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Fondazione Eni Enrico Mattei

Report

Access to Energy and Economic Development in Ghana

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Abstract

Energy is essential to guarantee access to clean water, sanitation, schooling and business in developing countries, and represents a key factor for growth and development. Despite its wealth of resources, Sub-Saharan Africa is among the world's regions with the lowest energy consumption per capita and the largest concentration of energy poverty. Ghana is a rapidly growing Sub Saharan country, and it is among the most successful in improving electricity access. This report provides an overview of the country's energy sector and energy access in terms of both electricity and modern fuel and cooking technologies. It then describes the policies and strategies to increase energy access in the country. Finally, it examines the challenges the country faces in increasing access to modern energy, the possible solutions, lessons learned, and policy recommendations.

Table of contents

01

Introduction: Current Situation And Trends In Global Access To Energy

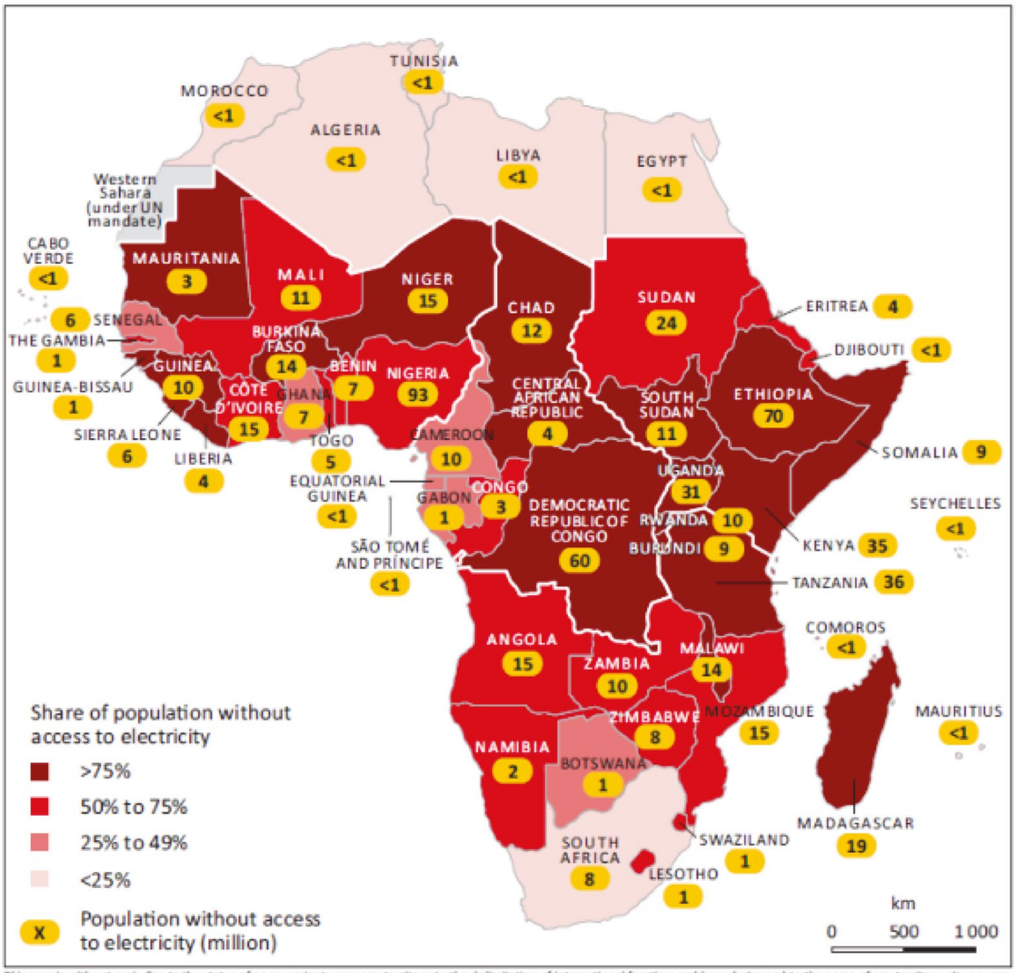
Energy is a key condition to guarantee access to clean water, sanitation, schooling and business in developing countries and represents a key factor for growth and development. From a general point of view, it is still debatable whether access to affordable, reliable, safe and clean energy should be considered a human right or an instrumental right, as fundamental needs may be guaranteed through energy. However, not only the clear correlation patterns between modern energy and economic and human development, but also the strong evidence on the causal relationship of access to modern energy on welfare and quality of life are sufficient elements to clearly underline the crucial role of access to modern energy in sustainable development.

Energy poverty can be defined as lack, scarcity or difficulty in accessing modern energy services by households. In particular, it refers to the access to electricity and to modern and clean cooking facilities. The concept of energy poverty, strictly related to that of access to energy, is highly contentious and no universal definition exists. The definition proposed by the International Energy Agency (IEA) implies "a household having reliable and affordable access to clean cooking facilities, a first connection to electricity and then an increasing level of electricity consumption over time to reach the regional average" (IEA 2013). One could notice that such definition does not take into account the access to energy for business and economic activities, an aspect of vital importance for economic development.

The International Energy Agency estimates that currently 1.18 billion people (16% of the worldwide population) lack access to electricity and 2.74 billion (40% of the global population) rely on traditional cooking methods based on the use of biomass (IEA 2016). This is "only" 300 million people less than in 2000, the first year in which the International Energy Agency has started tracking electricity access data. The global trend hides very stark differences among regions (IEA 2014). The geographical distribution of such phenomena is uneven across the world. People without electricity are mostly in Africa (53%) and developing Asia (43%); similarly, those still relying on traditional cookstoves and fuels are concentrated in developing Asia (68%) and Africa (29%). Within countries, the lack of access to modern energy services is concentrated in rural areas where 80% of energy poor people live.

Despite its considerable wealth of resources, Sub-Saharan Africa remains the region with energy consumption per capita among the lowest in the world and the greatest concentration of energy poverty, with 65% of the population, 633 million people, lacking access to electricity and about 80%, 792 million people, without access to clean cooking. Progress has been registered in some countries in Africa, among them Ghana, but overall in most Sub-Saharan African countries the extension of electricity access struggles to keep the pace with a fast-growing population that outpaces the efforts in place. Figure 1 shows the shares and numbers of people with no access to electricity. Considering the Sub-Saharan area, one can notice that few countries among which Senegal, Ghana and Cameroon have reached the target of having less than 50% of the population without access. The case of Ghana, as we shall see, represents an impressive example of progress. However, in most of Sub-Saharan countries the situation is still difficult, with the majority of population living without access to electricity. This is, for example the case for Ethiopia, DRC and Uganda where 70, 60 and 31 million of people, respectively, have no access. In Nigeria, the most populous country in Africa, although the national electrification rate has reached 45% and is expanding rapidly, still 93 million people do not have access.

According to the IEA's scenarios, the situation regarding access to electricity is expected to evolve significantly by 2040, but not for Sub-Saharan Africa. In particular, while most countries are expected to reach the target of universal access (47 million energy poor people are expected to be in developing Asia), Sub-Saharan Africa will lag behind. It has been projected that more than 90% of people without electricity will be in Sub-Saharan Africa in 2040 (about 489 million people). Progress in access will allow to reduce the numbers of energy poor people, also in the light of demographic growth, compared to the current situation. However, this will be concentrated in urban areas through centralized grid connections, while the 95% of the population without electricity will be concentrated in rural population.



This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

Figure 1. *Share and number of people without access to electricity by country, 2012 - Source: IEA (2014)*

Regarding access to modern cooking stoves, nearly 730 million people in sub-Saharan Africa use traditional inefficient stoves and solid biomass as fuel for cooking. The majority of the population in such a situation is concentrated in five countries, namely Nigeria, Ethiopia, DRC, Tanzania and Kenya, as depicted in figure 2, however this is due to the size of their population. Indeed, in 88% of sub-Saharan countries, more than half of the population rely on solid fuel and inefficient stove to cook, while in 48% of sub-Saharan countries more than 90% of the population live in such a situation, particularly in rural areas.

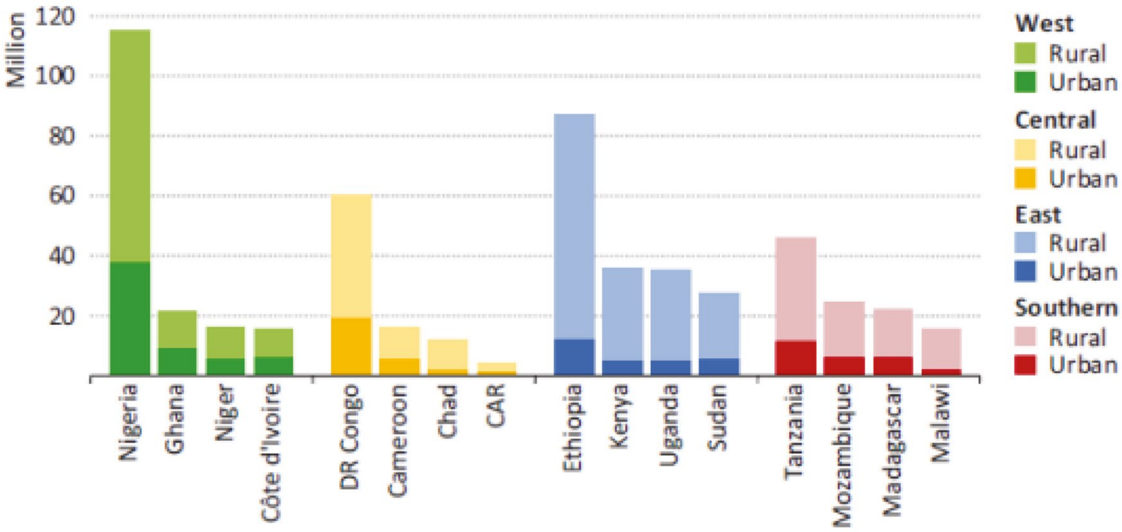


Figure 2. *Largest population relying on use of solid fuel for cooking in sub-Saharan Africa, 20 - Source: IEA (2014)*

In sub-Saharan African countries, cooking represents about 80% of total residential energy demand, while in OECD countries this share is about 5% (IEA 2014). This is can traced back to two main reasons. First, households' limited budget and subsistence lifestyle does not allow to allocate large shares of budget to energy goods. Hence, most is spent to satisfy basic needs such as cooking food. Second, the methods and tools used for cooking are often extremely inefficient. The main fuels used for cooking usually vary between rural and urban areas. In rural areas, the use of solid biomass (fuelwood and agricultural waste) is nearly exclusive, while in urban areas more variety is observed. Despite the slow penetration of LPG and keresone for cooking, charcoal is still one of the main fuel for cooking in urban areas, given its higher energy content, low price and ease to transport compared to fuelwood.

The World Health Organization estimates that the use of traditional methods of cooking, through wood and biomass combustion, has severe consequences on the health of households, due to indoor air pollution. The Global Burden Disease study estimates that almost four million people die every year from indoor air pollution due to the use of traditional cooking fuels and stoves (Lim et al. 2013, Martin et al. 2011). Moreover, the extensive use of wood as main energy fuel impacts the local environment, due to deforestation, soil degradation and erosion. At global level, inefficient biomass combustion is a major determinant of black carbon, a contributor to global climate change. Emissions from cooking stoves continue to be a major component of global anthropogenic particulate matter (UNEP/WMO, 2011) particularly in developing countries, for example in Africa and South Asia where emissions from cooking stoves are well over 50% of anthropogenic sources (Bond et al., 2013).

