increased use of LPG in developing countries. This includes insight into opportunities and barriers for LPG as a means to increase access to modern and affordable energy as well as impacts regarding greenhouse gas emissions (ToR).

The motivation for commissioning such a study is the fact that an overwhelming majority of households in many developing countries are characterized by lack of access to modern and clean cooking fuels and technologies. These households use biomass energy for their cooking and heating needs – in the form of woodfuels including firewood or charcoal which is often sourced from unsustainable forest outtake or highly inefficient production processes and used on primitive and inefficient cooking facilities. **Achieving the Sustainable Development Goal of Universal Access to Energy implies that 3 billion people around the world must gain access to modern fuels and technologies for cooking by 2030**. This study considers the role that LPG could play in this respect and the potential impact increased uptake of LPG could have on global climate gas emissions, forest loss, and for households currently using traditional biomass for cooking. It considers the enabling factors that need to be in place to enable such transition and the efforts by governments and international actors to promote the transition, and takes a special look at the conditions for LPG uptake in four selected countries, The DRC, Ethiopia, Ghana and Tanzania.

The findings and messages presented in this report emerge from studies and research into a broad array of literature in the field of clean cooking, biomass and forest conservation, climate change, and case studies, combined with the authors' experience and complemented by interviews with global actors, development agents, private sector and government authorities.

On the global and general level, notable findings include that

Biomass remains by far the dominant fuel used for cooking in many developing countries, in particular in Africa. Unsustainable use of forest resources for among other purposes household energy represent significant pressure on forest resources and contribute to deforestation. The close to 3 billion people world-wide that still lack access to clean fuels and technology for cooking, suffer from a range of negative effects. **The most prominent of these effects may be the detrimental impact on health**, in particular on women who are responsible for cooking in most households using biomass. Research indicates that direct exposure to smoke from traditional forms of fuels and methods for cooking leads to about 2.2-3.6 million excess deaths per year, making it the single most important cause of death among these populations and causing welfare losses in the magnitude of USD 1.52 Trillion per year. In addition to these premature deaths, indoor cooking causes a range of cardiovascular, respiratory and eye diseases. The use of LPG in developing countries in the Far East, Latin America and to some extent North Africa has increased significantly over the past 20 years. In India, Brazil, Indonesia and Morocco, to mention some, LPG is now the dominant household energy source. LPG use is increasing also in Sub-Saharan Africa (SSA), though still at a low level and mainly in large cities. **Only in a few SSA countries has LPG taken any significant share of the household energy market.** The uptake is often characterized by a phenomenon called 'fuel stacking': Households that get access to LPG use it in combination with other fuels rather than switching completely to LPG for all cooking purposes. Fuel stacking entails diversifying their energy sources, rather than relying only on one fuel for food preparation.

Technically, LPG is a by-product from the petroleum extractive industry and in abundant supply globally, but supply is unevenly distributed, and dominated by North America and the Middle East. **Bio-LPG is an exact substitute for fossil LPG**, and technical potential exists in many developing countries. So far, Bio-LPG has not been commercialized in developing countries, but a number of studies are on the way which will bring more insight and potentially create a basis for exploiting this as a renewable source of cooking energy.

In comparison to biomass, use of **LPG causes minimal household pollution and negative health impacts**. Being an *Energy Access 'Tier 4'* solution, it has lower emissions than all cooking fuels and technologies other than solar and electricity, compares positively with biogas and alcohol fuels, and is several times better than

Improved Cookstoves. **Handled correctly and subjected to proper regulation and control, it is a very safe technology**, but weak regulation and lack of control mechanisms has resulted in improper maintenance and handling in some markets and caused several serious accidents, giving LPG a reputation as unsafe.

LPG is a private sector-driven industry with significant potential for job creation and entrepreneurship, also in the local setting through engagement in the downstream part of the value chain.

Increased uptake of LPG could contribute to reduced poverty and in particular an improved situation for women and girls, who are mainly involved in cooking and fuel collection**.** Realistically, the potential for reducing the amount of time for woodfuel collection may be limited in the short to medium term, as woodfuel is mainly done in rural areas where LPG uptake will be slower. Nevertheless, transitioning to LPG can reduce the time spent by women for cooking. The positive health effects will also primarily benefit women. **Promoting LPG would be an important and strongly positive contribution on the humanitarian agenda**, e.g. if used to improve the energy situation in refugee camps across the world.

Replacing biomass fuels by LPG will reduce pressure on forest reserves, which is a significant challenge in most of the countries where biomass is widely used as household energy. Unsustainable harvesting of forest biomass gives a higher fraction of non-renewable biomass in woodfuels used for cooking. Despite being a non-renewable fuel that will imply a certain level of emissions, **LPG can contribute to reducing net GHG emissions** through more efficient combustion and cooking than biomass, leading to lower emissions of CO_2 and black carbon per unit of heated food. The exact, quantified substitution effect from such replacement however depends on a range of factors, including to what extent the outtake of biomass is sustainable in the specific country, as well as the efficiency level of the technologies that LPG would replace and the cooking methods applied. However, it is clear that the positive effect on deforestation of substitution of woodfuels with LPG will be significantly greater than by transitioning to Improved (biomass) Cookstoves.

For LPG to increase to a significant or dominant market position in Sub-Saharan African countries, an enabling environment for the sector must be in place. Elements that make up this environment include **technology and design** that make the alternative attractive in the specific cultural and social setting they are promoted. All parts of the value chain must be in place and functional, and a distribution system to enable **feasible access for the users** must exist. Ensuring this requires both public and private investments at a level that allows for economies of scale, supporting in making the sector commercially viable. Sufficient attention on policy and strategic level, with clear **responsibility allocation and appropriate regulation** of the sector, is required. Importantly, regulation must also take into account regulation of the key 'competing fuel', namely charcoal, a sector which often is strongly informal and unregulated, but often difficult to target as it is also a large employer. Further, ensuring access is often not sufficient; **knowledge and awareness to LPG as a safe and clean alternative** must be developed. Additionally, since LPG not only requires an investment into the technology (stove and cylinder purchase, or deposit) but often also represent higher running costs than the available alternatives (including biomass), it may be necessary to put in place **consumer finance solutions, smart business models, subsidies** or other ways to ensure that the affordability issue does not become a barrier. While cost-benefit analyses are usually strongly positive for LPG on the global level, on the household level the costs are often monetary while the benefits are less tangible. The additional fact that the benefits are particularly important for women and less felt by men, makes positive decision even more challenging. This increases the affordability challenge and slows transition.

Given the strongly positive effect that increased uptake of LPG as an alternative to traditional biomass based cooking and household energy use can have, and the important contribution such it would make toward achieving the SDGs', it is striking **how little attention this area has attracted in the international donor community**. On a general level, clean cooking has for decades received relatively less attention than for example access to electricity. However, even to the extent clean cooking has been in focus, LPG has received less attention and less funding than for example Improved (biomass) Cookstoves. The reason appears to be that for some donors any support to fossil energy becomes unacceptable and LPG falls outside the definition of target intervention areas. Electricity for cooking can be an attractive clean cooking option in areas where electricity access can be secured and where supply capacity is sufficient. It should however be noted that increasing by a significant amount the share of households using electricity for cooking would place strong pressure on power transmission, distribution and generation capacity, which is already constrained in many countries.

There are nevertheless a number of **global organisations that do emphasize the important role LPG can play in solving the 'cooking energy problem'**, save millions from death and disease from indoor pollution, and reduce deforestation and GHG emissions. This includes the UNDP, DIFID, WHO, Global LPG Partnership and the Clean Cooking Alliance,. The World Bank/ESMAP seem to pursue a more "technology neutral" approach to Clean Cooking.

While the LPG sector is, at least to a large extent, private sector driven, large international and global corporations are also largely absent from the scene in developing countries. In these countries, the **sector is thus relatively fragmented, characterized by many smaller, mostly national companies**.

On country level, the interviews and document review undertaken reveal that different countries have significantly diverging starting points and prospects for making LPG an important part of the household energy portfolio.

Among the four countries studied, **Ghana is the only one where LPG as taken a significant share of the market** and is set to continue to increase. The demand is increasing in urban areas in Tanzania, but ignorable in Ethiopia and, so far, in DRC.

In all four countries, biomass is the predominant source not only in the household energy mix but also in the national level primary energy use, and deforestation is a major challenge. Potential for biogas production exists in all four countries, but Bio-LPG is not explicitly explored to date. Ghana is the only country which supplies a significant share of the LPG from domestic resources (44%). Clean cooking is a focus area established policies and strategies in all four countries, but the extent to which these are followed by concrete plans and budgets vary.

Only Ghana has established **specific targets for LPG's share of the household energy market** (50%) and included LPG explicitly in their INDCs.

DRC is in the process of establishing an LPG strategy and programme, including a short term target of 250 000 in the first phase, implying an increase that is important in relative terms but also that it will take a substantial amount of time before LPG can gain any significant share of the household energy market.

Tanzania targets 75% clean cooking access by 2030 but does not identify a specific proportion targeted for LPG. Tanzania does however grant VAT exemption for LPG (but not for the stoves/cylinders).

Neither fiscal nor other benefits or specific measures to promote LPG are considered in Ethiopia. A range of supporting interventions and measures are however expected to be a part of DRC's future efforts to increase LPG use.

Tanzania has a viable **regulatory system** in place, while Ghana has defined the same but faces some challenges in phasing it in. The regulatory environment is under development in DRC, while the sector does not receive political attention in Ethiopia.

There are strong similarities among the countries with regard to the barriers that hinder increased uptake. While it requires strong and targeted efforts to get all the elements in the enabling environment in place, it appears that **availability, awareness and affordability are or will be factors of particular importance in the all countries**.

Takeaways for further consideration of LPG in the Energy development assistance agenda

The following six statements present key takeaways that emerge from the research and interviews undertaken during this study:

1. **LPG has the potential to substitute charcoal and woodfuels for a substantial part of household energy and could contribute positively toward several of the SDGs,** including Access to Energy, Climate Change, Health, and Gender/Equality (SDG nos. 7, 13, 3, and 5).
2. **LPG is 'clean' and sustainable** - although it is non-renewable - (at least in the medium term) and can represent substantial positive impact on several important sustainability factors, such as creating jobs and reducing deforestation, GHG emissions, and the number of deaths that each year are caused by indoor pollution.

3. **There has been a low level of engagement by international development partners in the area of LPG promotion** to date. With the exception of a number of global and multilateral organisations, most actors that have been most active in promoting clean cooking appear to have largely overseen the positive effect that LPG substitution can have.
4. **Possible interventions in any of the four countries studied need to take into account the starting point and conditions for promotion of LPG.** DRC and Tanzania may have the largest potential for interventions at programmatic level: with DRC at an early stage of LPG promotion and Tanzania with a positive regulatory environment, increasing demand and a potential market in large and densely populated peri-urban areas. In Ethiopia, it does not appear likely that LPG will compete with electricity by receiving particular favourable conditions as long as there is no determined policy decision to promote it as a preferred cooking solution; but LPG might be included in the energy policy dialogue with the authorities. Ghana is the country where LPG penetration has come the farthest, both as prioritized solution and in terms of market share. With favourable policies in place, assigned responsibility within the authority apparatus, and high and increasing demand, it is now implementation that needs to accelerate; besides that, the most important contribution in Ghana may be to build down the availability barrier by supporting capital mobilization to facilitate investment in building out infrastructure.
5. **There is a significant and untapped potential among urban households as well as the growing demographic spheres referred to as 'peri-urban areas'.** This market could be reached with targeted policies and support measures.
6. **LPG represents an important yet only partial solution for the billions that must gain access to 'clean and modern cooking solutions' before 2030.** The ambition of shifting the billions using biomass over to sustainable and 'clean' fuels, is likely not possible without allowing LPG to play an important role at least in the medium term. But, in particular in Sub-Saharan Africa, continued use of biomass appears unavoidable in rural areas and in the medium term. This emphasizes the need for strong efforts also to ensure widespread availability and uptake of Improved Cookstoves, although it is not as effective as LPG as a way to reduce the health burden, the pressure on forests, and GHG emissions.

Figure 0-1 Access to clean cooking fuels and technologies, with LPG as an important element, plays a meaningful role in achieving several of the Sustainable Development Goals (SDGs). While Health, Energy Access, Climate Action and Gender equality may be the most evident, development of a sustainable LPG sector can also contribute to reducing poverty and inequalities, creating jobs, and making cities and communities more sustainable. Finally, a strong international partnership can support the efforts to scale up LPG and clean cooking in developing countries.

List of Abbreviations

BCR	Benefit-Cost Ratio
BCRM	Branded Cylinder Recirculation Model
CCA	Clean Cooking Alliance
CCCD	Consumer Controlled Cylinder Model
DFID	Department for International Development (United Kingdom)
DRC	Democratic Republic of Congo
ENERGIA	International Network on Gender and Sustainable Energy
ESMAP	Energy Sector Management Assistance Program
EWURA	Energy and Water Utilities Authority
fNRB	fraction of Non-Renewable Biomass
FONAREDD	French abbreviation of REDD+ National Fund
GHACCO	Ghana Clean Cooking Alliance
GHG	Greenhouse Gas
GLPGP	The Global LPG Partnership
GOT	Government of Tanzania
GWC	Global Warming Commitment
GWP	Global Warming Potentials
HAP	Household Air Pollutants
ICS	Improved Cookstoves
INDCs	Intended National Determined Contributions
LMICs	Low and Middle-Income Countries
LPG	Liquefied Petroleum Gas
LULUCF	Land Use, Land-Use Change, and Forestry
MECS	Modern Energy Cooking Services program
MoE	Tanzania's Ministry of Energy
MT	Million ton
Mtoe	Million ton equivalent
NBPE	National Biogas Program
NDF	Nordic Development Fund
NGO	Non-Governmental Organisation
n.d.	No date/not dated
PAYG	Pay As You Go
PBPA	Petroleum Bulk Procurement Agency
PCIA	Partnership on Clean Indoor Air
PM	Particulate Matter
REDD+	Reducing Emissions from Deforestation and forest Degradation in developing countries; the role of conservation, sustainable forests management, enhancement of forest carbon stocks
SDG	Sustainable Development Goal
SLCPs	Short-Lived Climate Pollutants
SSA	Sub-Saharan Africa
TOR	Terms of Reference
TPDC	Tanzania Petroleum Development Corporation
TPES	Total Primary Energy Supply
UN	The United Nations
UNCDF	United Nations Capital Development Fund
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNHCR	United Nations Refugee Agency
WHO	The World Health Organization
WLPGA	World LPG Association

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Preface

This is the Final Report of the Study on the Potential of Increased Use of LPG for Cooking in Developing Countries.

The study is carried out by Multiconsult, assigned by Norad under the Framework Agreement for consultancy services within Energy and Development.

- The following NORAD personnel is supervising the assignment: Petter Nore
- Inge Harald Vognild (formal/contract management)

The following consultancy team members have contributed to the assignment:

- Mari Sofie Furu (Team Leader) - Multiconsult
- Leif Lillehammer (Technical lead expert) – Multiconsult
- Lars Kåre Grimsby (Researcher/Technical Expert) – NMBU

The study presents the results and findings of the authors' research. Any opinions and subjective statements are fully at the account of the authors and does not necessarily reflect Norad's views.

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1 Introduction

1.1 General

This report is the Draft Report for the Study on the Potential of Increased Use of LPG for Cooking in Developing Countries. The Draft Report provides a short introduction with a description of the background of the study followed by a section outlining the purpose and the scope of the study. The latter is then followed by a Chapter presenting the findings of the study, including country deep-dives in a separate section, subsequently followed by overall conclusions in Chapter5.

1.2 Background

Liquefied Petroleum Gas (LPG) is used worldwide for cooking, but to a lesser extent in most developing countries. LPG is a non-renewable fuel. However, it is widely acknowledged that use of LPG has few documented negative health effects compared to cooking with firewood and charcoal.

Demand for firewood and charcoal as a source of cooking energy is one important driver for deforestation in Sub-Saharan Africa. Increased use of LPG is considered as one of several possible ways to relieve the pressure on forest resources. Biomass based cooking is also a source of both climate gas emissions and indoor pollution from black carbon. Reduced reliance on forest biomass for cooking could contribute to reduce greenhouse gas emissions from land use, land-use change, and forestry (LULUCF). Reducing the need for biomass for cooking also has potential to reduce time use for and various risks associated with firewood gathering which is a significant burden on women and children in rural areas. Use of woodfuels for cooking also has significant negative effects on health due to the exposure to smoke in particular in indoor settings, which mainly impacts women and girls, which could be eliminated or reduced through switching to clean cooking fuels such as LPG.

The market for LPG for cooking in developing countries is increasing in several countries, but without targeted support the uptake happens primarily among urban and relatively wealthy parts of the population. Various barriers for uptake imply limited market-based development among the poor and in rural areas, where the majority of the population still lives.

Even in households who use LPG, LPG is often used only for part of the cooking (fuel stacking), rather than completely replacing other energy sources.

National governments and the international community have to date implemented a range of interventions to contribute to improved cooking technology in developing countries. However, compared to other parts of energy sector development assistance, the efforts in this area have been insignificant, and in particular LPG has received little attention by the traditional bilateral and multilateral donors. The clean cooking promotion efforts have only in some countries overcome the key financial, economic, technical, logistical, and socio-cultural barriers to transition.

Norway has since 2010 supported the Clean Cooking Alliance, who work broadly with the cooking energy transition agenda, including LPG. Other than this, Norwegian energy related development assistance engagement in the LPG Sector has to date been very limited.

On this background, Norad has decided to undertake a study on LPG. The study has an Energy Access perspective (SDG[1] 7) as well as a Climate Change mitigation perspective (SDG 13). Additionally, clean cooking is also relevant for SDG 3 Health, and SDG 5 Gender.

[1] *Sustainable Development Goals (UN, n.d.)*

2 Purpose and Scope of the Study

2.1 Purpose of the Study

The purpose of the study is to provide Norad with fact-based knowledge regarding increased use of LPG in developing countries. This includes insight into opportunities and barriers for LPG as a means to increase access to modern and affordable energy as well as impacts regarding greenhouse gas emissions (ToR).

2.2 Scope

The Scope of Work defined in the Terms of Reference (TOR) is threefold: (i) LPG fact-finding (global level assessment), (ii) Increase access to reliable, sustainable and modern energy at an affordable price (country studies for Democratic Republic of Congo (DRC), Ethiopia, Ghana and Tanzania), and (iii) Reduction of greenhouse gas emissions for the energy sector (global level assessment). Each section is based on a set of specific research questions[2].

(i) LPG fact-finding is intended to build a better knowledge about the technical features of LPG as fuel and as cooking method, global supply and demand of LPG, and how it compares to other fuels in terms of emissions and impact on the user, including Bio-LPG, as well as about how and by whom expansion of LPG as a cooking fuel is promoted. (ii) calls for mapping and assessment of use of LPG in four countries with focus on programmes and measures targeting increased update of LPG, barriers for uptake in the specific country setting, the potential for biogas[3] and the impact increased uptake could have on deforestation.

(iii) calls for a mapping of how LPG contributes to Greenhouse Gas (GHG) emissions, its potential for reducing such emissions from other forms of cooking, and to what extent LPG use could reduce the pressure on forest resources.

2.3 Overall Approach and Methodology, Literature Review and Sourcing of Information

The Terms of reference ask for a presentation of facts about LPG as a basis for knowledge build-up. In addition to the technical features of the fuel and its application methods, we find it important to present LPG in the context of clean cooking in general. In addition to some key knowledge facts about clean cooking where there appears to exist a large degree of consensus, we find it valuable to also explore the wide range of factors that govern the success of efforts to promote adoption and sustained use of cleaner and more efficient household energy. There appears to be less degree of consensus around these factors, but it is important to understand the interplay between these factors and why the transition doesn't happen through mere market mechanisms. Insight into specific interventions aimed at enabling transition, and why some efforts fail and some succeed, also brings about a better understanding of the complexity of the clean cooking agenda. Therefore, we have expanded the study to include a discussion around some of these factors although some may not have been explicitly included in the research questions in the TOR.

The key dimensions and factors for LPG- scaling up and sustained adoption, and their interrelationships are illustrated in Figure 2-1, e.g.:

1) Enabling environment
2) Industry structure, value chain and market rules
3) Energy pricing and costing
4) Consumer demand; and
5) User and community perceptions

2 The full list of research question is included in the Terms of Reference which are provided in Appendix III.

3 Biogas here is considered as a different product from Bio-LPG which is described in section (i). Biogas is primarily a mixture of methane and carbon dioxide, produced by the anaerobic digestion of biodegradable organic materials (feedstocks such as manure, food processing residues, waste-water treatment sludge and energy crops). Biogas generated in small sized digesters can be used for cooking and lighting and has emerged as a substitute for firewood for cooking purposes in some areas, primarily in rural East Africa (IEA 2019). Landfill gas is another gaseous fuel generated from the organic fraction of municipal waste. Landfill gas projects are becoming increasingly common in Africa. (IRENA 2015).

