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Fueling The Change: The Journey From Biomass To Modern Source

PAOLA GIORDANO
Research Assistant

MIRABELLE ASSOGBA
Research Assistant, IMDE

AHMAD RAHNEMA ALAVI [1]
Professor

Abstract

In Côte d'Ivoire, as in most sub-Saharan countries, massive burning of biomass — used as cooking fuel — has terrible consequences on people's health. After malaria, lower respiratory infections are the second cause of death in the country, accounting for 11% of total deaths. Deaths correlated with indoor air pollution due to cooking are estimated to be 22,000 per year. The impact in terms of deforestation is also very serious. A study carried out by BNETD in 2016, related to quantitative factors of deforestation, showed that the area covered by forest decreased from 24.36% in 1990 to 10.56% in 2015.

On the positive side, the use of butane for cooking is expanding rapidly in the country, especially in urban areas. Today, it is possible to find a butane cylinder used for cooking in 92% of the households in Abidjan, although most of the time it is not the main fuel used.

This paper provides an overview of the current situation in Côte d'Ivoire's cooking fuel sector and on the progress made so far in the process of switching from traditional sources to cleaner and more modern ones. The aim of the paper is to understand what barriers are still limiting the adoption of modern fuels, what alternatives have been tried so far in order to break those barriers down, and what opportunities arise for private entrepreneurs willing to enter the Ivorian market and accelerate the process of switching to modern cooking fuels.

The analysis conducted in this paper is based on information publicly available, or obtained from industry experts or representatives of the key companies and institutions operating in this sector, and on the results of a field survey conducted by ENSEA (Ecole Nationale Supérieure de Statistique et d'Economie Appliquée).

Keywords: Energy; Côte d'Ivoire; cooking fuels; butane; biofuels; ethanol; biogas

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Contents

Executive Summary

The problem of access to energy in sub-Saharan African (SSA) countries is often discussed by limiting the perspective to the electricity needs of the population. However, the vast majority of energy consumption in the region is represented by cooking and heating needs, supplied by dangerous and inefficient sources — such as charcoal and firewood. The lack of access to modern and cleaner cooking fuels affects more than 700 million people in SSA. Due to air pollution from the use of firewood and charcoal, 600,000 Africans are killed every year.

Likewise, in Côte d'Ivoire biomass and waste represent 72.5% of the country's energy mix and are mainly addressed to the cooking needs of the residential sector. Massive burning of biomass has heavy consequences on people's health: after malaria, lower respiratory infections are the second cause of death in the country, accounting for 11% of total deaths. Moreover, in the last 25 years biomass burning contributed to the reduction of the country's forested area from 24.36% to 10.56%.

In 1992, aware of these aspects, the government started a butanization program, aiming to expand the use of butane for households' cooking needs. The program is still in place and acts in two ways:

1. Maintaining the price of liquefied petroleum gas (LPG) within affordability limits, through a subsidization policy that allows households to pay a price lower than the market price, today fixed at 2000 West African CFA francs (FCFA) for a 6 kg cylinder and 5200 FCFA for a 12.5 kg cylinder, and a transport equalization system that allows the cost of transport to be leveled out across the country to maintain affordable prices, even in more remote areas.

2. Attracting participants from the private sector and building an efficient distribution network, through the payment of a fixed distribution margin that grants distributors a fair income and through the concession of exclusivity agreements to those who expand their distribution network to less densely populated areas.

As a result, the consumption of butane rose from 22,000 tons to 24,000 tons in the years between 1980 and 1994, to 60,000 tons in the year 2000 and up to almost 270,000 tons in 2016. Today, 70% of Ivorian households use butane.

However, butane is struggling to completely replace biomass. In fact, only 17% of households use butane as their exclusive fuel, while most of the households use it in combination with charcoal or firewood. Overall, the consumption of butane, at 6.17 kg/capita, is still very low if compared with other emerging economies, such as Thailand, which consumes more than three times this amount, or Indonesia, whose consumption is almost four times that of Côte d'Ivoire.

On the demand side, the high up-front investment required for cooking with butane seems to be the main constraint.

In fact, although butane's price is competitive compared with the two other current fuel options (firewood and charcoal), the start-up investment, represented by the cost of a new burner and cooker, and the deposit paid for the cylinder at first purchase, can represent an insurmountable barrier for a household, especially when purchasing on credit is not an available option. Similarly, the minimum 6 kg format of the butane cylinder implies an up-front payment for future consumption, placing butane at a further disadvantage compared with firewood and charcoal, which can be purchased in smaller quantities — even just for daily needs.

On the demand side, cultural and traditional factors seem to further slow the transition to butane, either because of people's preferences or simply because the option to cook in a different way is not even taken into consideration.

On the supply side, an increase in butane production seems to be held back by availability constraints.

Despite the measures put in place by the government to establish a commercially viable LPG distribution network in remote and less densely populated areas, 54% of rural households still need to walk more than 30 minutes to reach the closest selling point. The lack of an official distribution network is often covered by the presence of small independent retailers. Interestingly though, independent retailers are not formally recognized as part of the butane value chain, and their margins are not regulated. In practice, a non-official — but apparently generally accepted — margin of FCFA 200 is often applied to the final price for the proximity service provided. However, sometimes this margin has been reported to reach up to FCFA 500, increasing the price of a B6 bottle up to 25% over the regulated price.

In addition, irregularities and delays in the supply, and the resulting shortages, are a real problem. This affects 28% of retailers — especially the smaller ones, which are also the closest to the households.

Moreover, the butanization program doesn't come without risks for the country. As 92% of Côte d'Ivoire's supply of butane relies on imports, this exposes the country to the volatility of LPG prices on the international market caused by changes in the price of crude, seasonality, production overhang and freight rates. Butane imports impacted the balance of payments by about US$95 million in 2015, and if the current consumption trend continues in the future, by 2020 the entailed expense can be estimated at US$240–US$400 million. Furthermore, to maintain the regulated price of butane, the subsidy could exceed US$300 million in 2020, with an impact on the price of other refined oil products (such as gasoline and diesel), whose taxation is currently subsidizing butane.

Aware of the difficulties that the butanization program has reaching more remote areas, at least in the short term, and perhaps as an attempt to limit the risks implied by the program, the government has also been involved, since 2011, in the REDD+ program, aiming to put in place a national strategy to establish a sustainable value chain for charcoal. This program acts in three main ways: 1) by re-organizing and regulating the supply chain for charcoal, which currently is primarily an informal sector 2) by encouraging the adoption of more efficient carbonization techniques and the valorization of biocharcoal produced from agricultural waste, given the significant stocks produced by Ivorian agricultural activities 3) by promoting the adoption of improved cookstoves to increase cooking energy efficiency through education and the sensitization of households.

Taking advantage of the government's interest in the country making the transition to cleaner cooking fuels, and given the obstacles currently constraining the potential demand for cleaner fuels, some opportunities have arisen for private entrepreneurs who operate in the industry to enter the Ivorian market and accelerate the process of switching to modern cooking fuels.

- The barrier of the high up-front investment costs required to use butane for cooking could be overcome through the pay as you go (PAYG) business model, which in Côte d'Ivoire has already been applied to the solar sector but has not yet reached LPG distribution. This is, for example, the solution adopted in Tanzania by KopaGas. However,

in Côte d'Ivoire, the fixed distribution margin set by the government could currently represent an obstacle for the development of PAYG, making it difficult to recover the additional cost implied by this model.

- An increase in the domestic supply of LPG by processing locally available natural gas could decrease Côte d'Ivoire's dependence on international imports. The conversion of the gas currently estimated to be flared in the country could generate 23,000 tons of butane, equivalent to 9% of the current demand for butane.

  Alternatively, natural gas for cooking could be provided to those households or industries that are currently using butane (especially in Abidjan) to free up butane for more remote areas. The economic convenience of using natural gas as a cooking fuel rather than for other uses, such as producing electricity, should be assessed.

- For rural areas, where butane still seems to be a rather distant solution, and given the high availability of agricultural waste, quantified as 6 Mtoe, the opportunity to produce ethanol gel as a cooking fuel could be assessed. Our preliminary analysis identified molasses as the best feedstock to be used to produce ethanol. Although at this moment locally produced ethanol would not be competitive, in the future it could become a viable alternative due to the high volatility of butane prices in the international market. Moreover, considering other benefits of the domestic production of ethanol as a renewable cooking fuel (such as the impact on the balance of trade and on the agricultural sector), we believe that a comprehensive feasibility study should be carried out to analyze the real potential and estimate the production cost, based on more accurate data.

- Côte d'Ivoire has one of the best potentials for gas generation from biomass in Africa, in terms of both agro-industrial waste and household waste, with an annual capacity estimated at 12 million tons of biomass. However, biogas has never really taken off in Côte d'Ivoire because of the high start-up costs (over US$400 for a small domestic anaerobic digester) and the complexity of managing it. However, innovative solutions at the village level could be considered, on the example of what (B)energy is doing by offering low-tech, low-cost mobile biogas solutions through local franchises to households in rural Africa, Asia and Latin America. Alternatively, the country could consider implementing a large-scale dissemination of biogas plants, as Nepal did with the Biogas Support Programme (BSP), through which more than 26,000 biogas plants were installed in low-income households.

From a policymaker's perspective, some steps could be taken to help overcome the barriers identified and provide a breeding ground for new solutions:

1. Support the diversification and inclusivity of the financial system and the further development of alternative technologies, such as mobile banking, to improve access to credit and, ultimately, the affordability of modern sources of energy.

2. Consider alternative ways of regulating the LPG cylinder refilling process to improve the circulation of butane cylinders and avoid shortages.

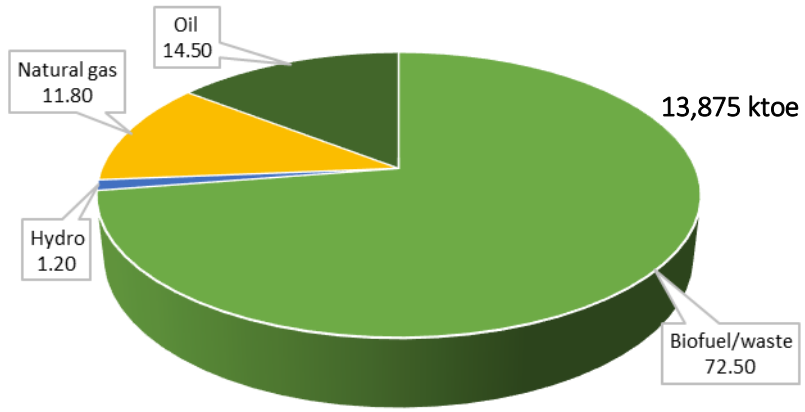
3. Consider recognizing independent retailers as part of the butane price structure, and regulate their margins to allow them to participate in the profit generated by the sector and to avoid the application of excessively high margins.

1. Introduction

1.1. Cooking Fuels: The Elephant in the Room

As for most sub-Saharan countries, the largest part of the primary energy mix of Côte d'Ivoire is represented by biomass. Biomass mainly consists of firewood, charcoal and agriculture waste; sources of energy mostly used by the residential sector for heating and cooking. In 2014, these sources represented 72.5% (10,110 ktoe)[2] of Côte d'Ivoire's primary energy supply (see Figure 1).

Figure 1
Share of Total Primary Energy Supply



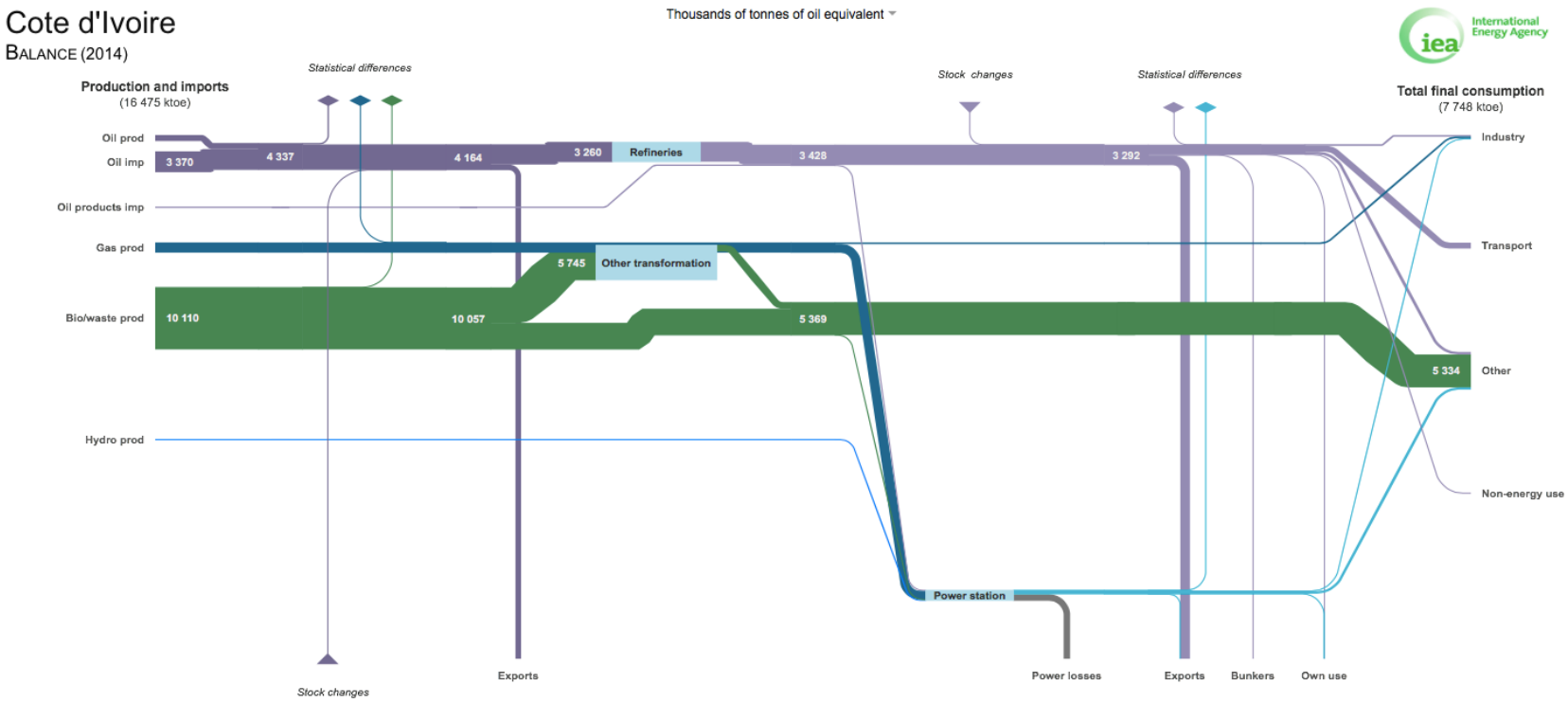
Source: Prepared by the authors based on International Energy Agency (IEA) data from Statistics by Country © OECD/IEA [online]. [Accessed on September 10, 2017.] Available from https://www.iea.org/statistics/statisticssearch/report/?year=2015&country=COTEIVOIRE&product=Balances.