Projections for access to clean cooking facilities show less progress than in the case of electrification, as about 1.85 billion people are expected to rely on traditional fuel and cookstoves by 2040, 38% of which (about 700 million people) living in Sub-Sahara Africa. Once again, the highest incidence will be experienced in rural areas, where the establishment of clean fuel supply networks will be most difficult. Rural population is expected to rely on solid biomass and improvement in access will be reached through the adoption of more efficient and clean biomass cookstoves.

02 Conceptual Framework

2.1 Access to Electricity and Development

Access to electricity can impact household welfare, economic development and poverty reduction through a vast range of channels and mechanisms. From a household perspective, access to electricity means the opportunity to purchase electric appliances, depending on the wattage level made available, such as lights, refrigerators, TVs, heating and cooling appliances and electric machinery for small business. The demand for electric appliances in developing countries is expected to grow dramatically in the next decades (Wolfram et al., 2012) and is shown to be non-linearly connected to income growth (Gertler et al., 2016). As far as the impact of adoption of individual appliances is concerned, Barreca et al. (2016) find that air conditioning lowered heat-related mortality in the US and there is strong emerging evidence of the link between temperature and economic activity (Burke et al., 2015; Adhvaryu et al., 2016) which highlights the scope for adaptation strategies to climate change.

Few studies assess the potential impact of refrigerators on food security and health. Gonzalez and Rossi (2007) find suggestive evidence of the impact of better quality of electricity provision on health outcomes related to nutrition, due to the increase in refrigerator use. Media exposure can have important impacts on development outcomes (La Ferrara, 2016), particularly on female empowerment (Jensen and Oster, 2009), divorce (Chong and La Ferrara et al., 2009), social capital (Olken, 2009) and fertility (La Ferrara et al., 2012). Besides media exposure, the introduction of electricity also seems to negatively affect fertility, particularly in the short-run (Fetzer et al., 2013; Burlando, 2014; Grimm et al., 2015).

Electricity is also considered a fundamental driver for the development of economic opportunities and improvement in households' productivity in both agricultural and non-agricultural sectors, by providing motive power. In the agricultural sector, it would power farm machinery such as water pumps, fodder choppers, threshers, grinders, and dryers. Electricity would contribute to the modernization of agriculture by extending cultivable land through irrigation. This would lead to increases in labour demand and in productivity (Cabraal et al., 2005). In the non-agricultural sector, electricity could contribute to the development of small business opportunities, for example, in the food processing value chain, in handicraft production, carpentry and retailing.

The first and most widespread electric appliance adopted in newly electrified contexts is lighting, particularly in remote areas (Barnes, 2007; Bensch et al., 2011; Bernard, 2012). This is motivated both by the often low-wattage made available by grid or off-grid solutions, and by the households' relatively low ability to pay for other electric appliances. Lighting can have direct impacts on health, via the substitution of more pollutant kerosene lamps, but also potentially influences the allocation of time of all household members: women and children can divert time from fuel collection to more productive activities, such as studying or income generation. People can also benefit from greater flexibility in time allocation through the day and evening derived from better lighting. Electric light can also generate high saving from expenditure in alternatives, such as kerosene lamps, candles, diesel generators and batteries. By influencing the reallocation of activities and leisure, electric light can also have impacts on fertility, beyond the aforementioned effect through media exposure.

Finally, electrification may impact households' outcomes through public good benefits, such as increased security through lighted streets, better schooling and health services, lower environmental contamination and degradation (IEG, 2008). A representation of the causal chain linking access to electricity to economic development and poverty reduction is provided in figure 3.

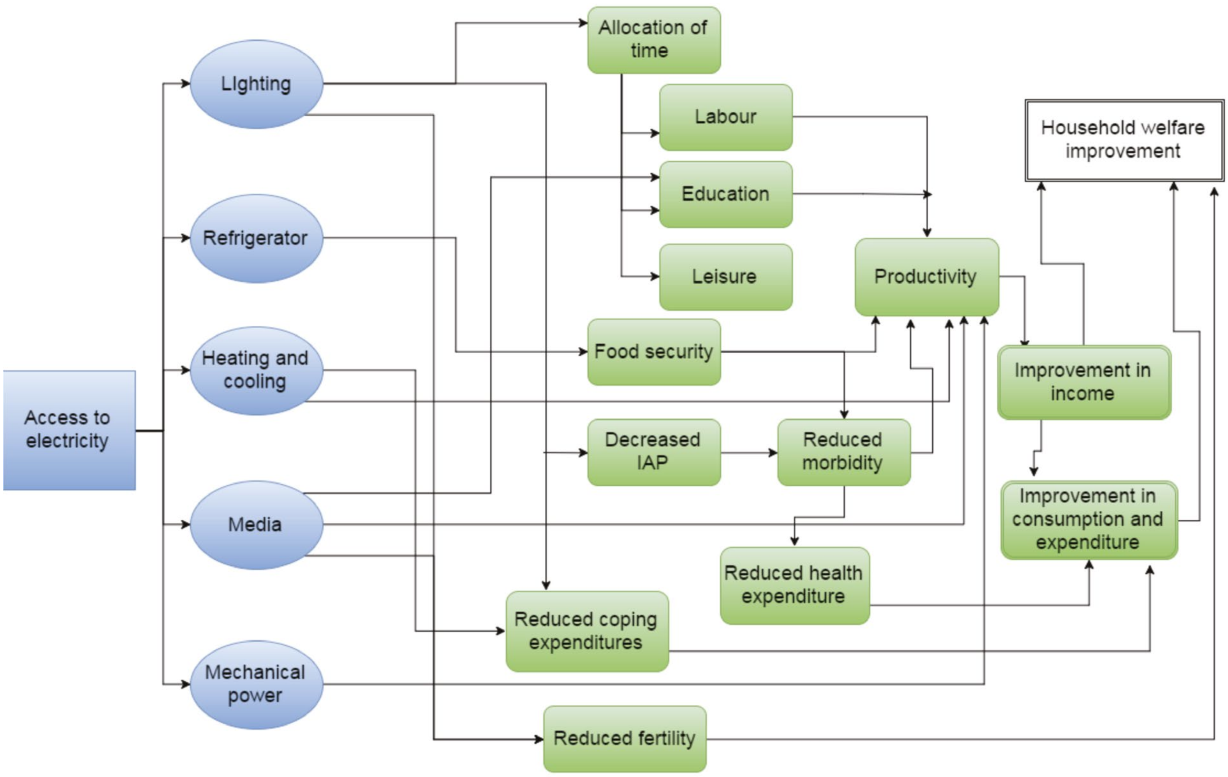


Figure 3. *Causal chain of impacts of access to electricity - Source: Bonan et al. (2017)*

After reviewing the literature on the impacts of access to electricity adequately tackling the methodological challenges related to causal attribution, Bonan et al. (2017) find that the impact of electrification on time allocation and labour market outcomes seems to be one of the most robust, although still not definitive. The results seem to support the mechanism of substitution from agricultural to non-agricultural activities, leading to gains in productivity and wages, ultimately leading to income increases and welfare improvements. Impacts on expenditure and wealth are more uncertain, and depend on the type of technology (on-grid vs off-grid). The evidence of the impact of electricity on health outcomes is extremely limited but seems to support that the substitution of kerosene lamp with electric bulbs generates decreases in indoor air pollution exposure and respiratory diseases. The impact of electricity on schooling outcomes is somehow mixed. Overall, electrification seems to be beneficial for household's welfare. However, one has to note that the dimension of benefits seems to vary across geographical regions. In particular, the impacts in the African context, after excluding the case of South Africa, seem to be quite modest (Peters and Sievert, 2016).

As for the specific case of Ghana, Akpandjar and Kitchens (2017) investigate the impact of Ghanaian electrification expansion between 2000 and 2010 on the structure of employment and the household. They find that individuals in households with a residential electricity connection are more likely to operate a non-agricultural small business, are less likely to work in agriculture, are more likely to be employed, have higher occupational scores, and are more likely to be in wage-earning occupations. In particular, head of households connected to the grid are 6.8 percentage points more likely to operate a non-agricultural small business and 12 percentage points less likely to work in agriculture than non-connected heads of household. Relative to the mean, this suggests that there is a 29.2% decrease in agricultural employment. There is also evidence that individuals with access to electricity are 3.9 percentage points more likely to work as a wage-earning employee instead of being self-employed (17% increase with respect to the mean). Taken together, the size of the increase in the operation of small businesses and movement to wage-earning occupations explain the overall decrease in employment in the agricultural sector. This reveals a remarkable change in the labour market structure, with people moving from low-value and low-skill in the agricultural sector to higher-value and higher-skill occupations in the proto-industrial sector. While the data used do not allow to assess the extent to which these changes led to increases in household income, it is likely that such reallocations across sectors led to increases in income. Such result has been confirmed in other contexts like El Salvador, India and Brazil (Barron and Torero, 2016; Burlig and Preonas, 2016; van de Walle et al. 2015; Chakravorty et al. 2014; Lipscomb et al. 2013). The authors also find that electrified households tend to adopt labour-saving electric stoves and are less likely to use wood fuel for cooking. While on average 47.39% of households used wood fuel as their primary cooking fuel, households with electricity were 15.29 percentage points less likely to use wood fuel (32.26% decrease relative to the mean). Moreover, they find that the use of electric stoves increases by about 48% relative to the mean, although the diffusion of such tools remains at low levels. Electrification also changes the structure of the household and seems affects relevant spheres such as fertility and education. It is found that in electrified households the number of children below five years decreases by 12% and children tend to have more schooling. This result it consistent with the possibility that electricity frees up children from household chores and the need for them to seek employment outside the home. This is also confirmed by the fact that child employment (in the house or outside) decreases.

2.2 Access to Modern Fuels and Cooking Technologies and Development

The use of ICS may have positive consequences on household welfare and sustainable development, from several points of view: health, time allocation and reduced expenditure in fuels, due to efficiency gains.

Regarding the first channel, the World Health Organization (WHO) claims that IAP caused by the use of traditional cooking stoves and fuels such as firewood and biomass has severe consequences on health. Indoor smoke inhalation is among the underlying causes of pneumonia and heart diseases, which are among the leading causes of the global burden of disease (Ezzati and Kammen, 2001). Household air pollution is estimated to be responsible for about 4 million deaths per year (Martin et al., 2011; Lim et al., 2013). Such numbers are greater than deaths from malaria, HIV/AIDS and tuberculosis (WHO, 2008), which are expected to decrease substantially by 2030, whereas the current pace of fatal respiratory diseases due to IAP is not expected to decrease. The adverse effects of IAP on health are particularly severe in women and children (Smith et al., 2004). As for Ghana, it has been estimated that exposure to smoke from traditional cookstoves and open fires causes about 18,000 deaths in Ghana, every year, including about 2,200 children, year as a result of acute lower respiratory infections caused by the use of solid fuels (GACC, website).

The adoption of ICS can therefore contribute to a decrease in morbidity, particularly that related to respiratory diseases, through the lower exposure to IAP.

Inefficient stoves require longer cooking and fuel-gathering times. This task is mainly carried out by women and children, who divert time from education and income-generating activities (Barnes and Toman, 2006), although these aspects are strongly related to cultural and behavioural traits which differ from place to place and may slacken the pace of change. The adoption of ICS could therefore contribute to a reallocation of time towards more productive activities, such as study and income generation.

Finally, more efficient stoves can generate a decrease in fuel consumption and expenditure, with the possibility of diverting consequent saving into other expenditures, perhaps more productive. A graphical representation of the conceptual framework going from access to ICS to household welfare, through different channels, is provided in figure 4.