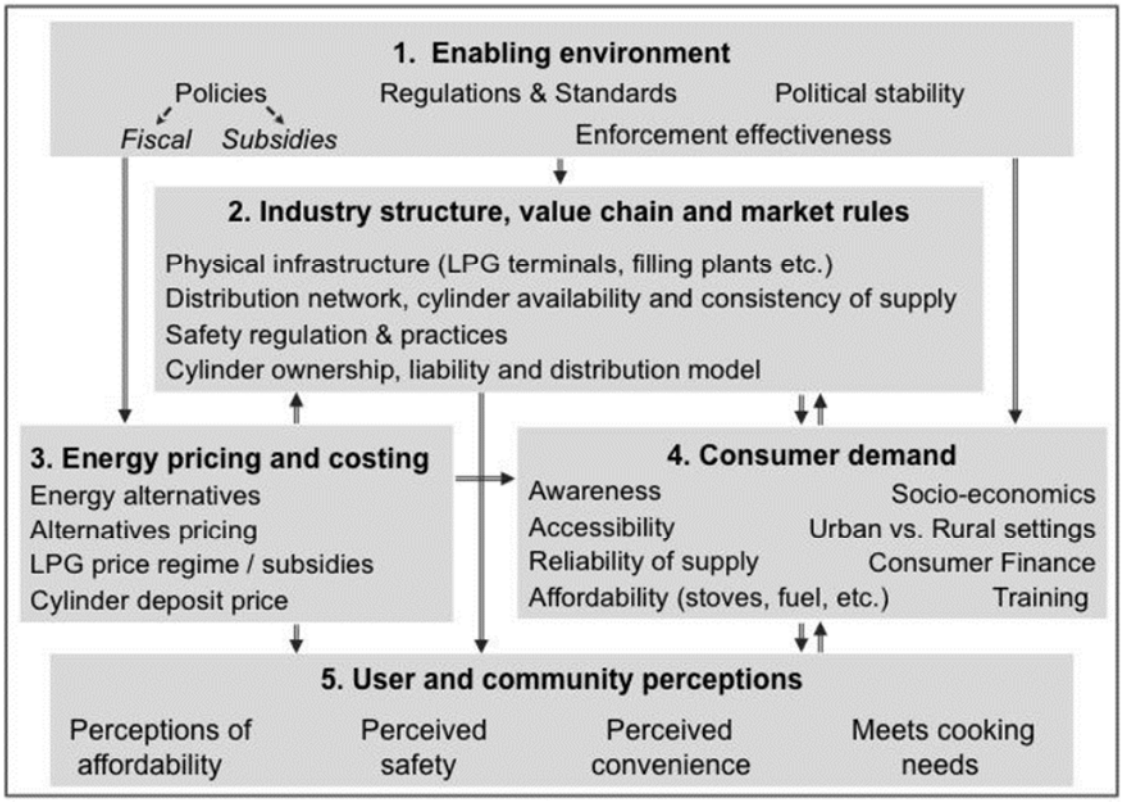


Figure 2-1 Model describing the key dimensions and factors for LPG-scaling up and sustained adoption (Source: Bruce et al. 2017 based on Rosenthal et al. 2017)

For both the global assessment and the country studies the consultant developed an LPG Fact Finding, Questions and Research Matrix[4] that guided both secondary documentation review and interviews as basis of answering out the scope and questions outlined in the ToR and Section 2.2.

Through the study the Consultant has built up a library of policy and research papers, reports and other sources of information which represents a significant knowledge base. References to these sources of information are actively used throughout the report. While the restriction on the volume of the report has limited the amount of detail and made many of the assessments relatively condensed, the library and knowledge base can be handed over to Norad for further reading if of interest. Much of the material is available online.

2.4 Stakeholder Consultations and Interviews

A detailed plan with relevant Global level interview objects as well as targeted country level interviews/consultations was drafted and presented in the Inception Report. The questionnaire matrix was used as basis for the interviews to ensure attention to all research questions. A full list of interviewees is included in Appendix I and include:

- Champions: Global LPG Partnership, Global Alliance for Clean Cookstoves
- Research: University of Liverpool, University of Dar es Salaam and Cicero
- International community/Donors: World Bank, SNV and KfW
- Private sector actors: Shell, Equinor, Kopagas

On the country level, considering the time constraint of the study, we aimed for one or two interviews for each county, targeting the following type of actors:

[4] *Presented in the June 2020 Inception Report for this study.*

- Responsible ministries and authorities;
- Regulators or agencies mandated with cooking energy promotion
- Global or international actors or donors active in the sector in the country
- Companies active in LPG business in the country

Picture: An Afghan girl carries home a new gas stove (Source: WHO 2016 – Credit: Reuters (Fayaz Kabli)

2.5 Structure of the report

Chapter 3, Global Assessment, describes the key characteristics of LPG as a fuel; the level of production and consumption in the world and in Africa, as well as the emissions from and safety and health issues related to use of LPG. Additionally, we briefly describe the market structure and typical value chains for distribution of LPG for cooking purposes, as a basis for better understanding of the enablers and potential barriers for increased uptake (Section 0). In Section 3.4 we turn the focus to the possible implications of increased use of LPG on some key development aspects, while Section 3.4 answers part (iii) of the Scope of Work, namely assessment of the potential impact on GHG emission and deforestation that a large-scale transition to LPG and away from biomass-based fuels may have. The final section looks as some of the key champions working to drive the LPG for cooking agenda, as a means to achieving the Global Sustainability Goals (SDGs), and briefly discusses why LPG as an alternative fuel for household cooking so far has received little interest among international development partners.

Chapter 4 presents the findings from the four country studies, including a brief discussion of some differences and parallels among the four countries.

Chapter 5 summarizes the findings and presents a number of key take-aways for potential further work with LPG within the Norwegian Development assistance agenda.

3 Global Assessment

There appears to be wide consensus about some key knowledge related to LPG. About 40 % of the world's population still uses solid biomass fuels such as charcoal and firewood for cooking in stoves with low efficiency, the burning of which has deleterious health, economic, and environmental consequences. Every year up to four million people die prematurely from the effects of household air pollution caused by cooking with solid fuels—almost all of them in low- and middle-income countries (WHO[5] 2014; Forouzanfar and others 2016). In addition, use of these fuels imposes massive economic costs. Household air pollution in low- and middle-income countries caused an estimated $1.52 trillion in economic losses and $94 billion in lost labour income in 2013 (World Bank 2016). Use of solid fuels for cooking in urban areas causes forest loss and degradation along major transport routes and in remote areas where land is cleared for agricultural production. The need to adopt energy efficient and clean cooking fuels and stoves is thus urgent (Van Leuween et al., 2017).

For some of the research questions there exist fewer established 'truths' and lower degree of consensus. These are in particular issues revolving around the wide range of factors that govern the success of efforts to promote adoption and sustained use of cleaner and more efficient household energy. These factors fall into a number of domains ranging from household socio-economic status and cultural preferences, through to government policy, regulation and investment. For LPG, establishing an enabling environment, improving market conditions, developing the value chains, and gain a better understanding of the demand-side of the product appear to be vital to enhance uptake (Bruce et al., 2017). It is important to understand the interplay between these factors and gain insight into specific interventions, why the transition doesn't happen through mere market mechanisms, and why some efforts fail and some succeed.

3.1 LPG Fact Finding

LPG key characteristics

Liquefied petroleum gas (LPG), known in some countries as propane, butane, bottled gas, or cooking gas—is a clean-burning and efficient cooking fuel used by almost three billion people worldwide.

LPG is a by-product of oil and natural gas production and petroleum refining and is produced in a highly purified state. It consists of a varying blend of light hydrogen-carbon compounds, the two main ingredients being propane (C_3H_8) and butane (C_4H_{10}). LPG can generally be differentiated from other energy sources on the basis that it combines portability with convenience, high energy and low sulphur content, and its clean burning nature. LPG is non-toxic, colourless and odourless; the characteristic smell is from an odorant added to aid detection of leaks (Bruce et al., 2017). Although today some 40% of LPG still comes from oil refineries, it is expected that this fraction will decline in both relative and absolute terms as LPG supplies rise due to increased natural gas production worldwide (Oglend et al. 2015).

Unlike natural gas, LPG can be easily liquefied under moderate pressure. The resulting ease of transport and storage of LPG gives this fuel considerable advantages in terms of efficiency and distribution in LMICs compared with other major clean cooking alternatives. Electricity for example, while clean (at the point of use) and practical, requires costly and extensive distribution infrastructure as well as sufficient generation capacity – the development of which represents its own environmental and climate related challenges, for example in the case where power generation is based on fossil sources. Small-scale off-grid solutions have to date limited generation capacity and in rural areas where these prevail, limited availability and cost of electric cooking equipment is an additional limitation. Natural gas is not available in many low and middle-income countries (LMICs) and has to be piped into homes, also requiring distribution infrastructure. As electricity and natural gas grids can successfully displace LPG in cities as countries develop, LPG assets can be increasingly redeployed to peri-urban and rural settings (Bruce et al., 2017).

Bio-LPG is a non-fossil fuel, produced from renewable feedstocks such as vegetable oil, animal fat (e.g. tallow), waste oils or other cellulosic waste material (DECC 2014). Bio-LPG as a product has identical

[5] *World Health Organisation*

characteristics to conventional fossil fuel-derived propane or butane and LPG and can be substituted in all existing applications of LPG, from transport to cooking and heating. Current production is primarily aimed at vehicle fuel (autogas) for the European market (NESTE 2015). Under Supply and Demand below (page 14), we discuss briefly whether Bio-LPG can have a potential as alternative to LPG for cooking.

Figure 3-1 Photo: LPG cylinders in India, left (Source: Wikipedia). Bio-LPG cylinder, right (Source: GreenLPG)

Past and Present World Production and Consumption of LPG

LPG is primarily used by commerce and households for cooking and heating purposes. The residential sector accounted for almost 50% of LPG global consumption in 2014 (Argus and WLPGA, 2015), representing, together with the petrochemical sector at 28%, the dominant users. Globally, LPG is currently in abundant supply and its production has recently been growing at 3% to 4% a year, such that LPG availability has consistently exceeded consumption (Figure 3.2). From 2009, this trend has been mainly the result of US shale gas development, which provides LPG as a by-product (Øglend et al. 2015). In 2014, LPG production LPG surplus reached almost 10 million tonnes, equal to 3.5% of total production (Argus and WLPGA 2015). Some of this excess is vented or flared at oil and gas production sites on a daily basis, thereby wasting this valuable fuel resource and emitting the fuel carbon back into the atmosphere.

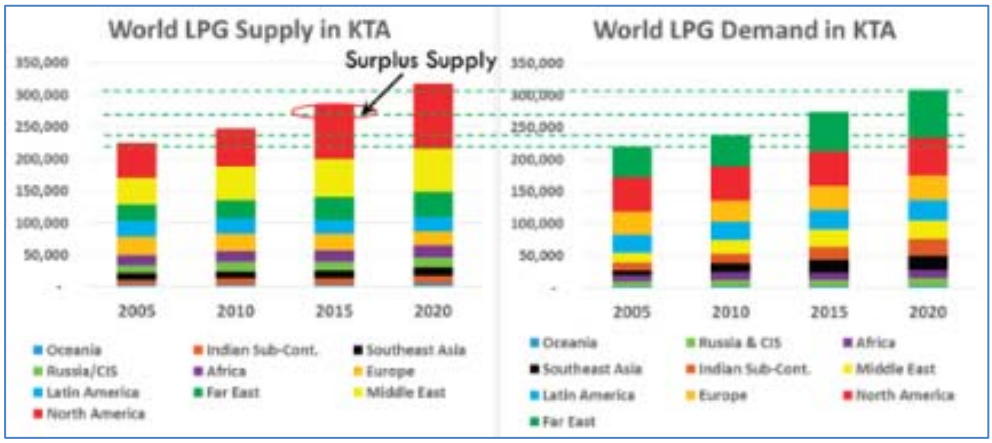


Figure 3-2 Source: Butane-Propane News, August 2020/World Energy Consultants LLC

In 2020, total global production of LPG is expected to pass 300 MT, with an estimated surplus of 10-15 MT[6].

All world regions currently produce LPG, with North America, the Middle East and the Asia-Pacific region being the top three producers. Industry forecasts predict continued growth in LPG production, driven mostly by natural gas extraction. These trends are leading many governments, including in Africa and Asia, to confidently plan LPG into their future energy portfolios. However, developing countries and regions generally remain in a situation with production deficit. In 2014, 16 million tonnes of LPG were produced in Africa,

[6] *Article: Butane-Propane News, August 2020*

primarily by Algeria (55%), followed by Angola (13%), Egypt (10%) and Nigeria (9%), while total consumption in the region was 13 million tonnes. The Asia-Pacific region produced 61 million tonnes, primarily by China (41%), followed by India (12%), Japan (9%), South Korea (5%) and Thailand (3%), and consumed 99 million tonnes (Argus and WLPGA 2015, Bruce et al. 2017).

As shown above, Africa's consumption of LPG is minor on the global scale. However, LPG can play a key role in the less developed world, and recent figures highlight LPG penetration into a number of new markets. In some countries, LPG has long been an aspirational fuel choice for many urban and rural poor (Van Leeuwen et al. 2017). Sub-Saharan African growth was at almost 9%, with Nigeria leading the way with an estimated consumption of 780,000 t/yr. The country is likely to be the first in sub-Saharan Africa to consume more than 1 MT annually in the next few years. Robust economic growth in a number of countries combined with additional imports — mainly from the Mideast Gulf — resulted in most countries in the region seeing additional uptake of LPG. Further primary infrastructure projects in Kenya and South Africa among others are expected to help sustain this trend in the future (Argus 2019).

LPG supply – demand balance

Globally, an LPG surplus exists: it is an unavoidable by-product of oil and natural gas production and oil refining, and some of the surplus goes to waste through venting or flaring at oil and gas production sites, spewing carbon back into the atmosphere instead of putting it to use. On a domestic level, however, it is a scarce resource: many countries need to import LPG, which is a drain on already strained foreign capital reserves. Oil-rich countries such as Ghana and Nigeria have the resource available, but investment in refining or processing plants is necessary. While Ghana has invested in two LPG plants based on the oil and gas exploration, Nigeria to date has no such plants, despite a government ambition to be self-supplied with LPG.

Bio-LPG as a substitute for fossil LPG

Production of renewable LPG is already underway and holds promise for further expansion. Traditionally, LPG (propane, butane and the mix of the two) has come from fossil fuel sources, as a by-product of primary oil and gas production and of oil refining. **Bio-LPG**, on the other hand, refers to green LPG that comes from renewable sources. Both propane and butane Bio-LPG is green, climate-friendly and part of the progression toward a circular economy, while being compatible with, and usable in, existing LPG infrastructure and markets.

To date, Bio-LPG is only pursued in developed markets, as a by-product of bio-diesel production (propane Bio-LPG). Appropriate policy and investment could make bio-LPG production available for the market and enable its contribution to the supply of cooking fuel (Bruce et al. 2017), but to the extent of our knowledge, no developing country has yet embarked on this strategy at scale.

Under a grant from the UK DFID[7] Modern Energy Cooking Services program (MECS), GLPGP is leading an analysis entitled *'Assessing Potential for Bio-LPG Production and Use within the Cooking Energy Sector in Africa*'. The final report was published in September 2020[8].

The evidence summarised in the GLPGP 2020 Report indicates that there are economically viable methods to make butane Bio-LPG from renewable feedstocks, especially organic wastes in low and middle-income African settings. For example, Bio-LPG can be produced using the biogas coming from anaerobic digestion of agricultural residues or of municipal solid waste. The report recommends further research into economic and technical feasibility of Bio-LPG in three key markets (Ghana, Kenya and Rwanda), and the GLPGP is expected to lead the further effort.

3.2 The LPG industry and value chain

For any interventions to increase uptake of LPG, an overall understanding of the supply chain is useful. The 'LPG Value Chain' is made up of a number of different steps between the raw form of LPG up to the final consumer.

[7] *Department for International Development*

[8] *Assessing Potential for Bio-LPG Production and Use within the Cooking Energy Sector in Africa, MECS 2020*

As will be discussed further, an important barrier to uptake (or, enabler to the extent it is well functioning), is the infrastructure required for distribution, of both LPG and the equipment, from import or production to the final customer who employ it for cooking purposes. Depending on the setting and relevant regulations, details differ from market to market, but the value chain is generally made up of the elements in the chain illustrated in Figure 3.3.

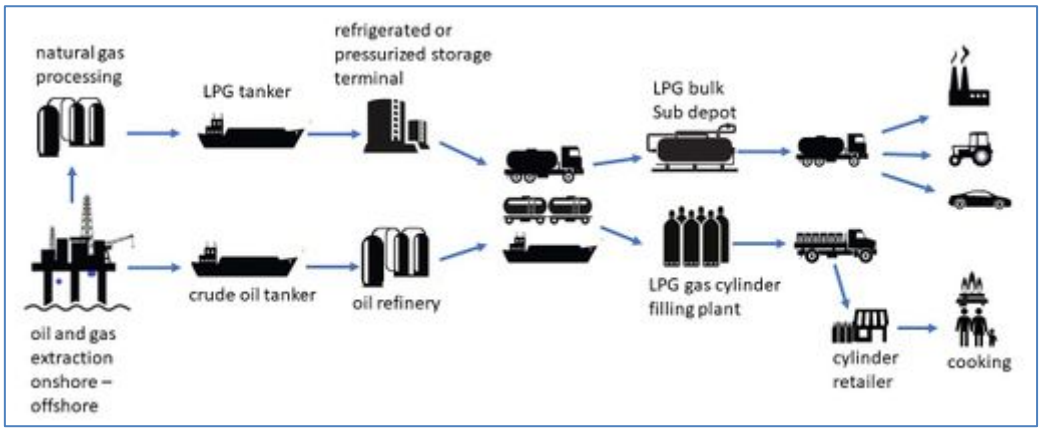


Figure 3-3 Typical LPG value chain

As explained above, LPG either comes directly from gas wells or is a by-product of crude oil refining. Subsequently, it is delivered from supply points in a liquefied form to primary bulk storage facilities, where it is stored under refrigeration or pressurisation. The owners/operators of bulk storage facilities may also be the importers and have the necessary transport facilities. LPG for cooking is brought to cylinder filling plants. The cylinders are either owned by the bottling company or by distributers or by the consumers (some more discussion on the different distribution systems below). The filled cylinders are distributed to a network of intermediaries, who operate depots and the necessary transportation facilities. The cylinders are supplied to retail points, where they are sold to customers. Empty cylinders are either returned along the chain to the filling plant or directly brought to a filling station by the customer.

Figure 3-4 Household LPG equipment (Photo: Jumia, Uganda)

LPG is thus a sector with many opportunities for commercial actors in production and services at local and central level. The regulatory and enabling environment must be adapted in order to engage commercial actors to invest and operate in the market, as discussed under 'enablers and barriers' below.

On the customer side, the purchase of an LPG stove, access to an LPG cylinder (owned or availed through deposit mechanism, see distribution models below), a tube to connect the stove to the cylinder, and possibility to refill the cylinder, is necessary.

Prevailing distribution system models

Variations of two main cylinder distribution models prevail in the markets and the choice of model and regulation of the same can have significance as an Enabler – or represent at Barrier:

In the *Consumer Controlled Cylinder Model (CCCM),* the consumer owns the cylinder and is fully responsible for maintaining the cylinder. The consumer can refill it at any refilling station.

In the *Cylinder Recirculation Model (BCRM) t*he LPG marketing company owns the cylinder and hence, is fully responsible for maintaining the cylinder. Consumers can refill the cylinder only at authorized stations of the marketing company. The consumer generally pays a deposit to obtain the first cylinder from authorized distributers, which is typically set below the cost of the cylinder, plus the purchase price of the LPG it contains. Empty cylinders are exchanged for a full cylinder of the same brand for the refill price.

Practitioners appear to strongly encourage the BCRM model to enable market growth, for various reasons. As discussed in Section 0, the choice of model influences important issues related to affordability, accessibility, safety, and commercial capital mobilization.

The main disadvantage of the CCCM is a possible decline in cylinder safety, leading to an increased risk of fire and explosion accidents. In addition, the CCCM is susceptible for black market LPG activities by unlicensed and uncertified refilling businesses disregarding safety.

Main disadvantages of BCRM are the often higher end consumer cost of the cylinder and the refilling and the exclusion of small enterprises from the LPG business .

Price of LPG use compared to other fuels and technologies

Affordability is a key potential barrier for LPG uptake (ref. Section 0). Cost comparisons will vary depending on the different country settings and the alternatives that are available for the users; but since LPG as opposed to fuelwood collection and cooking over three stones implies cash payments, the user must as a minimum participate in the cash economy. Further, while for example charcoal can be bought in small quantities depending on the cash available to the user at the time of purchase, LPG requires upfront investment in the equipment, and refilling usually is provided for full bottles, requiring upfront payments of gas for a few weeks or a month. This already excludes some people from the market.

As mentioned above, global cost comparisons are challenging because the cost of biomass varies so significantly, stove efficiency varies, and the money value of time is valued differently. Even LPG at the user level easily becomes higher as areas grow more rural, due to the cost of distribution. In this perspective, the graph in Figure 3-5 from WHO 2016[9] is illustrative of how 'cost' of any of the available technologies can be viewed from different perspectives, including emissions, time cost, and capital cost.

Evidence from Ghana, DRC and a range of other countries confirm that the net cost of transition to LPG from the technologies that LPG promotion efforts aim to abandon, usually is positive (i.e. more expensive).

In some countries, electricity is considered a viable source of energy for cooking. This primarily refers to countries which have achieved near-universal access to electricity and have reliable and cost-competitive power supply. The source of power generation will also be a factor to consider in a sustainability perspective.

Specifically, induction stoves have been considered an efficient solution where power supply is sufficient and stable. Induction stoves are suitable to cook a wide range of daily food and are much more efficient than the electric coil stoves. However, as the connected load requirement for this solution is high, it is unlikely in a short term scenario that induction stoves represent a broad-based solution for African countries[10],[11].