Biomass and waste produced in the country are, in part, transformed into charcoal through the carbonization process and are, in part, used directly for fuel (firewood). The final consumption of biomass in the country is 5,334 ktoe and it is supplied almost exclusively to the residential sector (4,779 ktoe) and mainly used for heating and cooking (see Figure 2 and Figure 3).

Following the initiatives put in place over the years by the government to promote the substitution of biomass with more modern sources of cooking fuel, the consumption of liquefied petroleum gas (LPG) rose from 22,000 tons to 24,000 tons in the years between 1980 and 1994, to 60,000 tons in the year 2000 and up to almost 270,000 tons in 2016 (Ministère du Peétrole, 2017). In particular, consumption of butane showed a sharp increase starting in 2011 (see Table 1).

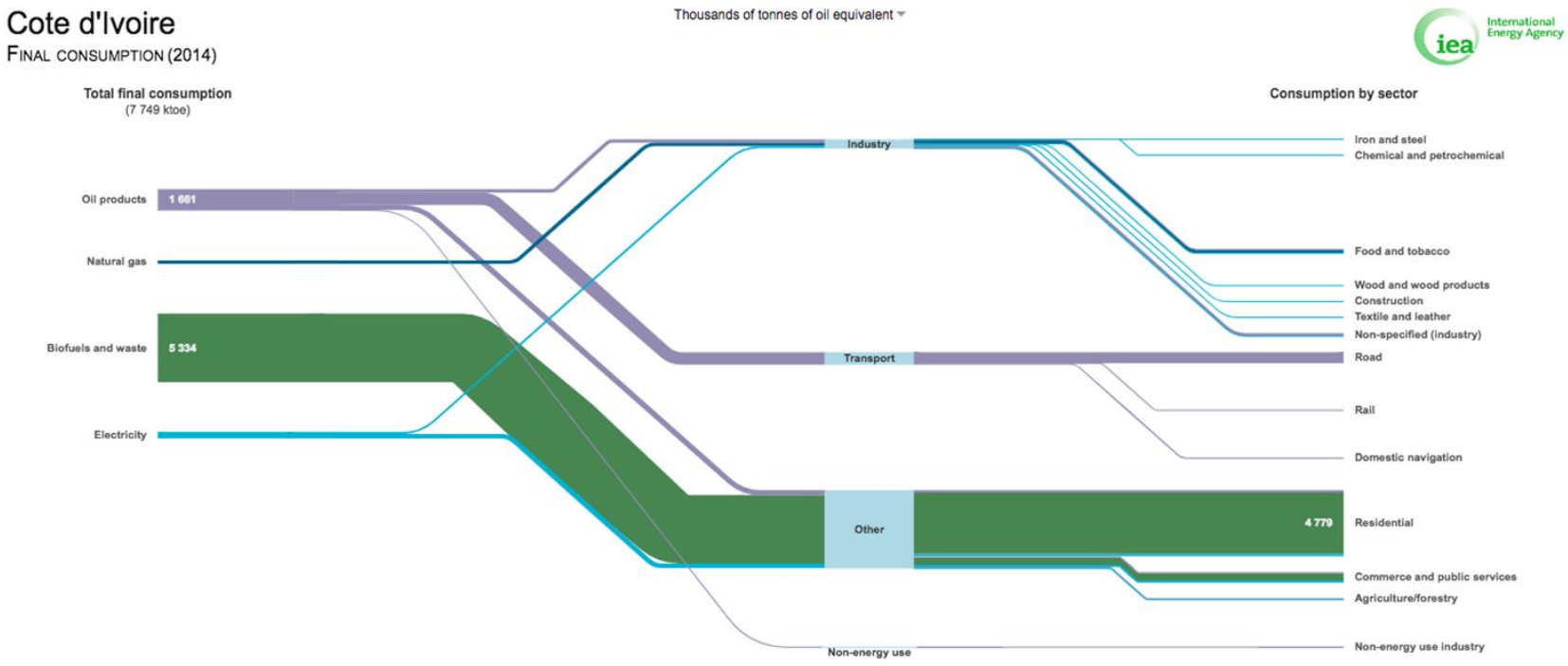
[2] Thousands of tons of oil equivalent.

Figure 2
Domestic supply and consumption of energy (2014)



Source: International Energy Agency (IEA) from Energy Balance Flows © OECD/IEA [online]. [Accessed on September 10, 2017.] Available from http://www.iea.org/Sankey.

Figure 3
Domestic consumption of energy by sector (2014)



Source: International Energy Agency (IEA) from Energy Balance Flows © OECD/IEA [online]. [Accessed on September 10, 2017]. Available from: http://www.iea.org/Sanke

Table 1

Quantities and shares of fuels consumed over the period 2010–2016

	2010		2011			2012			2013		2014		2015		2016	
	000 tons	% on total sources	000 tons	% on total sources	% yoy increase	000 tons	% on total sources	% yoy increase	000 tons	% yoy increase	000 tons	% yoy increase	000 tons	% yoy increase	000 tons	% yoy increase
Firewood	4,216		4,332			4,439										
Firewood equivalent in tons of butane	1,186	56.3%	1,219	56.6%	2.8%	1,249	55.6%	2.5%		-100.0%						
Charcoal	1,226		1,267			1,307										
Charcoal equivalent in tons of butane	791	37.6%	817	37.9%	3.3%	843	37.5%	3.2%		-100.0%						
Butane	128	6.1%	117	5.4%	-8.8%	155	6.9%	32.4%	179	15.8%	206	14.8%	242	17.5%	269	11.2%
Total in equivalent tons of butane	2,105	100.0%	2,153	100.0%	-2.7%	2,247	100.0%		179							

Source: Prepared by the authors. Consumption of firewood and charcoal based on data from Opendata Côte d'Ivoire reporting data from Institute National de la Statistique (INS) [online]. [Accessed in September 2017.] Downloadable from: https://data.gouv.ci/donnee/data_details/consommation-du-bois-de-chauffe-par-les-mnages-de-2008-2012708#. Consumption of butane based on data from Direction Générale des Hydrocarbures, Ministère du Pétrole, de l'Energie et du Développement des Energies Renouvelables. 2017. *Annuaire des Statistiques des Hydrocarbures en Côte d'Ivoire*. Edition 2017. Côte d'Ivoire.

Despite the strong growth of the butane sector, especially in recent years, consumption of LPG per capita is still low, at 6.17 kg. Although Côte d'Ivoire's situation is better than many of its African neighbors, consumption is still low compared with other emerging economies, such as Thailand, which consumes more than three times this amount, or Indonesia, whose consumption is almost four times that of Côte d'Ivoire (see Table 2).

Table 2

Consumption of LPG per capita in 2015

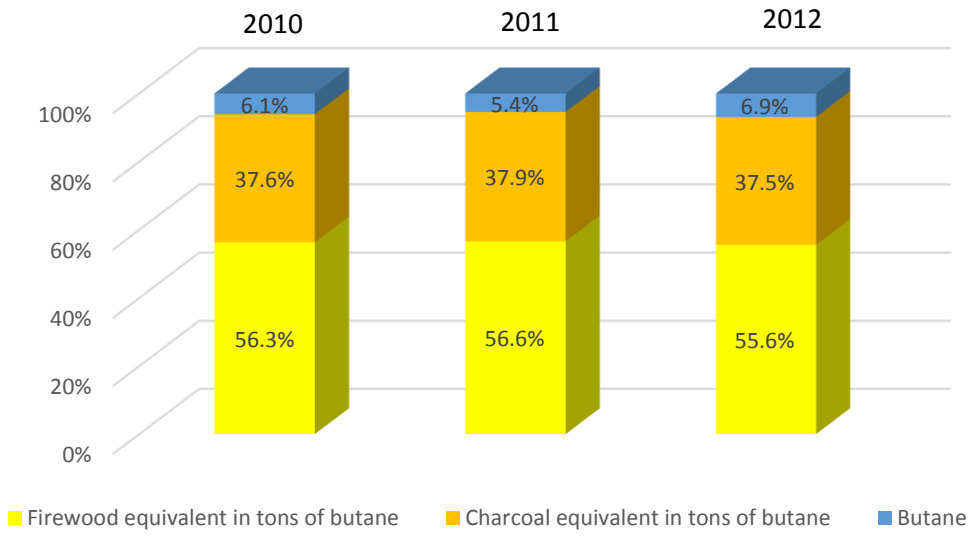
Country	Population (millions)	LPG consumption for residential use (000 tons)	LPG per capita (kg/inhabitant)
Ghana	27.41	205	7.48
Côte d'Ivoire	22.7	140	6.17
Kenya	46.05	60	1.3
Nigeria	182.2	22	0.12
Thailand	67.97	1,343	19.76
Indonesia	257.56	6,115	23.74
World	7333.78	117,661	16.04

Source: Prepared by the authors based on International Energy Agency (IEA) data from Statistics by Country © OECD/IEA [Online]. [Accessed on September 10, 2017.] Available from: https://www.iea.org/statistics/statisticssearch/report/?year=2015&country=COTEIVOIRE&product=Indicators.

The expansion of butane use is still at its inception and this source is still playing a very limited role in the cooking fuel mix of the country. In 2012, consumption of butane accounted for less than 7% of total cooking fuel consumption, with firewood and charcoal largely prevailing (see Figure 4).

The development of renewable energies in Côte d'Ivoire (other than hydro power plants) is still limited to a few pilot projects, with hardly anything in the field of cooking energies. Potential sources exist but are not exploited yet. Biomass residues are used for just 5% of the national potential and only by some agro-food industries for their own heat and electricity needs.

Figure 4
Quantities of fuels consumed over the years (equivalent tons of butane)



Source: Prepared by the authors. Consumption of firewood and charcoal based on data from Opendata Côte d'Ivoire reporting data from Institute National de la Statistique (INS) [online]. [Accessed in September 2017.] Downloadable from: https://data.gouv.ci/donnee/data_details/consommation-du-bois-de-chauffe-par-les-mnages-de-2008-2012708#. Consumption of butane based on data from Direction Générale des Hydrocarbures, Ministère du Pétrole, de l'Energie et du Développement des Energies Renouvelables. 2017. *Annuaire des Statistiques des Hydrocarbures en Côte d'Ivoire*. Edition 2017. Côte d'Ivoire.

In the meantime, massive burning of biomass has terrible consequences on people's health. After malaria, lower respiratory infections are the second cause of death in the country, accounting for 11% of total deaths.[3] This data is not surprising, considering that the smoke produced by the typical cooking fire in one hour is equivalent to that of 400 cigarettes.

Woodcutting for firewood and charcoal production has a devastating impact on deforestation as well. An analysis conducted in the context of the national REDD + strategy (BNETD — Etc Terra — Rongead, 2016) shows that in 25 years (1990–2015), the country's forested area decreased from 24.36% (corresponding to 7.8 million hectares) to 10.56% in 2015 (3.4 million hectares). This study determines that deforestation is caused by three main factors: expansion of

[3] Center for Disease Control and Prevention (CDC), based on information from the World Health Organization. 2012. *Country Health Profile 2012, Cote d'Ivoire* [online].[Accessed May 17, 2018.] Available from https://www.cdc.gov/globalhealth/countries/cote-d-ivoire.

agriculture, exploitation of forestry (including the cuts to be used as firewood or to produce charcoal for cooking needs) and infrastructure extension.

1.2. Firewood: The Cheapest Alternative

The consumption of firewood steadily increased between 2008 and 2012, when it was estimated at 4,439,000 tons — equivalent to 1,249 tons of butane (see Table 3).

Data collected by the Institut National de la Statistique reported a price per kg of firewood of FCFA 38/kg in Abidjan (2012). A StovePlus study (2015), reported a price of FCFA 37/kg in rural areas and urban areas outside Abidjan, but an average price of FCFA 53/kg in Abidjan. At a conservative price of FCFA 38/kg, the value of firewood consumption can be estimated at around FCFA 167 billion (US$315 million). Since most firewood consumption takes place in rural areas, with women and children in charge of collecting sticks, firewood can be a zero-cost fuel. Of course, collecting firewood implies a significant opportunity cost, limiting the time for women and children to improve their education and engage in income-generating activities. However, in rural households where economic opportunities are scarce, the opportunity cost might be given little consideration.

Table 3
Domestic consumption of firewood, 2008–2012

	2008	2009	2010	2011	2012
Firewood (000 tons)	3.830	4.099	4.216	4.332	4.439
Equivalent in tons of butane (000 tons)	1.078	1.153	1.186	1.219	1.249
Value of consumption (billions of CFA)	149	163	156	182	167
Price per kg in Abidjan (CFA)	39	40	37	42	38

CFA 1,000 = US$1.8254 at 13/9/17

Source: Opendata Côte d'Ivoire based on data from Institute National de la Statistique (INS) [online]. [Accessed in September 2017.] Downloadable from: https://data.gouv.ci/donnee/data_details/consommation-du-bois-de-chauffe-par-les-mnages-de-2008-2012708#.

The firewood supply chain is well organized, although on an informal basis. Firewood producers are usually farmers that cut and saw the wood and sell it to wholesalers. Wholesalers transport the wood to urban areas and sell it to retailers. Retailers normally place an order with the wholesalers for a certain amount of wood, which is delivered directly into their vending site. Wood is then sold in small bundles in makeshift structures or open-air spaces, which minimizes operation expenses. Many families make a living from the firewood chain on an informal basis.

1.3. Charcoal: The Transition Choice

Consumption of charcoal steadily increased between 2008 and 2012, when it was estimated at 1,308,000 tons, equivalent to 843 tons of butane (see Table 4). Charcoal is a very popular choice in the northern and central regions of Côte d'Ivoire and it is mainly used in urban areas, often in combination with LPG.

At an average price of FCFA 140/kg, charcoal represents a business of around FCFA 183 billion (US$330 million).

Most of the charcoal value chain is on an informal — often illegal — basis, involving many actors and permeated with rent-seeking. Trees are provided by forest owners, cut by loggers and finally transported to charcoal producers. Charcoal producers use a traditional kiln to transform wood into charcoal through the process of carbonization. Often this process is done with an earth pit kiln and consists of digging a pit, stacking dried wood, covering it with soil and grass to prevent contact with air, lighting the wood and allowing it to slowly carbonize for three to 15 days. Charcoal is then distributed to wholesalers and, lastly, to retailers in urban area.

Table 4
Domestic consumption of charcoal, 2008–2012

	2008	2009	2010	2011	2012
Charcoal (000 tons)	1.138	1.192	1.226	1.267	1.308
Equivalent in tons of butane (000 tons)	734	769	791	817	843
Value of consumption (billions of CFA)	154	138	168	205	183
Price per kg in Abidjan (CFA)	135	116	137	162	140
CFA 1,000 = US$1.8254 at 13/9/17					

Source: Opendata Côte d'Ivoire based on data from Institute National de la Statistique (INS) [online]. [Accessed in September 2017.] Downloadable from: https://data.gouv.ci/donnee/data_details/consommation-du-bois-de-chauffe-par-les-mnages-de-2008-2012708#.