The evidence of the causal impact of access and usage of ICS on household welfare is very sparse and mixed (Bonan et al. 2017). Results vary significantly in relation to location and products, and generally suggest that the success of programs in generating sustained impacts over time relies on understanding and developing both the supply and the demand side. “Fit for all” products do not appear as viable solutions; therefore, improved cookstoves need to fit local contexts and preferences.

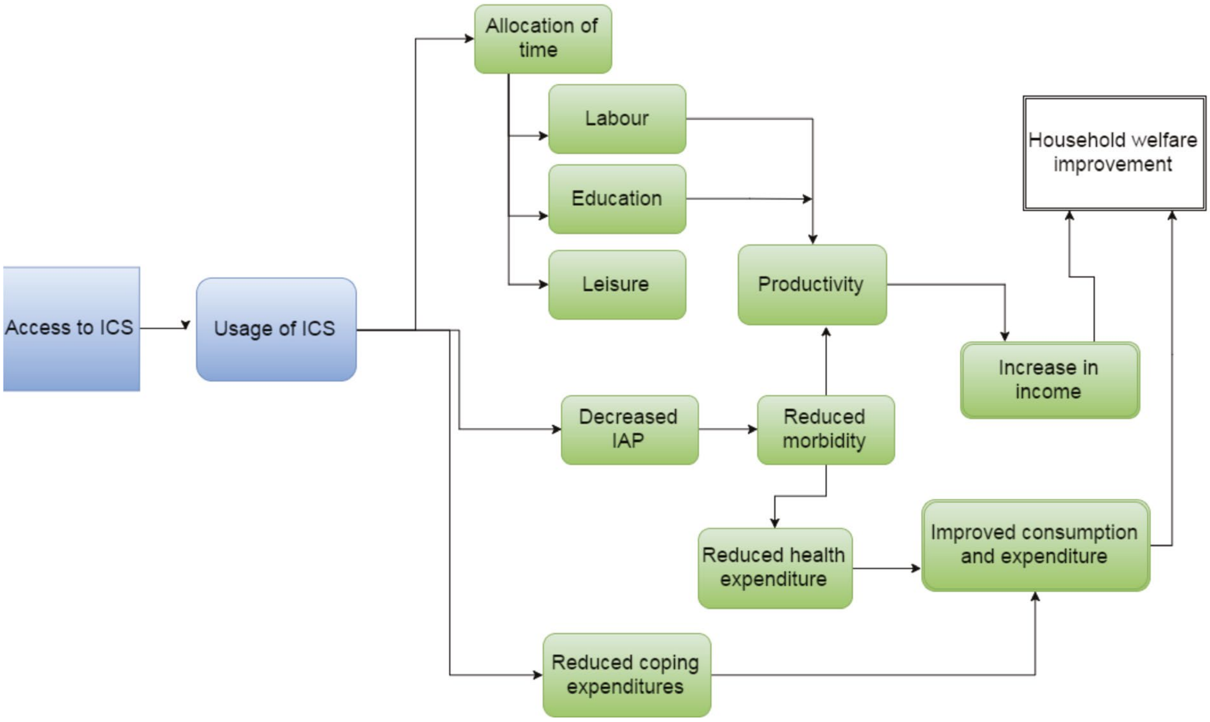


Figure 4. *Causal chain of impacts of access to ICS - Source: Bonan et al. (2017)*

The process of households' choice of cooking fuel is centered on two main strands: fuel switching and fuel stacking. The idea of an energy ladder implies the movement of households towards more sophisticated energy sources and cooking tools, as their income increases. This may occur through a linear process of fuel switching (Heltberg 2004) or through energy stacking, i.e. both modern and traditional fuels and cookstoves, not being mutually exclusive, are used at the same time (Ruiz-Mercado et al. 2011, Masera et al. 2000).

03 Country Overview

3.1 Macroeconomic Focus

Ghana is a rapidly growing Sub Saharan country which gained independence on 6 March 1957. Ghana has a registered population of 27 million people (World Bank, 2015) up from 2010 census which estimated 24.1 million citizens. Its population growth has been steady since 1960, growing at an average rate of 2.2% every year (Figure 5). With this pace Ghana's population is expected to reach 80 million individuals by 2100.

The population is evenly distributed across genders. Out of the 27 million citizens, around

50.9% is composed by male, while female population is around 49.1%.

As of 2016, Ghana's fertility rate was 3.94 children per woman in rural areas and 2.78 children per woman in urban regions.

Ghana has also experienced rapid urbanization since the mid-1960s. From an estimated 23.1% of total population living is urban areas in 1960, the population living in cities reached 51% in 2014 (World Bank, 2015).

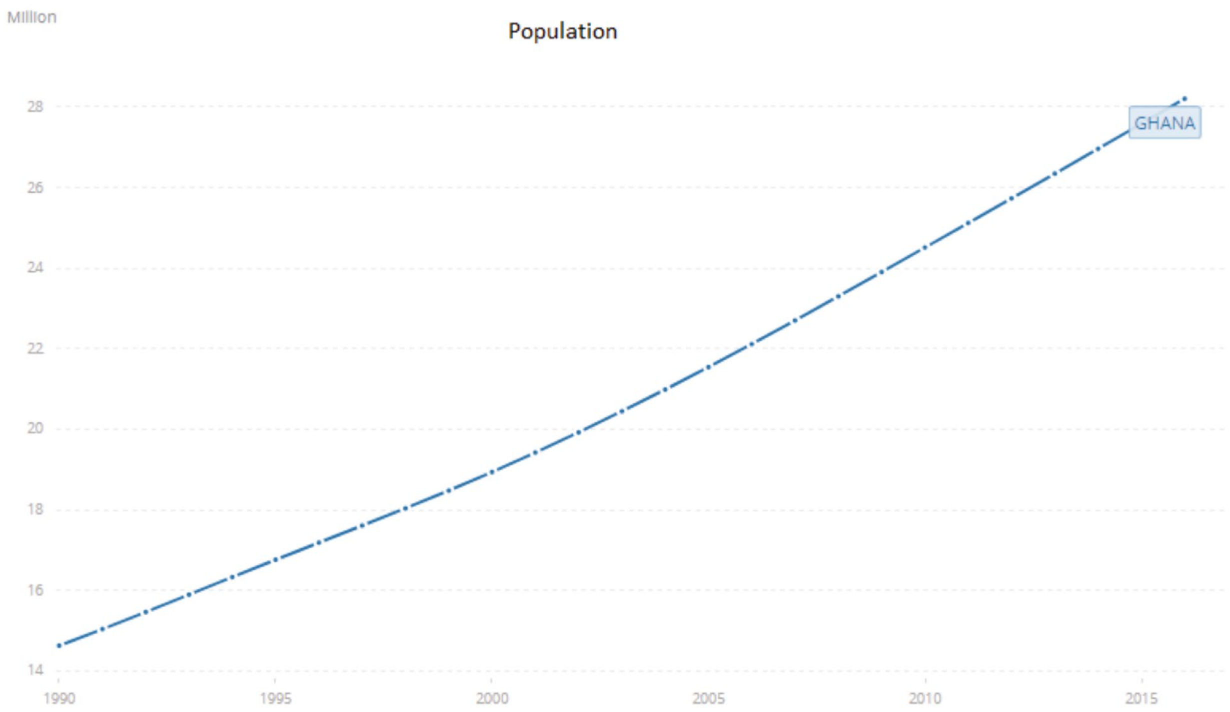


Figure 5. *Population in Ghana, 1990-2015 - Source: World Development Indicators*

Rapid urbanization has coincided with fast economic growth. From 1990 to 2008 Ghana's economy grew constantly with higher rates compared to the rest of the Sub Saharan Africa, therefore reducing the pre-existing gap. Since 2009 GDP per capita accelerated its growth finally closing the gap with the rest of SSA in 2012. Since 2012 the economic expansion has flattened, while still over-performing that of the Sub Saharan Africa which has been declining until nowadays (Figure 6).

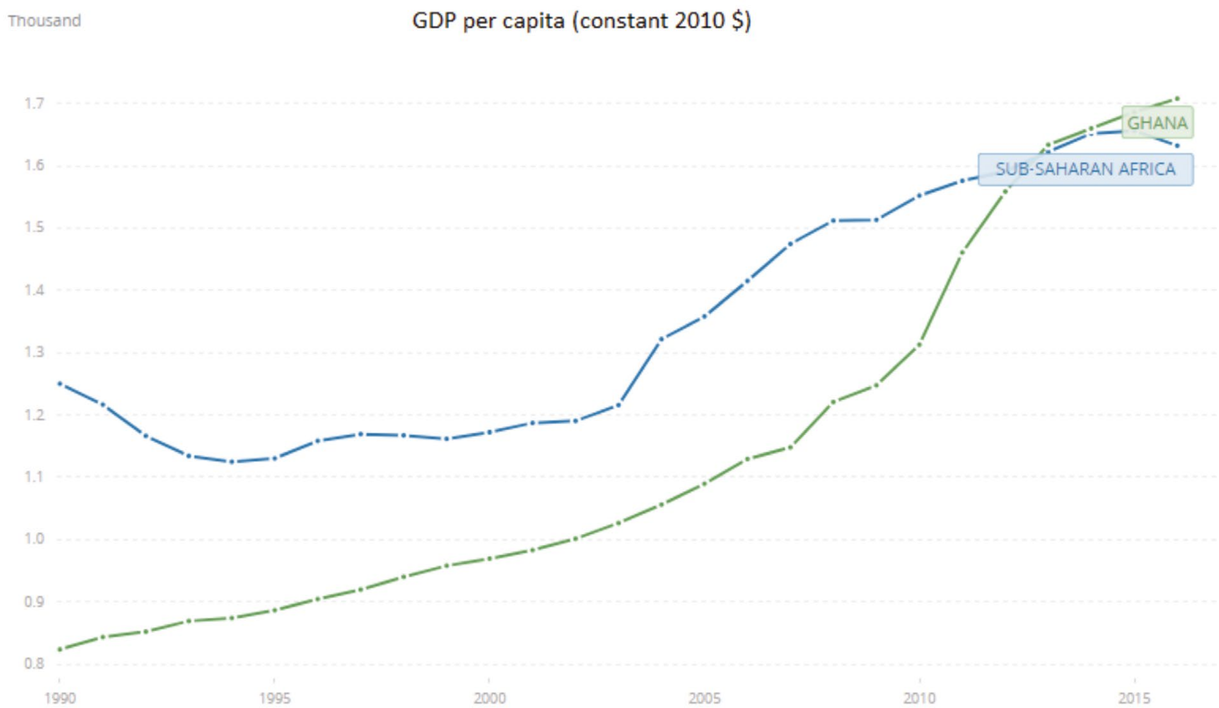


Figure 6. *GDP per capita in Ghana and Sub-Saharan Africa, 1990-2015 - Source: World Development Indicators*

Ghanaian economy is heavily dependent on agricultural sector which employs 56% of the total labour force, accounting for 37.5% of GDP, while manufacturing sector accounts for 7.9% of its GDP (World Bank, 2017). The economy relies also on export of gold, cocoa and timber towards the rest of the world. Concerning poverty threshold: approximately 50% of Ghanaian population live on less than $2 per day.

Ghana's recent economic performance enhanced in the first half of 2017 (GDP grew by 6.6% up from 4.4% registered in the second half of 2016). This comes after significant financial slippage which occurred in the previous year. Public deficit also decreased during the first half of 2017 to 2.7% of GDP (down from 3%). Moreover, the Sub Saharan country achieved 0.579 in Human Development Index (medium) ranking 139th in the world (UN Development Programme, 2016).