[9] *WHO 2014: IAQ Guidelines: household fuel combustion – Review 11: Costs and financing*

[10] *A study by TERI shows that the connected load required for 50% of households to use induction stoves at 1300 volts for 2 hours per day is almost the* double of current installed capacities *in Bangladesh, and* thirteen times *those of Kenya (Orf Online, 2019).*

[11] *Multiconsult estimated in 2017 that a scenario where between 2-7% of Tanzania's urban population use electricity for cooking would imply a power consumption of close to 1 TWh annually by 2030.*

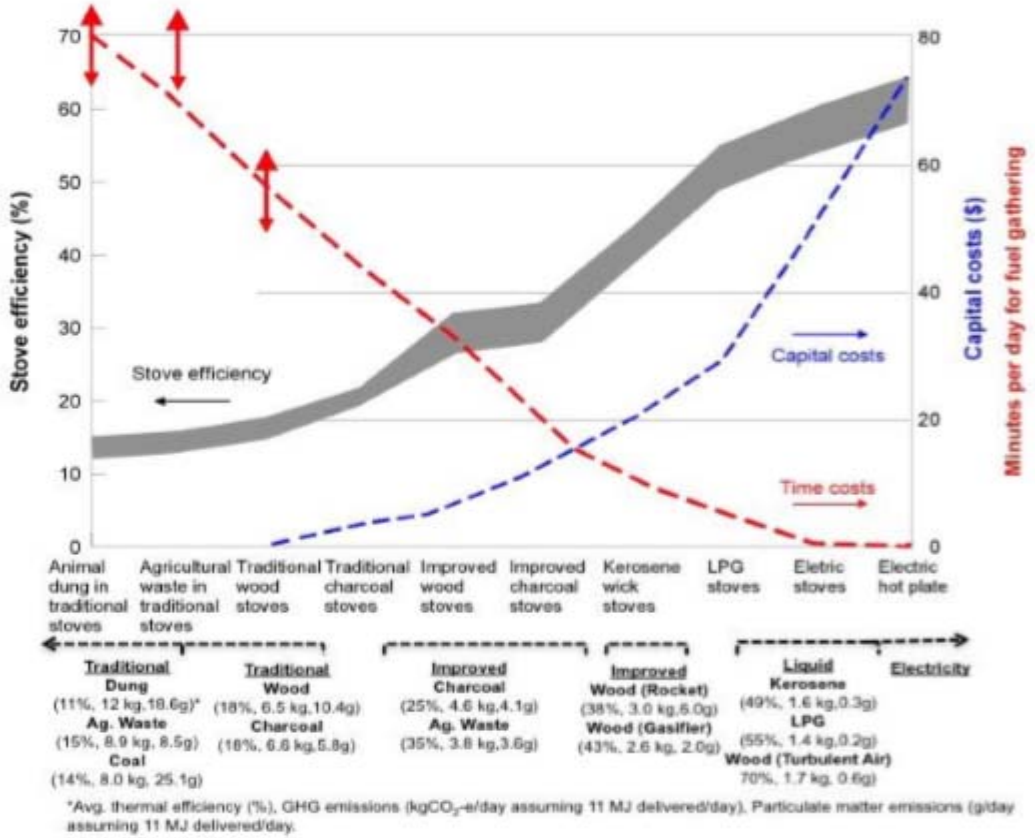


Figure 3-5 WHO 2016: Reproduced with permission from the International Institute for Applied Systems Analysis (IIASA) Note: Most emission factors are in terms of TSP not PM2.5. Specific values used for rocket and blower for PM, assumed same emission factor.

Box 1 New business models to address affordability and access barriers and enable increased uptake

Pay as You Go LPG

Just like in the case of access to electricity, there is no one-fits-all solution to reach universal access to clean cooking. Some market actors are developing innovative, context-appropriate and technologically sound solutions to make sustainable cooking available for people who until now have been barred from advancing on the energy ladder.
Pay as You Go LPG is one potential approach to address barriers in particular related to affordability among poorer customer segments. The business model is similar to the off-grid solar energy solutions offered by companies such as M-Kopa and Lumos Global, which also allow their customers to pay for their solar systems in instalments through mobile money. The concept is already implemented or in testing in Kenya, Tanzania and Rwanda.
In a PAYG LPG scheme, the household signs up and are provided with a full tank of LPG, usually against a deposit. Some companies also provide the stove on a lease basis together with the first delivery. The flow of gas from the cylinder is controlled by the company through a "smart meter" connected to the cylinder valve. The company can monitor and activate the supply of gas upon the customer's purchase of LPG credits with mobile money. Before their credit runs out, the system notifies the customer so that they can top up their credit, not risking running out of gas in the middle of cooking a meal. The company thus also knows when the cylinder is nearing empty and can contact the customer for a replacement by a full cylinder.

The key benefits with the PAYG LPG scheme include:

- By establishing themselves as service providers rather than fuel distributors, PAYG LPG companies offer free delivery and safe installation, while retaining ownership of the cylinder which gets replaced or refilled once the customer runs out of fuel; this eliminates the high cost of a cylinder for the customer and addresses safety and canister delivery issues;
- By installing a meter which enables remote monitoring of fuel consumption and the ability to switch the flow of the fuel on and off, customers are able to pay only for the amount of gas they consume on a PAYG basis, just like in the case of mobile phones or off-grid solar systems; this means that instead of paying for the total amount of gas in the cylinder, a customer can top up their credit as much or as little as (s)he can and whenever cash is available and allows the customers start cooking again without leaving their homes;
- By offering stove and accessories financing customers can pay off these critical components in instalments; making it more affordable.

However, barriers remain before this concept can truly be scaled up and make significant contributions to increased uptake. Some of these include:

- The need for the company to be actively engaging in last-mile distribution, often bringing the replacement cylinder to the customer's house, pushes for high granularity of the distribution system, and makes the model feasible only in densely populated areas. In less populated areas, with larger distances between customers, financial viability will be a high barrier. Further, the services will be more expensive than full LPG cylinder picked up from a distributor's service point by the customer themselves.
- Even when starting to adapt a new fuel such as LPG, many households do not switch fully, but continue to use several fuels interchangeably. For a service provider, this implies lower rate of turnover and challenges business viability;
- The business model is not yet proven. Business viability will require fast expansion to reach scale, and building such scale requires significant capital. While a recent acquisition in the sector (Circle Gas/Kopagas) is a positive sign, the business case must be convincing for capital to be attracted to the business of providing modern cooking solutions to Africa's population.

Box 1 New business models: PAYG. Sources: Engineering for Change, Article February 2017; Africa Business Insight, November 2017; Visit to Kopagas, October 2018 (Multiconsult); Interview with GLPGP, August 2020.

Safety issues

With regard to safety issues, focus is often on benefits of switching from solid-biomass fuels to LPG. As discussed in section 3.3, the many misconceptions of LPG as dangerous is a particular barrier to uptake, making awareness building among key users a key issue.

LPG is a non-toxic but highly flammable fuel that needs to be handled according to good safety practices. All LPG appliances throughout the supply and distribution chain (e.g. storage tanks, trucks, cylinders etc.) are designed specifically for accepting only this fuel, providing an additional level of safety and control (Bizzo et al. 2004). LPG for household use is generally stored in cylinders made of steel or, increasingly in some wealthier countries, of mixed materials. Cylinders need to be regularly inspected, maintained and 'requalified'[12], or scrapped if in poor condition. Cylinders have a life span of twenty or more years if correctly maintained. Proper cylinder and stove positioning, adequate ventilation and regular inspections of the cylinder and piping system can effectively prevent accidents (Bruce et al. 2017). Requalification standards and practices (including requalification time) vary from country to country. Effective scrapping policies are therefore important (WLPGA 2015b).

Consumer safety can be protected by adequate regulation and enforcement of safety practices, as well as by provision of adequate user training in the correct use of the LPG equipment and early detection of leaks in

[12] *A term used by the LPG industry to indicate that the cylinders need to be re-tested and certified for future safe use.*

case these occur. Where good industry safety practice and national regulations are in place and complied with, LPG does have a good safety record. Unfortunately, there exist several examples of poor regulation and enforcement leading to fires and explosions (WLPGA 2015a).

In countries where proper safety regulation is enforced, LPG cylinders are sold only by legitimate marketers and filled to the correct level (Bizzo et al. 2004). Overfilling of cylinders, as happens for example in situations where 'black markets' are active and the cylinder filling is not carried out at an authorised filling station, can increase the risk of explosions. The so-called 'cylinder recirculation model' (see Section 3.2 for description of the main distribution models) is widely regarded as a requirement if high levels of safety are to be achieved. However, in many other countries the customer is expected to own the cylinder; consequently, cylinders do not regularly come back to an expert facility for inspection and repair, thereby increasing safety hazards (Bruce et al. 2017). As will be discussed in Section 1.1, Ghana has experienced the caveats with the customer owned model and is in the process of moving to the recirculation model.

3.3 Use of LPG in developing countries - Enablers and barriers

In general, the transition to modern fuels has been slow in most low-income countries, and as population growth has neutralized positive developments, the number of people using solid fuels (including biomass such as wood, charcoal, dung, or crop residues as well as coal) for cooking has remained at around 2.8 billion since 1990 (Bonjour et al. 2013; Rehfuess et al. 2006).

As mentioned above, Sub-Saharan LPG growth has been strong; but from a very low level, and partly countered by population growth. Further, part of the LPG consumption is used for other purposes than cooking (such as vehicles and industry). The proportion of people that rely on solid biomass for cooking remains very high across the developing world, and at an average of 72% in Africa (WHO statistics 2018). Only five Sub-Saharan African countries had reached clean fuels uptake above 60% in 2018.

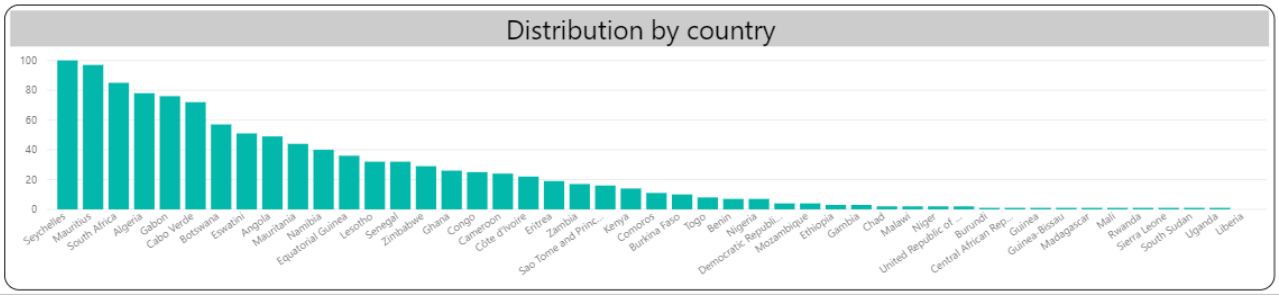


Figure 3-6 Sub-Saharan Africa, Proportion of population with access to clean fuels and technologies in 2017 (including electricity, LPG, natural gas, biogas, solar and alcohol fuels), Source: WHO 2018

To enable a more profound transition to clean cooking alternatives like LPG, it is necessary to understand what factors can enable – or if not in place act as barriers for such an uptake.

Such enablers and barriers have been comprehensively reviewed at global level in a range of studies, including those of Puzzolo et al. (2013) and Rehfuess et al. (2014). Some comprehensive country studies include those of Gould and Urpelainen (2018) for rural India and Thoday et al. (2018) for Indonesia. Puzzolo et al. (2013) and Rehfuess et al. (2014) further developed a comprehensive framework of factors influencing uptake of cleaner cooking alternatives (Figure 3-7).

The framework encompasses seven domains. The framework highlights the central role of fuel and technology characteristics and shows how two other domains—characteristics of households and settings; knowledge and perceptions—primarily operate at the household and community level. The remaining four domains—financial, tax, and subsidy aspects; market development; regulation, legislation, and standards; programmatic and policy mechanisms—primarily operate at the program and societal level (Figure 3.4). Enabling or limiting factors affecting short-term adoption may differ from those affecting longer-term sustained use. In addition, uptake may occur equitably or inequitably across population groups that differ by socioeconomic status and urban–rural location and is also likely to be influenced by gender-related factors.

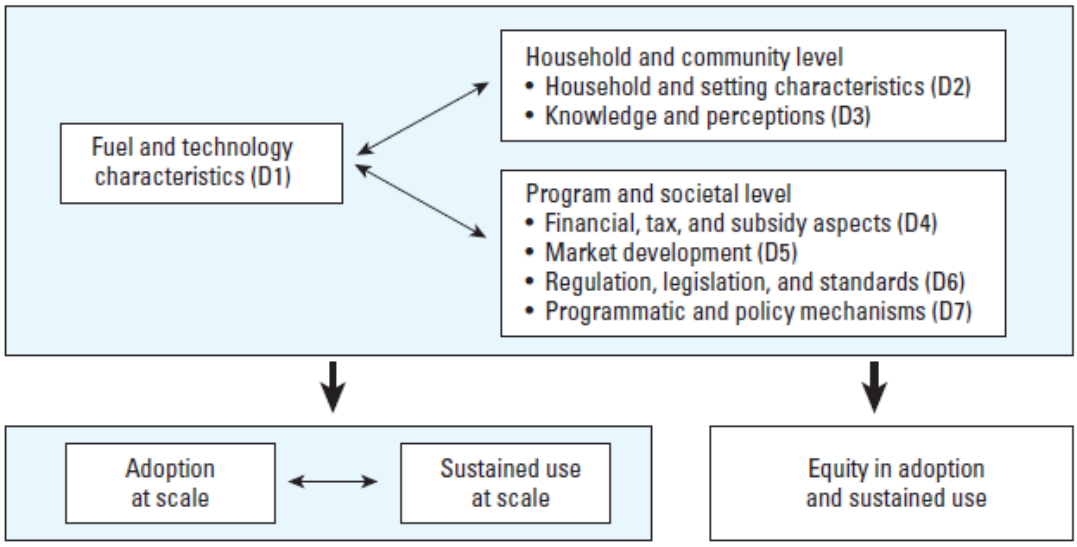


Figure 3-7 Framework of domains for the factors enabling or limiting uptake of cleaner cooking technologies. This framework illustrates how seven domains (D1-7)—one relating to the characteristics of the intervention, two operating at the household/community level, and four operating at the program/societal level—affect uptake of IS. Uptake at scale comprises short-term adoption as well as longer-term sustained use and may take place in equitable or less equitable ways. Factors within these seven domains may enable or limit one or several aspects of adoption, sustained use, and equity (Rehfuess et al. 2014).

The work of Rehfuess et al. (2014) reviews and assess enablers and barriers for Improved Cook Stoves (ICS) in general. Puzzolo et al. (2013) applies the same framework to LPG, as summarized in the following.

Domain 1: Fuel and technology characteristics

Fuel savings and impact on time: Although LPG is generally considered to be an expensive fuel, when costs for biomass fuels are relatively high, LPG can be favoured. In Indonesia, monthly savings associated with LPG use instead of kerosene use reported by users was considered an important enabler for successful fuel switching (Budya and Arofat 2011). LPG is also reported to cook faster than kerosene and firewood stoves (Budya and Arofat 2011, Terrado and Eitel 2005).

General design requirements: Many studies confirm the fundamental requirement that ICS for woodfuels, as well as LPG stoves, are designed to meet user needs in preparing local dishes, with traditional cooking utensils and available fuels, and matching the preferred tastes. In some settings, stove designs must also meet other household energy needs such as seasonal space heating. Failure to effectively address these issues almost guarantees that the improved stove will not be adopted and used long-term or that it will be used for some but not the majority of purposes. Short durability, and demanding cleaning and maintenance requirements, can also represent barriers for uptake (Rehfuess 2014).

Domain 2: Household and setting characteristics

Socio-economic status: Income and/or household expenditure are important features in LPG uptake, and a switch seems to require a certain threshold of income or household expenditure (USAID 2005). Higher education among women and men also increases uptake (Rehfuess et al. 2014).

Household ownership structure: Larger family size appears to act as a barrier to adoption, possibly due to the low value assigned to time and labour used to collect firewood and/or the need to cook for more people. Large household size is often associated with low socio-eco status. Meanwhile, house ownership is an enabler, which is likely to partially reflect socioeconomic status, but also willingness to invest in home improvements. In fact, the lack of a permanent home or kitchen, as well as space limitations, can be impediments to purchasing a built-in stove (Rehfuess et al. 2014).

Multiple fuel and stove use (stacking): Most studies from developing countries show that LPG use is accompanied by use of other fuels, and most often traditional and biomass (also referred to as 'fuel stacking' elsewhere in literature and in this report). Widespread use, and availability, of LPG will act as an enabler, whilst the perception of lower fuel cost associated with the more traditional fuels will act as a barrier of change for LPG becoming a relatively more important fuel in the household mix (Puzzolo et al. 2013).

Geography and settings: Adoption and use is generally greater in urban settings, where population is denser making distribution points accessible for more people, knowledge dissemination reaches more people, and income levels are higher on average. Rural areas, in addition to being on average poorer, face additional barriers, including relatively higher prices of LPG, transport over long distances to get to refilling stations, less access to credit etc. (Puzzolo et al. 2013). Additionally, woodfuel and charcoal are relatively cheaper and easier to access in rural areas, making LPG less competitive. In this perspective, it is worth mentioning the potential in the fast growing 'peri-urban' spheres in many developing countries. These are areas where population density is high, which enables efficient distribution systems and creates local entrepreneurship opportunities. Incentives (financial, awareness, business development support, charcoal regulation etc.) may however be required for this market potential to be reaped.

Domain 3: Knowledge and perceptions

Smoke, health and safety: Negative perceptions and fear of LPG explosions or lack of knowledge on the safe use function are important challenges to overcome in promoting LPG adoption. On the other hand, various studies report that LPG is often perceived as a cleaner fuel than wood, which can act as an enabler (including that of having a cleaner kitchen) (Puzzolo et al. 2013).

Total perceived benefit: Prior knowledge of LPG use was usually accompanied by a greater level of awareness of its benefits and increasing willingness to adopt. Knowledgeable users consider LPG equipment easy to use (Puzzolo et al. 2013, Budya and Arofat 2011). This emphasizes the importance of awareness and knowledge building.

Tradition and culture: Cultural aspects such as cooking habits and food taste are also important in relation to uptake of LPG. Preference for food tasting of smoke and the habit of cooking outside can reduce the likelihood of LPG adoption and use, especially in rural areas. On the other hand, the widespread and growing use of LPG in many developing countries suggests that such preferences only operate as a barrier in some circumstances, and can change over time and with increasing familiarity with LPG (Puzzolo et al. 2013).

Domain 4: Financial, tax and subsidy aspects

As shown in section 3.1, transitioning from traditional fuels to LPG requires an initial investment for equipment as well as cash payments for fuel throughout the life of the equipment. Affordability barriers thus must be addressed on several levels: financing the upfront investment, and running costs, both of which are more expensive than traditional fuels. Subsidies, consumer finance, and suitable business models are therefore important enablers for transition.

Stove cost and stove subsidies: As LPG use requires up-front purchase of a stove, the cost is an important barrier to adoption and/or repurchase. Such affordability challenges may be overcome through government- or market-led economies of scale to reduce stove prices, or stove subsidies (Reuhfess et al. 2014, Puzzolo et al. 2013). Establishing leasing or rental options could be alternative approaches to reduce this barrier, if feasible from a business perspective.

Fuel cost and subsidies: The price of the LPG fuel itself (as opposed to the initial costs of stove, regulator and gas bottle) is an important issue in relation to resistance to fuel switching, especially for poorer and rural households. For these, low prices and availability of traditional fuels and poor road infrastructure (which increases fuel price due to transportation costs) negatively influenced uptake. Fuel subsidy may therefore be an issue of critical importance (Puzzolo et al. 2013). The fact that the majority of charcoal, which LPG in many cases would replace, is distributed outside the formal economy and thus escape VAT or other taxation regimes, giving this LPG an additional relative disadvantage. In countries where biomass has become less available due to tough restrictions on outtake/protection of forests, LPG/non-biomass options become more viable.

Payment modalities: Methods of payment for LPG stoves and bottles include loans, credit and payments in instalments. Since users struggle with the recurrent high cost of LPG refills, the use of smaller 3 kg bottles to reduce these costs was found to be beneficial (Puzzolo et al. 2013, Budya and Arofat 2011). Other initiatives include smart metering pay-as-you go systems, for example PAYG in Kenya and Kopagas' Pay as You Cook model in Tanzania and Kenya (see Box 1 and Chapter 1).

Programme subsidies: Aspects such as the provision of financing facilities for retailers, financial incentives to rural entrepreneurs to set up an LPG business, and programmes/initiatives covering the costs of user training on safe LPG use, are all reported as positive factors in setting up sustainable LPG markets (Puzzolo et al. 2013).

Domain 5: Market development

Demand creation and supply chains: Creating demand through appropriate and, potentially, setting specific strategies, is important for LPG uptake (demand creation). Modes of demand creation include general awareness-raising activities about the benefits of LPG (e.g., through media campaigns) and personal contact through women's organizations or company representatives. Product demonstrations and "word-of-mouth" advertising appear to be the most important general drivers of adoption. A demand-driven approach facilitates long-term adoption and use, whereas coercive approaches based on deliberate misinformation or false promises are likely to favour rejection of the LPG technology despite initial uptake. Demand can be met only if those raw materials, stove parts, or complete LPG stoves not available locally are made accessible to users through well-managed supply chains. Supply chains may be newly established or make use of existing production and dissemination networks. Road infrastructure has an impact on distribution and availability, including prices (Reuhfess et al. 2014).

Business and sales approach: Both government-led and market-based programmatic approaches ultimately rely on functional, self-sustaining businesses to produce, disseminate, and maintain LPG stoves in order to be successful (Reufhess et al. 2014). On the plus side, the fact that the sector is largely private sector driven creates a big potential job creation effect of increased use of LPG.

Domain 6: Regulation, legislation and standards

Regulation, legislation and standardisation are key factors in creating an enabling environment. Policy and legislation are fundamental to controlling LPG price volatility, including importation issues and regional price variations. Price volatility and lack of control over large regional price differentials adversely affect adoption and sustained use of this fuel. Additionally, as will be seen for example in Ghana, the regulation of cylinder distribution has significant impact on the ability to scale up investments and increase availability into gradually more rural areas, and on safety in maintenance and refilling.