2. LPG: Fuel for the City

2.1. The Butanization Process

Among modern cooking fuels, LPG is the most widely used and, in particular, butane — which better fits with Côte d'Ivoire's weather conditions.

In 1992, the Ivorian government, aware of the effects of massive burning of biomass on people's health and on deforestation, started a butanization program, aimed at expanding the use of butane for household cooking. The program is still in place and acts in two ways:

1. Maintaining the price of LPG within affordable limits, through a subsidization policy that allows households to pay lower than the market price and a transport equalization system that allows transport costs across the country to be leveled out and maintains an affordable price, even in more remote areas.

2. Attracting participants from the private sector and building an efficient distribution network, through the payment of a fixed distribution margin that grants distributors a fair income and through the concession of exclusivity agreements to those who expand their distribution network to less densely populated areas.

As a result, the consumption of butane rose from 22,000 tons to 24,000 tons between 1980 and 1994, to 60,000 tons in the year 2000 and up to almost 270,000 tons in 2016.

In particular, since 2012, following the end of the post-electoral conflict, there has been a significant economic upturn, marked by a rapid increase in gross domestic product (GDP) (from US$27.04 billion in 2008 to US$35.37 billion in 2014) and a reduction of poverty (the poverty rate has decreased from 51% of the population in 2011 to 46%), which has triggered a rapid expansion in the use of butane. Usage increased from 117 thousand tons in 2011 to 269 thousand tons in 2016, with an average year-over–year (YOY) growth rate of 18% (see Table 5).

Table 5
LPG supply in Côte d'Ivoire, 2005–2014

TM	2010	2011	2012	2013	2014	2015	2016
Production				14,574		11,962	22,006
of which SIR:	7,850	2,036	868	2,970	9,034	8,989	15,945
of which LION:[4]				11,604		2,973	6,061
Imports				169,546		232,572	247,696
Exports	9,426	2,253	2,310	4,782	5,071	2,647	818
Consumption	128,275	117,005	154,890	179,338	205,889	241,887	268,884

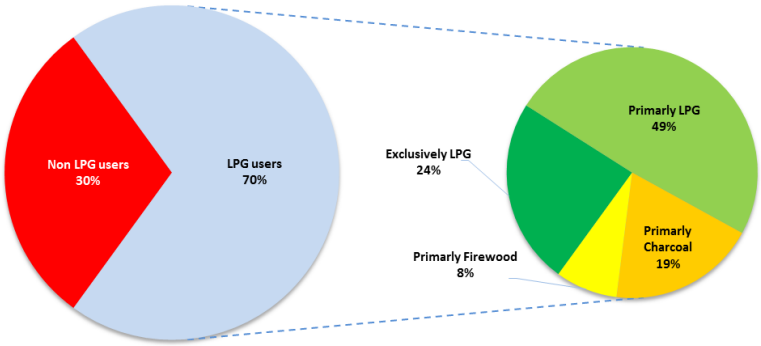
Source: Prepared by the authors based on Direction Générale des Hydrocarbures, Ministère du Pétrole, de l'Energie et du Développement des Energies Renouvelables. 2016 and 2017. *Annuaire des Statistiques des Hydrocarbures en Côte d'Ivoire.* Edition 2016 and 2017. Côte d'Ivoire and on BNETD. 2016. *Projet de construction d'une unité de production de gaz propane en Côte d'Ivoire.* Republique de Côte d'Ivoire.

A survey conducted by the authors and the Ecole Nationale Supérieure de Statistique et d'Economie Appliquée (ENSEA)[5] revealed that 70% of Ivorian households use LPG for cooking. Remarkably, 73% of LPG users indicate it as primary fuel, either as an exclusive fuel (24%) or used in combination with alternative fuels (49%). However, the proportion of total households that exclusively use LPG as fuel is only 17%, while 83% of the total number of households still rely mainly on firewood and charcoal for cooking (see Figure 5).

[4] For the year 2015 to 2016, LION production was calculated as follows: (consumption + exports)-(imports + SIR production).

[5] H. Kouadio, A. F. Houndoga, P. Giordano, M. Assogba, A. Rahnema, 2018. *Contraintes d'adoption du GPL en Côte d'Ivoire: constats et conclusions de l'enquête de terrain.* IESE Business School. Unpublished study.

Figure 5
Households using LPG as primary or alternative fuel



Source: H. Kouadio, A. F. Houndoga, P. Giordano, M. Assogba, A. Rahnema, 2018. *Contraintes d'adoption du GPL en Côte d'Ivoire: constats et conclusions de l'enquête de terrain*. IESE Business School. Unpublished study.

Moreover, the situation varies significantly depending on the area of residence. While in Abidjan almost all the households using LPG use it as the primary fuel (93%), this proportion is lower in other urban areas (61%) and even lower in rural areas (55%), where, instead, there is a greater use of charcoal and firewood (see Table 6).

Table 6
Use of firewood, charcoal and LPG as the primary fuel by LPG users

	Abidjan	Other urban areas	Rural	Ensemble
Firewood	1	13	15	8
Charcoal	6	26	30	19
LPG	93	61	55	73
Total	**100**	**100**	**100**	**100**

Source: H. Kouadio, A. F. Houndoga, P. Giordano, M. Assogba, A. Rahnema, 2018. *Contraintes d'adoption du GPL en Côte d'Ivoire: constats et conclusions de l'enquête de terrain*. IESE Business School. Unpublished study.

A study conducted on a national level by the Institut National de la Statistique (INS) shows that poor households lag behind: while 40% of poor households use LPG in Abidjan, just 1% use it in rural areas.[6]

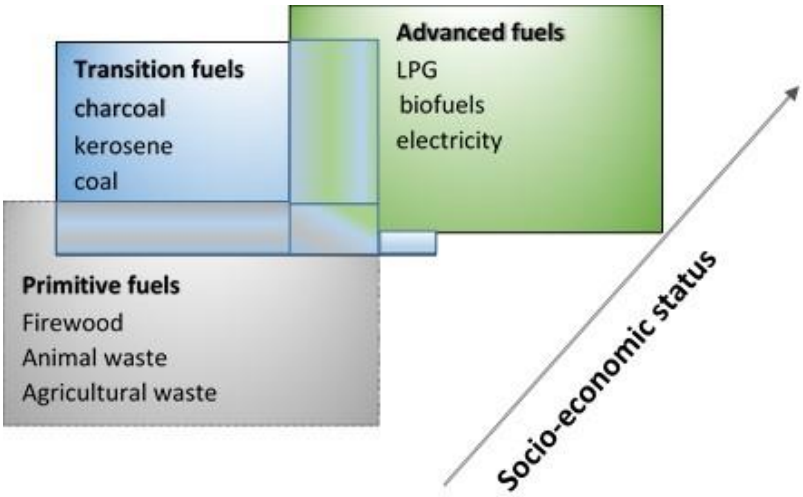
The practice of using more than one type of fuel in the same household is quite common to all developing countries, and it is aligned with the so-called stacking theory (see, for example, Leach,

[6] *Enquête sur le niveau de vie des ménages en Côte D´Ivoire* (ENV 2015) [online]. [Accessed on March 10, 2018.] Downloaded from: http://www.ins.ci/n/nada/index.php/catalog/42.

1992). According to this theory, as their income increases, households move up the energy ladder and use cleaner, more efficient and more expensive fuels, switching gradually from traditional biomass to electricity (see Figure 6). Interestingly, however, households do not simply substitute one fuel for another but, instead, start to diversify, adding more types of fuels in a process of fuel stacking. More specifically, the research thus far has shown that modern technologies are most commonly used for services such as radio and television (electricity) or to heat small amounts of beverages, such as tea and coffee (LPG), while traditional fuels are still used for the main and most energy consuming types of activities, such as cooking and heating the house.

In fact, switching into one single energy source would probably undermine the security provided by multiple energy sources, exposing the consumer to the risk of delays in fuel delivery, unreliable services and volatility of fuel prices. The slow transition into alternative cooking practices probably also has some correlation with the unwillingness to abandon the already familiar and traditional ways of cooking. Consequently, even the wealthiest households maintain the use of firewood or charcoal for preparing traditional meals.

Figure 6
Stacking theory



Source: Prepared by the uthors based on Van der Kroon, B., Brouwer, R., Van Beukering, P.J.H. 2013. *The energy ladder: Theoretical myth or empirical truth? Results from a meta-analysis.* Renewable and Sustainable Energy Reviews [online]. [Accessed on May 16, 2018.] Downloadable from: https://www.sciencedirect.com/science/article/pii/S1364032112006594.

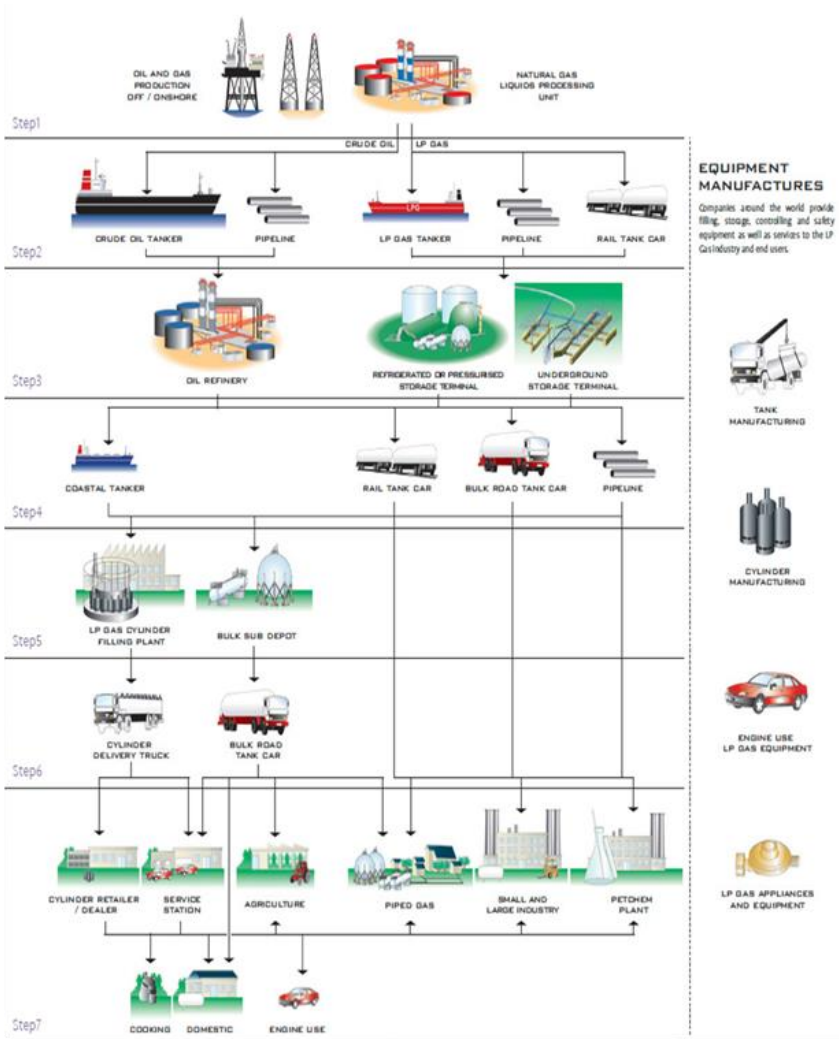
2.2. The LPG Supply Chain

2.2.1 Production

LPG originates in two ways: it can be recovered during extraction of natural gas or oil from the earth, or it can be obtained through the refining process of crude oil (see Figure 7). Nowadays, 60% of the world's LPG is obtained through the first process and 40% through the second. In Côte d'Ivoire local production satisfies only 8% of the internal consumption of butane, while imports represent 92% (Ministère du Pétrole, 2017).

Domestic supply of LPG reached 22,000 tons in 2016 and was carried out in two plants: LION GPL and the Société Ivoirienne de Raffinage (SIR) plant. LION GPL is a natural gas processing unit, with a capacity of 80 MMSCFD,[7] owned by block CI-11's consortium of owners and operated by the state oil company, Petroci. The company mission is the extraction of LPG (butane and propane) effluent from blocks CI-11, CI-26 and CI-40. At the end of this process, about 8% to 10% of raw natural gas is converted to LPG, representing about 6 MMSCFD. In 2016, LION GPL had a production of 6,000 tons. The SIR refinery is co-owned by the Ivorian government, which is the main shareholder (through Petroci), and international oil groups, both public and private.[8] In 2016, SIR had a production of 15,945 tons.

Figure 7
The LPG supply chain



Source: World Liquefied Petroleum Gas Association – WLPG.

[7] MMSCFD stands for Million Metric Standard Cubic Feet a Day.

[8] The current ownership structure of SIR is Petroci: 45.74%, Total: 20.35%, Sociedad Nacional de Combustiveis de Angola (Sonangol): 20%, Burkina Faso: 5.39%, Elf Aquitaine: 5%, Raffinage de Sahara Ltd: 1.98%, Cote d'Ivoire state: 1.54%). Based on information from the SIR Website [online]. [Accessed on May 4, 2018]. Available from http://www.sir.ci/index.php/societe/presentation.

2.2.2. Imports

The only authorized importers of LPG in Côte d'Ivoire are SIR and Petroci.

In 2016, cumulative imports of LPG reached 247,696 tons, 67.7% of which were by SIR and 32.3% by Petroci. Trade Map,[9] which provides data on quantities and values of imports, indicates that in 2016, 36% of imports came from African countries (25.5% from Equatorial Guinea, 10.4% from Nigeria), 36.4% from the United States and 15.3% from South America (9.8% from Venezuela and 5.5% from Argentina) (see Table 7).

Table 7
Origin of petroleum gas and other gaseous hydrocarbons, quantity and value imported by the top main suppliers, 2016

Country of origin	Imported Quantity (tons)	Imported value (US$000)
United States of America	74,610	31,501
Equatorial Guinea	52,132	20,541
Venezuela	20,031	10,292
Nigeria	21,322	8,877
Argentina	11,204	4,487
Other countries	25,377	9,958
Total	204,676	85,656

Source: Prepared by the authors based on ITC, 2018, *Trade Map — Trade statistics for international business development* [online]. [Accessed on April 10, 2018]. Available from: https://www.trademap.org.

2.2.3. Stockage

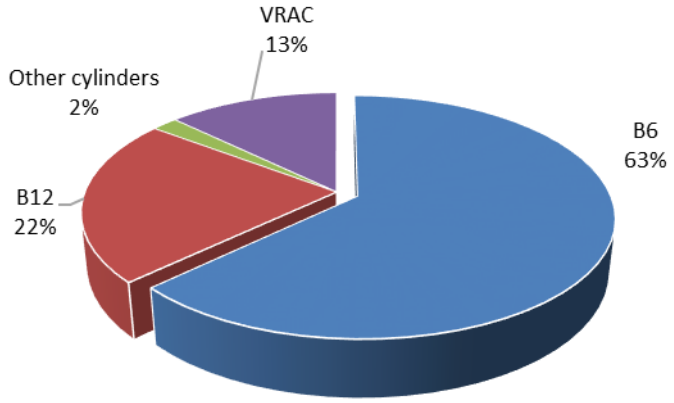
LPG is generally stored in pressurized tanks (vessels or spheres) in intermediary storage centers. The country's LPG stockage capacity stands at 19,398 tons (2016). Therefore, with internal consumption at 268,884 tons in 2016, the current stockage can grant the country a 26-day supply (Ministère du Pétrole, 2017).