Looking at the short-term, economic forecasts are positive, with GDP per capita expected to grow by 6.1% in 2017 and to maintain the positive momentum for the biennium 2018-2019 (Ghana National Bank, 2017).

However, challenges remain. In fact, GDP growth is mainly caused by the expansion of the oil sector; while non-oil sector is expected to grow by 4.3% only by 2018 (well below the announced objective of 6-10%). The dependence of Ghana's economy on the oil sector makes the country particularly vulnerable to oil price fluctuations.

Concerning the political development of the country, Nana Dankwa Akufo-Addo was elected President in December 2016. The political race took place in a nonviolent environment and Akufo-Addo won the elections with large gap which makes room for the President to carry out his program of reforms. The country, hence began a period of political stability which is essential in order to accomplish the objectives of the Sustainable Development Goals (henceforth SDGs) and in particular the SDG 7 (i.e. ensure the access to affordable, reliable, sustainable and modern energy for all).

However noteworthy monetary difficulties remain. The latter mainly involve public spending shortage and poorly performant but expensive secondary education. Thus, Ghana's medium term economic performance lies on the ability of the government in implementing the stabilization program through carrying out fiscal consolidation.

3.2 Energy Sector

Electricity represents the 11% of total energy consumption in Ghana, while 60% derives from traditional biomass and the remaining 29% from oil products (see Figure 7).

Ghanaian electric network operates through a system of government-owned or with government participation companies. Electric generation and transmission are operated by two state-owned companies, respectively the Volta River Authority (which was created with the Volta River Development Act in 1961 and whose primary purpose is to generate and supply power for Ghana's needs) and the Ghana Grid Company (established in 2008 with a mandate of ensure the provision of transparent, non-discriminatory and open access to the transmission grid for all the participants in the power market).

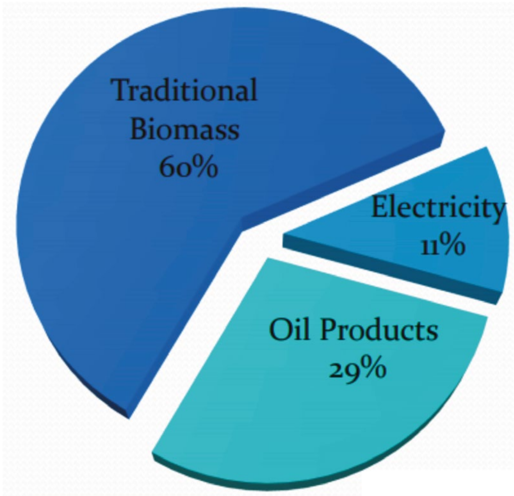


Figure 7. *Total energy consumption in Ghana, by fuel type, 2014 - Source: World Bank 2014*

Local distribution is performed jointly by the Electricity Company of Ghana and the Northern Power Department. Specifically, the Electricity Company of Ghana is directly operated through the Ministry of Energy of Ghana and it covers around thirty percent of the total land mass of the country (ECG, 2014). The Northern Power Department is the sole electricity supply of three northern regions of Ghana: Northern, Upper East and Upper Over. These state-owned organizations are overseen by the Open Utilities Regulatory Commission (PURC), created in 1997.

Electricity is mainly generated by three hydroelectric dams. In particular, the first dam to be built in Ghana was the Akosombo hydroelectric plant, which was developed in 1962 by damming the Volta River. A second dam, the Kpong, was built in 1982. Finally, the most recent one, the Bui dam was finished in 2013. The Bui dam was essential in lowering the recurrence of blackouts. However, power discontinuities remain (Ghana Energy Commission, 2016). Hydroelectric power production accounts for about half of the total generation capacity. The remaining half is covered by thermal power plants based on a combination of oil and natural gas. Renewables account for a very limited share, i.e. less than 0.1% of total generation capacity. Table 1 shows Ghanaian generation plants as of end of 2015 by fuel type.

During the period from 1990 to 2000, power utilization developed from 4457GWh to 6033GWh, with an average rate of 9.42% per year. The increase in electricity consumption was only partially due to an increase in population, which grew by an average of 2.6% per year, while the rest of the growth is explained by the dramatic increase in the access to electricity rate. The recent substantial growth in electricity use, not adequately counter-balanced by the growth in electricity supply, is one of the reasons for power discontinuity in Ghana (Akuffo, 2009; World Bank 2015).

GENERATION PLANT	**FUEL TYPE**	**CAPACITY (MW)**		**TOTAL GENERATION**	
		Installed	Average Available	GWh	% Share
Hydro Power Plants					
Akosombo	Hydro	1,020	375	4,156	
Bui	Hydro	400	330	870	
Kpong	Hydro	160	105	819	
	Sub-Total	***1,580***	***760***	***5,845***	***50.86***
Thermal Power Plants					
Takoradi Power Company					
(TAPCO)	Oil/NG	330	300	1,784	
Takoradi International Company					
(TICO)	Oil/NG	330	320	1,336	
Sunon–Asogli Power (SAPP)	NG	200	180	1,185	
Tema Thermal Plant1 (TT1P)	Oil/NG	110	100	541	
Tema Thermal Plant2 (TT2P)	Oil/NG	49.5	30	215	
CENIT Energy Ltd (CEL)	Oil/NG	110	100	317	
Mines Reserve Plant	Oil/NG	80	40	170	
Takoradi T3#	Oil	132	3.6	31	
Karpower*	HFO	250	225	64	
	Sub – Total	***1,591.50***	***1,298.60***	***5,643***	***49.1***
Renewables					
VRA Solar	Solar	2.5	1	4	
	Sub – Total	***2.5***			***0.04***
Total		**3,174**	**2,058.60**	**11,492**	

Table 1. *Installed Grid Electricity Generation Capacity operational as of December 2015 - Source: Ghana Energy Outlook, 2016*

3.3 Energy Access in Ghana

3.3.1 Electricity

Among Sub-Saharan countries, Ghana is among the most successful in improving electricity access. This is mainly due to the long and strong political commitment since the launch of its National Electrification Scheme in 1989. According to the statistics provided by the World Bank[1], referring to 2014, 78% of the Ghanaian population have access to electricity, while about 6 million people still do not. The country shows relevant inequalities in access between urban and rural areas. While in the former access exceeds 91%, electricity reaches only 63% of the rural population. This shows a remarkable improvement since the 2008 DHS wave of data collection. At that time, 61% of households had access to electricity, leading to a 28% growth rate; the sharpest increase has occurred in rural areas where access grew by two thirds (from 38 to 63%), while for urban households it moved from 85 to 91% (7% growth rate). This increase is partially attributed to the rural electrification programmes implemented by successive governments in recent years.

The progress is even more striking if compared to the rest of Sub Saharan region whose total population with access to electricity was 37.4% (up from 26.5% in 2000) while the rural access to electricity slightly increased from 10.4% in 2000 to 17.9% in 2014. Figure 8 shows the trend in overall electrification rates in Ghana and in the Sub Saharan Africa. Figure 9 shows the trend in the access to electricity in urban and rural areas.

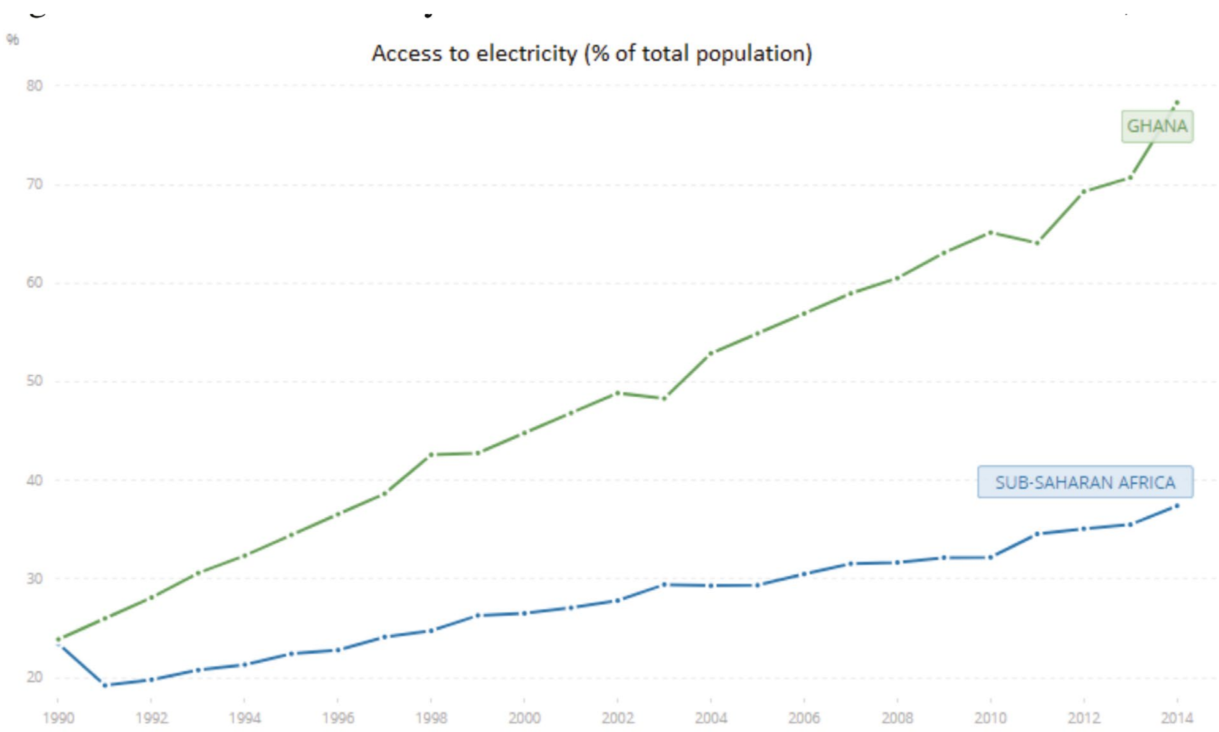


Figure 8. *Access to electricity in Ghana and Sub-Saharan Africa 1990-2014, share total population - Source: World Development Indicators (WDI)*

1 *The data source for these figures is the Demographic and Health Survey (DHS), a national representative household survey that provides data for a wide range of monitoring and impact evaluation indicators in the areas of population, health, and nutrition.*

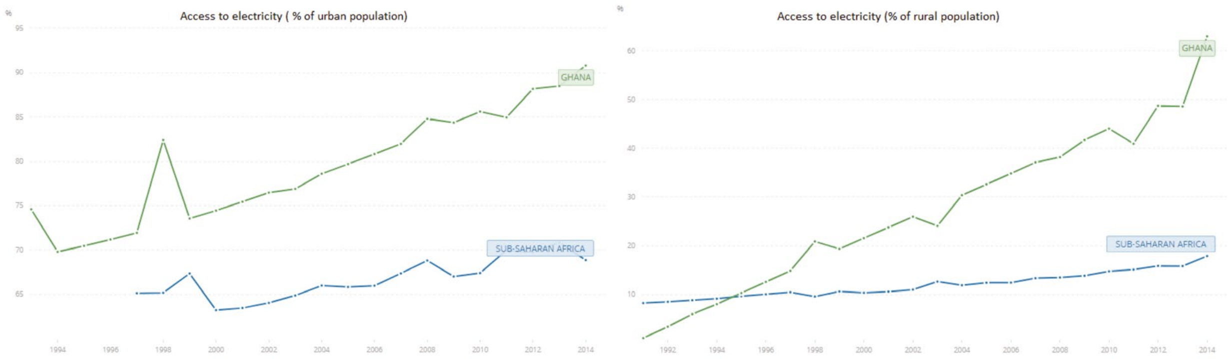


Figure 9. *Access to electricity in Ghana and Sub-Saharan Africa 1990-2014, share of urban (right) and rural (left) population - Source: World Development Indicators (WDI)*

Table 2 compares the electricity access rates in Ghana in 2000 and 2014 with a selection of African countries. This shows that Ghana is the second African country in term of access to electricity after South Africa and the fastest developing one.