In regard to the relative cost of LPG as an alternative to charcoal, the regulation of the charcoal industry is an important factor to consider. In countries where biomass has become less available due to tough restrictions on outtake/protection of forests, LPG/non-biomass options become more viable.

Enforcement mechanisms: Enforcement of standards is required to ensure LPG safety; lack of oversight mechanisms and insufficiently regulated expansion of the LPG market contribute to the release into the market of unsafe products, which may further reinforce general fears concerning the use of LPG (Budya and Arofat 2011).

Domain 7: Programmatic and policy mechanisms

Institutional arrangements: Strong institutional arrangements to prepare for large-scale implementation and the presence of an implementing agency with overall responsibility were argued to be an essential component for the success of the LPG conversion programme in Indonesia. Government support at the highest level was also found to be important in this programme. In particular, having one ministry to co-ordinate other ministries and stakeholders facilitated programme implementation (Budya and Arofat 2011). In general, various institutional arrangements are needed to address key issues of price volatility and ensuring adequate LPG imports (Puzzolo et al. 2013). Despite this knowledge, coordination among all the stakeholders

in the clean cooking agenda is often weak, or non-existent. The main reason for this appears to be that clean cooking is often not recognized as a separate field of and responsibility is not assigned to any entity. At the same time, there are a long range of different stakeholders. In the public space, the issue touches into the mandates of energy authorities, health authorities, authorities with responsibility for rural development, natural resource authorities, to name some. Further, there are diverging interests within particular the charcoal industry, a huge employer in many countries, as a strong lobbying group which may feel threatened by LPG as an alternative to charcoal, potential takes full responsibility

Training: Small-scale initiatives to support user training for safe use of LPG are valuable and were found to positively affect demand. Provision of user training is an aspect which should not be overlooked as a means of reducing fear of explosions (Bates 2009). Training through the value chain, e.g. local business and providers, can also play an important role.

Developing sustainable LPG promotion programmes

According to GLPGP, experience shows that the above factors are all necessary elements to consider in developing plans for increased uptake of LPG. A thorough understanding of each of the elements, and the opportunities and challenges each of the represent in the specific country context, and developing regulations and action plan that specifically address the challenges and seize the opportunities, is the 'recipe' and has potential to produce solid results. Countries who embark on the effort can build on experiences in building such networks in for example Ghana and Cameroun, whose plans build on this methodology.

Studies to understand the success stories of for example India (who transitioned from 50% to 95% penetration of LPG), Indonesia, Morocco, Brazil and other South American countries, may also represent worth-while learning opportunities. WLPGP summarizes these experiences into 6 key factors (Box 2).

Box 2 WLPGA

Developing sustainable LPG promotion programmes

World LPG Association (WLPGA 2013) summarizes the six key factors that governments and stakeholders must consider in order to accelerate and to sustain an LP Gas market transition from early-stage to mid-stage as follows:

1. How to create and to sustain necessary and sufficient conditions for the LP Gas industry to increase continually and substantially the quantity of safe cylinders in use in the market,
2. How to establish (or to guide a transition to) a convenient (having LP Gas retail outlets within end-user walking distance), reliable, effective and efficient market-wide cylinder distribution system for filling, refilling, inspecting, repairing and retiring of LP Gas cylinders,
3. How to ensure a consistent, high level of safety for end-users of LP Gas over time,
4. How to ensure that LP Gas remains physically available to supply the market without interruption or shortages,
5. How to ensure that financial flows from LP Gas consumers back to the investors in LP Gas cylinders and to the suppliers of LP Gas remain adequate for the legitimate participants in each part of the supply chain to perform their role and to grow over time,
6. How to align and optimise governmental fiscal and pricing policies (if any) regarding LP Gas and LP Gas equipment (domestic and imported) relative to competing fuels.

Box 2 Key factors to consider in developing a sustainable LPG promotion (WLPGA 2013)

3.4 Implications of increased uptake of LPG in developing countries and Contribution to global Greenhouse Gas Emissions

This section assesses possible effects of increased use of LPG with a focus on i) Health and ii) Emissions from use of LPG for cooking. After establishing the emissions from LPG as compared to other cooking fuels and technologies, the implications of this on the potential for reduction of GHG emissions and deforestation from transition to LPG is assessed.

Health impacts

With regard to health issues, the evidence of the benefits of switching from solid-biomass fuels to LPG is well documented (see for example Grieshop et al. 2013 and Goldemberg et al 2018).

As mentioned above, almost 3.1 billion people, or just over half (53%) of the population in LMICs and 43% of the global population cook with polluting fuels. Reliance mainly on polluting fuels vary widely from region to region; with the African, the South-East Asia and the Western Pacific Regions having by far the highest proportions of household primarily using polluting fuels for cooking (WHO 2016).

The estimates of deaths caused by household air pollution (HAP) vary. According to a recent review article by Goldemberg et al. (2018) the current state of scientific understanding indicates that the health impact resulting from **direct exposure to smoke from biomass cooking leads to about 2.2–3.8 million excess deaths per year[13], accounting for about 3.9%–6.4% of global mortality**. This makes air pollution (household and ambient) the largest environmental source of ill-health globally. The two types of air pollution are linked, however, in that about 500 000 deaths from the total mortality figure due to ambient air pollution, are attributable to the global contribution from household fuels (Chafe et al. 2014, Lelieveld et al. 2015, GBD MAPS Working Group 2018). See also tolls for deaths in 2013, due to ambient and household air pollution, in the WB and IHME (2016) study referred to below.

The effects of replacing traditional forms with clean fuels and technologies will not only be improved health; the monetary loss of these premature deaths should further strengthen the case for action.
A joint study of the World Bank and the Institute for Health Metrics and Evaluation (IHME) from 2016 seeks to estimate the costs of 5.5 million premature deaths related to air pollution in 2013. In this study, cause of death is attributed both to HAP and ambient particular matter ($PM_{2.5}$), with HAPs accounting for 2.9 million. Estimated loss of welfare is based on two valuation approaches with equal weight: (1) a welfare-based approach that monetizes the increased fatality risk from air pollution according to individuals' willingness to pay (WTP); and (2) an income-based approach that equates the financial cost of premature mortality with the present value of forgone lifetime earnings. Estimated loss of labour income is also estimated. The results from the study show that on a global level, the **loss of welfare from these deaths (caused by HAP and $PM_{2.5}$ combined) amounts to $5.11 trillion annually; and labour income loss to $225 billion. Isolating the losses from HAP in low and middle income countries, the corresponding figures are $1.52 trillion and $94 billion.**

As indoor, traditional cooking is the main cause of HAP, shifting to cleaner fuels like LPG can have paramount effects. The latest understanding of the air-pollution-exposure–risk relationship suggests that emissions from cookstoves have to be reduced significantly in order to adequately protect human health. Unfortunately, even today's best improved biomass cookstoves are not yet able to reliably deliver this level of performance in the field (Goldemberg et al. 2018), and LPG remains still a cleaner alternative.

HAP (and PM emissions) for different type of cookstoves, including LPG, is portrayed in Figure 3-8 Grieshop et al. 2013) in section. LPG (and Kerosene) cookstoves are by far the cleanest technologies with the lowest values of PM concentrations compared to the other cookstove types (biomass and coal), and even better than the most advanced improved biomass cookstoves (wood fan assisted advanced stoves).

For comparison, the PM emissions from the daily use of a single traditional woodstove are similar to that from a dirty "super-emitting" heavy-duty diesel truck driving 20 km (Subramanian et al. 2009).

[13] WHO reports Exposure to smoke from cooking fires causes 3.8 million premature deaths each year, mostly in low- and middle-income countries.

The promotion and use of gas and LPG as household fuels has not, until quite recently, been linked to the health agenda surrounding continued use of biomass. Some recent major government-led programs (for example in Indonesia and India) to enhance the use of LPG have however been launched driven **in large part motivated by health concerns**.

Emission levels from use of LPG

Combustion of petroleum-based fuels – but also solid biomass fuels, emit carbon dioxide to the atmosphere. Solid biomass fuels are commonly categorized as *renewable*, implying zero or low *net* emissions of GHG. However, in recent years there is increasing awareness that household burning of biomass in fact is a significant source of GHG emissions, due to unsustainable forest harvesting and biomass resource management.

As shown in the following, **despite being a fossil fuel, the actual emissions from use of LPG in cooking are very low.** This is illustrated in Figure 3-8 and Figure 3-9, which show emissions from use of LPG as compared with a variety of stove and fuel options[14], with regard to **Particular Matter** and **Climate Impact**, respectively.

With regard to Particular Matter, the study *Health and climate benefits of cookstove replacement options (*Grieshop et al., 2011), estimates daily PM emission rate and the estimated PM intake for an individual in the same room as the stove. Particular matter $PM_{2.5,}$is a measure of Household Air Pollutants (HAP), which is strongly associated with household health impacts (see the previous section on health impacts). **The combined emissions of Particular Matter from production and use of LPG, as well as the daily intake for the user, are ignorable compared to all the alternatives included in the comparison.**

The findings are summarized in Figure 3-8. Daily emission rates capture the impact of stoves on urban and regional air pollution, which is an important impact from solid fuel use (Bond et al., 2004a). Daily PM intake relates more directly to health risk that the person cooking is exposed to (Grieshop et al. 2007). For both daily PM emissions and intake is clear from the figure that LPG, together with Kerosene, ranks among the cleanest household cooking alternative available, with subsequent less impact on health issues than the alternatives[14].

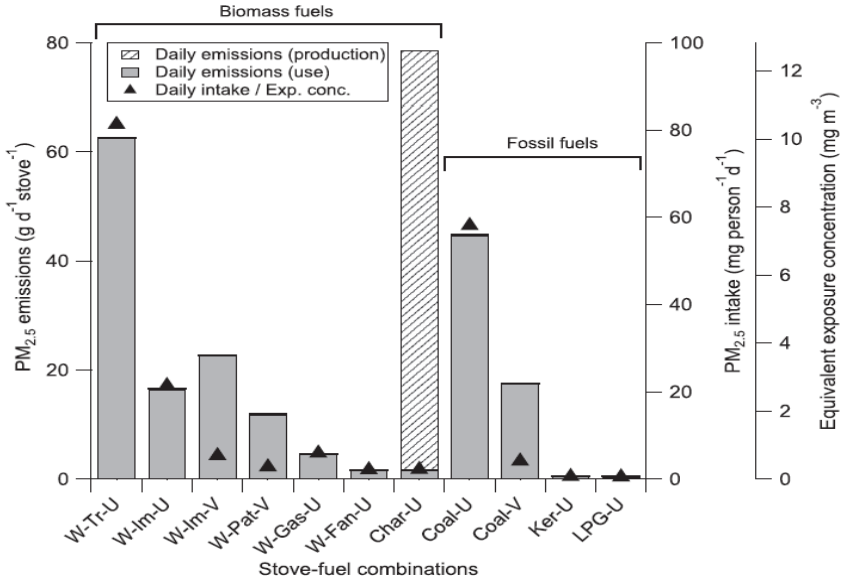


Figure 3-8. Estimates of PM emissions, individual intake and equivalent exposure concentration for different stove options including LPG (Grieshop et al. 2011). Acronyms: W=wood, Tr=traditional stove, U=unvented (i.e. stove no chimney); Im=improved stove; Pat=Patsari improved stove; V=vented (i.e. stove with chimney); W-Gas=wood gasifier (advanced) stove; W-Fan=wood fan-assisted (advanced) stove; Char-U=charcoal stove; Kero-U=kerosene wick stove, LPG-U=LPG metal stove, Coal-U/V=unimproved/vented coal stove used in China.

[14] *The stoves evaluated represents a range of unimproved and improved options in use, including unvented and vented stoves using renewable and non-renewable fuels. Stoves vary among attributes such as fuel type, stove type, and venting status. Estimations further make a range of assumptions related to thermal efficiency and density of fuel energy associated with the different technologies. Electricity is not included. Emissions from use of electricity in cooking is zero; but total emissions will be determined by the source of energy generation (e.g. whether from fossil of renewable sources).*

With regard to climate gas emissions, the same study by Grieshop et al (2011) assesses specific GHG drivers that is part of the *Kyoto Global Warming Commitment* such as CO_2, CH_4 and non-Kyoto components as per Grieshop et al. (2011). Figure 3-9 shows the climate active emissions (most of which are warming, while some are cooling) for the same range of solid biomass fuel stove types as in Figure 3.8 in terms of their *Global Warming Commitment (GWC[15])*

The results show wide variation in the overall GWC of the different fuel and stove types. The emissions from the climate active pollutants are presented on the basis of estimated annual fuel usage per stove, i.e. adjusted for the efficiencies of the various fuel/stove combinations. The highest contributions come from charcoal (even when fully renewable) and from coal. The other fossil fuels, LPG and kerosene, have lower contributions to warming than most of the wood-burning stoves **when 50% renewability (of the biomass) is assumed**. For LPG, the GWC is lower even than the advanced fan-assisted stove under the same renewability assumption, but not when the full renewability is assumed (Bruce et al. 2017).

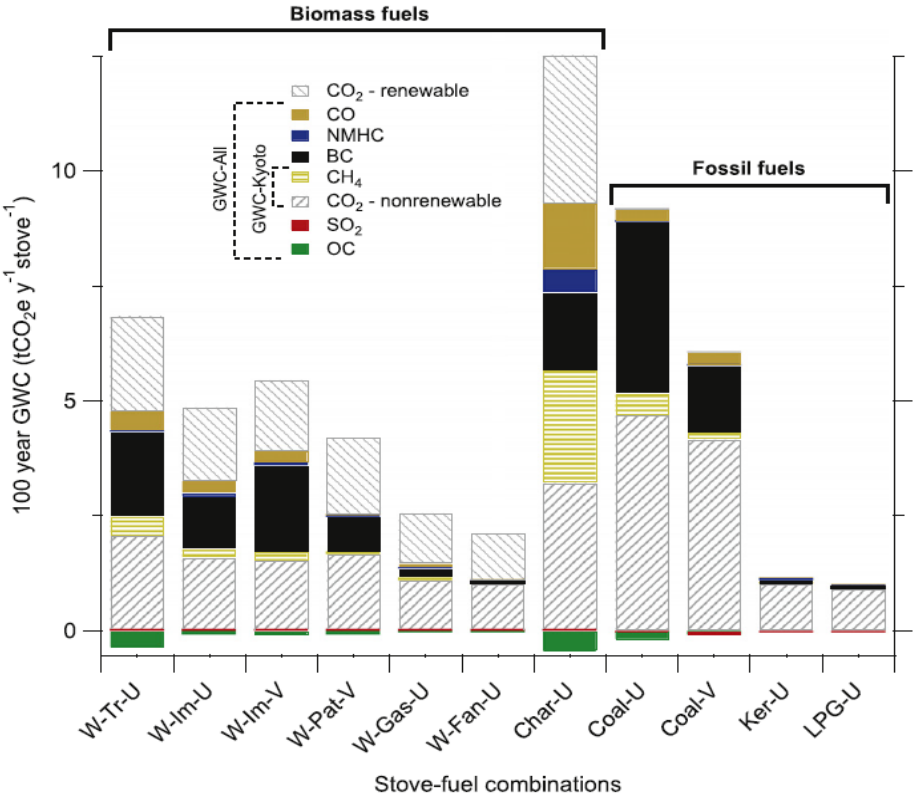


Figure 3-9. Climate Impact of stove/fuel combinations estimated using GWC over a 100-year horizon, including LPG. Acronyms: BC=black carbon, CO=carbon monoxide, CO_2=carbon dioxide, CH_4=methane; NMHC=non-methane hydrocarbons, OC=organic carbon, SO_2=sulphur dioxide (Grieshop et al. 2011)

Figure 3.8 and 3.9 combined show that **LPG is amongst the cleanest household stove/fuel technologies both with regard to HAP (and subsequently health) and to GHG emissions[16].** This can also be illustrated through the ISO IWA guidelines for CO and $PM_{2.5}$ measuring of cookstove performance. According to these, LPG stoves are rated in Sub-Tier 4 (see also Figure 3-1010 in Section 3.5)[17]. Shen et al. (2018) furthermore tested 5

[15] *The concept of Global Warming Potential (GWP) was developed to allow comparisons of the global warming impacts of different gases. Specifically, it is a measure of how much energy the emissions of 1 ton of a gas will absorb over a given period of time, relative to the emissions of 1 ton of carbon dioxide (CO_2). In the Global Warming Commitment (GWC), the actually measured or modelled gas content evaluations are used for the estimation of gas X relative input into the current and future greenhouse warming. Comparing GWC of different fuel/stove combinations requires multiplying the emissions of individual GHGs by their global warming potentials (GWP) and combining this into an overall GWC (Bruce et al. 2017).*

[16] *Electricity and electric stoves/cookers are not included, presumably because they would have zero emissions in use. Actual emissions would need to take into account the source of electricity generation, of which emissions vary greatly.*

[17] *When $PM_{2.5} \leq 41$ mg/MJ_d and CO $\leq$ 8 mg/MJ_d.*

different types of LPG stoves, with test results under various conditions all resulting in ranking within Tier 4 for both CO and $PM_{2.5}$ emissions. As mentioned above and further discussed in Box 3, while LPG is a fossil fuel, the cookstove thermal efficiency contributes to these results.

Box 3 Cookstove thermal efficiency

Cookstove Thermal Efficiency

Although biomass fuel cycles based on fully renewable harvesting of wood or agricultural residues are much closer to being CO2 neutral than fossil fuel burning, traditional and even most improved and some advanced biomass stoves have a lower thermal efficiency (in the range of 12-25% efficiency, than liquid or gaseous fuel technologies. The resulting incomplete combustion of fuel carbon, which produces SLCPs, means that solid fuel stoves make an important contribution to global warming even when the fuel is renewable (Bruce et al. 2017).

LPG cookstoves have efficiencies of 45-60%, which is generally consistent across a wide range of conditions. Although some fan-assisted advanced biomass cookstoves can reach efficiencies of 30-55% when tested in the laboratory, thus approaching that of LPG and other clean fuels, their actual performance in everyday use is notably lower. For example, **one study from India found in-home efficiency of between 17-25% for two types of advanced biomass fan stove** (Muralidharan et al 2015)).

This striking difference between performance found with ideal laboratory protocols compared to real-world conditions is,

Box 3 Cookstove Thermal Efficiency

Potential for contributions to reduced Global Greenhouse Gas Emissions

Given the above conclusion, that LPG represents lower climate gas emissions than the alternatives it is natural to compare with, it can be assumed that transitioning from biomass use for cooking purposes to use of LPG has a potential for mitigating such GHG emission. However, as the following will show, there is no one standard measure that can be applied to estimate the substitution effect.

The discussion below focusses on emissions from LPG use as compared with use of biomass, which is the baseline for 80-90 % of the population in Sub-Saharan Africa.

GHG emissions from combustion of LPG can be estimated with some precision due to the extensive information about production of the fuel, and relatively uniform thermal efficiency in use of LPG for cooking. As shown above, disregarding renewability of the fuels, the CO_2-e emissions in cooking with LPG are several orders of magnitude lower than for kerosene and solid biomass fuels (Kaur-Sidhu et al. 2020). Additionally, according to an ESMAP[18] study by the World Bank LPG has a negligible environmental footprint, emitting negligible amounts of black carbon and other short-lived pollutants that contribute to global warming (Van Leuween et. al, 2017).

However, quantifying the potential *gain* from a transition is challenging, as there is uncertainty and variation in GHG emissions stemming from combustion of solid biomass fuels. Although Grieshop et al. (2011) have produced important figures from their review reported above, uncertainties still exist (See below).

Three important factors contribute to the uncertainty of GHG emissions from residential woodfuel use:

1) knowledge base and variation in Global Warming Potential (GWP) from Black Carbon and gases such as methane (Short-Lived Climate Pollutants, SLCP);
2) variation in thermal efficiency and emissions of different types of woodfuel stoves used under different conditions, and in different fuel switching scenarios;
3) uncertainty and variation in sustainability of forest resource use and thereby fraction of Non-Renewable Biomass (fNRB) used in residential sector.

With regard to point 2), a growing literature base addresses the uncertainty and variation in thermal efficiency and emissions of different types of woodfuel stoves used under different conditions. Uncertainties stem for example from potential differences between laboratory and real-world testing (see also Box 2) of emissions (Garland et al., 2017). The practice of fuel stacking or multiple fuel use also contributes to the

[18] *Energy Sector Management Assistance Program*

uncertainty of the effect of ICS (Masera et al. 2000). In a report by Bruce et al (2017), an overview of the evidence base on the impact of LPG use on the climate and forests is provided. One gap in the existing knowledge is the lack of estimations of net climate relevant emissions impacts from historic data on household fuel switching that reflect actual conditions of stove use and fuel stacking. However, this complexity is increasingly taken into account in recent studies of LPG in societal energy transitions.

With regard to point 3) above, combustion of solid biomass fuels contributes to climate change through black carbon emissions. Black carbon is the second most important GHG after CO_2, and **in Asia and Africa residential solid biomass fuel use accounts for between 60 and 80% of total black carbon emissions** (Bond et al. 2013). IPCC (2013) shows that there is large uncertainty and variation in the extent of the GWP from black carbon. Black carbon, but also methane, are powerful warming agents on shorter timescales that may disrupt regional climate systems such as the Monsoon (Ramanathan & Carmichael, 2008). According to WHO (2015), when these SLCPs are accounted for, the use of biomass fuels compares unfavourably with LPG in terms of climate impacts. UNEP and others conclude that implementation of 14 measures reducing black carbon and methane emissions could avoid 0.5 degrees Celsius of warming by 2050 (Shindell et al., 2012).