In Côte d'Ivoire the storage of LPG is mainly carried out by Petroci (6,300 tons) and Gestoci (4,000 tons). Gestoci is a joint venture of the main oil marketing companies operating in the country, both public and private, with the scope to gain economies of scale. Gestoci owns and operates a main deposit of LPG in Vridi (Abidjan), near the SIR refinery, and another two inland deposits in Bouaké and Yamoussoukro. Some private distributors also have their own storage centers, such as Oryx, for example, with its 2,650 tons stockage capacity.

2.2.4. Filling and Distribution

LPG is either sold in bulk or bottled in cylinders of 6, 12.5, 28.5 or 38 kg. The consumption of bottled butane is dominated by the 6 kg (B6) and the 12.5 kg (B12) formats, which account for 63% and 22%, respectively, of total consumption and which are directed at residential use. Butane sold in bulk (VRAC) is mainly for industrial use and is not subsidized (see Figure 7).

Figure 8
LPG consumption by packaging, 2016



Source: Direction Générale des Hydrocarbures, Ministère du Pétrole, de l'Energie et du Développement des Energies Renouvelables. 2017. *Annuaire des Statisques des Hydrocarbures en Côte d'Ivoire*. Edition 2017. Côte d'Ivoire.

Filling centers are located in Abidjan and owned by the distribution companies. The majority of cylinders are imported (see Figure 9).

Figure 9
Petroci

Supply of cylinders: Petroci's case

Petroci used to have a manufacturing unit producing B6 and B12 cylinders — with capacity of 500 bottles per day (41,286 units in 2013) and a cost of production of FCFA 9000 for a B6 bottle — which shut down in November 2017. Nowadays, Petroci butane cylinders are imported and come from two main sources: Tunisia (MBG, subsidiary company of Poulina Group Holding) and Thailand (Sahamitr Pressure Container PLC.).

Source: Petroci.

From the filling centers, LPG is then transported to the distribution centers. Until recently, the distribution sector was led by Petroci. However, its market share declined from 33% in 2012 to 22% in 2016 and, eventually, in July 2017, the government announced the privatization of Petroci's LPG distribution network as part of its activities restructuring plan.[10] Under the privatization plan, Petroci will apparently keep its import mission, while the private investor selected will resume the filling and distribution activities. Currently, the main distributors in the Ivorian LPG market are Oryx (see Figure 10), Total, PetroIvoire, Saphyr, Corlay, Vivo Energy and Mobil.

[10]Petroleumafrica.com. (2018). Petroleum Africa | Continental Focus, International Reach [online].[Accessed April 2, 2018.] Available from www.petroleumafrica.com/cote-divoire-to-sell-petrocis-lpg-distribution-business.

Figure 10
Oryx

One of the main distributors: Oryx

Oryx Energies owns 2,650 MT of storage capacity in the country and three filling plants, one in Vridi (Abidjan), one in Bouaké and one in the east of the country, recently opened to respond to the growing needs of this important agricultural zone.

With 1,150,000 LPG cylinders per year, Oryx is one of the main distributors in the country.

Oryx also directly supplies commercial and industrial sectors with bulk LPG, including the agro, food and metals industries, hotels and restaurants.

Oryx Energies has been present in Côte d'Ivoire since 2001, but it accelerated its penetration of the market in 2005 with the purchase of Shell's LPG business and assets, reaching a sizeable share of the market.

Source: Oryxenergies, 2018. *Home — Oryx Energies* [online]. [Accessed on May 4, 2018]. Available from: http://www.oryxenergies.com/fr/notre-implantation/cote-ivoire.

2.2.5. Retail

Customers can purchase butane at the official distributors' station services or mono-brand shops (Oryx, Total, Petroci, etc.), or in independent retailers' shops, which usually sell different brands.

Since cylinder sizes and distribution margins are fixed by the government, distributors need to leverage factors other than price and size to differentiate from competitors (see Figure 11).

Figure 11
Total: Strategies for differentiation

Total:

In the LPG segment, Total is mainly focused on the sale of bulk LPG, with a 33% of the Ivorian bulk market share. Cylinders for domestic use are sold through its gas station network of 168 stations service, of which 65 in Abidjan and suburbs. Because the distribution margin is fixed by the government and the cylinders' sizes are settled as well, to differentiate from competitors, Total plays with three factors:

1. Safety: through good maintenance of LPG bottles.
2. Honest filling: bottles are filled for the full quantity payed, and not less than that
3. Location of gas/LPG stations and additional services offered.

Source: Total.

2.3.LPG Price Structure

The government regulates the distribution and retail price of butane as part of the butanization program it has put in place.

The maximum distribution price — or *prix maximum de cession* (PMC) — paid by the distributors to the importers is calculated every three months, using the formulas established by interministerial decrees:[11]

PMC = *prix parité importation + autres charges et rémunération + péréquation produit + conformité* aux normes de qualité

Prix parité d'importation (PPI) consists of the price of butane in the international market of Rotterdam,[12] plus the cost of freight, insurance and port handling.

Autres charges et rémunération consist of other import costs, including the importer margin.

Péréquation produit is a reserve created to cover any deficit that might arise from having a fixed-price structure. Since the price of imports is fixed by the government every four months, differences might arise between this price and the real price of imports, especially given the high volatility of the butane market. The péréquation produit is therefore meant to cover deficits and grant the country a continuous provision of butane.

Conformité aux normes de qualité (CNQ) is the amortization cost of the investments made by SIR to improve the quality of the oil product in order to conform with regulations.[13]

The maximum retail price, or *prix maximum à la pompe* (PMP), is based on the distribution price, plus transportation, distribution costs and margin plus taxes, according to the following formula:

PMP = PMC + customs and other taxes + *péréquation transport* + distribution costs and margin

In particular, *péréquation transport* regulates the cost of transferring butane via different deposits in the national territory and allows the same retail price to be maintained across the whole country. The government collects a fixed transportation margin (currently FCFA 3,810/ton) per each ton of butane sold. All the margins collected are then redistributed to the transporters, according to the quantity delivered and the distance traveled. In practice, a surcharge is applied to consumers in Abidjan to subsidize the transport of butane to consumers in more remote areas of the country.

Distribution costs and margin is set by the government cover all other types of distribution costs, including the amortization of storage and filling capacity.

The Retail Price paid by the customer is currently fixed as follows:

- 6 kg bottle (B6) — FCFA 2,000 (US$3.61)
- 12.5 kg bottle (B12 — FCFA 5,200 (US$9.38)
- 28.5 kg unsubsidized bottle (B28) — FCFA 18,535 (US$33.45)

[11] Arrete interministeriel n.33-34-35-36-37 du 29 mars 2013. Ministère des Mines, du Pétrole et de l'Energie, Ministère auprès du Premier Ministre, chargé de l'Economie et des Finances, Ministère du Commerce, de l'Artisanat et de la Promotion des PME.

[12] Specifically, the price used in the formula is the average of the *FOB Seagoing* daily quotations published by Platts LPG Gaswire in the section "NEW FOB Seagoing" in the month preceding the day on which PMC is calculated.

[13] Specifically, CNQ is calculated as (Investments approved by the government + interests)/(15 x Total annual production of oil products by SIR), taking into consideration an amortizing period of 15 years.

Based on the above regulation, we simulated the price-build-up structure for B6 and B12 (see Table 8 and Figure 12).

Table 8
Simulation of price build-up for B6 and B12 for year 2017[14]

			B6			B12	
2017	US$/mt	CFA/mt	**CFA/ 6 kg**	%	CFA/mt	**CFA/ 12.5 kg**	%
FOB*	328	181,641	1,090	39.4%	181,641	2,271	42.2%
Freight**	31	17,167	**103**	3.7%	17,167	**215**	**4.0%**
Insurance and Losses		696	**4**	0.2%	696	**9**	**0.2%**
Port		4,350	**26**	0.9%	4,350	**54**	**1.0%**
PPI		203,855	1,223	44.3%	203,855	2,548	47.4%
Import costs and margin		5,687	**34**	1.2%	5,687	**71**	**1.3%**
Péréquation produit		60,000	**360**	13.0%	60,000	**750**	**13.9%**
Distribution Price* **		**269,542**	**1,617**	58.5%	**269,542**	**3,369**	**62.6%**
Transport equalization		3,810	**23**	0.8%	3,810	**48**	**0.9%**
Distribution cost and margin		174,181	**1,045**	37.8%	144,181	**1,802**	**33.5%**
Taxes		12,965	**78**	2.8%	12,965	**162**	**3.0%**
Unsubsidized Retail Price		**460,498**	**2,763**	100.0%	**430,498**	**5,381**	**100.0%**
Subsidy			**-763**	-27.6%		-181	**-3.4%**
Retail Price			**2,000**	72.4%		**5,200**	**96.6%**

*The regulation requires the use of the section "NEW FOB Seagoing" in *FOB Seagoing*, published by Platts LPG Gaswire, as the reference for calculating the butane retail price. In this simulation, the FOB reported is based on the average butane N Sea NWE FOB for 2017, quoted by Thomson Reuters EIKON.[15]

**The interministerial decree doesn't make reference to a specific source for this component. The freight cost has therefore been estimated by the authors on the basis of information reported in "LPG Forecaster Q1, May 2016", by Drewry Maritime Research, which quoted the average spot price for the voyage NWE-Algeria at US$33.2/ton and the average cost of a one-month charter of a 3000 m3 (about 6,000 tons) ship at US$230,000 for that reference period.

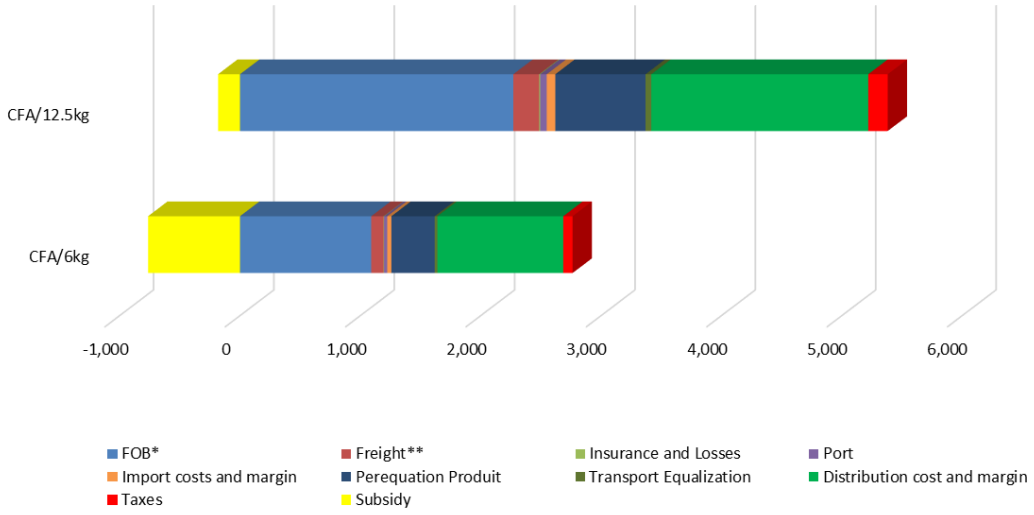
***Among the components used to calculate the distribution, data corresponding to the cost of conformité aux normes de qualité was not included because we were unable to find information about investments made by SIR to improve the quality of oil products.

Source: Prepared by the authors.

[14] PPI, distribution prices and retail prices reported in the table are the authors' estimations based on formulas provided in the interministerial decrees that regulate butane prices and on information available. Subsidy has been estimated as a difference between the retail price obtained through the formulas and the retail price established by interministerial decree no. 35 of March 29, 2013.

[15] Datastream. (2018) *Thomson Reuters EIKON Datastream* [online]. [Accessed in April 2018.] Available at: Subscription Service.

Figure 13
LPG price structure



Source: Prepared by the authors.

The analysis of the simulated price structure suggests some interesting observations:

1. The price of purchase on the international market (FOB) represents39% and 42% (for B6 and B12, respectively) of the final price of a butane cylinder (before subsidy). However, it has to be noted that, because of the high volatility of the butane market, the incidence of FOB on the final price of butane can vary significantly. For example, in 2012, when the yearly average quotation reached US$885/ton, FOB cost had a substantially higher impact on the final price, at 61% (see Table 9).

   As a consequence, the level of subsidy from the government is also highly variable. In our simulation for 2017, with a FOB of US$328/ton, the level of subsidy is around 27% of the retail price for B6. However, in the simulation for 2012, with the average FOB at US$885/ton, the subsidy reaches 58%, taking into consideration that, at that time, the retail price of B6 was fixed at FCFA 1800. In fact, on December 31, 2012, to face the situation of increasing import costs, the government increased the regulated retail prices of B6 and B12 from FCFA 1800 to FCFA 2000 and from FCFA 4000 to FCFA 5200, respectively.

   An article appeared in the online news Abidjan.net on January 4, 2013, that corroborates our analysis: "*If B6 has gone from FCFA 1800 to FCFA 2000, B12 from FCFA 4000 to FCFA 5200.... we should not necessarily see these prices but really know how the government is fighting to solve them, despite high imports. Indeed, in the international market, Côte d'Ivoire buys B6 at FCFA 4100. To support housewives, it was sold at FCFA 1800. The state then lowered its subsidy from 56% to 51%.*"

2. Distribution costs and margin make up for another 38% of the final retail price before subsidy. However, as per the other cost components, it has to be taken into account that this percentage is inversely proportional to the butane import price level. For example,

in 2012, when butane prices reached a peak, distribution costs and margin used to weigh around 24%, according to our simulation (see Table 9).

The remuneration margin for butane sold in B6 cylinders is set at a higher level compared to butane packaged in B12 (at FCFA 174,181/mt versus FCFA 144,181 /mt), probably because of higher filling costs per kg (more cylinders required).

Table 9
Simulation of price build-up for B6 and B12 for year 2012[16]

			B6			B12	
2012	US$/mt	CFA/mt	**CFA/ 6 kg**	%	CFA/mt	**CFA/ 12.5 kg**	%
FOB	885	442,500	2,655	61.4%	442,500	5,531	64.1%
Freight	31	15,500	**93**	2.2%	15,500	**194**	**2.2%**
Insurance and Losses		1,603	**10**	0.2%	1,603	**20**	**0.2%**
Port		4,350	**26**	0.6%	4,350	**54**	**0.6%**
PPI		463,953	2,784	64.4%	463,953	5,799	67.2%
Import costs and margin		5,687	**34**	0.8%	5,687	**71**	**0.8%**
Péréquation produit		60,000	**360**	8.3%	60,000	**750**	**8.7%**
Distribution Price		**529,640**	**3,178**	73.5%	**529,640**	**6,621**	**76.7%**
Transport Equalization		3,810	**23**	0.5%	3,810	**48**	**0.6%**
Distribution cost and margin		174,181	**1,045**	24.2%	144,181	**1,802**	**20.9%**
Taxes		12,965	**78**	1.8%	12,965	**162**	**1.9%**
Unsubsidized Retail Price		**720,596**	**4,324**	100.0%	**690,596**	**8,632**	**100.0%**
Subsidy			**-2,524**	-58.4%		-3,432	**-39.8%**
Retail Price			**1,800**	41.6%		**5,200**	**60.2%**

Source: Prepared by the authors.