Country	Access to electricity (% of population)		Access to electricity, urban (% of urban population)		Access to electricity, rural (% of rural population)	
	2000	2014	2000	2014	2000	2014
Ghana	44.8	78.3	74.4	90.8	21.6	63.0
Congo, D.R.	6.7	13.5	20.0	42.0	10.0	40.0
Congo, R	28.6	43.2	..	60.8	15.4	10.4
South Africa	70.6	86.0	89.7	94.1	45.2	71.5
Nigeria	42.7	57.7	76.6	78.4	24.5	39.3
Senegal	36.8	61.0	77.1	85.0	9.6	32.7
Cote d'Ivoire	47.6	61.9	79.3	84.0	23.2	36.5
Ethiopia	12.7	27.2	76.2	92.0	4.0	12.2
Kenya	15.7	36.0	58.9	68.4	5.0	12.6
Uganda	8.4	20.4	50.2	51.4	2.6	10.3
Sub-Saharan Africa	26.5	37.4	63.2	68.9	10.4	17.9

Table 2. *Access to electricity in selected Sub-Saharan African countries, % of population - Source: World Development Indicators*

Electricity access rates are not evenly distributed within the country. Table 3 shows the regional differences in electricity access. Specifically, in the Greater Accra region almost the whole population has access to electricity; while in the Norther, Upper west and Upper east regions barely half of the population is provided with electricity.

Regions	Population	Electricity Access	Households (HH)	HH with access	Pop with access
Greater Accra	4,010,054	97%	1,036,426	1,005,333	3,889,752
Ashanti	4,780,380	82%	1,126,216	923,497	3,919,911
Volta	2,118,252	65%	495,603	322,142	1,376,863
Brong-Ahafo	2,310,983	67%	490,519	328,648	1,548,358
Northern	2,479,461	50%	318,119	159,060	1,239,730
Upper East	1,046,545	44%	177,631	78,158	460,479
Upper West	702,110	40%	110,175	44,070	280,844
Eastern	2,633,154	70%	632,048	442,434	1,843,207
Western	2,376,021	68%	553,635	376,472	1,615,694
Central	2,201,863	81%	526,764	426,679	1,783,509

Table 3. *Access to electricity by region, % of population and households - Source: Kemausuor et al., 2011*

3.3.2 Modern Fuel and Cooking Technologies

The bulk of energy consumption is based on fuelwood, and 90% is obtained directly from natural forests (Quartey et al., 2014). The recent trend in consumption of wood fuels has been relatively stable from 2002 to 2010 as shown in Figure 10, however from 2011 the trend has reversed upwards, increasing from 19.9 million tonnes in 2010 to 31.9 million tonnes in 2012 (Ghana Energy Commision, 2015).

The demand for fuelwood is thus a major driver of forest degradation and the release of greenhouse gas (GHG) emissions as pointed out in Risoe (2013). Reducing the demand for fuelwood as a low carbon development (LCD) measure is, therefore, an important strategy to reduce drivers of deforestation and forest degradation to mitigate climate change, while generating financial flows from forest carbon activities under the Clean Development Mechanism, REDD+ (Reducing Emissions from Deforestation and Forest Degradation), and Nationally Appropriate Mitigation Activities (NAMAs).

As far as fuels for cooking are concerned, according to the DHS data, about 70% of the overall population rely on solid fuel for cooking[2], while only 24% declared to use LPG and 1.5% electricity. Once again, differences between rural and urban areas are remarkable. About 87.5% of the rural population use solid fuel for cooking, compared to 55% in urban areas. In rural areas, the most used fuels are wood (66% of the population) and charcoal (21%), while in urban areas charcoal prevails (42%), followed by LPG (37%). The progress with respect to the previous wave of data (2008) seems less sizable than for electricity access. Overall the population relying on solid fuel for cooking experiences a negative 20% growth rate (from 87 to 70%), with the sharpest decrease in urban areas from 75 to 56% (-26%), compared to rural areas (from 97 to 87%, -9%).

2 Solid fuels include coal/lignite, charcoal, wood/straw/shrubs/grass, agricultural crops, and animal dung.

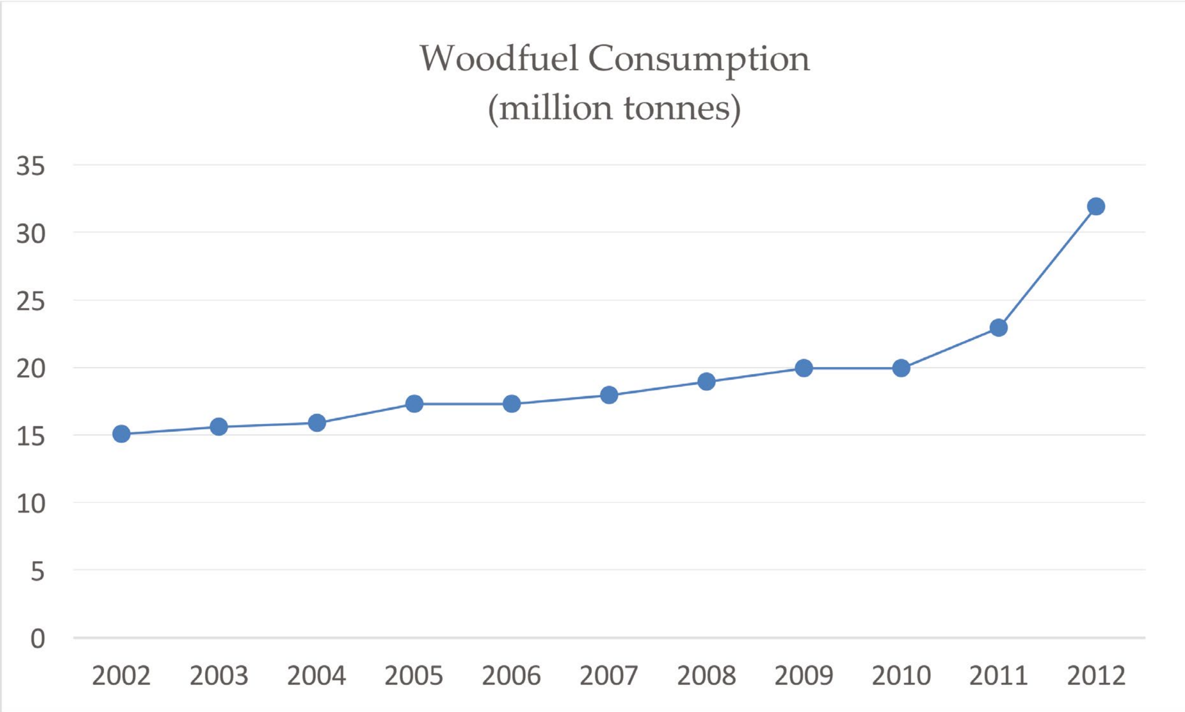


Figure 10. *Wood-fuel consumption in Ghana 2002-2012 - Source: Jooste et al., 2014*

Togobo (2006) shows that in 2005 less than 10% of Ghana's population has access to LPG as modern cooking system. In 2014 the percentage increased to 20%, with the highest penetration rate of LPG achieved in the region of Accra (30% of households use LPG as main source of cooking system). Nevertheless, discrepancy between rural and urban use of LPG remain, with 2% of the rural population using LPG and 17% of the total urban population having access to the improved cooking system. Overall, Ghana has a higher penetration of clean fuels and technologies for cooking than the average of Sub-Saharan countries. Moreover, during the last decade the pace of progress in Ghana (17.9% per year) appears faster than the rest of Sub-Saharan countries (1.3% per year) (Figure 11).

Mensah and Adu (2015) report results similar to the ones in the DHS, using another source of data, i.e. the fifth and sixth rounds of the Ghana Living Standards Survey (GLSS) conducted within 2005/06 and 2012/13 respectively by the Ghana Statistical Service. The authors report a significant change in the consumption patterns of fuels for cooking. In particular, they find that the use of solid fuels for cooking decreased from 89.2% to 76.4% between 2005 and 2013, while the use of modern fuels as cooking fuel increased from 10.8% to 23.6%. They also find that the use of inefficient fuels is negatively associated to standard of living. However, there is also evidence that even in relatively wealthier households, corresponding to the 4th and 5th wealth quintiles, the use of solid fuel is still predominant. The authors suggest two reasons for explaining such findings: first, the supply of LPG is often discontinuous and subject to recurrent shortages, therefore households tend to avoid switching exclusively to LPG. Second, the access to LPG supply is geographically concentrated in urban and peri-urban areas. This excludes wealthy households who could afford the purchase of LPG from its full adoption.

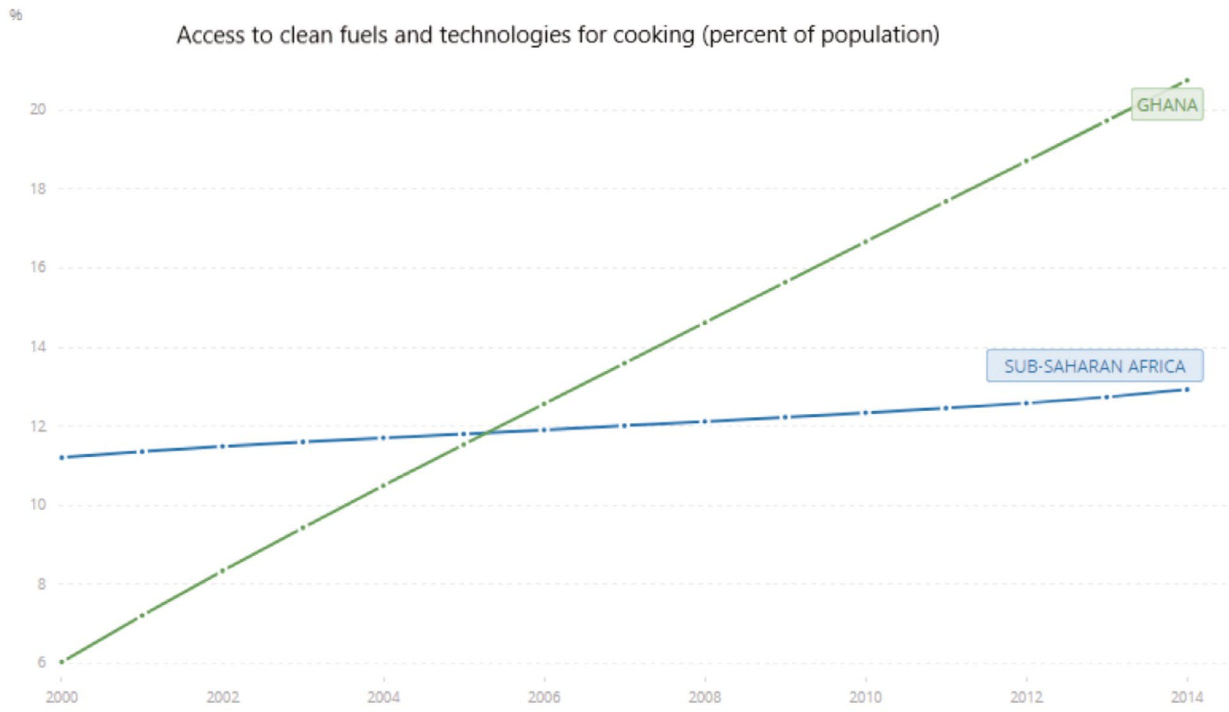


Figure 11. *Access to clean fuels and technologies for cooking in Ghana and Sub-Saharan Africa 2000-2014, share of total population - Source: World Development Indicators (WDI)*

In order to facilitate international comparison as well as to increase the ability to monitor progress in the transition towards the access to modern energy services and modern fuels and cooking stoves, the IEA proposed the Energy Development Index. It is a multi-dimensional indicators and tracks at household and community level. At household level, it tracks the levels of access to electricity and of use of clean cooking facilities. At community level, it measures the access to energy for public services (schools, hospitals, clinics, water and sanitation, street lighting, etc.) and for productive use (agriculture, manufacturing, industries and services). The World Energy Outlook Report 2012 shows the international ranking of developing countries and reports the values of the index for 2010 and 2002. One can notice that Ghana is the 50th country, out of 80 in the overall ranking, while it scores 4th out of 29 sub-Saharan African countries shown, after Botswana, Gabon and Senegal. However, the rate of change from 2002 to 2010 is amongst the highest overall.