Bailis et al (2015) found that one third of global woodfuel consumption is unsustainable. Forests are not replanted, resulting in a net addition of GHG in the atmosphere. The fraction of non-renewable biomass (fNRB) has been used in recent studies to estimate GHG emissions from combustion of woodfuels in different scenarios and contexts (Singh et al, 2017; Serrano-Medrano et al, 2017).

From the above, it is clear that biomass harvesting contributes to significant levels of GHG emissions, in addition to the negative effect it has on deforestation as well as health as discussed above: **burning of woodfuels accounts for more than one gigaton of CO_2-e per year** to the global carbon budget; or **about 2% of total global emissions**. However, the uncertainties as described also make it difficult to estimate the exact substitution effect of LPG for biomass use in an emissions perspective.

Some evidence-based findings nevertheless exist. A study by Serrano-Medrano et al. (2017) in Mexico compares different scenarios including fuel stacking with LPG, wood-burning stoves, and different fNRB fractions. Idealized policy measures to promote a gradual increase of LPG use would result in mitigation of GHGs ranging from 50 $MtCO_2$-e to 126.3 $MtCO_2$-e. **This was equivalent to 14% to 35% of emissions in a "business as usual" scenario, and up to 11% of projected country GHG emissions to 2030** (Serrano-Medrano et al, 2017).

A recent study from India estimates that the fuelwood displaced due to increased LPG access between 2001 and 2011 was approximately 7.2 million tons, giving an **estimated reduction of 6.73 $MtCO_2$-e** (Singh et al. 2017)[19].

Finally, a report by WLPGA (2018) models the potential for mitigating GHG emissions by substitution of fuelwood with LPG. The model uses standardized values for efficiency and finds that annual per capita cooking requires 43 kg LPG instead of 400 kg of wood. The model further considers forest regrowth time, stove efficiency, soil carbon, and time horizon. On this basis, **the potential for carbon reduction from switching from wood to LPG rages between 60 and 70 percent** in this scenario.

If residential LPG becomes an important element in 'energy access' scenarios for poor populations globally, modelling studies find that increasing energy access can have a net cooling impact on the climate by 2100 (Bruce et al. 2017).

The above examples provides two key insights, namely that i) **a transition to LPG from use of woodfuels for cooking represents potentials for emission reductions that could be significant**, but that ii) **the actual level of this effect varies so much from context to context that results from one study cannot be easily transferred to another setting or extrapolated to indicate global savings potential**.

[19] The modelling was based on an fNRB of 0.3 and assumed 6.19 million tons reduction of woodfuel use in urban regions, and 0.99 million tons in rural regions due to the displacement of solid biomass fuels from increased access to LPG.

Potential for contribution to reduced deforestation

According to IEA, bioenergy accounts for about 10% of global primary energy use. Of this, the majority is solid biomass fuel burned for household cooking and heating in the global South (IEA, 2010).

This is an important contributor to degradation of forests and deforestation. According to a recent report by UN Food Agency (UNFA, 2020), while the rate of deforestation globally declined in the decade from 2010 to 2020, Africa was the only continent where deforestation rate continues to increase.

Studies of domestic energy use suggest that socio-economic status is positively correlated not only with the quantity of fuels used, but also the quality of the energy. However, as households grow increase their income, they use multiple fuels in increasingly complex ways through fuel stacking behaviour (Choumert et al, 2019). This means that while the consumption will increase with socio-economic development, a switch to higher-quality fuels can be expected, but consumption patterns also become less predictable. There exist initiatives to facilitate this transition by promoting LPG in urban areas of SSA. However, as described elsewhere in this report, there is still little empirical evidence of the exact substitution effects of this transition. This makes it difficult to model the effect of a transition without taking very specific contextual parameters into the equation.

As above, results from studies from various contexts can nevertheless give clear indications of the *possible* substitution effect:

Charcoal production and consumption is linked with deforestation and climate change (Bailis et al. 2017). Two studies from India (Singh et al. 2017) and Mexico (Serrano-Medrano et al. 2017), respectively, could give indications of the potential for mitigation of deforestation from transitioning from woodfuels to LPG. Both studies suggest a higher potential for transitioning from woodfuel to LPG in **urban areas**. Applying these results to an African context must be done with caution, since the demographic profile of Sub-Saharan Africa is different from that of India and Mexico. In those two countries, approximately 75% live in urban areas, and "only" around 50% of the households use fuelwood as primary source of energy. In Sub-Saharan Africa (SSA) about 50% of the population lives in rural areas, and solid biomass energy is used by 80-90% of the households. However, given that in many countries, such as Tanzania, charcoal is the primary fuel in even urban and peri-urban areas (Mwampamba 2007), a transition should be possible and should have effect on the pressure on forests.

In Tanzania, Dar es Salaam alone consumes more than 500 000 tons of charcoal per year, corresponding to half of the countrywide consumption (World Bank 2009). Tanzania lost about 373 000 Ha/year of forest between 1995 and 2010 (TFS 2015). Although much of this forest loss is due to clearing of new land for agriculture and other human activities, substitution of biomass with LPG has potential to mitigate forest loss.

Box 4 presents an example estimate of avoided deforestation by substitution of half of the Dar Es Salaam consumption of charcoal with LPG, based on standard values for energy efficiency of stoves and charcoal conversion, energy density of fuels and forest biomass.

Example of substitution effect estimate

LPG substitution effect on forest loss

Charcoal	***250 000***	**tons; production requires -**
	1 000 000	tons woody biomass (Charcoal kiln 25% efficiency)
	10 000	Ha forest, assuming 100 tons/Ha
	29	GJ/ton, charcoal
	0.3	conversion efficiency, charcoal stove (30%)
	2 175 000	GJ useful energy generated from 250 000 tonnes of charcoal
	45	GJ/ton, energy in LPG
	0.6	conversion efficiency, LPG stove (60%)
LPG	***80 556***	**tons, required to substitute 250 000 tonnes of charcoal**

Box 4 Stylized estimation of substition of charcoal in Tanzania corresponding to half of the consumption in Dar es Salaam (or ca 25% or total national consumption). Estimate based on standard values for energy efficiency of stoves, charcoal converstion efficiency, energy density of fuels and forest biomass.

Given the assumptions made, the example shows that **substituting 250 000 tons of charcoal with 80 556 tons of LPG in Dar es Salaam could save about 10 000 Ha forest per year.** Against average losses of approximately 373 000 Ha in the period mentioned, this would imply a 3% reduction of forest loss in Tanzania.

Taking the example further, the total current consumption of more than 145 000 tons LPG per year in Tanzania replaces cooking energy worth 18 000 ha of forest.

Despite the uncertainties that prevail making standardized substitution effect factors unavailable and context specific research not applicable as general measurements, in the face of the fact that over half of all woody biomass harvested globally is used for cooking, attention to the clean cooking agenda is of crucial importance in the climate perspective. Consumption of biomass fuels will continue to increase, but it is clear that substituting even only of fractions of household energy use would contribute positively, both with regard to GHG emissions and forest protection.

As a clean, efficient, and feasible at least in relatively densely populated areas in the medium term, the evidence is sufficient to conclude that LPG should represent a part of the solution.

3.5 Driving the agenda: LPG Champions – and sceptics

Attention to the clean cooking agenda been step-childly handled by many national governments; not because it's not recognized as a problem, but it has often been considered a poverty issue; does not produce the political gains of for example a large, new power plant; and the responsibility is spread over many different authorities and stakeholder groups. Despite the recognition of the importance of the issue with regard to both poverty and pollution/climate, **the mobilization of international community funding and support to clean cooking has so far been lagging far behind all other energy sub-sectors** (electrification, renewable energy development etc.).

However, as focus on the climate, environment and health impact of unsustainable cooking increase, brought about partly by the international community such as the SE4ALL agenda, attention has picked up. Several public and private organizations and institutions, governments, private companies and other actors are involved in promoting LPG promoting clean cooking and LPG across the world. When it comes to LPG, however, despite the positive effects it can have on health, protection of forest resources, climate change, poverty etc as discussed above, it has been a challenge to mobilize funding to support governments in implementing promotive interventions. The following presents a discussion around **the role of LPG in achieving SDGs** and why funds mobilization is a challenge, followed by a selection of actors in the promotion of LPG as a sustainable cooking fuel.

LPG as an element in achieving the SDGs

Universal access to clean and modern energy is addressed in SDG7 'affordable and clean energy for all', and a key challenge of the commitment in SDG7 is to achieve clean cooking LPG or electricity in low-income settings. Providing access to clean and modern energy also touches on SDG3 'health and well-being', SDG5 'gender equality' and, SDG13 'climate action' (WLPGA 2019).

Transition to improved cooking methods including LPG thus would contribute to all these SDGs. The ambition of shifting the billions using biomass over to sustainable and 'clean' fuels, is likely not possible without allowing LPG to play an important role at least in the medium term. As noted above, LPG has a significantly higher impact on health than ICS. This is, among other, illustrated through the Tier classification[20], **where LPG is listed as Tier 4, compared with ICS which remain at Tier 1-2**.

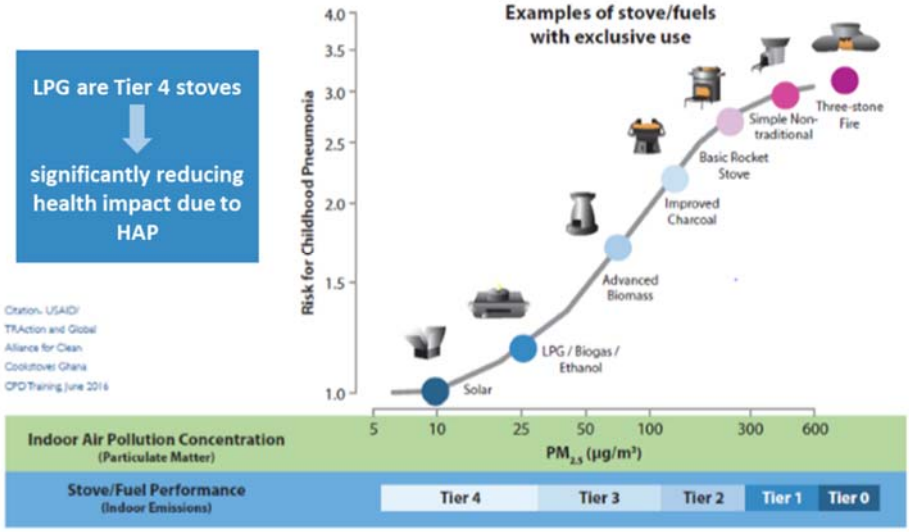


Figure 3-10 LPG is Tier 4 classified. Adapted model after SNV (2014)

At the same time, LPG is at least for the medium term, only a part of the solution. As mentioned above,although India has proved that transition to LPG by the vast majority of a great population is possible, the demographics of India are so different from those of SSA that a realistic approach to addressing the clean cooking problem cannot be based on one single substitute for unsustainable biomass based cooking only.

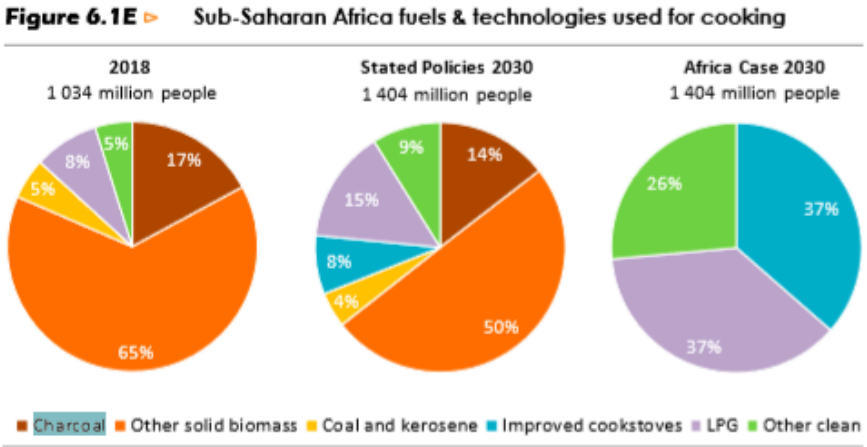


Figure 3-11 The IEA Africa Energy Outlook identifies LPG as a key element in future cooking fuel mix. The Africa Case assumes full achievement of the SDGs. (See Chapter 1 for explanation of the scenarios.)

[20] *The Global Tracking Framework and the Multi-Tier Framework, World Bank/ESMAP 2013*

Is LPG a sustainable and 'clean' cooking fuel?

With regard to LPG as a part solution to the cooking problem, some actors express scepticism to promoting use of LPG. Such scepticism can have several reasons. One factor may be the strict and narrow definition of sustainability as regards the household energy agenda: as LPG is a fossil fuel the desire to mitigate greenhouse emissions by relying on "renewable" resources can favour promotion of improved biomass cookstoves, instead of enabling optimized approaches that also focus on the large positive health impact of LPG (Goldemberg 2018). As an example, although KfW as mentioned above has cooperated with GLPGP on several reports and research, and are considering LPG as an intervention area, the German Government has expressed scepticism, referring to the fact that LPG is a fossil fuel and does not fit in a renewable and climate promotion perspective. NDF (Nordic Development Fund) equally excludes LPG as an eligible technology in their programmes. SNV' focus on ICS also appears to be fuelled by the Dutch government's scepticism to LPG.

Proponents of LPG, including ESMAP (World Bank) and the GLPGP however argues that the environmental footprint of LPG is negligible compared with the only realistic alternative in the near term, biomass. Improved biomass stoves are still far from achieving efficiency and cleanliness levels that effectively reduce the environmental, climate and health impact of such fuels. Further, it makes sense to use a resource that is available in many setting (e.g. oil and gas extractive countries such as Nigeria and Ghana, and in the future also Tanzania) that otherwise is wasted through flaring. Thus, although the actual effect on climate and forest remains difficult to quantify exactly, it is clear that a transition away from biomass fuels to LPG will have a positive net effect.

In recognition of the latter, it appears that global focus is now shifting towards making clean fuels available (LPG and electricity) rather than making available fuels cleaner. Further, it is argued, one has to consider the realistic alternatives. As mentioned above, traditionally efforts to improve the cooking energy situation has focussed on improving biomass cooking through improved stoves. This is important in areas the availability barrier is high, i.e. in very rural areas. With regard to electricity, which may be completely clean at the user level, other impacts are significant. This includes the source of power generation (whether renewable or fossil), and the need to build out transmission infrastructure with the environmental and land take related challenges that follow.

Other aspects – Poverty and Equity considerations

The aspect that most clearly emerges in relation to LPG adoption and use is the problem of disadvantaged families being unable to afford **the cost** of a new LPG stove and bottle, and the cost of refilling bottles. Puzzolo et al. (2013) found both to be prohibitive among poorer communities when no form of subsidy or financial support was applied. Consumer financing schemes, including Microfinance, can be successful in supporting disadvantaged families in acquiring LPG equipment, but refilling costs may continue to be a barrier (Bates 2009, Puzzolo et al. 2013). New business models such as PAYC can play a role but the commercial sustainability of the model is not yet proven.

LPG adoption and sustained use in **rural areas** encounters similar problems. The high price of LPG in rural areas, which may be as much as three times higher than in urban areas, is related to the higher cost of distribution and exacerbated by poor road infrastructure. Such high costs discourage LPG use in rural areas, with less access to credit for the initial purchase of the LPG stove and bottle being additional limiting factors (Puzzolo et al. 2013). See some comments in Section 3.3 ("Domain 4") and Box 1 about innovative business models.

As the LPG sector is largely private sector driven, its **job creation** potential could be significant. While the core infrastructure related to port and storage capacity as well as central refilling posts may require public interventions, once that is in place the gradual build-up of distribution network does not represent unsurmountable investments, and has high potential for local employment and entrepreneurship. This is additionally a key factor in enabling a gradual build-up of availability and access into less densely populated areas.

With regard to **gender and women's situation,** LPG can induce a reduction in women and children labour time in fuel collection and cooking where there is dependence on solid fuels, and opening up opportunities for greater engagement with education and the labour market. LPG cookstoves heat quickly and provide

considerable control over the desired level of cooking power, so users can benefit from time savings through faster cooking (Bruce et al. 2017). In Sri Lanka, for example, this time saving was estimated at 2 to 3 hours per day (Wickramasinghe 2011). Similarly, a study from India reported that after introduction of LPG in the lower regions of Himalaya, men stopped fuelwood collection and women reduced the time spent for collection from 2.2 to 0.2 hours per day (Nautiyal 2013).

Finally, the area of **humanitarian interventions** is worth some attention. The global number of refugees or forcibly displaced people reached 65.6 million in 2017, and few places in the world is energy poverty rifer than in refugee camps. About 80% of those who live in camps have absolutely minimal access to energy for cooking and heating, and an estimated 20,000 displaced people die prematurely each year from respiratory illnesses as a result of household air pollution caused by burning wood, charcoal, kerosene and other fuels indoors. A case study by UNEP (United Nations Environment Programme) showed that in a particular setting, an LPG programme would yield a benefit-cost ratio (BCR) of 1.76 (UNEP 2017).

Global Organizations promoting LPG

The **World LPG Association (WLPGA)** is the authoritative voice of the global LPG industry representing the full LPG value chain. The primary goal of the Association is to add value to the sector by driving premium demand for LPG, while also promoting compliance to good business and safety practices. The WLPGA brings together over 300 private and public companies operating in more than 125 countries involved in one, several or all activities of the industry; develops long-term partnerships with international organisations; and implements projects on local and global scales. The Association was established in 1987 and granted Special Consultative Status with the United Nations Economic and Social Council in 1989.

It has also developed long standing partnerships with other international bodies such as various departments of the UN, the World Health Organization (WHO), Regional Development Banks and a number of well-respected international NGO[21]s such as the Partnership on Clean Indoor Air (PCIA) and E+Co. The geographical spread and diversity of the WLPGA's membership makes the association a representative, trusted and logical partner in international discussions.

Due to the decline in the interest of major players in the developing markets (see below), WLPGPs ability to mobilize significant funding for initiatives such as their "Cooking for Life" advocacy program, has been very limited.

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 renewable liquefied petroleum gas (bio-LPG) as well as conventionally produced LPG for clean, modern cooking. Its mission is to assist developing countries to plan, finance and implement national-scale availability and use of liquefied petroleum gas (LPG and bio-LPG), to help prevent the some 4 million annual deaths, severe forest loss, and vast impact on women's and children's time and health, caused by societal dependence on solid fuels for cooking.

GLPGP partners with host country governments and other stakeholders to create national plans for rapid, sustainable scale-up of LPG and bio-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. GLPGP has engaged with the governments of eight African countries – Cameroon, Ghana, Kenya, Nigeria, Rwanda, South Africa, Tanzania and Uganda – in planning, policy and regulatory reforms, and investments. GLPGP also works with regional partners like the Economic Community of West African States (ECOWAS).

The **Clean Cooking Alliance (CCA),** focusing not only on LPG but also other clean cooking solutions, was established by the United Nations Foundation and Shell Foundation in 2010 with a mission to save lives, reduce black carbon and greenhouse gas emissions, build a commercially sustainable industry, and meet the millennium development goals. Since then, the organization has grown from an infant stage to become a

[21] *Non-Governmental Organization*

global platform with close to 2000 loosely defined partners in 54 partner countries, and permanent presence in eight focus countries.

Throughout its existence, CCA has advocated the importance of ensuring access to and adoption of clean cooking solutions for close to three billion people who are currently exposed to health hazard due to smoke and black carbon emissions. Unsustainable cooking methods also has negative impact on the environment, climate change, and household economies – and is an issue that in particular impacts women.

Several of the organizations within **The United Nations (UN) family** support the agenda. **WHO (The World Health Organization)** has formally recommended LPG and gas-based cooking as an important Household Air Pollution (HAP) mitigation solution that should be urgently considered for implementation at scale, including in the widely referenced *Indoor Quality Guidelines* (WHO 2014). **UNDP** and **UNCDF** have provided grants to develop the LPG sector in DR Congo through FONAREDD, the DRC REDD+ fund. Together with GLPGP, **UNHCR** is working on creating a Global LPG market creation fund for supplying clean cooking with LPG to the millions of refugees under its care, and is expected to be seeking international community support for this.

The **International Network on Gender and Sustainable Energy (ENERGIA)** was founded in 1996 as an informal network with a shared mission of promoting policies and actions to recognise, validate and support women's roles in sustainable and socially inclusive energy systems. As long as gender inequality persists in the energy sector globally, ENERGIA's mission is "to increase women and men's equal and equitable access to and control over sustainable energy services as an essential right to development". ENERGIA's strives toward involving women in the development, delivery and use of modern energy with the main goals of that sustainability and adoption rates of these services are enhanced.

International Financing Institutions and Development Agencies

While clean cooking has been gradually picked up as area of focus and interventions by most international agencies and main donor countries, targeted push for LPG promotion is less visible. According to GLPGP, none of the major donor countries and bilateral/multilateral agencies have neither real experience with the LPG sector, nor senior staff with knowledge of LPG operations or of the enabling environment required to nourish public and private investment at scale to grow an LPG sector.

The World Bank had, until a few years ago, a prohibition on supporting fossil fuel projects for clean cooking. According to GLPGP, this has changed, with clean cooking studies and funding efforts currently carried out by ESMAP, and the newly established $500 million USD Clean Cooking Fund which does not exclude LPG projects[22].

DFID has not developed a policy on LPG for clean cooking but supports LPG research through funding to the Modern Energy Cooking Services (MECS) project[23] managed by Loughborough University, which covers primarily electricity but includes funding also for LPG studies/projects.