3. Costs and margins of retailers are not specifically regulated. Instead, these cost components are included in distribution costs and margin, therefore leaving the different actors involved in this part of the supply chain to come to an agreement on how to share the distribution margin. As an example, we report the conditions required by Petroci to install a butane retail point (see Table 10). Although currently displayed on Petroci's website, these conditions must have been applied before 2013, since prices of FCFA 1800 and FCFA 4000 are quoted for B6 and B12, respectively. At that time, Petroci was establishing, among the other conditions, a dealer's margin of 10% (FCFA 165) on a B6 bottle and a margin of 7.5% (FCFA 250) on a B12.

[16] PPI, distribution prices and retail prices reported in the table are the authors' estimations based on formulas provided in the interministerial decrees that regulate butane prices and on information available. Subsidy has been estimated as a difference between the retail price obtained through the formulas and the retail price established by interministerial decree No. 35 of March 29, 2013.

Table 10
Installation cost for a new Petroci bottle retailer

CONDITIONS D'INSTALLATION D'UN NOUVEAU REVENDEUR						
DEVIS POUR UNE INSTALLATION DE 100 BOUTEILLES						
Type d'emballages	**Quantité**	**Consigne**	**Prix de cession revendeur**	**Total**	**Prix public**	**Marge revendeur**
B6	50	12000	1635	681750	1800	165
B12	40	20000	3720	948800	4000	280
B28	10	34545	8530	430750	9000	470
			TOTAL	**2 061 300**		
DEVIS POUR UNE INSTALLATION DE 150 BOUTEILLES						
Type d'emballages	**Quantité**	**Consigne**	**Prix de cession revendeur**	**Total**	**Prix public**	**Marge revendeur**
B6	80	12000	1635	1090800	1800	165
B12	50	20000	3720	1186000	4000	280
B28	20	34545	8530	861500	9000	470
			TOTAL	**3 138 300**		

Source: Petroci, 2018. *PETROCI - HOLDING: Société Nationale d'Opérations Petrolière de Côte d'Ivoire* [online]. [Accessed on May 4, 2018.] Available from: http://www.petroci.ci.

3. Barriers to the Expansion of Butane Use

The plan started by the government to bring LPG to households seems to have been successful in Abidjan. Measures such as the transport equalization system and the exclusivity agreement granted to distributors willing to expand their network in rural areas helped the expansion of LPG use in other main cities outside Abidjan. By allowing households to pay lower than the market price, the butanization program adopted by the Ivorian government accelerated the expansion of LPG use in the country. From the perspective of deforestation, the measures taken apparently had a positive impact. In fact, the average annual deforestation rate of 4.32% from 1990 to 2000 decreased to 2.69% in the period from 2000 to 2015 (BNETD — Etc Terra — Rongead, 2016).

However, although present in some measure in urban households, butane is struggling to completely replace charcoal. In rural areas, the presence of butane is still very limited. Overall, the per capita consumption of butane is still very low if compared with other emerging economies. Why are the incentives put in place by the butanization program not enough for butane to reach to rural areas? What barriers are still preventing a complete transition from biomass to modern cooking solutions in urban areas? Is butane affordability the real key factor? Or are there other aspects constraining the demand and supply of butane in the country? And what are the risks entailed by the butanization program?

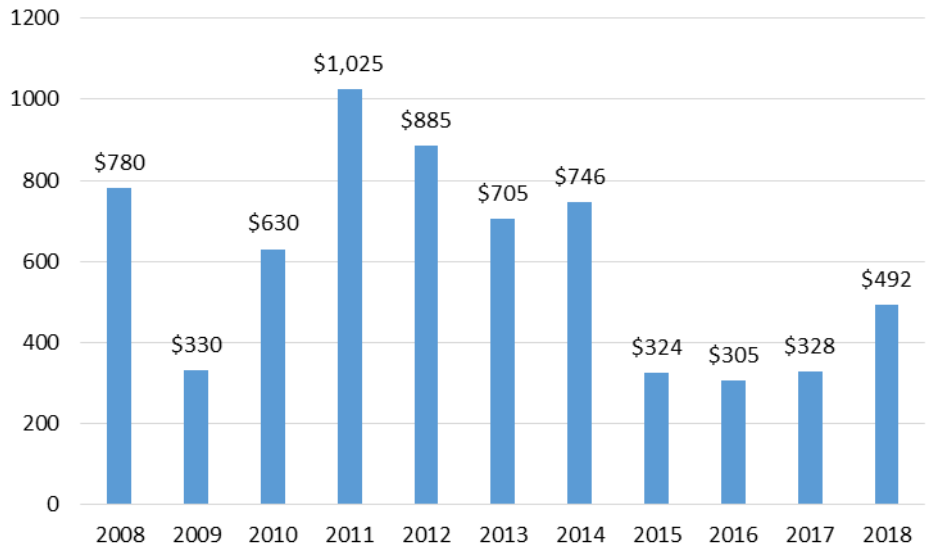
3.1. Risks of Expanding Butane Use

As a first observation, because Côte d'Ivoire-s supply of LPG relies heavily on imports (92%), this exposes the country to the volatility of LPG prices on the international market because of crude price levels, seasonality, production overhang and freight rates (see Figure 14).

Secondly, the more consumption increases, the stronger the effect on the country's balance of payments. If the LPG consumption trend observed in the years 2012 to 2016 continues in the future (at an average growth rate of 18.3%) and imports are maintained in the same proportion at current butane price levels (average FOB in first 5 months 2018 was US$492/mt), by 2020 the entailed expense will be around US$240 million. Should the butane price peak again at the same levels of 2012 (average FOB in 2012 was US$885/mt), the entailed expense would reach US$430 million.

Lastly, since the government subsidizes LPG through taxation of other fuels (cross-subsidy), any increase in the use of butane or on import prices will have a direct impact on the amount of taxes imposed on other fuels. At current butane price levels, and assuming that LPG consumption keeps growing at 18.3% per year, by 2020, butane would require a subsidy of FCFA 80 billion (US$146 million) to maintain the current regulated price. Should FOB increase at the levels of 2012, the subsidy required would be FCFA 196 billion (US$363 million).

Figure 14
Annual evolution of butane quotations (Butane N Sea NEW FOB US$/MT)



Source: Datastream. (2018) *Thomson Reuters EIKON Datastream* [online]. [Accessed in April 2018.] Available at: Subscription Service.

3.2. Constraints on the Demand Side

3.2.1. High Recharge Cost and Up-Front Investment Required

The field survey conducted by the authors and ENSEA reveals that households are not resistant to the adoption of LPG as a cooking fuel. In fact, most of the households not yet using LPG declared they would be willing to switch (87%). The main factor hindering the switch appears to be affordability in terms of both the cost of LPG itself (cost for recharging the bottle) and the up-front investment required.

Cost of Recharge

Based on the official sale prices, calorific value and cookstove efficiency, butane appears to be competitive with the other two cooking fuel options currently available to Ivorian households (firewood and charcoal), especially in urban areas.

In fact, we estimated the cost of B6 at FCFA 11.05/MJ,[17] significantly lower than charcoal and firewood in urban areas (FCFA 17.8/MJ and FCFA 15.4/MJ, respectively) and quite comparable in rural areas (FCFA 9.8/MJ and FCFA 10.8/MJ, respectively) (see Table 11).

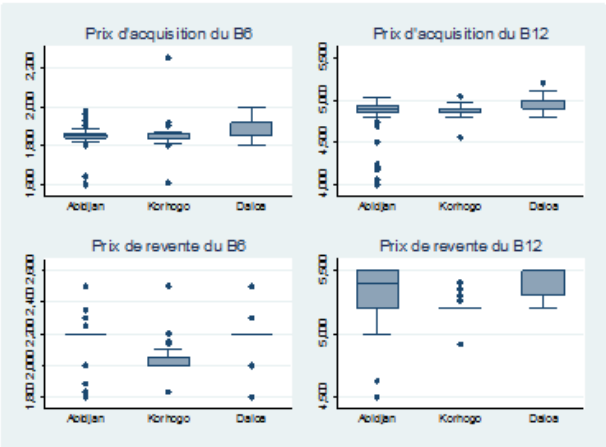
Table 11
Compared cost of fuel

	FCFA /unit		FCFA/kg		FCFA/MJ	
	Urban areas	Rural areas	Urban areas	Rural areas	Urban areas	Rural areas
Firewood	FCFA 53 /kg	FCFA 37/kg	53	37	15.4	10.8
Charcoal	FCFA 1900/15kg	FCFA 1000/15 kg	127	67	17.8	9.8
LPG (6 kg)	2000/6 kg	2000/6 kg	333	333	11.05	11.05
LPG (12.5 kg)	5200/12.5 kg	5200/12.5 kg	416	416	14.37	14.37

Source: Estimation by authors.

However, despite being regulated at a level of FCFA 2,000 for B6 and FCFA 5,200 for B12, the actual retail price of butane is often higher. The field survey conducted by ENSEA reveals that the average retail price applied by butane retailers (other than gas stations, which in general apply the regulated price) is FCFA 2,200, with some observations peaking up to FCFA 2,500 for B6. For the B12 format, most of the observations lay in a range between FCFA 5,200–FCFA 500. (see Figure 14).

Figure 14
Retail price of butane in B6 and B12 format in different geographic areas



Source: H. Kouadio, A. F. Houndoga, P. Giordano, M. Assogba, A. Rahnema, 2018. *Contraintes d'adoption du GPL en Côte d'Ivoire: constats et conclusions de l'enquête de terrain*. IESE Business School. Unpublished study.

[17] MJ (Megajoule) is a unit of energy equal to one million joules.

Up-Front Investment

The choice of butane as cooking fuel implies a high capital investment, represented by:

- the cost of cookstoves
- the deposit paid up-front for the cylinder at first purchase
- the minimum 6 kg format, which implies paying in advance for future consumption, placing butane at a further disadvantage compared with firewood and charcoal, purchased in smaller quantities — even just for daily needs.

a) Cost of Cookstoves

Firewood Cookstoves

Cooking with firewood doesn't necessarily involve capital investment in cookstoves. In fact, the typical stove, called a three-stone stove, is literally made out of three stones that support a pot (see Figure 14). Improved cookstoves exist on the market, such as the Mousso Telia, which has the advantage of being more efficient and faster — thanks to a better heat conservation — and cleaner, since it releases less smoke. Prices range from FCFA 800 to FCFA 3000, depending on the size.

Figure 14
Trois pierres (*three-stone*)

Photo: ENR Afrique/Pearltrees.

Charcoal Cookstoves

For charcoal, different models of stoves exist, usually handcrafted by artisans organized in small informal enterprises and sold locally in the street or door to door. The most common models are the four-square and the Mousso Telia for charcoal, with prices ranging between FCFA 3500 and FCFA 9000, depending on the size (see Figure 15). Aside from local artisans, a few larger companies (e.g. Soutra Fourneaux and Green Ker) have a larger-scale production and engage in awareness-raising activities.

Figure 15
Stoves for charcoal: four-square (left) and Mousso Telia (right)

Photo: on the left from StovePlus (2015), on the right from Shammesh NGO (2017).

Butane Cookstoves

For cooking with butane, there are different cookstove options available, depending on the size of the LPG bottle. The 6 kg bottle doesn't require a cookstove, it can be used directly with a burner and a Faitout adapter (see Figures 16 and Figure 17), whose price ranges between 1,000 and FCFA 5,000. Larger bottles require a specific cookstove, whose price is in the range of FCFA 25,000 to FCFA 28,000.

Figure 16
Faitout adapter for B6

Photo: Itallocation/Skyrock.com (2017).

Figure 17
Cookstoves for B12 and B28

Photo: Prepared by the authors (2017).

b) Deposit for Cylinder

When buying LPG for the first time, the customer is required to pay a deposit for the cylinder. Deposits required for the cylinders are currently as follows:

- 6 kg bottle (B6): FCFA 14,000
- 12.5 kg bottle (B12): FCFA 19,800
- 28.5 kg bottle (B28): FCFA 27,000

After the first purchase, the buyer is entitled to take a full bottle and pay just for the cost of fuel by returning an empty bottle.

C) Refill Cost

LPG cylinders need to be fully refilled, for a minimum amount of FCFA 2000 (6 kg bottle). Firewood and charcoal, on the other hand, can be purchased in smaller quantities, providing a better match with the household income, often earned on a daily base. The significant start-up investment required to switch from firewood or charcoal to cleaner cooking fuels can represent an insurmountable barrier for Ivorian households (see Table 11).

Table 11
Comparison of start-up costs for butane, charcoal and firewood

	6 kg		12.5 kg	
	FCFA	US$	FCFA	US$
Butane				
Cylinder deposit	14,000	23,69	19,800	33,504
Burner	3,000	5,076	-	-
Cooker	1,000	1,692	22,000	37,226
Total capital investment	**18,000**	**30,458**	**41,800**	**70,730**
Minimum purchase	**2,000**	**3.77**	**5,200**	**9.80**
Charcoal				
Cooker	**3,500**	**5,922**		
Minimum purchase	**100**	**0.19**		
Firewood				
Cooker	**800**	**1,354**		
Minimum purchase	**37–53**	**0.07–0.1**		

Source: Prepared by the authors.

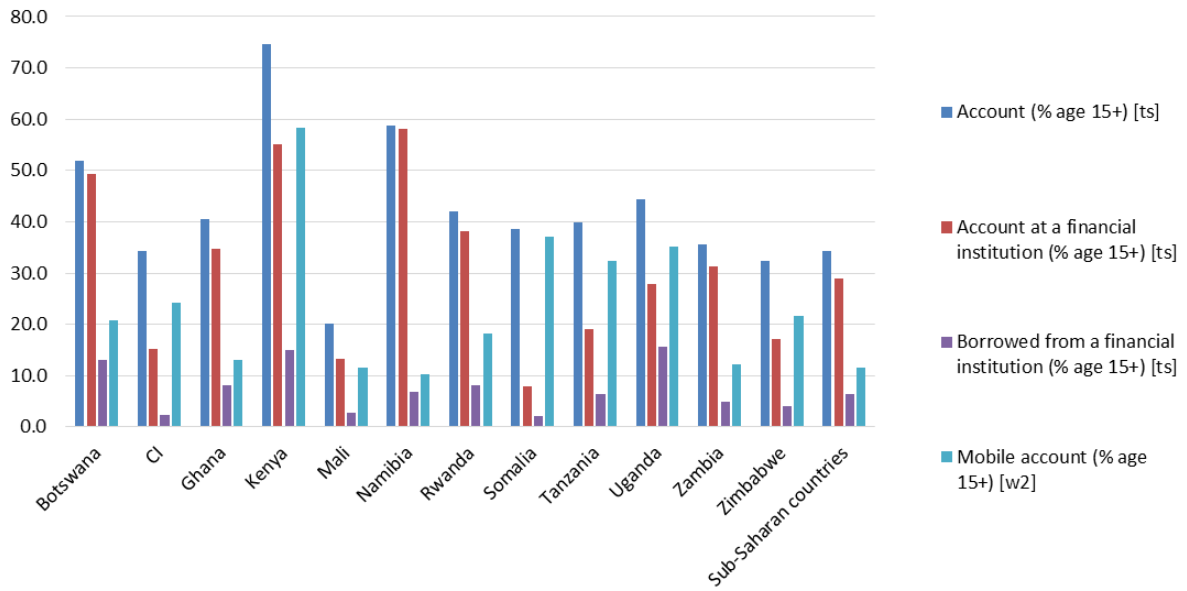
To better contextualize the concept of affordability in the Ivorian reality, it is necessary to take a closer look at the economic conditions of local households and the impact of cooking fuel expenditure on their budget (see Exhibit 1).