04 Policies and Strategies to Increase Energy Access in Ghana

4.1 The Rise of Electrification in Ghana

The first intervention which initiated the electrification growth, was the creation of the Rural Electrification Project (REP) which took place in 1970. The principal goal of the REP was that to enhance the access to electricity of the rural population.

The Rural Electrification Project run until 1989 when it was replaced by the National Electrification Programme (NEP). The difference between REP and NEP stands on the main objective. Whereas REP focused on rural areas and on towns with population between 1000 and 5000 inhabitants, NEP main goal was to provide complete access to the whole country. In particular, areas with more than 500 residents were also targeted.

In 1989, when NEP replaced the REP the population having access to electricity was 28% of the total, in 25 years it grew until reaching 80%. The increase in electrification rate occurred both in rural areas when the residents having access to electricity increase from 5% in 1989 to 63% in 2014 and in urban areas where in 1989, 42% of residents had electricity; in 2014 the portion of residents having electricity reached 90% (WB, 2015).

Abavana (2012) shows that NEP initially focused on the provision of electricity to most urbanized areas, cultural and historical locations along with those with tourism potential. The distribution network was expanded through the integration of the public sector with the private one. The expansion of the high-voltage transmission grid in the period between 1990 and 2010 is depicted in figure 12. Aglina et al. (2016) show that the National Electrification Programme (NEP) had a cost of 2000 USD per household each year. Given the limited resources, NEP planned the expansion with revisions every five years.

Since NEP's target was not only urbanized regions, a secondary component of the latter was the Self-Help Electrification Project (SHEP), whose main interest was devoted to rural areas. The areas lying within 20km from 33kV or 11kV gridline were eligible to apply to grid extension, provision of extensions and all the necessary material for electrification. The SHEP project had three phases and by 2005 the project aided 3,026 towns and communities in their electrification efforts, with a cost of 130 million US. (Ghana Ministry of Energy, 2010). SHEP, therefore helped raising the rural access rate to 60.3% in 2014 (World Development Indicators).

In 2005, a second initiative took place, that was the creation of the Ghana Energy Development and Access Project (GEDAP). The aim of the project was to further increase energy access by extending the grid to urban and rural areas in a continuous matter with regard to hospitals, schools and other state-owned facilities. The project cost was of 210 million USD and was financed both from the collaboration of public and private sector and the multilateral loans obtained from the World Bank (Mahu and Essandah, 2011). The project also supplied over 130,000 households living in rural areas with solar PV home system and mini grid.

Figure 12. *High-voltage transmission grid expansion in Ghana, 1990-2010 - Source: Akpandjar and Kitchens (2017)*

In 2007 the Affordable Lightning for All (ALFA) project was launched. The ALFA project aimed to providing affordable lighting to people in un-served areas. Specifically, the projects incentivized the adoption of reliable and affordable solar lanterns by creating a supply chain model for the products. ALFA project was realized as a collaboration among the Dutch government, NGOs and Phillips Electronics.

Finally, the collaboration between the government of Norway and Ghana led to the creation of the ZEM Ghana isolated mini grid initiative. A top down approach which consist in giving a rural electrification operator the role of electrifying a territory and operating the system in the long run. The collaboration main target is the improvement in electrification in rural areas of Ghana and a more sustainable development of the targeted areas.

The main challenge in the path towards universal access to electricity in Ghana is represented by the population living in communities with less than 500 people which are not currently included in the eligibility criteria for grid expansion. Mensah et al. (2014) estimate that the number of people in such living in such small communities by 2020 could reach 3.2 million.

4.2 Policies for the Expansion of Modern Fuels and Technologies for Cooking

Since 1989 the Ghanaian Government committed on the promotion of LPG, particularly in urban areas for domestic and commercial heating and cooking. Recently, LPG has been largely employed in the industrial and transportation sectors. The

LPG promotion exercise has been conducted with two strategies. First, as Figure 14 shows, LPG subsidies increased to 88% of its retail price. However, since February 2013 the subsidies to LPG were substantially lowered. This increased the retail price of LPG by 60% (Ofori, 2015).

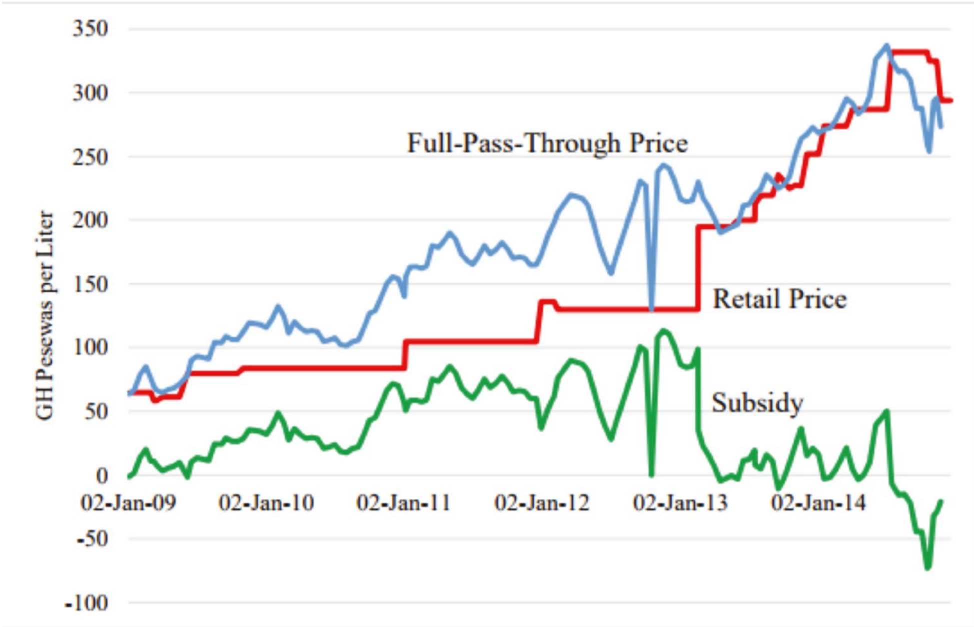


Figure 13. *LPG Prices and Subsidies in Ghana, 2009-2014 - Source: Ofori, 2015*

Cooke et al. (2014) show how fuel price subsidies have largely failed to meet distributional goals since they depend on the level of consumption. This allows high-income households to benefit more from fuel subsidies since their consumption of fuel is the highest among income groups. Table 4 shows the fuel price subsidies out the relative full-pass-through price across income quintiles.

Subsidies	**Income Quintile**				
	1	**2**	**3**	**4**	**5**
Gasoline	0.9	1.35	1.62	3.35	92.78
Diesel	0.12	0.63	1.45	1.33	96.46
LPG	0.16	0.69	2.17	11.43	85.55
Kerosene	10.69	13.88	18.06	20.96	36.42
Total	2.97	4.14	5.83	9.27	77.8
1 - Poorest, 5 - Richest.					

Table 4. *Distribution of Fuel Price Subsidies Across Income Groups in Ghana (%) - Source: Cooke et al (2014).*

This figure is similar to the average subsidization rate for LPG which in sub-Saharan is estimated to be around 40% (IEA, 2014). The second peculiar strategy is the model for the penetration in the retail market, based on the fact that consumers own their bottles and commute to purchase LPG from retail filling-stations. On the top of that, Ghana's Petroleum Minister recently launched a program to provide households with cooking gas connections. As of 2017, the program has distributed 70,000 LPG cylinders to families across six regions (GACC, website).

On the diffusion of improved cookstoves, the Government had an active role since the Ministry of Energy's Ahibenso coalpot program in the 1990s. The program was aimed at supporting the development of the cookstove sector, from production, to promotion and marketing. However, the program failed to create a self-sustained value chain, the production stopped with the depletion of the government funding and the impact of the initiative was relatively limited. In the early 2000s, new initiatives rose, driven by the international cooperation and the non-governmental sector. In particular, EnterpriseWorks/VITA, a division of Relief International (RI/EW), developed a sustainable production and supply chain for 'Gyapa' stoves (see Figure 14), a model of stoves which are more efficient that the traditional ones. Later, two companies were created: Toyola Energy and Man & Man Enterprise, with Toyola having about 2/3 and Man & Man with 1/3, respectively, of Relief International/EnterpriseWorks' production capacity. Since 2011-12 two other players entered the cookstove market: CookClean and CEESD/ Envirofit Project.

The cookstove sector can be now considered self-sustained as its value chain generates profits at each step (manufacturing, distribution and retail).

However, these improved stoves only account for about 5% of the total cookstove market and lead to relatively limited reductions in emissions (GACC, 2012). One of the major obstacles to sector development lays in the limited financing which would allow increasing producers' capacity. Although few carbon financing initiatives are currently in place, private capital appear extremely limited and expensive, with interest rates for commercial loans which may reach 30%.

Figure 14. *Gyapa stoves - Source: http://www.gyapa.com/products.html*

Since the launch of the of the Global Alliance for Clean Cookstoves (GACC), which calls for 100 million homes to adopt clean and efficient stoves and fuels by 2020 and aims to draw the international attention on this issue, the government partnered and contributed to create the Ghana Alliance for Clean Cookstoves (GHACCO). This allowed to improve the locally produced Gyapa-style cookstove through a variety of innovations to further increase efficiency and reduce emissions and contributed to the support of awareness and educational campaigns.

4.3 Policy Objectives and Strategies for the Future

Even before the launch of SE4All Initiative, the Government of Ghana committed to realize two important targets related to the path towards universal access to modern energy. First, the Government aimed at expanding access to LPG for 50% of the population by 2015. Now such objective has been delayed to 2020. Second, the Government targets universal access to electricity by 2020, by pursuing the NEP.

Specifically, in the context of the vision of the energy sector, the government outlined the following objectives:

1) **Enhancing the overall power supply shortage and ensure system stability**
   To improve the total power supply and reducing the power shortage in the country, substantial investments in Liquefied Natural Gas (LNP) are needed. In this regard, initial steps have already been made, such as issuing licenses to supply LNG thus its supply is expected to grow starting from 2018.

   More attention on the management of power supply by different sources is expected in order to ensure continuous power supply without interruption

2) **Plan grid expansion**
   In order to expand the transmission lines, the planned grid expansion programmes especially those connected with transmission upgrades, should be expedited and completed on schedule to facilitate the smooth and efficient evacuation of the available power.