SNV is a not-for-profit international development organisation and aim at helping people living in poverty raise incomes and access basic services. Energy is one of three focus sectors together with agriculture and water, sanitation and hygiene. Clean cooking is among SNV's key intervention areas, with targets to contribute to access to biodigesters for more than a half million people and access to other improved and clean cooking technologies for 2.5 million people. LPG specifically, however, has not been a targeted solution, partly due to the Dutch government reluctance to consider LPG a part of a 'clean cooking' agenda. SNV has contributed to the clean cooking agenda in several countries, including supporting the establishment of the national Clean Cookstoves Alliances in Ghana in 2013 and in Ethiopia in 2019. They also run the SEEECS (Strengthening Enabling Environment for Clean Cooking) programme in Ethiopia, funded by the Dutch government.

KfW has worked with the Clean Cooking for Africa Scientific Advisory Board (SAB) to build the evidence base for clean cooking with LPG, through a peer-reviewed scientific report, *Liquefied Petroleum Gas as a Clean Cooking Fuel for Developing Countries: Implications for Climate, Forests and Affordability.* This report is widely referenced by practitioners, as it brings together recent findings that the use of LPG instead of

[22] *GLPG, interview*

[23] mecs.org.uk

traditional biomass fuels and kerosene, among the 3.1 billion people currently using these, would contribute little or no net climate warming effect and would protect forest resources. KFW is considering LPG as a potential area of interest for investment and are looking for entry opportunities. KfW also expressed interest in exploring cooperation with other partners, such as Norad, for blended financing opportunities. On the other hand, such initiatives may face resistance by the German Government (see discussion above).

Commercial/Private Sector Actors

Major oil & gas majors (Shell, BP, Exxon, Chevron) and some secondary players (Repsol) have previously been involved in international mid and downstream LPG distribution and marketing, but have according to GLPGP[24] more recently retreated from this business. The two exceptions are **Total** and, somewhat, **Equinor**. Total has elected to preserve LPG activities in some of its countries, as a source of incremental profit from service station networks. The reason for the general withdrawal appears to be related to (1) negligible impact of LPG activities on group profit, (2) low upside compared to other uses of capital, and (3) high risk regarding reputation and liability spilling over from non-compliant and/or unsafe practices by local LPG sector competitors in developing countries (i.e. cylinder cross filling and unsafe filling).

The market gap created by the retreat of large multinational players has been filled by the increase in number of smaller, mostly domestic, LPG pure players that specialize in LPG distribution. Some of these are mentioned in the country studies in Chapter 1.

There are a few examples of player that invest in exploring new business models to expand the market and overcome the affordability barrier, as mentioned under the cost related 'enabler'/barrier above.

One of these is **Circle Gas/KopaGas. Kopagas** is an LPG marketer in partnership with Oryx Energies in Tanzania. Capitalising on the emergence of mobile money in East Africa, Kopagas designed and developed software and metering technology, specifically a pay-as-you-go (or Pay as You Cook, PAYC) smart meter for LPG cylinders. A deposit is paid (USD 30 to 60) and users are provided with a cylinder with "smart meter", as well as stove. Customers pay for the LPG they consume in smaller amounts (CCA, n.d.). 5). **Circle Gas** was established in 2018 by a group of investors and identified KopaGas as the technology required to achieve their vision: to "bring clean cooking to low-income earners at a scale never achieved before". The Kopagas acquisition is thought to be the largest-ever pure private equity investment in the clean cooking technology sector.

[24] *Puzzolo, interview*

4 On the ground: The LPG situation in selected Sub-Saharan African countries

In this chapter, we explore the situation on the ground in four selected countries: **The Democratic Republic of the Congo (DRC), Ethiopia, Ghana, and Tanzania**. While **all four countries acknowledge the challenges related to the unsustainable use of biomass in their policies**, establishment and implementation of specific plans and institutional structures to facilitate the transition vary in degree. We also find that the approaches to address the clean cooking agenda vary substantially. The starting points for a potential scaling up of the LPG use are equally different; LGP has a significant market share only in Ghana, while demand is increasing organically in Tanzania, but strongly concentrated to the capital area. GLPGP is actively working with two countries (Ghana and DRC), and only these same two have established specific targets for LPG use.

The striking common denominator is, however, the strong dominance that use of biomass resources has in the overall energy mix and specifically in household energy. With the exception of Ghana, the rate of access to clean fuels and technologies in 2017 was below 5%; with Ethiopia, DRC and Tanzania topping the list of countries in terms of number of people without such access, amounting to a combined 135 million people in 2017 (WHO, 2019). In all four countries, deforestation is rife, and the use of biomass contributes greatly to the pressure on the forest resources.

Another common factor is the large theoretical potential for biogas based on agricultural and livestock residue, as well as waste. Several biogas programmes have been implemented at various scale and with various success. For various reasons biogas is mostly seen as a relatively small, but not unimportant, part of the cooking energy mix. As opposed to biogas, Bio-LPG is not explored in any of the countries but a study is underway covering among other countries Ghana.

In *Africa Energy Outlook 2019* (IEA 2019), IEA presents a scenario where all SDGs are achieved by 2030; the *Africa Case*[25]. **LPG is considered to play a role in all four countries** in this scenario, ranging from 9% in Ethiopia to 43% in Ghana. This is however in sharp contrast to what the same authors expect to have given the 'Stated Policies' of the respective countries, ranging from 1% (DRC) to 28% (Ghana) (Figure 4-1).

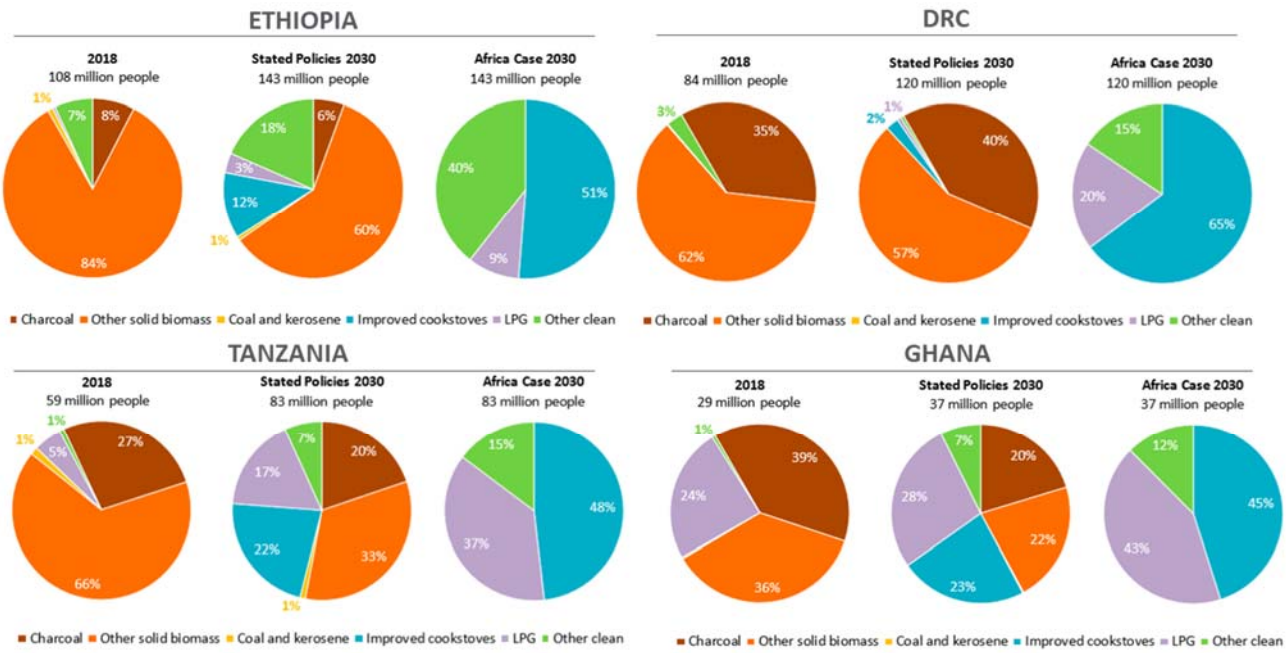


Figure 4-1 Fuels and Technologies used for Cooking (Source: IEA 2019) (NB. Biogas is included in the 'Other clean' category).

[25] *The **Stated Policies Scenario** reflects (IEA's) measured assessment of today's policy frameworks and plans, taking into account the regulatory, institutional, infrastructure and financial circumstances that shape the prospects for their implementation. **The Africa Case** is built on the premise of Agenda 2063, the continent's inclusive and sustainable vision for accelerated economic and industrial development. Faster economic expansion is accompanied by the full achievement of key Sustainable Development Goals by 2030. These include full access to electricity and **clean cooking** and a **significant reduction in premature deaths related to pollution**.*

4.1 Ghana

Overview

Clean cooking has been high on the agenda for the Government of Ghana for several decades, and as of 2020 LPG remains in focus as a key solution in the country's approach to ensuring access to modern cooking for the population. This is embedded in the National Energy Policy, the SE4ALL Country Action Plan, and concretized with the *National LPG Policy (NLPGP)* approved in 2017.

The Government's target is 50% uptake by 2030; which is an ambitious, but with efficient implementation, likely not unattainable goal. Various publicly driven efforts, (including a rural LPG programme) have made big parts of the population recognize LPG as an attractive method of cooking, based on its 'modernity' and cleanliness, and around 25% are reported to use LPG for at least part of their cooking. Nonetheless, the large majority of Ghanaian households still rely on firewood and charcoal for cooking, and Ghana has among the fastest deforestation rates in the world. In particular the limited impact of the rural efforts highlights the challenges related to availability in rural areas, together with lack of awareness and appreciation of the benefits, safety concerns and affordability barriers.

The National Assessment of LPG as Cooking Fuel in Ghana (KFW 2019) summarizes the challenges and the potential gain of successful implementation of the NLPGP as illustrated below.

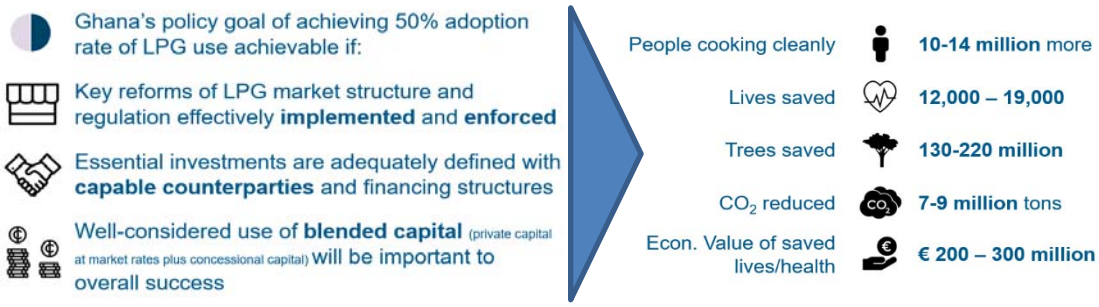


Figure 4-2 Challenges to overcome and potential results of Ghana's LPG policy. (KFW 2019)

(Note that the 'essential investments' considered are estimated to a total of EUR 335 million in investments, with cylinders making up the largest share (EUR 235 million).)

Use of LPG in Ghana

According to the Energy Commission (2018), National LPG per capita in 2017 was 12.4 kg/capita. Around 70% of the consumption amount is used as vehicle fuel, with residential users consuming an average of 4.3 kg per capita. 24,5% of the population were reported as LPG users in 2017, and the number of users is increasing as more users take up LPG as partial or full solution. The rural-urban divide is however large, with 6% versus 35% penetration, respectively[26].

Certain statistics regarding institutional and commercial use have not been found; but it appears that schools use LPG to a certain degree[27], and caterers reported a clear preference for LPG in one study.

Market regulation and structure

The main regulation for LPG is the *Petroleum Products Code of Practice* for handling, Storage, Distribution and Maintenance of LPG in Domestic, Commercial, and Industrial Installations.

[26] *Key statistics on the LPG market in Ghana are available e.g. in the Energy Commission, 2018. National Energy statistics* http://www.energycom.gov.gh *Energy outlook for Ghana.*

[27] *In a survey by GHACCO in 2018, it appears that around 40% of schools have LPG. Actual use depends on the kind of meal cooked, suggesting that those schools who use LPG use other fuels interchangeably.*

Ghana targets a deregulated market for LPG, with a full cost-recovery pricing model. A previous VAT exemption was abandoned due to the inability to differentiate the vehicle fuel market from the cooking purpose, for which the benefit was intended.

LPG is used for two main purposes, namely domestic (mainly for cooking) and autogas (for vehicles). About 40% of the 316,400 MT LPG consumed in 2017 was sourced from two processing plant, while 60% is imported.

The market structure is characterized by the Customer Controlled Cylinder Model but there is an explicit strategy in the LPG Policy to move to the BCRM. This will be achieved through gradual phasing-out and roll-out, aiming at achieving full transition within 2 to five years. Bulk Distribution Companies (BDCs) sell LPG from bulk storage facilities to Oil Marketing Companies (OMCs) or LPG Marketing Companies (LPGMCs) who in turn supply their refilling plants and dealers. The Ghana Cylinder Manufacturing Company (GCMC) is the only company manufacturing and supplying LPG cylinders to the RLP, but has constrained production capacity. Refilling Plants and dealers receive the product into their storage and retail to consumers.

Biogas potential

Bio-LPG is not currently a realistic alternative to fossil LPG in Ghana but will be studied in-depth by GLPGP to assess the technical potential and viability of future Bio-LPG production and replacement of fossil LPG.

With regard to other potential biofuels for cooking, bioethanol and biogas are both clean fuels with considerable potential in Ghana. GIZ has assessed the theoretical potential of electricity generation from biogas to more than 800 MW (GIZ 2014). A feasibility study for biogas in 2014 included an assessment of biogas for institutions, and targeted installation of 200 biodigesters (Hanekamp et Cudjoe 2014). However, on the household level, biogas is unlikely to meet the needs at national scale (KFW 2017).

Government policies and action

The NLPGP was approved in 2017 and seeks to review the industry, the existing market structure and distribution model; to identify challenges facing the industry; and provide the Government with intent and direction for the LPG sector. A roadmap is established to guide the process toward achieving the target of 50% LPG penetration. The Energy Commission is tasked with leading the effort, including coordination across the various stakeholders involved and the different areas of interest, while The National Petroleum Authority (NPA) is responsible for NLPGP implementation, which started in 2020 after a two-year period of planning.

Apart from the overall goal of 50% uptake, specific targets include:

1. Develop a market-driven structure to ensure safety, increased access and adoption of LPG (implying move to the BCR Model, and develop the required infrastructure).
2. Enhance the capacity of existing regulatory institutions in order to meet the regulatory requirements of the new market structure.
3. Ensure robust and standard Health, Safety and Environmental throughout the value chain.
4. Ensure the sustainability of supply under the new market structure
5. Ensure local content and participation in line with the Downstream Local Content Policy.

Targets for both LPG and efficient cookstoves are included in Ghana's **Intended National Determined Contributions (INDCs):** "Scale up adoption of LPG use from 5.5% to 50% peri-urban and rural households up to 2030". While the NDCs address gender under other sections, the cooking target does not directly mention women[28].

The indicative budget for implementing the policy is ca. **USD 25 milllion**, but will be revised as a result of less compensation required in a gradual introduction of the BCRM model[29].

Ghana has signed up as CCA Implementing Partner and launched **Ghana Clean Cooking Alliance (GHACCO)** in 2012 with the support of SNV, ORGIIS, CCA and World Education Incorporated.

[28] *Targeted results for the cooking related target in the NDC:*

1) 39,500 hectares of woodland saved from degradation; 2) Reduction in indoor pollution resulting from wood fuel usage; 3) Reduction in smoke related respiratory and eye diseases; 4) Reduction in household cooking fuel expenditure; 5) Job creation through the manufacture and sale of efficient stoves.

[29] *Compensation to customers who currently own their cylinders.*

Barriers and enablers

The barriers and enablers described in the main chapter are generally applicable to the Ghanaian LPG market. Based on the experience with previous and current efforts the following barriers deserve a specific mention in the context of Ghana:

Availability: LPG demand is steadily increasing, and LPG is now the fuel of choice for Ghanaian consumers. Further expansion of the sector is supply-constrained; partly by limited storage capacity (17,000 MT), while the CCCM model hinder market expansion and infrastructure to distribute to rural areas. The BCRM will imply a few central filling plants at the core of the distribution system, potentially addressing at least partially this issue.

Safety: Several accidents have given LPG a reputation as a dangerous fuel; again, the CCCM model is considered to cause maintenance and checking and recertification of the cylinders to be is irregular and uncontrolled, and proper handling is not guaranteed.

Affordability: Various studies[30] show that benefits associated with a transition to LPG far outweigh the costs bus as the benefits are partly intangible or realized at society level and not , and not necessarily valued by the consumer as decision maker. Different studies also apply different values to the same parameters; with some studies showing that positive benefits outweigh the costs, but consistently showing that the transition has a net cost also in the longer term (not only the investment).

The cost factor will also vary between rural and urban areas, with distribution and logistics adding a significant premium to the cost at household level; and with a lower cost base case (larger share of self-collected woodfuel in the energy mix).

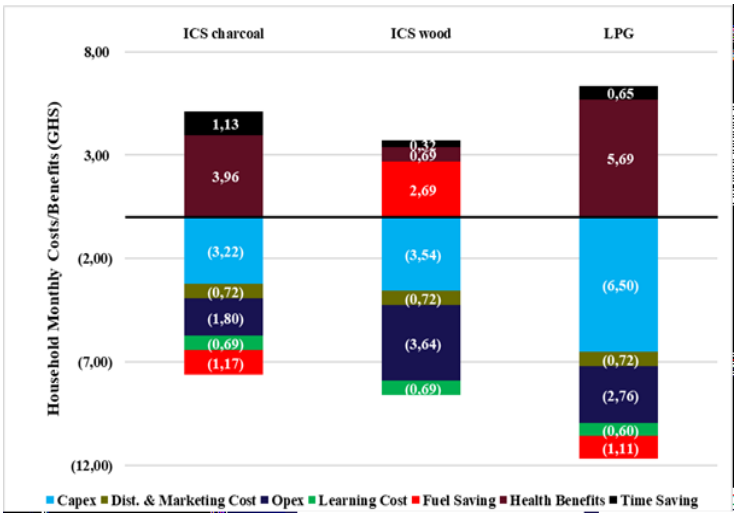


Figure 4-3 Figure Composition of Costs & Benefits for Mean Parameter Values. Source: GHACCO/SNV Costs and Benefits

Ghanaian consumers are to a quite significant level reported to value the cleanliness and health aspect of LPG, and willing to pay for it. However, without addressing the affordability barrier, LPG will remain a choice for the relatively wealthy part of the population.

The BCRM is expected to address part of this problem; with the customer having to pay a deposit rather than the full price of the cylinder. Other models being employed include smaller cylinders (e.g. 3 kg as opposed to the usual 5 or 12 kg), while the 'Pay as You Cook' model has not yet been tested in Ghana.

The impact on deforestation

Deforestation is one of the Government's key motivations for the strong emphasis on LPG. Ghana has one of the highest deforestation rates in the world, with one third lost between 1990 and 2010, and the country's greenhouse gas emissions profile is dominated by emissions from land-use change and forestry (53% of total emissions) and energy (25%).

GLPG (GLPG 2018) estimated potential averted deforestation in three different scenarios. According to this study, increased LPG use has the potential of saving from 11 – 21 million trees annually relative to base case projections in 2030; with 127 - 221 million trees saved between 2020 and 2030. Estimated potential for GHG emission reduction contributions in the same scenarios indicated potential of 10 million MT of CO2 emissions by 2030.

[30] *E.g. Hutton et al (2007)*

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

Figure 4-4 Reduction in annual and cumulative CO2eq emissions from increased LPG consumption relative to base case scenario. Source: GLPG 2018

4.2 The Democratic Republic of the Congo (DRC)

Overview

DRC is home to the world's second largest tropical forest massif after the Amazon with nearly 155.5 million hectares of forest. Forests in the DRC (60 % of the Congo Basin) are rich in animal and plant biodiversity (5th in the world) and provide important goods and services (non-wood forest products, timber, wood energy, bushmeat, traditional pharmacopoeia, etc.) on which the lives of thousands of rural people depend.

Biomass in the form of logged fuelwood remains the principal source of cooking energy for more than 90 % of the population in the DRC. Households and street vendors rely heavily on charcoal (or firewood) for daily cooking (87 % in Kinshasa). Companies, such as bakeries, breweries, restaurants, brickmakers and forgers in aluminium, also depend on firewood or charcoal for their daily work.

The United Nations Capital Development Fund (UNCDF)'s Clean Cooking Market Incubation programme aims to reduce reliance on wood fuel as a clean cooking energy source. This will be done by supporting the distribution of improved, efficient cooking solutions (that consume less-to-no wood fuel). In 2019, UNCDF established a locally based team of clean energy experts, who embarked on a detailed market scoping. This included business health and investment readiness assessments of over 50 enterprises involved in clean cooking activities, and efficiency and consumer field testing of over 24 clean cookstoves, ***LPG systems*** and electric stoves to benchmark the quality of products currently in the market[31].

In 2016 the Central African Forest Initiative (CAFI) approved USD 200 million for the implementation of the national REDD+ Investment Plan through FONAREDD and signed a letter of intent (LOI) with DRC. USD 15 million of this sum was dedicated to the Energy Program, developed and to be carried out by UNDP and UNCDF, and approved by FONAREDD in 2019. One of the four main components of this program is dedicated to LPG:

1. Integration of a fuelwood component in the national Energy policy;
2. ***Support for the development of LPG (sourcing and market development);***
3. Support for industrial-scale production and dissemination of improved cookstoves; and
4. Support for micro-hydropower

The LPG development component will focus on Kinshasa as a priority, and a few other urban centres, mobilizing at least USD 30 million in support of the deployment of LPG to provide access to at least 250 000

[31] https://www.uncdf.org/article/5341/what-does-the-clean-cooking-market-look-like-in-the-drc

households with an LPG volume of 15 000 tones/year after 5 years (GLPGP, pers. com.). GLPGP has a taken a leading and key role vis-à-vis the initiative.