3.2.2. Lack of Access to Credit

Only one out of eight Ivoirians, or 15% of the population, owns a formal bank account (World Bank, 2014). This is a low rate if compared with the average for sub-Saharan countries, at 28.9% (see Figure 18). The main reason seems to be the high transaction costs of opening and managing an account.

Similarly, the percentage of population that borrows money from financial institutions is as low as 2.3%, versus an average of 6.3% for sub-Saharan countries. The weak use of formal accounts is partially offset by a high incidence of mobile accounts, with 24.3% of the population owning one, versus an average of 11.5% in sub-Saharan countries. However, it seems that, at least for now, these accounts are mainly used to transfer money between one person and another or to top up mobile phone credit rather than for savings or to obtain credit, as happens in Kenya or Tanzania.

Figure 18
Percentage of people owning bank accounts and mobile accounts in Côte d'Ivoire

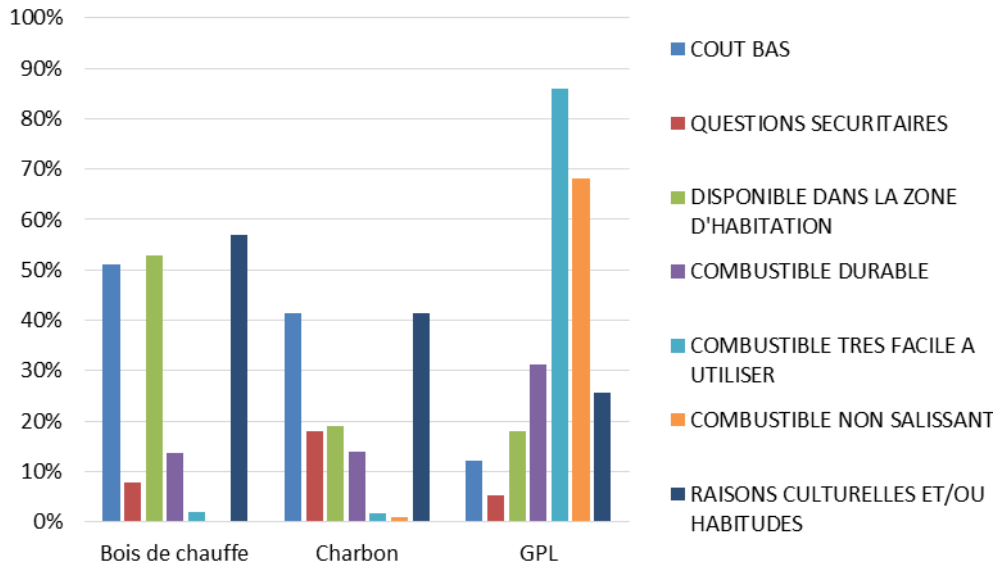


Source: Demirguc-Kunt et al., 2018, *Global Financial Inclusion Database, World Bank* [online]. [Accessed on April 10, 2010.] Available from: http://databank.worldbank.org/data/reports.

3.2.3. Cultural Aspects

Culture, traditions and habits seem to further slow the transition to butane, either because of people's preferences or simply because the option to cook in a different way is not even taken into consideration. In fact, since traditional meals require cooking on an open fire, taste preferences can represent an obstacle in the process of switching from traditional fuels to more modern ones Many families have been cooking over open fires for generations and are often reluctant to change their habits or, more simply, they don't even take into consideration the possibility of cooking in a different way. In the study conducted by ENSEA, households using alternative fuels in combination with LPG indicated cultural reasons and habits as one of the main reasons for using firewood or charcoal (see Figure 19).

Figure 19
Reasons for using firewood, charcoal or LP as primary fuel



Source: Kouadio, H., Houndoga, A. F., Giordano, P., Assogba, M., Rahnema, A. 2018. *Contraintes d'adoption du GPL en Côte d'Ivoire: constats et conclusions de l'enquête de terrain*. IESE Business School. Unpublished study.

3.3. Constraints on the Supply side

Despite the fact that homologated retail prices have been established by the government and are generally applied by the service stations and shops affiliated to big distributors, independent retailers often apply prices up to 25% above these levels. The sale of butane at higher than regulated prices suggests the presence of constraints on the supply side.

The results of the field survey conducted by the authors and ENSEA show that the main constraints on the supply side seem to be represented by the lack of an efficient retail network and specifically:

- Lack of sale points, especially in rural areas
- Disruption in supply

Besides affecting butane price levels, the lack of retail points and infrequent deliveries might make customers perceive LPG as an unreliable source of energy and weigh against the decision to switch — or, at least, to completely switch — to LPG.

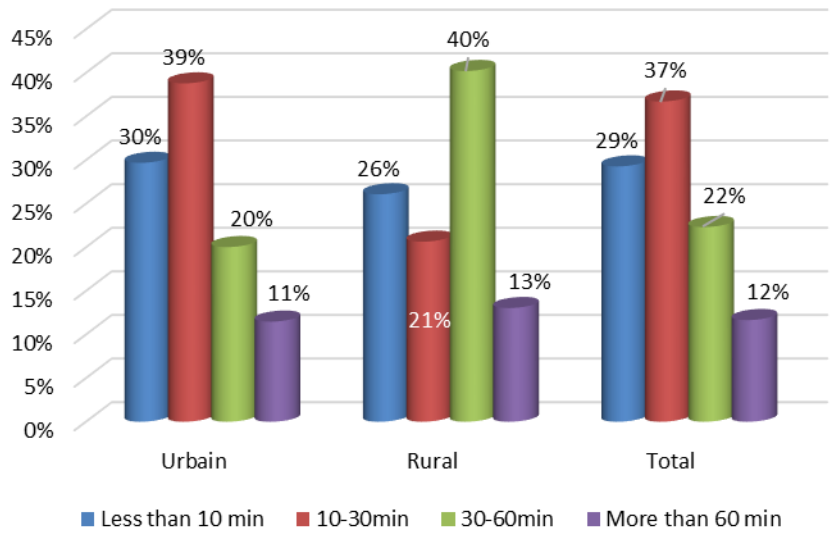
3.3.1. Lack of Retail Network

From a distributors' perspective, it is difficult to establish a commercially viable LPG distribution and retail network in areas with low population density and poor roads. The absence of economies of scale in delivering to rural customers is a strong barrier to the expansion of LPG use.

The measures currently in place, and in particular the equalization transport system and exclusivity agreements, seem to partially help the expansion of retail points in urban areas outside Abidjan but are not obtaining the same effect in rural areas.

In fact, the ENSEA study reveals that 54% of rural households need to walk more than 30 minutes to reach a butane selling point (see Figure 20).

Figure 20
Walking distance to the closest LPG selling point



Source: H. Kouadio, A. F. Houndoga, P. Giordano, M. Assogba, A. Rahnema, 2018. *Contraintes d'adoption du GPL en Côte d'Ivoire: constats et conclusions de l'enquête de terrain*. IESE Business School. Unpublished study.

The lack of an official distribution network is often covered by the presence of small independent retailers, who play an important role by making the distribution network of butane more widespread and by covering those areas not reached by large distributors.

Interestingly though, independent retailers are not recognized by the Ivorian authorities as part of the butane value chain and their margins are not regulated, even though, in practice, a non-official — but apparently generally accepted — margin of FCFA 200 is often applied to the final price for the proximity service provided. Occasionally, this margin has been reported to reach up to FCFA 500, increasing the price of the B6 bottle to 25% more than the regulated price.

Fight against Expensive Life and Observatory of Prices, a commission under the Ministry of Commerce, Crafts and Promotion of SME that monitors prices for food items and household goods and periodically compiles a report with the observed prices, indicates a reference price of FCFA 2100–FCFA 2200 and FCFA 5300–FCFA 5400 for B6 and B12, respectively, in all the different areas of Abidjan, except for the Plateau, the central business district (March 2017).[18]

The data reported by the ENSEA study seems to confirm this data, showing an average retail price for B6 of FCFA 2,200, with some observations peaking up to FCFA 2,500, and most of the observations in a range between FCFA 5,200 to FCFA 500 for B12 (see Figure 14).

[18] Ministère du Commerce, de l'Artisanat et de la promotion des PME. 2018. *Paniere de la ménagère* [online]. [Accessed on May 4, 2018.] Available from: http://commerce.gouv.ci/fichier/evolution-des-prix-de-la-semaine-du%20-14-au-17-mars-2017.pdf.

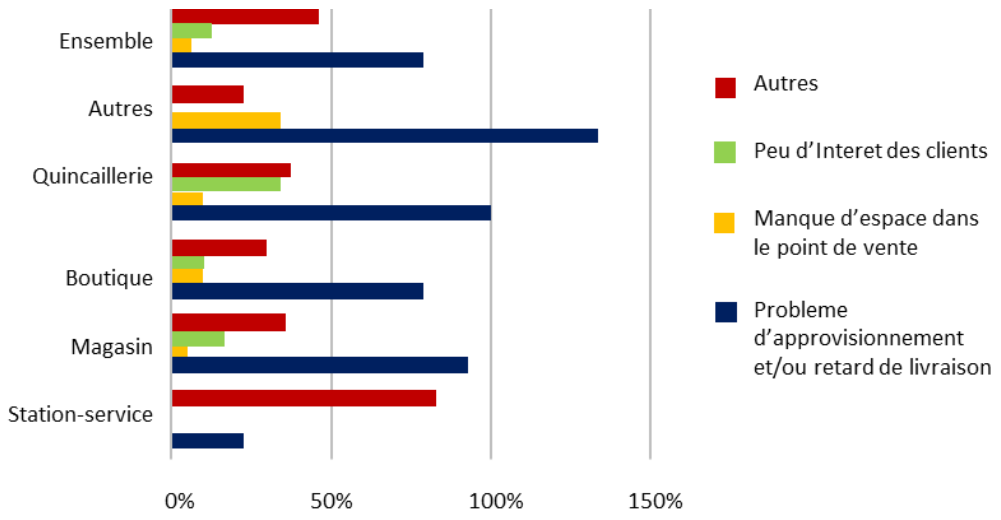
Independent retailers are somehow permitted to charge an extra margin up to FCFA 200 (which translates to a customer price of up to FCFA 2200 for B6 and FCFA 5400 for B12) as a compensation for their higher operating costs in providing a proximity service. An article[19] on the website of the Ministry of Commerce on February 2, 2017, reported that Sirgaz, the syndicate of independent butane retailers, officially asked to be recognized as part of the supply chain of butane and to receive a formal compensation for the proximity service they are providing.

3.3.2. Irregularity of Supply

The field survey conducted by the authors and ENSEA reveals that shortages of LPG are a real problem. In fact, 28% of retailers did not have B6 at the time of the survey and 40% claimed to have faced a shortage in the three months preceding the survey.

In addition, 45% of households experienced a lack of availability of LPG in their usual store at least once in the previous 12 months. Unfortunately, this situation has a greater effect on the small independent retailers, who are also the closest to households, while it has less of an effect on the service stations, since they are generally the official sales outlets belonging to the distributor of the LPG brand. The main reason for this problem, according to the resellers interviewed, is related to supply problems and delivery delays. (see Figure 20)

Figure 20
Reasons for LPG shortages in the last three months per type of retail point



Source: H. Kouadio, A. F. Houndoga, P. Giordano, M. Assogba, A. Rahnema, 2018. *Contraintes d'adoption du GPL en Côte d'Ivoire: constats et conclusions de l'enquête de terrain*. IESE Business School. Unpublished study.

[19] Ministère du Commerce, de l'Artisanat et de la promotion des PME - République de Côte d'Ivoire. 2018. *Site officiel* [online]. [Accessed on May 4, 2018.] Available from: http://www.commerce.gouv.ci/actualite.php?id=602&depart=92&c=s.

The reasons behind the delays could be in various points of the supply chain (insufficient imported GPL, lack of stockage capacity, limited transport or distribution capacity, lack of storage or bottles, constraints at the filling center).

Stockage Capacity

In 2016, the Direction Générale des Hydrocarbures reported a butane stockage capacity of 19,398 tons, for a national consumption of 268,884 tons, therefore granting up to 26 days of consumption. As reported, stocks are currently managed in a just-in-time modality. Although on one hand this strategy presents the advantage of minimizing stockage costs, on the other hand it increases the risk of incurring shortages, especially in countries where controlling the logistic process can be challenging.

Moreover, if the current trend of consumption (18.3% average rate of growth in the last five years) persists in the future years, consumption will exceed 500,000 tons by 2020, with days of granted consumption dropping to 13.

The government seems to be aware of this constraint, and the National Development Plan 2011–2030 illustrates a series of projects aimed at expanding LPG storage capacity, among those in particular:

- Projects to increase the stockage capacity of GESTOCI in Abidjan (4,000 tons), Yamoussoukro (4,000 tons) and Bouaké (4,000 tons)
- Projects to increase the stockage capacity of PETROCI in San Pedro (6,000 tons), Yamoussoukro (4,000 tons) and Bouaké (4,000 tons).

3.3.3. Process of Refilling Cylinders

In Côte d'Ivoire, as in the other West African Monetary and Economic Union (UEMOA) countries, the LPG cylinder refilling policy provides that empty cylinders can only be replaced by cylinders of the same brand.

Buyers can therefore exchange their empty bottles only if the same brand is available in the shop. In case of shortage, the empty bottle must be taken back home and it is not possible, for example, to leave it at the store as a reservation until a full bottle is delivered.

This way of operating might slow down the circulation of cylinders, and shortages might arise.

A specific study should be conducted to assess whether the lack of storage capacity and the current cylinder refilling process represent a constraint to an efficient supply chain and to identify and understand other possible reasons behind butane shortages.

3.3.4. A Not-So-Encouraging Business Climate

In an interview in the *LPG Business Review*, Blaise Edja — general manager of Global LPG Business at Oryx Energies – calls for the government to provide an environment:[20]

[20] LPG Business Review. 2016. *Understanding LPG in West Africa* [online].[Accessed in January 2018]. Available from http://www.lpgbusinessreview.com/2016/07/26/understanding-lpg-in-west-africa.