3) **Achieving 50% nationwide penetration of LPG**
   National LPG penetration share increased from 6% in 2000 to 18% in 2010 and is currently around 23%. However, the expansion of LPG usage throughout the country is not smooth (e.g. from 2013 to 2014 LPG supply decreased by 4.1%, while increasing by 15,5% during the following year). Therefore, the target announced by the Ministry of Energy of achieving 50% of LPG penetration by 2020 is expected to be missed at this LPG penetration rate. To achieve the target envisioned by the Ministry of Energy, the measures to support and accelerate the supply and use of LPG can be synthesized as follows (Ghana Energy Outlook, 2016):
   (a) Deliberate government policy to make the LPG produced available for local consumption as against export;
   (b) Removal of price distortions
   (c) Re-capitalising Ghana Cylinder Manufacturing Company (GCMC) to expand production capacity with the production of cylinders focused on small sized cylinders that would be portable and affordable to households in rural communities.
   (d) Constructing LPG storage and supply infrastructure in all regional and district capitals in the long term.

In this light, the Ministry of Petroleum and the National Petroleum Authority need to consider investment incentives to encourage the Oil Marketing Companies and other interested investors to set up more LPG storage and distribution centers in order to increase access and consumption (Ghana Energy Outlook, 2016).

4) **Making energy affordable to achieve the universal energy access by 2020**
   In this regard Ghana's government needs to

attract investments from NGOs and private companies in order to enhance the existing network and make the latter more reliable both in the short and in the long run. Moreover, to achieve the universal electricity access by 2020, the government need to increase finances for rural electrification and assist the private organization in grid extension.

5) **Secure long-term fuel supplies for the thermal power plants**
In the light of the prevailing electricity supply deficit, the Government of Ghana, in 2015 started undersigning international thermal power contracts for more than 1,000 MW. This is comparable to twice the electricity generated by the Hydropower station of Akosombo. Out of the 1000 MW thermal power already signed, half have already been installed starting in 2016 while the remaining half is currently installed throughout the biennium 2017-2018.

6) **Diversify the national energy mix by promoting renewable energy sources nuclear and Coal**
In this regard Ghana's government has committed to increase the reliance of the country on renewable energies through issuing provisional licenses for wholesale power supply stemming from renewable energy resources. Specifically, during the 2016 the government issues 18 more provisional licenses to Independent Power Producers (IPPs) proposing to develop a total of about 5,547 MW of electricity from various renewable energy sources. Thus, bringing the total up to 82 in 2016 from 64 licenses issued the year earlier (Ghana Energy Commission, 2016). Specifically, 55 of the licenses issued are for solar photovoltaic (PV) generation with a total capacity of about 2,749 MW.

However, only one out of the five planned solar projects could be successfully completed. The latter is the photovoltaic grid inter-tied plant by BXC (a private company) which currently generates 20 MW. Whereas the sea wave energy plant in the Greater Accra Region which is supposed to generate 14 MW is currently under construction and is expected to be completed by 2017. Finally, three more renewable energy power plants have been granted construction permits and are expected to be built in the biennium 2017-2018. These last three power plants are supposed to generate a total of 475 MW from solar and wind energy.

Moreover in 2016, the Energy Commission with its mandate to ensure the development and utilization of the renewable resources has initiated the "Rooftop Solar Programme" (RSP). The objective of the RSP is to mitigate the recent power supply shutdowns which frequently occur in the country. As the Energy Commission envisages, the objective of the programme is to reduce the daily national peak load by 200 MW through self-generation using solar photovoltaic (PV) technology.

Table 5 summarizes the provisional licenses issued for Renewable Electricity in 2016.

Category	Number of Wholesale Electricity Supply Licences			Total Proposed Capacity (MW)
	Provisional Licences	Siting Permits	ConstructionPermits	
Solar	55	20	2	2,748.50
Wind	9	2	1	951
Hydro	5	-	-	208.62
Biomass	2	-	-	68
Waste-to Energy	10	2	1	570.81
Wave	1	1	1	100,076
Total	82	25	5	5,546.93

Table 5. *Provisional Licenses issued for Renewable Energy Electricity, 2016 - Source: Ghana Energy Outlook, 2016*

05 Challenges and Possible Solutions in the Expansion of Access to Modern Energy

Based on the review of international cases and economic literature, this section provides an ample discussion of the main challenges faced, at the global level, in the attempt to expand the access to modern energy. Possible solutions, lessons learned, and policy recommendation are also provided.

5.1 Electricity

- **Barriers to electricity connection**

Successful rural electrification programs have followed several models which can be considered context-specific, for example through the involvement of the private sector or electric cooperatives. However, some common features seemed to have guided successful programs in their deployment (Barnes, 2007). First is the introduction of efficient, effective and equitable subsidies. Second is the presence of an adequate and effective implementing agency, with a high-degree of operating autonomy (particularly from possible political pressure) and accountability in the targets to reach. Third is adequate expansion plans, which consider the actual needs and possibilities of communities, ensure financial viability and economic impact: premature rural electrification may miss the objective of contributing to sustainable community development, if other conditions enabling economic development are not present. Fourth, tariff policy is an important ingredient as it has to ensure financial sustainability and cost recovery on the one hand, and, on the other, it has to consider customers' realistic ability to pay. Finding financial solutions for lowering the connection charges is also a driver of higher connection rates.

However, reaching rural villages with electricity does not necessarily mean connections for all the households, as connection to the grid may be expensive. Lee et al. (2016a) make a distinction between “off-grid” households that are too far away to connect to the grid without major investment, and “under-grid” households that live close enough to the grid to be connected to a low-voltage line at a relatively low cost. They show that among the latter group, only 5 per cent of rural households and 22 per cent of rural businesses are actually connected, even five years after the infrastructure building and despite the relatively high population density of the study area (rural Kenya). Levels of connection remain low even for relatively well-off households and businesses. In other studies, and locations, households’ connection in newly on-grid locations varies considerably: 23 per cent in Indonesia (Chakravorty et al., 2016), 50 per cent in India (Burlig and Preonas, 2016), 70 per cent in Rwanda (Lenz et al., 2017).

The individual decision to connect seems to be linked to the price of the connection, which may range between US$50-250; despite subsidization, such fees may be prohibitive for most poor households. In fact, while less than 5 per cent of the poorest rural households in Ghana and South Africa were connected to electricity, those in the richest quintile were more than 20 per cent (Heltberg, 2003). Lee et al. (2016b) study the demand side of grid connection in Kenya and find that moving away from full subsidization of connection costs leads to lower take-up rates than expected, namely 57 and 29 per cent subsidies led to a 23 and 6 per cent take-up rate, respectively. By randomly allocating 10 and 20 per cent discount vouchers for connection fees to rural Ethiopian households, Bernard and Torero (2015) find that connections increase, on average, by 18 per cent, revealing that connection fees represent a significant barrier to the adoption of electricity. Low connection rates have also been linked to low levels of understanding of payment systems or limited knowledge of the potential advantages of electricity (Ranganathan, 1993). The presence of important economic barriers to connection and electricity use is also shown in Hanna and Oliva (2015), who find that an asset transfer program in India led to a significant increase in the use of electricity as the main source of light.

Another relevant channel in household decision-making towards electricity connection is others’ connection behaviour. Bernard and Torero (2015) find evidence of the bandwagon effect: connection to electricity carries a social status so that neighbors’ connection decisions have an impact (decreasing in distance) on household connection decision.

Other explanations for reduced demand for electricity connections include bureaucracy, low reliability of power supply and credit constraints (Lee et al., 2016b), however they have not been directly and rigorously tested and they therefore need to be further investigated. As in many other cases of technology adoption, households may underestimate the benefits of electrification, perhaps perceiving it as a luxury good, instead of a productive investment (Bernard, 2012). Related to lack of knowledge and misperceptions, Peters et al. (2009) suggest that poor households may be afraid of misunderstanding the billing system. It would be interesting to test such hypotheses against the evidence, by evaluating the cost-effectiveness of information campaigns following the electrification expansion.

Another relevant barrier to the electricity connection is represented by the relatively high end-user's tariffs, which in many parts of sub-Saharan Africa do not fully reflect the cost of electricity supply. Tariffs tend to incorporate not only the cost of generation, but also transmission and distribution losses, investment and retail costs. This may lead to $60-$100 per MWh increase in retail price. As figure 15 shows, prices differentiate depending on end-use sector. Such differentiation reaches the highest level in Ghana, where services and industries pay two to three times more than the average cost of generation, while the residential sector has tariffs much closer to the cost of generation. The electricity price must reflect different stakeholders' needs, which often pull into opposite directions. From one side, prices should guarantee full cost-recovery and provide sufficient incentives for the private sector to increase power generation and infrastructural investment. On the other side, access to electricity for the poorer should imply affordable tariffs.

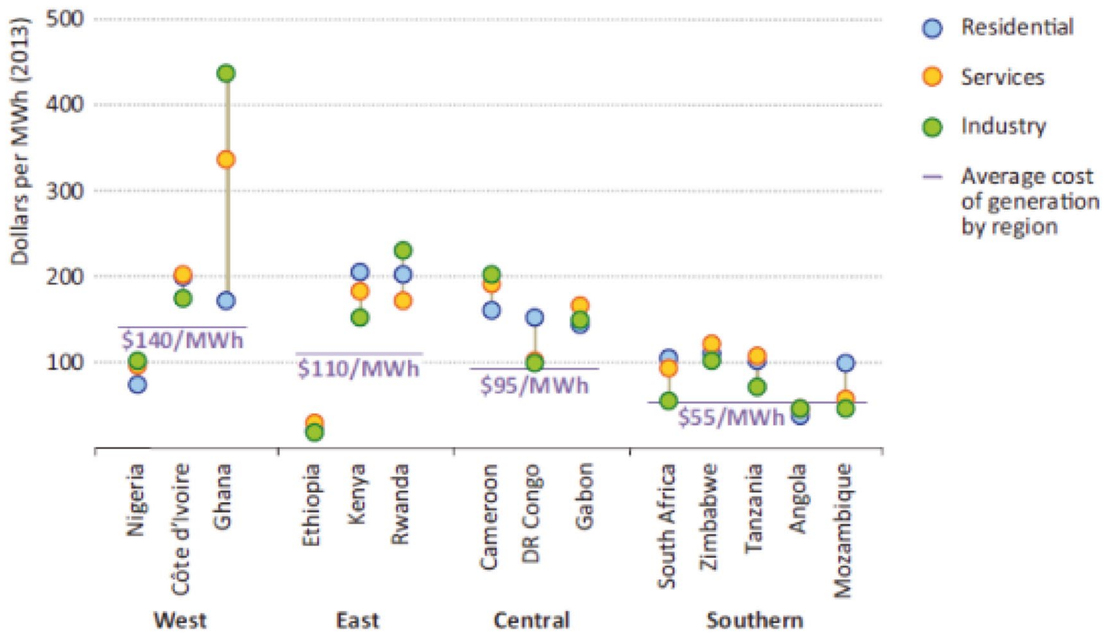


Figure 15. *Electricity prices by sector in selected African countries, 2013 - Source: IEA (2014)*

The effort to universal access should balance the necessary long-term sustainability of projects, which is essential in order to attract private investments, with the issue of access and affordability for the poorer. Affordability relates to the capability of households to be financially and economically capable of accessing and using electricity. The cost of the investment of individual households is related to the number of connections of geographically close households, pointing to the existence of positive externalities associated with new connections. This fact may justify mass connection campaigns at subsidized prices or stimulate the creation of innovative schemes aimed at overcoming the collective action problem, for example through group-based subsidies linked to the number of applicants (Lee et al., 2016b). Progressive tariffs, lifeline tariffs (households consuming below a certain amount per month receive a subsidy), and innovative financing solutions for connection fees, for example through microcredit or mobile payments, are among the possible tools governments can use to support access to and use of electricity by rural and poor households (Winkler et al., 2011). Such solutions need to be developed, designed to local context and eventually tested against evidence.