Use of LPG in DRC

DRC has very limited experience in use of LPG so far. Consumption in 2019 was estimated to 750 tons. Less than 1% of the households use LPG, those that do usually use LPG for only part of their cooking (ref. 'Fuel stacking' explained in the main section). The Energy Program aims to scale this considerably up (15 000 tones/year), especially in some target urban areas.

In IEA's Africa Energy Outlook (2019) scenarios for fuels and technology use for cooking for Democratic Republic of Congo, the African Case (AC) builds on up-scaling of LPG up to 20% by 2030.

In the SP, more people gain access to clean fuels and technologies for cooking by 2030, but 70% of the population still lack access. To bridge the gap in the AC and achieve full access to clean cooking for all, liquefied petroleum gas (LPG) is the most scalable solution for urban settlements, with improved biomass cookstoves doing most to provide access in rural areas.

Market regulation and structure as well as government policies and action

As there is virtually no market for LPG at present, achieve the ambitions of FONAREDD or IEA Energy outlook for upscaling of LPG in DRC requires fast development of a market with proper regulation and structure as well as associated government policies and actions. GLPGP is supporting the government in preparing a Pre-master Plan to understand the state of play (DRC baseline context including analysis of the value chain) and set the overall targets and key steps to achieve them. This will subsequently be followed by a Regulatory Road Map focusing on creating an enabling environment, obligations and sanctions, support to the distribution model and marketers, licensing and permitting rules, pricing and tax regimes, levelling the "playing field with electricity, investment level (and mobilizing investors), microfinance/consumer finance, communication and capacity building. The first stage target is to ensure access to LPG for 250 000 households to replace charcoal[32].

The major existing distribution and marketing companies in the market are COETE GAZ and SOGAZ. For these countries to effectively drive the development through e.g. investments in the cylinders, incentives may be required to ensure sustainable margin and a sustainable business case.

Biogas potential

Biogas is not currently a realistic alternative to fossil LPG in DRC, but as for Ghana but will be studied in-depth by GLPGP to assess the technical potential and viability of future Bio-LPG production and replacement of fossil LPG. According to the World Biogas Association, DRC has opportunities to utilise biogas for renewable power generation, with reserves of biogas in Lake Kivu, which can be used as a renewable fuel for gas engines.

Barriers and enablers

The work to establish a national LPG strategy led by GLPGP can be expected to aim to address all the barriers and enablers described in the main chapter, which all will be relevant for the LPG future in DRC. A few deserve a specific mention in the context of DRC:

Availability: To achieve the expected LPG demand increase as foreseen in the FONAREDD plans or IEA Energy Outlook, DRC will need to overcome the challenge of expanding the sector in the face of supply- and demand-constraints. Storage capacity is limited and significant investment to build infrastructure to distribute to rural areas will be required, particularly challenging due to the sheer size of DRC and the remoteness of some rural areas. Enabling investments in infrastructure and distribution development will be a key factor.

Awareness: LPG is unknown as a clean and safe alternative among the population as well as in the public sphere. In a survey (CARID 20xx) only 1% of respondents in the capital Kinshasa reported a desire to move to LPG.

32

The impact on deforestation

According to the Global Forest Watch April 2019 report the DRC is the second-largest deforestation front in the world. From 2001 to 2019, Democratic Republic of the Congo lost 14.6Mha of tree cover, equivalent to a 7.3% p.a. decrease in tree cover since 2000, and 6.00 Gt of CO_2 emissions. The main causes of this phenomenon ranges range from slash and burn agriculture to the use of firewood and charcoal. The Minister of the Environment and Sustainable Development launched a campaign against deforestation in Kinshasa on March 19th, 2020. Among the main approaches of this campaign, the Government promotes use of LPG by households and other users of cooking fuel. The first stage is entirely financed by the DRC Government to the tune of more than 1.8 million euros (approximately 3.5 billion Congolese francs). Up-scaling of LPG as planned will help prevent pressures on the forest resources and its inherent ecosystems but will only be one solution among many required to prevent further deforestation in DRC.

4.3 Tanzania

Overview

Deforestation, indoor air pollution and burden on women have been on the agenda of the Government of Tanzania (GOT) and international development agencies for several decades. Introduction of Improved Cookstoves (ICS) for biomass fuels has remained one of the main strategies to address these challenges (EUEI PDF, 2014), but in recent years LPG has become more prominent on the agenda as a viable alternative to woodfuels through initiatives such as Sustainable Energy for All, SE4All (URT-MEM, 2017).

80% of Tanzania's Total Primary Energy Supply (TPES) is "Biofuels and waste" (IEA, 2020). In mainland Tanzania firewood (60.9%) is the primary cooking fuel, followed by charcoal (28.8%), industrial gas (3.2%), Electricity (2.1%), paraffin (1.3%) and solar (1.1% of households). Firewood is more commonly used in rural areas (84.8% of households) than in urban areas (17.4%) (URT, 2019).

The GoT's *National Energy Policy* sets a target of 75% of the population to have access to clean cooking technologies and identifies LPG as a fuel to modernize domestic energy use (URT, 2015a). The country's INDCs include an aim to contribute to mitigation by enhancing carbon sinks through forest conservation by substitution of biomass energy with other energy sources including gas (URT, 2015b), but without explicit mention of LPG, or women in relation to cooking.

High- and middle-income consumers in urban areas increasingly recognize LPG as a cost effective, clean and healthy energy option compared with charcoal. Over the past decade LPG supply for household cooking has increased steadily in Tanzania, from less than 20 000 metric tonnes (MT) in 2010 to more than 145 000 MT in 2019 (EWURA, 2019a). Demand is unevenly spread over the country's regions, with the lion's share of the development happening in the capital. Yet peri-urban areas are also growing and may be a new frontier for promotion of LPG. Although there is an awareness of the benefits among potential consumers, availability, safety concerns and affordability slow down further uptake.

Use of LPG in Tanzania

The demand for LPG varies across zones in mainland Tanzania. The Coastal Zone, which comprises Dar es Salaam, Pwani, Morogoro and Tanga regions, represents 50 % of the LPG consumption. The Northern Zone (Arusha, Kilimanjaro and Manyara regions) consumes 23 %; the Lake Zone (Mwanza, Mara, Geita, Shinyanga and Simiyu) 12 %, and the remaining four zones all have minor shares of the market (EWURA, 2019b).

LPG is the primary cooking fuel for 8.1 % of the urban households, and 0.4 % of rural households. The Household Budget Survey 2017-2018 shows that in Dar es Salaam, charcoal is the most popular fuel, used as primary fuel by 58.9 % of households. LPG ranks second, used as primary fuel by 13.3 % of the households (URT, 2019).

The poor spent about 35 % of their household income on energy while the better-off spent only 14 % (URT-MEM, 2015). "Fuel stacking" is commonly practiced in Tanzania across income levels and throughout the country (Choumert et al, 2018); particularly so in urban areas where many energy alternatives are available

(Doggart et al, 2020). Fuel stacking enhances security of supply and cost effectiveness of energy use for households but may also represent a barrier to market development for new energy sources.

Market regulation and structure

Tanzania's Ministry of Energy (MoE) is mandated to "provide reliable, affordable, safe, efficient and environment friendly modern energy services to all while ensuring effective participation of Tanzanians in the sector"[33]. Agencies and institutions under MoE that are relevant to regulation and promotion of LPG include the Energy and Water Utilities Authority (EWURA), *Tanzania Petroleum Development Corporation* (TPDC), *Petroleum Bulk Procurement Agency* (PBPA).

LPG operations are regulated by EWURA under jurisdiction including *The Petroleum (Liquefied Petroleum Gas Operations) Rules, 2018 GN 376*, and standards including *TZS 818:2004 Liquefied Petroleum Gas specifications*[34]. EWURA reviewed the price Setting Rules to include LPG in 2018, giving GoT more regulatory control of the market.

All LPG sold in Tanzania is imported. There are nine operational LPG receiving facilities in Dar es Salaam and Tanga with a total storage capacity of 16 973 MT. Tanzania has recently adopted a bulk procurement system (PBPA) to ease the importation of LPG. The retail market is regulated for BCRM distribution of LPG. In 2018, Oryx Gas had a market share of 49 %, followed by Mihan Gas (named Taifa Gas) with a market share of 18 %. Other companies are Lake Gas (12 %), Manjis Gas (11 %), Oilcom Gas (6 %), Orange Gas (2 %) and Mount Meru Gas (1 %) (EWURA, 2019b). Kopagas (see also Box 13.5) started operations in Dar es Salaam in 2014 and currently has 25 000 customers (Rodriguez, pers. comm.).

Potential for biogas

The potential for production for Bio-LPG is not explored but the resource availability is likely abundant (GLPGP, comm.).

Technical potential for biogas has been estimated to 165 000 installations for the country. Kilimanjaro, Mbeya, Iringa and Ruvuma have been estimated to have a potential for 34 000, 25 000, 19 000 and 13 000 installations, respectively (TDBP, 2009). The most recent, and by far the largest initiative to promote biogas is the Tanzania Domestic Biogas Program (TDBP). Launched in 2009, financed the Netherlands, implemented by CAMARTEC. TDBP constructed 12 000 small-scale digesters through TDBP phase I and aimed at another 10 000 through TDBP phase II (URT-MEM, 2017). The second phase of TDBP was financed by the Norwegian Ministry of Foreign Affairs over the through the Clean Energy Programme with the Rural Energy Agency (REA).

Government policies and action

GoT has numerous strategies and plans pertaining to LPG: Development Vision 2025 (1999), Long-term Perspective Plan (LTPP) 2011/12 – 2025/26, The National Natural Gas Policy of Tanzania (2013), Energy Subsidy Policy (2013), National Energy Policy (URT, 2015a).

The policy framework to meet the National Energy Policy includes: *Energy and Water Utilities Authority Act* (2001) and (2006), *Rural Energy Act* (2005), *The Petroleum Act* (2015), and *Public Private Partnership Act Nº. 18* (2010) and its policy (2009).

The Government's 2030 target for SDG7, goal 2, to increase "Population with access to modern cooking solutions" is to ensure that 75 % of the population uses either biogas, LPG, ethanol, natural gas, or charcoal in ICS. The baseline value was 16 % in 2012. Measures to meet targets under SDG7 are implemented through the SE4All agenda through GoT, where an objective is to disseminate 180 000 LPG stoves by 2022 (URT-MEM, 2017).

Through the National Energy Policy (URT, 2015a) the Government has been promoting substitution of charcoal and firewood by providing tax relief to stimulate the use of LPG in the country. EWURA have implemented policies to stimulate market development for LPG since the mid-2000s. In 2008-2009 import duties and VAT were removed from LPG (URT-MEM, 2015). All other cooking fuels have taxes, royalties,

[33] *Ministry of Energy:* https://www.nishati.go.tz/en/

[34] https://www.ewura.go.tz/regulatory-tools/

duties and levies. Charcoal is the most affordable fuel, and LPG ranks second (Doggart et al, 2020). As of yet there is no VAT exemption for stoves and other equipment for use with LPG.

Barriers and enablers

With reference to the Enablers and Barriers discussed in Section 0, the following elements are particularly noted in the Tanzanian setting:

Policy and Programmes: There is no national policy with an explicit LPG target, and no LPG promotion programmes under GoT. Setting targets for market expansion of LPG could be a yardstick to attract investors and support progress, including through public awareness campaigns on LPG benefits and safety.

It should be noted also that knowledge of potential for GHG mitigation and reduction of deforestation with introduction of LPG could increase policy attention, e.g. through support to research institutions in Tanzania. Dialogue and better coordination between agencies under Ministry of Energy and Ministry of Natural Resources and Tourism, and the Vice President's Office (Doggart et al, 2020).

"Fuel stacking" should be accounted for**:** When planning development in the energy sector, fuel stacking may be considered a rational strategy rather than an obstacle. Policies centred on price changes may not be effective in changing consumer behaviour unless alternative sources of energy are readily accessible (Doggart et al., 2020).

Availability: Import port facilities in Dar es Salaam and Tanga are so far underutilized but demand is growing, and once capacity is reached in a few years this will become a barrier for further supply growth. Financial support for investment in infrastructure is required to meet future demands.

There is also an insufficient number of cylinders to meet growing demand: There are currently between 1.5 million and 2.5 million cylinders in Tanzania (CCA, n.d.). To counter this supply constraint and enable LMCs to invest in cylinders and distribution expansion, access to favourably priced financial resources for private companies/LMCs or other incentives such as VAT exemption could be effective.

Awareness: Consumer preferences are often conservative and characterized by limited awareness about benefits and safety. Information and promotion focussing on LPG allowing faster cooking than charcoal and being safe, and significantly cleaner and healthier, could increase uptake (availability allowing).

Affordability: While the running cost of the fuel is becoming increasingly competitive in urban areas where charcoal prices have increased substantially, LPG requires upfront investment, making the solution unaffordable for lower-income users. Tax advantages and reforms could reduce this barrier, by for example 1) Reducing import duties and VAT for LPG appliances to reduce start-up costs for cylinder and stove; 2) Restrictions/regulation of charcoal sales; and 3) formalization of the charcoal sector[35,36]. The emergence of companies such as Kopagas that delivers services with consumer financing solutions integrated ("Pay As You Go (PAYG)", or "Pay As You Cook" LPG business models) can open the market for poorer customer segments. Additionally, enabling LMCs to procure smaller cylinders could reduce the high refilling cost of large cylinders.

Market development and expansion: Lack of access to financing and concessional funding for commercial enterprises in LPG: There has been limited interest from development agencies in supporting petroleum-based energy due to focus on climate change mitigation. As above, availability of investment capital that accepts below-market returns or terms, for example with emergent business models such as PAYG, is an important enabler.

The impact on deforestation

The annual consumption of biomass energy in Tanzania is estimated at 62.3 million m^3, while the sustainable yield is estimated at 42.8 million m^3, leaving a 19.5 million m^3 deficit (TFS, 2015). This "gap", defined as the negative difference between allowable cut and actual cut, is deforestation caused by clearing of new

[35] As proposed as measures in BEST (EUEI PDF, 2014)

[36] Experience from Kenya showed a massive increase in use of LPG after charcoal was banned

agricultural land and unsustainable use of woodfuels. In Tanzania about 373 000 Ha of forest was lost from 1995 to 2010 (TFS, 2015).

The gap is widening due to population growth and urbanisation. The population size in mainland Tanzania was 52 691 314 million in 2017-2018 (URT, 2019). The population grows at 2.9 % per year.

Rural use of firewood is less harmful to forests than charcoal burning and use of charcoal in urban areas is widespread in urban Tanzania (Mwampamba, 2007). Although the market for LPG is growing in urban areas, so is the consumption of charcoal. Charcoal consumption mainly in urban areas has nearly doubled over the past ten years due to urbanisation and high prices or scarcity of the alternatives such as kerosene, electricity and LPG. It is projected that demand for charcoal, without supply and demand side interventions will double by 2030, from approximately 2.3 million tonnes of charcoal in 2012 (URT, 2015a).

There is limited documentation of the impact potential of LPG introduction on GHG mitigation and reduction of deforestation in Tanzania. Doggart et al (2020) found in a survey in Dar es Salaam that LPG is mainly used in combination with other fuels. In a randomized controlled trial study in Dar es Salaam by Alem and Ruhinduka (unpublished), it was found that adoption of LPG stoves reduced charcoal use by about 30 % in the treatment group 15 months after the intervention. This could correspond to a reduction in deforestation of 0.038 ha/household/year. The estimate provided here should be used with caution. However, it is evident that substitution of woodfuels with LPG will reduce the need for forest biomass.

When addressing deforestation, it should be considered that the consumption of biomass energy in Tanzania is around 17 000 ktoe (IEA, 2020) and consumption of LPG 159 ktoe (EWURA, 2019a). Not only does one outnumber the other, but consumption of the two energy sources appear to increase at the same rate. LPG is likely to increase in popularity as primary fuel in urban energy use, but policies to mitigate deforestation should also consider how to manage charcoal value chains and forest management (Owen et al, 2013, Doggart et al., 2000).

4.4 Ethiopia

Overview

As in most sub-Saharan countries, a marked feature of Ethiopia's energy sector is the high dependence on biomass (firewood, charcoal, crop residues and animal dung). The bulk of the national energy consumption is met from biomass sources (Geissler et al. 2013). According to the most recent national energy balance from MOWIE (2016), 89% of all final energy supply was from biomass sources and the household sector consumed 90% of all energy consumed in 2014. Demand growth for fossil fuels and electricity is however higher than biomass fuels.

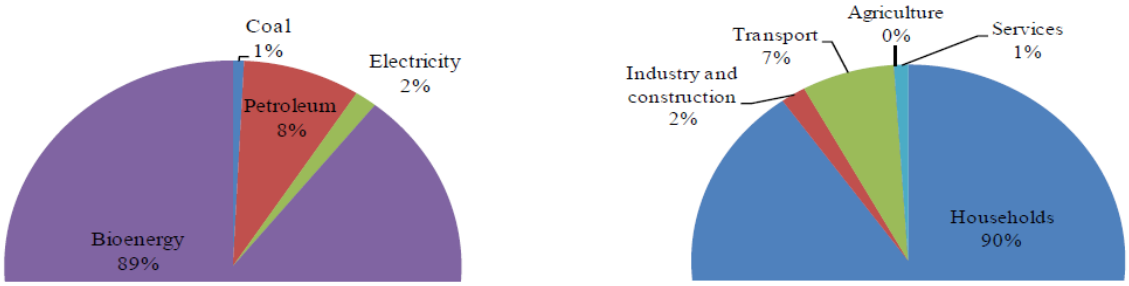


Figure 4-5 Ethiopia National Energy Balance, 2014 (total energy consumed=36.4 Mtoe). Source:

Households account for nearly all the biomass energy consumed; fossil fuels are used mainly by the transport sector; and electricity use is about equally distributed across households, industries and the commercial sector.

Use of LPG in Ethiopia

Ethiopia has very limited experience in use of LPG so far, and less than 1% and household use it, mainly in the urban areas and in combination with other fuels. Penetration of other improved cooking methods is also slow. A recent CSA survey shows that only about 10% of households use energy saving stoves (for baking)

and penetration of other modern and clean cook stoves is well below 10%. In rural areas fewer than 6% use improved and clean cook stoves and less than 3% fuels other than biomass; and even in urban areas more than 80% depend on biomass fuels. Modern bioenergy in the form of biogas and ethanol are used by less than 20,000 households throughout Ethiopia.

The clean 'fuel' of choice appears to be electricity, as shown by the relatively high proportion of urban dwellers owning electric facilities for cooking (Figure). Meanwhile, the International Energy Agency (IEA) in their Africa Energy Outlook (2019) "African Case" for Ethiopia assumes that in achieving the SDGs LPG could make up 9% of the mix (Figure) .

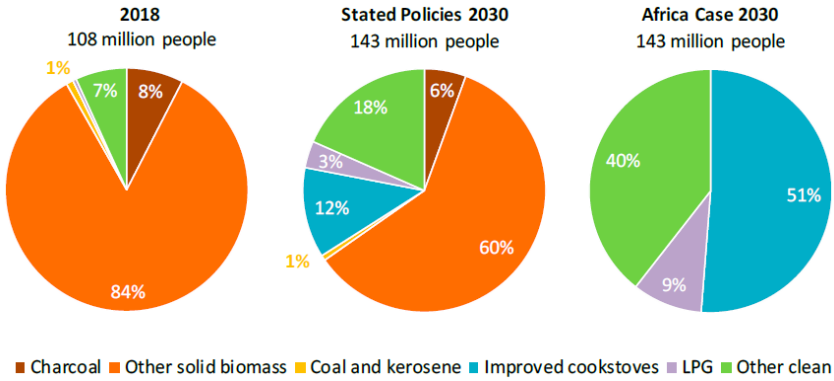
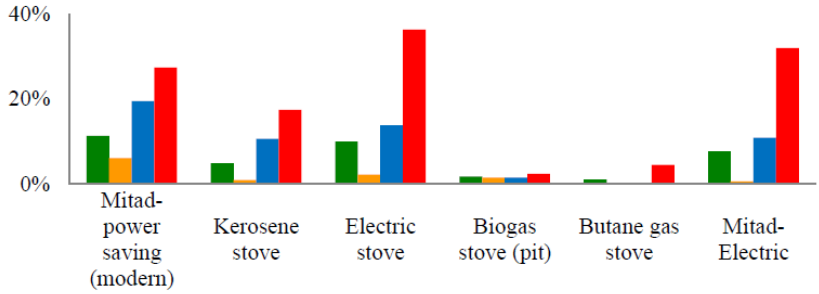


Figure 4-6 Fuel and technologies used for cooking in SP and AC scenarios (2030) against baseline (2018) for Ethiopia (IEA 2019).



	Mitad-power saving (modern)	Kerosene stove	Electric stove	Biogas stove (pit)	Butane gas stove	Mitad-Electric
Country	11%	5%	10%	2%	1%	8%
Rural	6%	1%	2%	2%	0%	1%
Small Urban	19%	11%	14%	2%	0%	11%
Large Urban	27%	17%	36%	2%	5%	32%

Figure 4-7 Stove ownership by households. Source: MEFCC and SNV (2018)37

Market regulation and structure as well as government policies and action

There is virtually no market for LPG at present (at least at national level), and where it is in the urban settings its mostly used together with other stoves or electricity based on the availability of the different energy sources. LPG used to be imported by the government and its price was also regulated just like other petroleum fuels. However, in the last couple of decades LPG price has not been regulated and, importation and distribution of the fuel has also been done by the private sector. Distribution of the fuel is limited only to major cities and it faces frequent interruption of supply. LPG is a fuel usually used by high income households because of its high price (MEFCC/SNV, 2018).