- offering investors the opportunity for a fair financial return
- developing and enforcing sound practices that ensure common rules for all, identifying and dealing with non-compliance and redressing those aggrieved by bad practice.

The government seems to be aware of the limitations in terms of opportunities for private investors in the Ivorian market. Among the main goals of the National Development Plan 2016–2020are those of strengthening governance, making it market-friendly and putting the private sector at the center of the creation of wealth: "The government will continue to promote the development of the private sector through the granted preferences, the establishment of guarantee funds for interventions in strategic and emerging sectors."

4. Alternatives to Butanization

The butanization program put in place by the government is producing effects in urban areas, but outside Abidjan the situation differs wildly. It might still take a long time before butane reaches rural areas where, in the meantime, biomass continues to be burnt massively. Over the years different initiative have taken place, both from the public and private sector, to alleviate the problems of deforestation and the impact on people's health caused by cooking with biomass.

4.1. Improvement of the Charcoal Value Chain

Aware of the difficulties of reaching more remote areas with the butanization program, at least in the short term, the government has also been involved, since 2001, in the REDD+ program (*Réduction des Emissions de gaz à effet de serre issus de la Déforestation et de la Dégradation des forêts*), which aims to put a national strategy in place to establish a sustainable value chain for charcoal.

This program is acting in three main ways:

- To encourage reforestation with specific types of trees that are particularly fit for the purpose of energy generation because of their high calorific value, rapid growth — even on degraded soils, high wood productivity and good regeneration capacity.
- To reorganize the value chain for charcoal, which is currently mainly an informal sector. In particular, by regulating the entire value chain, from forest exploitation to commercialization of final product, forming the *charbonnier* and encouraging the adoption of more efficient carbonization techniques (such as drying wood or using more efficient kilns), supporting the organization of charbonniers — who currently operate independently — into cooperatives, and reorganizing transport and distribution.
- To valorize biocharcoal produced from agricultural waste, given the significant stocks produced by Ivorian agricultural activities.
- To support the adoption of improved cookstoves to increase energy efficiency, by educating and sensibilizing households, and promoting the use of improved cookstoves for commercial activities, such as fish smoking and baking bread.

4.2. Experimenting With Biogas Technology

Experiments with biogas from household waste have been carried out in Abidjan. For example, SOFCEREQ is an Ivorian company specialized in renewable energies resulting from the valorization of biomass through anaerobic digesters.

Their largest projects so far have been the construction and installation of digesters for a school cafeteria and for a prison.[21] However, although this technology has the advantage of having zero marginal cost for the energy produced, the companies selling biogas systems for household use struggle to scale up, faced with the following main challenges:

- High investment cost0 — the Kenyan company Biogas International (www.biogas.co.ke), for example, sells different models with different specifications. The smallest one (domestic, for four to six people) costs 46,000 Kenyan shillings (US$445). The next one (domestic, for six to eight people) costs 61,000 Kenyan shillings (US$590).
- Difficult to manage — start up can be long due to the low growth yield of anaerobic bacteria and requires regular maintenance. Households therefore need to be trained to operate the system.
- People may not want to use it for food — although the biogas produced is perfectly good for cooking, most people would rather not use it.
- Lack of business models that allow the solution to be scaled — too expensive to do at household level and difficult to find a model to share the cost at a village/neighbor level.

5. Opportunities Envisaged in the Present Situation

Taking advantage of the government's interest in the country making the transition to cleaner cooking fuels, and given the obstacles currently constraining the potential demand for cleaner fuels, some opportunities are arising for private entrepreneurs who operate in the industry to enter the Ivorian market and accelerate the process of switching to modern cooking fuels.

5.1. Increasing the Proportion of Domestic LPG

The increase in the domestic supply of LPG by processing locally available natural gas, could decrease Côte d'Ivoire's dependence on international imports and therefore the risk of price volatility. The government seems to be taking steps in this direction. In fact the National Development Plan 2016–2020 outlines two projects for the construction of two LPG production units:

- LPG East for FCFA 90,000 million
- LPG West for FCFA 100,000 million.

Alternatively, expanding the natural gas network — nowadays serving just an industrial area in Abidjan — to supply natural gas to more industries, commercial businesses and even households that are already using LPG for cooking (especially those in Abidjan), could free up LPG for those

[21] http://energierenouvelable.sofcereq.ci/presentation-sofcereq-1/

households in more remote areas. The economic convenience of using natural gas as a cooking fuel instead of for other uses (for example, to produce electricity) should be assessed.

Furthermore, the country's plans to import significant quantities of liquefied natural gas (LNG) in the next few years (to meet the growing demand for power generation) could also create an opportunity to use part of this provision as natural gas for cooking.

5.2. Using the PAYG Model to Overcome Lack of Access to Credit

Our research shows that, while the price of the LPG fuel is competitive with the price of firewood and charcoal, the high up-front investment cost required by the use of butane for cooking can represent a barrier to the expansion of butane use.

The PAYG business model could help overcome this barrier. This is, for example, the solution adopted in Tanzania by KopaGas (see Figure 21), who split the start-up costs (cookstoves, cylinder and up-front refill) into small daily installments to be paid by the customers as a usage fee. Besides making LPG more affordable for its customers, KopaGas managed to improve its logistic efficiency and to provide a more reliable service by tracking its customers' behavior through the gas meter technology used in the PAYG model. However, in Côte d'Ivoire, the fixed distribution margin set by the government could currently represent an obstacle for PAYG's development, making it difficult to recover the additional cost implied by this model. The significant amount of money required to purchase cookstoves to use with LPG can represent an insurmountable barrier.

In Côte d'Ivoire, although the PAYG business model is already operated by companies in the solar industry (for example, PEG Africa and Zola), it has not yet reached LPG distribution.

The two main constraints that could prevent this solution from working are:

a) LPG retail price is fixed by the government (including the margins for distributors), making it quite difficult to recover the additional cost implied by this model.

b) Mobile money, a crucial aspect of the PAYG business model, is less popular In Côte d'Ivoire than in other sub-Saharan countries.

Figure 21
KopaGas

KopaGas is an LPG distribution company that has been operating in Tanzania since 2011. Tanzania is a country where only 5% of the population uses LPG, while the other 95% still rely on charcoal and biomass. Sebastian Rodriguez and Andron Mendes founded KopaGas to sell the technology that they had just developed: a gas meter and software allowing the level of gas in the cylinder to be monitored and the supply of gas to be switched on and off remotely. However, when they approached Oryx, the biggest LPG importer and distributor in Tanzania, to promote their smart meter, they realized that Oryx was not interested in buying the meter technology. That's how KopaGas ended up becoming one of Oryx's distributors, in order to use the technology they created. Today KopaGas is the third largest of Oryx's ten distributors.
Besides the traditional distribution model, which consists of delivering gas cylinders to walking-distance shops — where the customer pays a deposit to get the first cylinder, which they can then refill (changing an empty bottle for a full one) — KopaGas also operates the PAYG model, which can be summarized in the following three steps:

- KopaGas delivers the customer a kit, composed of a cylinder with attachments, a burner and a cookstove, for a total value of about US$100, upon an up-front payment of 10% (US$10).
- The customer ensures his or her supply of gas through the payment of installments as small as US$0.30–US$0.50 per day. Through the meter, customers are able to monitor their gas account and can decide to top it up for the amount that they desire.
- KopaGas can remotely monitor the level of gas in the customer's cylinder and know when it is time to pick up the empty bottle and deliver a full one, through their distribution network of 25 drivers.

By tracking consumers' behavior, the smart meter allows Kopagas to become more efficient in its logistics. In fact, if traditionally, four cylinders for each customer are needed along the supply chain to grant a continuous supply, by monitoring and understanding the customer's usage pattern, the number of cylinders drops to just two, and with it the distribution costs.
From the customer's perspective, the biggest gain is definitely that of overcoming the high up-front cost barrier. But also, he or she can count on a gas supply that is reliable and conveniently delivered to the door.
A crucial aspect, as for all PAYG models, is the ability to have a good partnership/deal with a telecommunications company and to harness mobile money technology, since most customers don't have access to bank accounts and can only use mobile accounts. In Tanzania, the mobile money penetration rate is very high, and the country benefits from a competitive mobile and telecommunications industry, which minimizes the transaction costs.
As for most of the companies operating the PAYG business model, the biggest challenge for Kopagas is represented by financing the cost of purchase of cylinders, put the smart meters and sell them together with the cookstoves. Kopagas is currently facing this challenge by diverting the profits generated by the "traditional model" into the PAYG branch. In the future, as Kopagas grows in the PAYG direction, the traditional model will be abandoned, saving the cost of the local retailer's margin (currently 15%).

Source: KopaGas.

5.3. Ethanol Gel for Cooking

5.3.1. Ethanol Production

Côte d'Ivoire offers a significant volume of agriculture waste and crops adequate for ethanol production. We conducted an analysis to identify the best crop to be used as feedstock for ethanol production and to assess the convenience of this alternative compared with the fuels currently used. The purpose of our analysis is to serve as a preliminary identification of opportunities.

In order to identify the best feedstock, we considered four criteria:

- The volume of domestic production of each crop available in the country
- Its current uses
- The potential of each crop to be transformed into ethanol, in terms of conversion rate
- The opportunity cost.

Our analysis suggests that molasses is the feedstock that better satisfies the above criteria (see Exhibit 2).

Molasses are a by-product of the manufacturing process of sugar. Côte d'Ivoire produces 105,000 tons of molasses,[22] which are mainly spread on roads to control dust. The opportunity cost of producing ethanol with molasses is therefore very low. In terms of volume, by processing all molasses currently produced a total of 28 million liters of ethanol could be obtained, equivalent to approximately 8.7% of the quantity of butane currently provided for residential use.[23]

Based on the cost of molasses in Côte d'Ivoire, and on the operating costs of ethanol distilleries (including the distillery margin), we estimated the production cost of liquid ethanol in Côte d'Ivoire to be in a range of US$0.27 to US$0.57/liter and gel ethanol to be in a range of 0.33 to US$0.68 liter (see Exhibit 2). Adjusted for fuel and cookstove efficiencies, the production cost is estimated to be in the range of US$0.015 to US$0.030/MJ and US$0.03 to US$0.05/MJ for liquid and gel ethanol, respectively, (or FCFA 8.31 to FCFA 16.61/MJ and FCFA 16.61 to FCFA 27.69/MJ). (see Table 12). A study conducted by UEMOA (M. Dianka, UEMOA, 2012) estimates the cost of producing ethanol gel from molasses in Côte d'Ivoire at FCFA 165/liter, equivalent to FCFA 12.8/MJ.

Comparing the cost of locally producing liquid ethanol or ethanol gel with the cost of importing butane, we can conclude that, at this moment (considering the average butane import cost for 2017), locally produced ethanol would not be competitive. However, due to the high volatility of butane prices on the international market, ethanol could easily become a viable alternative, as shown by the figures obtained considering the average butane import cost for 2012.

[22] Dr. F. Eba, Directeur de l'Unité Agricole Intégrée de Borotou-Koro at Sucreivoire (2017) indicates a production of 50,000 tons from Sucreivoire and 55,000 tons from Sucaf.

[23] After considering fuel efficiencies, 28 million liters of ethanol are equivalent to 23.7 million liters of LPG, which represent around 8.7% of the butane consumed by the residential sector (233,929 tons in 2016).

Table 12
Ethanol production cost vs. butane import cost

Product	Source	U$/liter	Fuel efficiency (MJ/liter)	Cost adj. for fuel eff. (U$/MJ)	Cost adj. for fuel eff. (FCFA/MJ)	Cookstove efficiency rate	Cost adj. for fuel and cookstove eff. (U$/MJ)	Cost adj. for fuel and cookstove eff. (FCFA/MJ)
Ethanol gel (molasses)	UEMOA study	0.3	22.0	**0.01**	**7.55**	59%	**0.02**	**12.80**
Ethanol gel (molasses)	Authors estimate	0.33-0.68	22.0	**0.02-0.03**	**8.31-17.11**	59%	**0.03-0.05**	**16.61-27.69**
Ethanol liquid (molasses)	Authors estimate	0.27-0.57	23.4	**0.01-0.02**	**6.39-13.49**	65%	**0.015-0.03**	**8.31-16.61**
Imported butane	PPI* 2017	0.21	27.70	**0.01**	**4.20**	62%	**0.01**	**6.78**
Imported butane	PPI 2012	0.46	27.70	**0.02**	**9.13**	62%	**0.03**	**14.72**

*PPI is the Payment Protection Insurance and includes costs of FOB, Freight, Insurance & Losses and Port fees

Source: Prepared by the authors.

Similarly, when comparing the retail price of each fuel, adjusted for fuel and cookstove efficiency (see Table 13), our analysis suggests that, at this moment, ethanol gel is not competitive with other fuels. In fact, ethanol gel would cost the customer FCFA 22.03/MJ, significantly more than firewood (FCFA 10.8 and FCFA 15.4/MJ, in rural areas and in urban areas, respectively), charcoal (FCFA 9.8 and FCFA 17.8/MJ, in rural areas and in urban areas, respectively) and butane (at a subsidized price of FCFA 11.05/MJ). Even without the subsidy, the price of butane would be FCFA 15.66/MJ, based on the average quotation of butane for 2017 (average FOB for Butane N Sea NEW at US$328/mt), and therefore more competitive than ethanol.

However, conclusions may vary depending on the reference period considered. Based on the average quotation of butane for 2012, (average FOB for Butane N Sea NEW at US$885/mt), we estimated an adjusted cost (without subsidy) of FCFA 26.5/MJ, which makes ethanol gel a competitive alternative.

Table 13
Retail price comparison of locally produced ethanol gel and other cooking alternatives available in Côte d'Ivoire

Product	Source	U$/liter	Fuel efficiency (MJ/liter)	Cost adj. for fuel eff. (U$/MJ)	Cost adj. for fuel eff. (FCFA/MJ)	Cookstove efficiency rate	Cost adj. for fuel and stove eff. (U$/MJ)	Cost adj. for fuel and stove eff. (FCFA/MJ)
Ethanol gel (molasses)	UEMOA study			**0.023**	**13.00**	59%	**0.040**	**22.0339**
Butane (subsidy)	Governmnt regulated price	0.34	27.70	**0.012**	**6.85**	62%	**0.020**	**11.0556**
Butane (no subsidy)	Authors est. based on av. FOB 2017	0.49	27.70	**0.018**	**9.71**	62%	**0.028**	**15.6621**
Butane (no subsidy)	Authors est. based on av. FOB 2012	0.82	27.70	**0.030**	**16.45**	62%	**0.048**	**26.5335**
charcoal		0.12-0.23	29.5	**0.004-0.007**	**2.27-4.27**	25%	**0.014-0.02**	**9.8-17.8**
firewood		0.07-0.09	15.6	**0.004-0.006**	**2.37-3.40**	22%	**0.027-0.039**	**10.8-15.4**
Electricity (induction cookstove)		0.149	3.6	**0.041**		90%	**0.046**	**25.4673**
Electricity (resistence cookstove)		0.149	3.6	**0.041**		55%	**0.075**	**41.6737**

Source: Authors.