Ethiopia's Draft Energy Policy (2013) does focus on clean (improved) cookstoves, and the Biomass Energy Strategy (BEST), issued in 2013, envisions sustainable biomass energy use. A national Improved cookstoves Investment Plan (IP) was launched in 2013 and promotes a "coherent, coordinated and programmatic approach" to the ICS sector. It seeks to address market barriers by supporting development of the supply

[37] *Butane here refers to LPG otherwise used in this report.*

chain; ICS product development for stoves to better meet consumer requirements; and increase financing for ICS from domestic and external sources (MEFCC/SNV 2018). **With regard to LPG, however, the government does not have any concrete plans or targets.** As mentioned above, electricity has increased much faster than LPG, and is believed to have displaced significant amounts of biomass energy used for cooking and baking in urban areas. Considering the goal for universal electrification by the GOE, electricity appears to be the prioritized choice to replace biomass in cooking.

Ethiopia is one of the Tier 1 countries of the MECS programme[38], however, electricity will presumably be the main focus for their services in Ethiopia.

SNV is actively supporting the clean cooking agenda, through the SEEECCS[39] project, with focus on improved cook stoves, biogas and biofuel. SNV also supported the recent establishment of the Ethiopia Clean Cooking Alliance.

Biogas potential

With 77% of agricultural families having cattle, Ethiopia has potential for biogas installation. SNV together with the Ministry of Energy has implemented a National Biogas Program (NBPE), constructing around 20 000 biogas plants until 2018. Ca 2% of households currently use biogas.

No evidence exists to suggest a role foreseen for Bio-LPG. Without any focus on building the infrastructure and increasing the use of LPG by households, the prospects for Bio-LPG will be weak.

Barriers and enablers

At the moment, it appears that most of the elements in an 'enabling framework for increased use of LPG, as described in Chapter 3, are lacking. In a possible future scenario, or even to achieve the IEA 2030 scenario of 9% use of LPG, all of these need to be addressed. In addition to the lack of policies and strategies, the 'Availability' barrier will obviously be significant initially; with supply constrained by both limited storage capacity and lack of investment in market expansion and infrastructure to distribute to rural areas. This is particularly relevant for Ethiopia due to the sheer size of the country and the remoteness of some rural areas.

Awareness and communication will be another key factor, and will be difficult to make efficient as long as Ethiopia maintains its high focus on electrification and the "clean" hydropower development rather than LPG upscaling. The large hydropower infrastructure will however mostly not electrify rural Ethiopia, at least in the near or medium distant future as it will take decades to electrify the country at large.

The impact on deforestation

Forests are important sources of economic and ecological service in the context of Ethiopia meeting critical development needs of the country and livelihoods of millions of citizens, particularly in rural areas. The total annual amount of fuelwood (and charcoal) consumed for cooking is 86 million tons, with only about 10% of it in the form of agricultural residue. Ethiopia's National REDD+ Strategy (2016) identifies extraction of wood for fuel (wood for charcoal making and wood consumed directly) as the main causes of forest degradation in Ethiopia. Charcoal production is deemed a particularly severe contributor to forest degradation. As Improved Cookstoves can only minimize part of this consumption, LPG in combination with electricity could contribute substantially to reducing forest degradation.

The REDD+ strategy targets until 2030 include dissemination of fuel-efficient stoves to 3 million households, promotion of biogas systems to 0.8 million households, and use of other alternative fuels (electricity, LPG, solar) by 1 million households (MEFCC and SNV 2018). However, adequate legal and institutional frameworks are not in place or have not been implemented effectively to arrest or reverse this threat, albeit tree planting has increased over the last years.

[38] Refer to Chapter 3; Modern Energy Cooking Services supported by DFID. Tier 1 countries are those that are considered relevant for MECS' services.

[39] Strengthening Enabling Environment for Clean Cooking Sector, Funded by the Netherlands Government

5 Main findings and key takeaways

In this study, we have described the characteristics of LPG, its typical value chain, and factors that can enable increased uptake of LPG as a cooking fuel. We have also considered a the effects that increase use of LPG, as a fuel alternative for the big number of people that currently mainly use biomass in the form of woodfuel or charcoal, may have on the household and societal level as well as in a climate change and deforestation perspective. Finally, we have studied the situation on the ground in four countries selected by Norad: DRC, Ethiopia, Ghana and Tanzania.

In addition to answering out the specific questions posed by Norad in the Terms of reference for the study, the insight gained through this study has allowed us to identify a number of 'take-aways' which we believe will be of particular interest for Norad's possible engagement in the clean cooking agenda going forward.

Summary of findings

First, it is worth recalling that **biomass remains by far the dominant fuel used for cooking in many developing countries**, in particular in Africa. Unsustainable use of forest resources for among other purposes household energy represent significant pressure on forest resources and contribute to deforestation. The close to 3 billion people world-wide that still lack access to clean fuels and technology for cooking, suffer from a range of negative effects. **The most prominent of these effects may be the detrimental impact on health**, in particular on women who are responsible for cooking in most households using biomass. Research indicates that direct exposure to smoke from traditional forms of fuels and methods for cooking leads to about 2.2-3.6 million excess deaths per year, making it the single most important cause of death among these populations and causing welfare losses in the magnitude of USD 5.11 Trillion per year. In addition to these premature deaths, indoor cooking causes a range of cardiovascular, respiratory and eye diseases.

The use of LPG in developing countries in the Far East, Latin America and to some extent North Africa has increased significantly over the past 20 years. In India, Brazil, Indonesia and Morocco, to mention some, LPG is now the dominant household energy source. LPG use is increasing also in Sub-Saharan Africa (SSA), though still at a low level and mainly in large cities. **Only in a few SSA countries has LPG taken any significant share of the household energy market.** The uptake is often characterized by a phenomenon called 'fuel stacking': Households that get access to LPG use it in combination with other fuels rather than switching completely to LPG for all cooking purposes. Fuel stacking entails diversifying their energy sources, rather than relying only on one fuel for food preparation.

Technically, LPG is a by-product from the petroleum extractive industry and in abundant supply globally, but supply is unevenly distributed, and dominated by North America and the Middle East. **Bio-LPG is an exact substitute for fossil LPG**, and technical potential exists in many developing countries. So far, Bio-LPG has not been commercialized in developing countries, but a number of studies are on the way which will bring more insight and potetially create a basis for exploiting this as a renewable source of cooking energy.

In comparison to biomass, use of **LPG causes minimal household pollution and negative health impacts**. Being an Energy Access *'Tier 4'* solution, it has lower emissions than all cooking fuels and technologies other than solar and electricity, compares positively with biogas and alcohol fuels, and is several times better than Improved Cookstoves. **Handled correctly and subjected to proper regulation and control, it is a very safe technology**, but weak regulation and lack of control mechanisms has resulted in improper maintenance and handling in some markets and caused several serious accidents, giving LPG a reputation as unsafe.

LPG is a private sector-driven industry with significant potential for job creation and entrepreneurship, also in the local setting through engagement in the downstream part of the value chain.

Increased uptake of LPG could contribute to reduced poverty and an in particular an improved situation for women and girls, who are mainly involved in cooking and fuel collection**.** Realistically, the potential for reducing the amount of time for woodfuel collection may be limited in the short to medium term, as

woodfuel is mainly done in rural areas where LPG uptake will be slower. Nevertheless, transitioning to LPG can reduce the time spent by women for cooking. The positive health effects will also primarily benefit women. **Promoting LPG would be an important and strongly positive contribution on the humanitarian agenda**, e.g. if used to improve the energy situation in refugee camps across the world.

Replacing biomass fuels by LPG will reduce pressure on forest reserves, which is a significant challenge in most of the countries where biomass is widely used as household energy. Unsustainable harvesting of forest biomass gives a higher fraction of non-renewable biomass in woodfuels used for cooking. Despite being a non-renewable fuel that will imply a certain level of emissions, **LPG can contribute to reducing net GHG emissions** through more efficient combustion and cooking than biomass, leading to lower emissions of CO_2 and black carbon per unit of heated food. The exact, quantified substitution effect from such replacement however depends on a range of factors, including to what extent the outtake of biomass is sustainable in the specific country, as well as the efficiency level of the technologies that LPG would replace and the cooking methods applied. However, it is clear that the positive effect on deforestation of substitution of woodfuels with LPG will be significantly greater than by transitioning to Improved (biomass) Cookstoves.

For LPG to increase to a significant or dominant market position in Sub-Saharan African countries, an enabling environment for the sector must be in place. Elements that make up this environment include **technology and design** that make the alternative attractive in the specific cultural and social setting they are promoted. All parts of the value chain must be in place and functional, and a distribution system to enable **feasible access for the users** must exist. Ensuring this requires both public and private investments at a level that allows for economies of scale, supporting in making the sector commercially viable. Sufficient attention on policy and strategic level, with clear **responsibility allocation and appropriate regulation** of the sector, is required. Importantly, regulation must also take into account regulation of the key 'competing fuel', namely charcoal, a sector which often is strongly informal and unregulated, but often difficult to target as it is also a large employer. Further, ensuring access is often not sufficient; **knowledge and awareness to LPG as a safe and clean alternative** must be developed. Additionally, since LPG not only requires an investment into the technology (stove and cylinder purchase, or deposit) but often also represent higher running costs than the available alternatives (including biomass), it may be necessary to put in place **consumer finance solutions, smart business models, subsidies** or other ways to ensure that the affordability issue does not become a barrier. While cost-benefit analyses are usually strongly positive for LPG on the global level, on the household level the costs are often monetary while the benefits are less tangible. The additional fact that the benefits are particularly important for women and less felt by men, makes positive decision even more challenging. This increases the affordability challenge and slows transition.

Given the strongly positive effect that increased uptake of LPG as an alternative to traditional biomass based cooking and household energy use can have, and the important contribution such it would make toward achieving the SDGs', it is striking **how little attention this area has attracted in the international donor community**. On a general level, clean cooking has for decades received relatively less attention than for example access to electricity. However, even to the extent clean cooking has been in focus, LPG has received less attention and less funding than for example Improved (biomass) Cookstoves. The reason appears to be that for some donors any support to fossil energy becomes unacceptable and LPG falls outside the definition of target intervention areas..

There are nevertheless a number of **global organisations that do emphasize the important role LPG can play in solving the 'cooking energy problem'**, save millions from death and disease from indoor pollution, and reduce deforestation and GHG emissions. This includes the UNDP, DIFID, WHO, Global LPG Partnership and the Clean Cooking Alliance, as well as WHO. The World Bank/ESMAP seem to pursue a more "technology neutral" approach to Clean Cooking. has also relatively recently included LPG as one element in the Clean Cooking area of intervention.

While the LPG sector is, at least to a large extent, private sector driven, large international and global corporations are also largely absent from the scene in developing countries. In these countries, the **sector is thus relatively fragmented, characterized by many smaller, mostly national companies**.

Different countries have significantly different starting points and prospects for making LPG an important part of the household energy portfolio. Among the four countries studied, Ghana is the only one where

LPG as taken a significant share of the market and is set to continue to increase. The demand is increasing in urban areas in Tanzania, but ignorable in Ethiopia and, so far, in DRC.

In all four countries, biomass is the predominant source not only in the household energy mix but also in the national level primary energy use, and deforestation is a major challenge. Potential for biogas production exists in all four countries, but Bio-LPG is not explicitly explored to date. Ghana is the only country which supplies a significant share of the LPG from domestic resources (44%). Clean cooking is a focus area established policies and strategies in all four countries, but the extent to which these are followed by concrete plans and budgets vary. Only Ghana has established specific targets for LPG's share of the household energy market (50%) and includes LPG explicitly in their INDCs. DRC is in the process of establishing an LPG strategy and programme. Tanzania targets 75% clean cooking access by 2030 but does not identify a specific proportion targeted for LPG. Tanzania does however grant VAT exemption for LPG (but not for the stoves/cylinders). Such benefits are not considered in Ethiopia but expected to be a part of DRC's future efforts to increase LPG use.

Tanzania has a viable regulatory system in place, while Ghana has defined the same but faces some challenges in phasing it in. The regulatory environment is under development in DRC, while the sector does not receive political attention in Ethiopia.

There are strong similarities among the countries with regard to the barriers that hinder increased uptake. While all the elements in the enabling environment need to be in place it appears that availability, awareness and affordability are or will be factors of great importance in the all countries.

Key takeaways

If we were to highlight six key messages that we find particularly important, we would include:

1. **LPG has the potential to substitute charcoal and woodfuels for a substantial part of household energy and could contribute positively toward several of the SDGs,** including Access to Energy, Climate Change, Health, and Gender/Equality (SDG nos. 7, 13, 3, and 5).
2. **LPG is 'clean' and sustainable** - although it is fossil - (at least in the medium term) and can represent substantial positive impact on several important sustainability factors, such as creating jobs and reducing deforestation, GHG emissions, and the number of deaths that each year are caused by indoor pollution.
3. **There has been a low level of engagement by international development partners in the area of LPG promotion** to date. With the exception of a number of global and multilateral organisations, most actors that have been most active in promoting clean cooking appear to have largely overseen the positive effect that LPG substitution can have.
4. **Possible interventions in any of the four countries studied need to take into account the starting point and conditions for promotion of LPG.** DRC and Tanzania may have the largest potential for interventions at programmatic level: with DRC at an early stage of LPG promotion and Tanzania with a positive regulatory environment, increasing demand and a potential market in large and densely populated peri-urban areas. In Ethiopia, it does not appear likely that LPG will compete with electricity by receiving particular favourable conditions as long as there is no determined policy decision to promote it as a preferred cooking solution; but LPG might be included in the energy policy dialogue with the authorities. Ghana is the country where LPG penetration has come the farthest, both as prioritized solution and in terms of market share. With favourable policies in place, assigned responsibility within the authority apparatus, and high and increasing demand, it is now implementation that needs to accelerate; besides that, the most important contribution in Ghana may be to build down the availability barrier by supporting capital mobilization to facilitate investment in building out infrastructure.
5. **There is a significant and untapped potential among urban households as well as the growing demographic spheres referred to as 'peri-urban areas'.** This market could be reached with targeted policies and support measures.
6. **LPG represents an important yet only partial solution for the billions that must gain access to 'clean and modern cooking solutions' before 2030.** The ambition of shifting the billions using biomass over

to sustainable and 'clean' fuels, is likely not possible without allowing LPG to play an important role at least in the medium term. But, in particular in Sub-Saharan Africa, continued use of biomass appears unavoidable in rural areas and in the medium term. This emphasizes the need for strong efforts also to ensure widespread availability and uptake of Improved Cookstoves, although it is not as effective as LPG as a way to reduce the health burden, the pressure on forests, and GHG emissions.

Appendix I. References[40]

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Appendix II. List of Interviewees

Organization	Name of interviewee(s)	Key topic(s)
Global organizations		
GLPG	Dr Elisa Puzzolo, Director of Research (and researcher at University of Liverpool); Mr Kimball Chen, founder and Chairman; Mr Alex Evans, Senior Advisor to the Chairman	LPG as an alternative cooking fuel in developing countries
GLPG	Dr. Puzzolo, Mr. Evans and Mr. John Hauge	DRC, LPG situation and prospects
GACC	Ms. Donee Alexander, Evidence & Impact	Impacts
GACC	Mr. Peter George, Private Sector and Investment	Markets and Private sector development
Research		
CICERO	Kristin Aune, Researcher	Impacts, climate
International Development partners		
KfW	Ms. Janne Rajpar	LPG promotion and support
SNV		LPG promotion and support
National actors		
National Petroleum Authority	Ms. Sheila Addo, Ag. Director Projects, Monitoring and Evaluation	Implementation of the National LPG Policy
GHACCO	Mohammed Aminu Lukumanu, Chief Executive Officer	Situation and Prospects for LPG in Ghana
University of Dar es Salaam	Remidius Ruhinduka, PhD. Lecturer at the Department of Economics	LPG in Tanzania
KOPAGAS	Dr. Sebastian Rodriguez Ms. Hanaan Marwah, head of Investment and Business Development	Pay as you Cook model, Tanzania market and development prospects
CCA Ethiopia	Ms. Konjit Negussu, Chief Executive Officer	LPG in Ethiopia

Appendix III. Terms of Reference

I BACKGROUND

Liquified Petroleum Gas (LPG) is used worldwide for cooking, but to a lesser extent in developing countries. LPG is a fossil fuel. However, use of LPG is recognized to have fewer (if any) documented negative health effects compared to traditional cooking (often over open fire). Demand for firewood and charcoal is one of the drivers for deforestation in Sub-Saharan Africa.

Increased use of LPG could thus relieve the pressure on forest resources, which again could contribute to reducing greenhouse gas emissions. Besides, more use of LPG could also reduce time use for women and children and reduce risks associated with collection of firewood and reduce pollution from black carbon emissions.

For the time being, LPG is primarily a realistic option only for the urban and more wealthy part of the population. Besides, LPG is used only for part of the cooking (stacking). Most households in poor countries cannot afford to use LPG (and other higher tier cooking solutions).

On this background, Norad has decided to undertake a study on LPG. The study has an energy access perspective (SDG 7) as well as a climate change mitigation perspective (SDG 13).

II PURPOSE OF THE STUDY

The purpose of the study is to provide Norad with fact-based knowledge regarding increased use of LPG in developing countries. This includes opportunities and barriers regarding LPG as a means to increase access to modern and affordable energy as well as impacts regarding greenhouse gas emissions.

III SCOPE

LPG fact-finding

- What is LPG (including bio-LPG)? *LK dok*
- How is LPG produced? *LK dok*
- What is present world consumption of LPG? Identify trends. *LK dok.*
- Identify emission levels from use of LPG. *LK study*
- Identify safety issues associated with household use of LPG. *LK dok GALPG. Leif study.*
- Which tier(s) in the SE4ALL/ESMAP Global Tracking Framework does use of LPG for cooking correspond to? *ISO-rangering – verifisere at det er top tier.*
- Identify the main champions among business actors and development organizations that promote increased use of LPG in developing countries. Why do some development organizations promote/not promote increased use of LPG? *Sammenligne info vi har. Social entrepreneurs, impact investment. GALPG liste – hvem er 'main'.*

Increase access to reliable, sustainable and modern energy at an affordable price (Country studies)

Undertake desk studies/digital interviews (and to the extent appropriate digital interviews) in order to map and assess use of LPG in (tentatively) the following countries: Democratic Republic of Congo (DRC), Ethiopia, Ghana and Tanzania. *Research for documentation. Some info probably comes from previous point. Interview those that show from light search. Interview of donor*

- What is status in LPG use? To what extent has use of LPG penetrated to poorer/rural parts of the population? To what extent do small and medium-sized enterprises, such as restaurants and workshops, use LPG?
- What is the Government's position and motivation for promoting/not promoting increased use of LPG?
- To what extent do Nationally Determined Contributions (NDC) refer to LPG? Do the NDCs refer particularly to womens' needs?
- Which measures does the government apply in order to promote use of LPG? (such as VAT exemptions, subsidies, etc). How much of the State budget or Gross Domestic Product is used to promote LPG?
- Who are the main commercial actors and development organizations involved in promoting LPG? To what extent do they pay particular attention to women's needs, including training and safety measures?
- Identify the main barriers for increasing the use of LPG (enabling environment, supply side, demand side)?
- Compare the costs of using LPG for cooking with other fuel sources
- What are the conditions/realism in poorer households switching from fire-wood and charcoal to LPG, taking initial costs and access to credit into account
- How can supply-side barriers be reduced, among other by utilizing domestic/local resources (petroleum-based and/or green LPG)? *LK: Tan har nok gjort noen vurderinger av dette.*
- Identify the re- or deforestation rate in recent years. To what extent is wood collection for firewood/charcoal a driver for deforestation? Assess the realism in promoting increased use of LPG as a deforestation mitigation measure
- To what extent does the country rely on domestic production of LPG versus imports? *LK – doc/stats finnes*
- Assess potential for domestic production and use of biogas *LK*

Reduce greenhouse gas emissions from the energy sector *LK tar hovedansvar her.*

- How much does use of LPG today contribute to global greenhouse gas emissions (million tonnes/% of total/petroleum sector)?
- To what extent will increased use of LPG affect global greenhouse gas emissions?
- To what extent could increased use of LPG decrease the pressure on national forest resources?
- Compare emissions from LPG used for cooking with corresponding emissions from use of firewood and charcoal, also taking deforestation issues into account

IV Review Team

The Review Team will consist of one team leader assisted by one or two team members.

V Implementation and work modality

The assignment will include review of relevant background material and documentation of relevant documents and interviews/meetings with relevant stakeholders. The Consultant should be available to initiate the work in June 2020 and complete the work in mid-September 2020.

Norad foresees that the assignment will require up to 9 working weeks / 360 hrs.

The Consultant will be responsible for the following tasks and deliverables (all meetings are to be held digitally for practical reasons - if travel would be necessary to conduct the meeting):

- Kick-off meeting with Norad
- Inception Report and proposed report structure/outline to be delivered to Norad before two weeks after signing of the contract
- Information gathering, including:
    - Study of relevant documents;
    - Meetings with stakeholders;
- Presentation of preliminary findings to Norad within 25 August.
- Submit draft report, 1 week after the meeting with Norad
- Final report (in English), 2 weeks after submission of Norad's comments to draft report. The final report shall address all assessments as described under Scope of Work. The final report shall be no longer than 30 pages (font 12) excluding an executive summary and annexes and be delivered in .doc and .pdf format.