Aside the economic convenience of ethanol, other advantages that should be considered are, for example:

- Creating an ethanol industry can help in the agricultural and industrial development of the country.
- By decreasing the need to import LPG, the domestic production of ethanol can impact positively on the balance of trade and reduce the risks arising from the volatility of LPG prices.
- Ethanol gel does not produced harmful emissions, unlike charcoal and firewood.
- Ethanol is non-explosive and, with gel added, it does not spill.
- The use of ethanol positively contributes to issues of deforestation.
- Ethanol ignites and extinguishes very easily.
- Ethanol is a sustainable and renewable cooking fuel.
- Ethanol gel could be made available in small quantities, adapting to customers' needs.

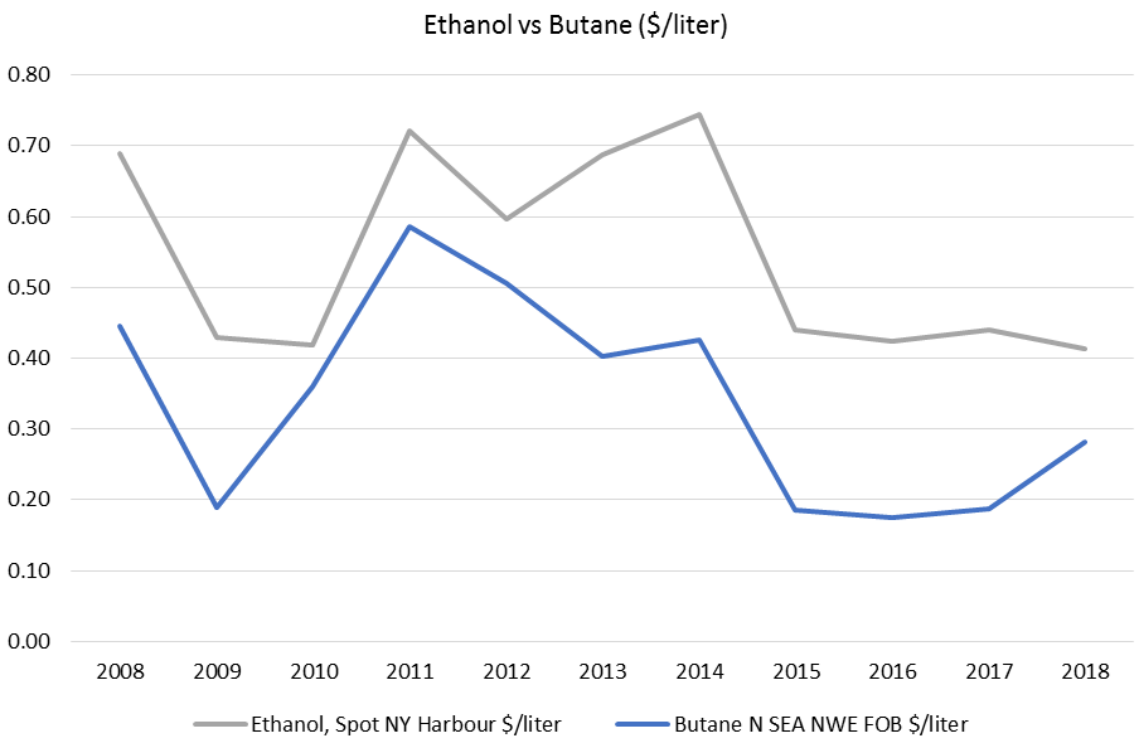
Considering the benefits of the domestic production of ethanol as a renewable cooking fuel, we believe that a comprehensive feasibility study should be carried out to analyze the real potential and estimate the production cost, based on more accurate data.

5.3.2. Ethanol Imports and Distribution

Finally, our analysis explores the possibility of Côte d'Ivoire importing ethanol as an alternative to producing it locally.

Historically, ethanol quotations present a spread over butane (see Figure 21) in the range of US$15 to US$55/liter.

Figure 21
Quotations of ethanol and butane (average for period 2008–2018)



Source: Datastream. (2018) *Thomson Reuters EIKON Datastream* [online]. [Accessed in April 2018.] Available at: Subscription Service.

The cost advantage of butane over ethanol is even higher when fuel and cookstove efficiency are considered (see Table 14).

Table 14
Compared cost of importing ethanol and butane

Product	Source	Quotation	U$/liter	Fuel efficiency (MJ/liter)	Cost adj. for fuel eff. (U$/MJ)	Cookstove efficiency rate	Cost adj. for fuel and stove eff. (U$/MJ)
Imported ethanol (liquid)	Spot NY Harbour average 2017 (Reuters)	1.67 U$/gal	0.44	23.4	**0.019**	65%	**0.029**
Imported butane	N Sea NWE FOB average 2017 (Reuters)	328 U$/mt	0.19	27.7	**0.007**	62%	**0.011**
Imported ethanol (liquid)	Spot NY Harbour average 2012 (Reuters)	2.27 U$/gal	0.60	23.4	**0.026**	65%	**0.039**
Imported butane	N Sea NWE FOB average 2012 (Reuters)	885 U$/mt	0.51	27.7	**0.018**	62%	**0.029**

Source: Authors.

The distribution process might give ethanol some cost advantage over butane. The analysis of the distribution chain is excluded from the scope of this analysis.

5.4. Biogas With Innovative Solutions or at a Large Scale

Côte d'Ivoire has one of the best potentials for electricity and gas generation from biomass in Africa, in terms of both agro-industrial waste and household waste, with an annual capacity estimated at 12 million tons of biomass. Biogas is a mixture of methane and carbon dioxide, and its properties are similar to those of natural gas. The possibility of producing biogas for cooking by converting green waste through anaerobic digestion could be explored (for more detailed information on biogas see Exhibit 3).

Biogas has never really taken off in Côte d'Ivoire because of the high start-up costs and the complexity of managing it. However, innovative solutions at the village level could be considered. One example is provided by (B)energy (see Figure 22), which is offering low-tech, low-cost mobile biogas solutions through local franchisees to households in rural Africa, Asia, and Latin America.

Figure 22
(B)energy

(B)energy is a Germany-based social business that offers low-tech, low-cost mobile biogas solutions through local franchisees to households in rural Africa, Asia and Latin America. Those who decide to invest in (B)energy's biogas technology become not only biogas users, but also biogas providers for others. By producing more biogas than their own family needs for consumption, the buyer can make an income through the sale of biogas, pay off the biogas investment and generate profit. The biogas produced by the biogas digester is carried home by the end-users in the innovative (B)pack: a plastic bag that can be carried as a backpack and hooked up to a biogas cooking stove once at home.

By working together with microfinancers and mobile money providers, (B)energy can offer microfinancing solutions to help local entrepreneurs afford the investment and to allow end-users to access the technology through installments.

Source: Prepared by the authors based on (B)energy, 2018. *(B)energy website* [online]. [Accessed on April 10, 2018.] Available from: http://www.be-nrg.com.

Alternatively, the country could consider implementing a large-scale dissemination of biogas plants, as Nepal did with the Biogas Support Programme (BSP), through which more than 26,000 biogas plants were installed in low-income households.

5.5. Biochar From Agricultural Waste

As Côte d'Ivoire's economy is based on agriculture, the country has a significant stock of agricultural waste that could be enhanced through the production of briquettes of biocharcoal. The potential of agricultural waste is estimated at more than 6 Mtoe, of which only 5% is currently processed (Sapphyre, 2016).

6. Recommendations for Public Policies

From a public perspective, some steps could be taken to help overcome the barriers identified and to provide a breeding ground for a new solution to:

1. Support diversification and inclusivity of the financial system and the development of alternative technologies, such as mobile banking, to improve access to credit and, finally, affordability of modern sources of energy

2. Take into consideration alternative ways of regulating the refilling process to improve the circulation of butane cylinders and avoid problems of shortages.

   In Kenya, for example, the government liberalized and regulated the market for the domestic LPG market segment. The new rules standardized the LPG cylinder sizes and valves, and made it mandatory for domestic LPG suppliers to supply a full cylinder to consumers, irrespective of the brand of cylinder the customer had. The new regulation also requires that all LPG marketers (brand owners) can only sell filled cylinders of their own brand, and all empty cylinders of other brands received from customers must be given back to the brand owners, in exchange for their own cylinders or a deposit refund at a pre-determined rate. This exchange and payment is coordinated through the LPG Cylinder Exchange Pool (the "Pool"), whose membership is compulsory for all domestic

LPG marketers.[24] The policies introduced by the Kenyan government aim at making the market more interactive and competitive, and help to overcome the problem of shortages. However, these policies are difficult to implement in practice and often create delays for the cylinder brand owner (cylinders can come back to the brand owner after several months).

3. Consider recognizing independent retailers as part of the butane value chain and regulate their margins. Independent retailers are operating a proximity service, which is important for the expansion of butane use in the country, and regulating their margin would allow them to participate in the profit generated by the sector and to avoid the application of excessively high margins.

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Exhibit 1
Economic Conditions of Ivorian Households

With a total population estimated at 23.7 million in 2016, the GDP per inhabitant of Côte d'Ivoire stands at US$1,526 (World Bank, 2016). Despite this relatively high GDP in comparison with that of the other West African Economic and Monetary Union (UEMOA) countries, 46.3% of Ivorians still lived below the poverty line (FCFA 737 per day) in 2015 (INS, ENV, 2015). Poverty is more pronounced in rural areas than in urban areas. The INS's Survey of living standards 2015 (Enquête Niveau de Vie) revealed that nearly half (45.6%) of household expenditure is devoted to food (cooking fuels included). The structure of household spending is as follow (see Table 1):

Table 1
Structure of household spending

Expenditure's item	Urban	Rural	Total (all population)
Food	39.10%	55.80%	45.60%
Shelter	20.80%	8.80%	16.10%
Education	4.10%	1%	2.90%
Healthcare	2.60%	3.20%	2.80%
Clothing	5.40%	6.30%	5.80%
Transportation	11.50%	11.40%	11.50%
Communication	7.70%	5%	6.60%
Goods	0.90%	0.60%	0.80%
Others	7.90%	7.90%	7.90%
Total	**100%**	**100%**	**100%**

Source: Authors based on *Enquête sur le niveau de vie des menages en Côte d'Ivoire* (ENV 2015) [online]. [Accessed on March 10, 2018.] Downloaded from: http://www.ins.ci/n/nada/index.php/catalog/42.

The average annual expenditure per capita is FCFA 386,215. In urban areas, it is FCFA 458,993 — well above the amount spent in rural areas: FCFA 31,315 per capita.

Although about 25% of Ivorians do not spend money on cooking fuels (see Table 2, cooking fuels are included in the item "shelter"), the average household monthly expenditure ¡ is approximately FCFA 11,000 for firewood, FCFA 13,000 for charcoal and FCFA 14,000 for LPG (StovePlus, 2015). For the most modest households, especially urban ones, expenditure on cooking fuels can represent up to 40% of their budget (StovePlus, 2015).

Populations in urban areas can be split into three socio-economic categories, according to StovePlus (2015) (see Table 2).

Exhibit 1 (continued)

Table 2
Description of socio-economic class of population in urban areas

Socio-economic class	Descriptions (occupations, housing and comfort)	Average revenues per year
Superior class	Business men, managers, senior executives of private sector	More than 4,000,000 FCFA
	Easy access to goods	
	Access to modern facilities, internet and cable TV	
Medium (or middle) class	Heads of department, foremen	4,000,000 FCFA
	Partial access to modern domestic facilities	
Modest class	Domestic workers, laborer	700,000 FCFA
	Sober housing, often precarious in informal urbanization areas	

Source: StovePlus avec l'appui d'EMC (2015). *Energies propres de cuis -son en Côte d'Ivoire – Situation & Perspectives*. Phnom Penh: StovePlus, a program by GERES en collaboration avec ECREEF. License: Creative Common Attribution CC BY 3.0.

Exhibit 2

Crop	SUPPLY (tons, 2013)					USES (tons, 2013)											AVAILABLE CROPS	ETHANOL/ BIODIESEL PROD. CAPACITY
	Production	Import	Export	Stock variation	Domestic supply	Losses	Feed	Processing	Food	other uses	Price (USD/ ton)	Conversion rate (liter/ton)	Feedstock cost per liter*	Other costs per liter**	Wholesale price per liter	Wholesale price per liter of gel***	(export+losses)+20% (feed)	liters
cassava	2,436,495	72	188		2,436,379	121,825	114,507	1	2,198,937	1,110	55-90	180	0,31-0,50	0.27	0.58-0.77		144,914	26,084,592
cocoa	1,448,992	744	1,032,055	-77,142	340,539	57,960			282,579		1,815						1,090,015	
nuts and products	558,195	311	440,148		118,358	4,960			113,398		1,500			0.27			445,108	
coffee	103,743	1,478	94,886	6,000	16,335				14,981	1,354	1,963						94,886	
cottonseed	265,000	120	89,949		175,171			169,171		6,000	1,780						89,949	
palm kernels	99,000	0	0		99,000			99,000									0	
palm oil	415,000	44,841	224,786	-40,000	195,055				181,741	13,314	695			0.27			224,786	
rubber	289,563	1,281	259,860		30,984					30,984	1,750						259,860	
yam	5,731,719				5,731,719	573,172	229,269		3,782,934	1,146,344							619,026	
sugarcane	1,968,917				1,968,917	19,689		1,921,228	28,000		22	81	0.27	0.27	0.54	0.65	19,689	1,594,809
sugar																		
maize	661,285	18,024	16,251		663,058	108,892	66,508		446,765	40,894	147	410					138,445	56,762,286
sorghum	50,472	654	3		51,123	5,818	8,600		34,529	2,176	315	402	0.78	0.27	1.06	1.27	7,541	3,031,482
rice (milled equiv.)	1,290,081	892,459	44,209	-461,769	1,676,562	198,461	133,400	25,263	1,291,382	28,056							269,350	
rice (paddy equiv.)	1,934,154	1,338,019	66,280	-692,308	2,513,585	297,543	200,000	37,875	1,936,105	42,063	244	430	0.57	0.27	0.84	1.01	403,823	173,643,890
molasses	105.000****				105,000	105,000					69	267	0-0.29	0.27	0.27-0.57	0.33-0.68	105,000	28,035,000

* Price of feedstock is assumed to be in a range of 0-0,29, considered its current uses

** The estimate of other cost components is based on production costs of ethanol in Brazil, reported on "Custos deproducao de Cana de Acucar, Acucar, Etanol e Bioelectricidad no Brasil: fechamento da safra 2015-16" Pecege, December 2016. Consulted on website https://issuu.com/_cbca/docs/relat__rio_2015.16, last accessed on April 25, 2018.

*** Wholesale price of ethanol gel has been estimated 20% higher than liquid ethanol, the same assumption used by the UEMOA study.

****Amounts produced by Sucrivoire (50,000) and Sucaf (55,000) indicated by Sucreivoire, 2017