- **Quality of supply and cost-recovery**

Access to electricity has risen dramatically in many developing countries, yet the provision of reliable electricity remains a challenge for policy makers and energy providers. Simultaneously, demand for electricity has gone up rapidly and is projected to continue rising, due to growth in household incomes, urbanization, and adoption of modern appliances. Many developing countries, including Ghana, subsidize electricity for residential and agricultural consumers (Vagliasindi, 2012). However, in spite of subsidized tariffs, repayment rates are very low and electricity transmission and distribution losses reach levels ranging from 10 to 25% of output in different countries (Figure 16).

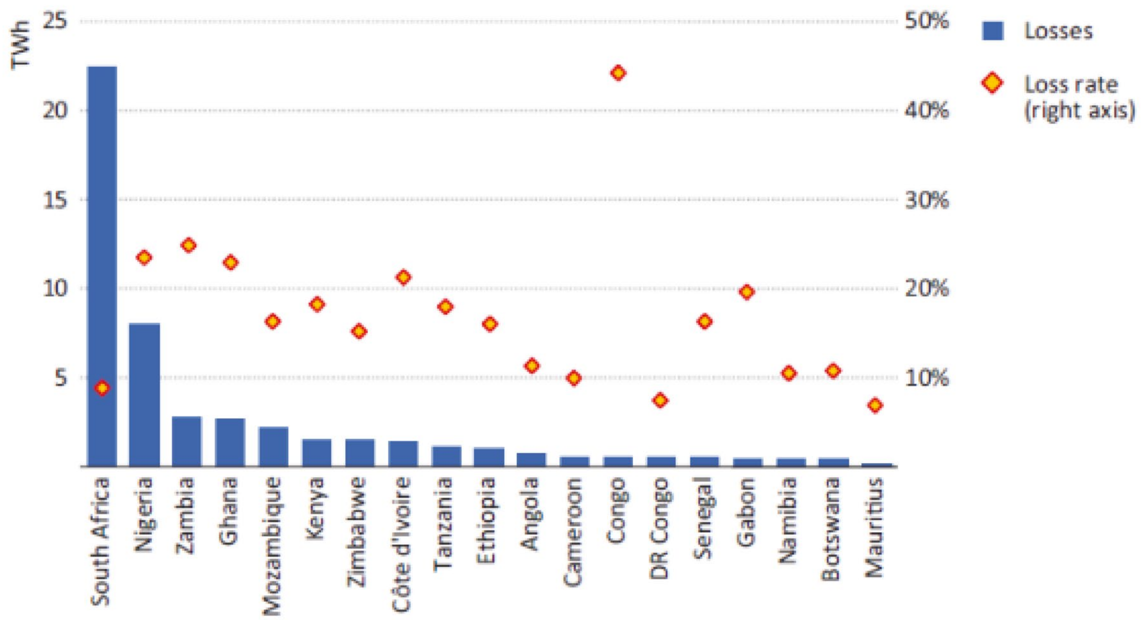


Figure 16. *Transmission and distribution losses and losses rates (as share of output) - Source: IEA (2014)*

Several factors contribute to that, namely electricity theft, billing irregularities and technical losses. The difficulty to collect unpaid bills has been cited as a major obstacle to improving electricity provision in India (Ahluwalia, 2002), Colombia (McRae, 2015) and South Africa (Szabò and Uhjelyi, 2015). Distribution losses are currently estimated to range from 17% to 21.7% for different Ghanaian distribution companies (Ebenezer, 2017). Table 6 reports distributions losses for the distributors ECG and NEDCo, which, in the period between 2010 and 2014, range between 20 and 25%. Such numbers appear way above the losses of typical electric company in developed countries, where they range from 5 to 8%. In that regard, the Government of Ghana committed to reduce transmission losses to 18% by 2018 (IEA, 2014).

Company		Year				
		2010	2011	2012	2013	2014
ECG	Total Purchases (GWh)	6,771	7,259	7,944	8,479	8,370
	Total Sales (GWh)	4,952	5,339	6,041	6,476	6,246
	Distribution Losses (GWh)	1,819	1,920	1,903	2,003	2,124
	Percentage Losses	26.9	26	24	23.6	25
NEDCo	Total Purchases (GWh)	635	719	822	937	998
	Total Sales (GWh)	473	581	658	737	758
	Distribution Losses (GWh)	162	138	164	200	239
	Percentage Losses	25.5	19.2	20	21.3	24

Table 6. *Main indicators for distribution companies in Ghana, 2010-2014 - Source: Ghana Energy Commision, 2015*

With repayment rates too low to recover the costs of generation and distribution, there is insufficient investment in new capacity and maintenance of existing infrastructure and electricity providers often have to resort to outages or rolling blackouts to manage the gap between supply and demand. A vicious cycle perpetuates if poor energy supply influences individuals' willingness to pay, actual payments of bills or theft. The situation is worsened by three further elements: low levels of income for large share of the population, the relatively high-end users' electricity tariffs and the large diffusion of inefficient electric appliances which lead to high electric consumption, even amongst the most disadvantaged population. The combination of these elements may generate situations where the share of electricity bills reaches disproportionately high levels of income. This makes illegal ways of getting electricity an attractive solution for meeting energy needs. The unfortunate reality is that, in many cases, electricity theft and non-payment can be both common and acceptable, cementing themselves as the norm. It is in these cases that it becomes important to understand the nature of these social norms and how they can be shifted.

Poor electricity infrastructures are considered among the most relevant barriers to economic growth, particularly for the development of industrial activities which heavily rely on the quality supply of electricity. The lack of quality and reliable electric infrastructures lead firms to self-generate energy, often with consequent higher costs. This is the case for several developing countries, particularly in Africa (Alby et al. 2011; Foster and Briceño-Garmendia, 2010). Rud (2012) studies the effects of the impact of the expansion of access to electricity on industrial growth in India and finds positive impacts on production levels and number of industrial activities, at regional level. An increase in the number of small manufactory activities as a consequence of electrification is also documented in Benin, though no effects on profits are found (Peters et al. 2011). Low quality electricity infrastructures, reflected by frequent shortages, have negative effects on revenues and productivity, due to higher energy costs. The effect is stronger for small firms, which are less likely to own generators to cope with shortages (Alcott et al. 2016, on Indian data). Losses in productivity due to unreliable electricity supply for industrial firms are also observed in

China (Fisher-Vanden et al. 2015). Unreliable and inadequate electric power supply also contributes to the reduction of investments in productive capacity by firms (Reinikka and Svensson, 2002 on a survey of Ugandan firms). Ryan (2013) finds that investments for the expansion of electric transmission infrastructures allowing for more capacity and eventually improving the quality of electricity supply would lead to large welfare gains, due to higher competition on the market.

Given the strict link between cost-recovery and quality of supply, the reduction of non-technical losses is considered a priority for the electricity sector operators. Commercial losses in distribution are mainly caused by three factors. The first is related to electricity theft through illegal connections to the grid. The second concerns people who are legally connected, but somehow are billed less than what they are actually consuming, for instance through meter tempering or incorrect meter reading. The third relates to quality of payments: people are billed correctly but the flow of payment is somehow irregular or below the expectations. Four main approaches can be used to address the issue of commercial losses: increasing willingness to pay for energy; making non-payment of energy costlier; making payment easier; and reducing bribes.

Several interventions and strategies in other countries and sectors, for example tax evasion, can provide useful suggestions to target the issue of improving bill repayment systems, dissuade electricity theft and making legal connection affordable and payment easy. For instance, the literature on tax evasion shows how quality of public service provision and trust in institutions can be related to higher rates of tax payment (Daude et al., 2012; Torgler and Schneider, 2009). Low willingness to pay, leading to low quality repayment, may also be caused by low levels of knowledge of the billing system, tariffs or effective consumption, and lack of trust in the provider. Education campaigns seem to succeed in curbing non-payment for public utilities, serving as a nudge to households (Szabò and Uhjelyi, 2015). Improvements in monitoring and sanctioning systems, and changes in the social and moral environment may all determine variations in the benefits and costs of non-payment. Again, the literature on tax evasion and corruption provides useful lessons on the effect of these costs. Increases in the tax rate are found to lead to increases in tax evasion (Fisman and Wei, 2004). Evidence suggests that threat letters making the risk of detection more salient are effective in curbing tax evasion (Slemrod et al., 2001; Fellner et al., 2013; Castro and Scartascini, 2015). Such letters seem to be even more effective when they are delivered in person (Doerrenberg and Schmitz, 2015). Besides monetary costs, the moral and social costs of evasion are also likely to be relevant, as demonstrated by the effectiveness of interventions including moral appeals or information on others' behavior into tax compliance appeals (Bott et al., 2014; Hallsworth et al., 2017). Similarly, appeals including religious quotes on the immorality of not-repaying one's debts have been found to significantly increase loan repayment in Indonesia (Bursztyn et al., 2015).

In the energy sector, social norms have been found to be effective in reducing energy consumption in developed countries (Allcott, 2011). This is one example of a wider strand of the literature studying the effect of behaviorally-informed interventions in energy policy, particularly in the field of energy efficiency and conservation (Alcott and Mullainathan, 2012; Ferraro and Price, 2013).

The combination of relatively high connection costs and tariffs on the one side, and of liquidity constraints and low-income levels of a large share of the population on the other side, discourages people from getting a legal connection and paying regularly, particularly in the presence of cheaper outside options. In South Africa a technological solution to illegal connections and the non-payment problem among low-income households has been the introduction of pre-paid electricity meters. These systems allow for small, frequent transactions which are compatible with liquidity constraints and difficulty smoothing income (Jack and Smith, 2015).

Finally, losses can be contrasted through supply side measures, addressing the incentives and constraints of those in charge of monitoring energy use and payment.

A growing literature shows how changing the incentive structure of public officials or tax collectors significantly affects tax evasion (Khan et al., 2015 for Pakistan). Changes in the structure and accountability system of public offices are also found to have large effects on losses from bribery and corruption. Making corruption more visible to, and thus possible to monitor by the public is also found to be effective in reducing leakage of public funds (Reinnika and Svensson, 2004). Increasing top-down monitoring and probability of being sanctioned is also found to reduce corruption in local spending, more than community monitoring (Olken, 2007).

- **The role of renewable energy**

To meet its energy vision (i.e. to provide the complete energy access to all households by 2020), Ghanaian government acknowledges the need to diversify the national energy mix by considering renewable energy resources such as solar, wind and hydro. In particular, it is considered as essential the promotion of renewable energy by bringing the share of renewables to 10% of the total national energy mix by 2020 (Atsu et al., 2016) however, renewables accounted for barely 1% of total energy mix in 2015.

Therefore, to realize the energy vision of Ghana, Ghana Energy Commission, 2016 reckons solar energy as a key energy sources for long-term development and reliability of power supply in the future, particularly for rural populations. To this extent the Strategic National Energy Plan (SNEP) was created in 2006 whose objective is that to promote and incentivize the development of renewable energy resources with particular regard to solar energy.

More recently, in November 2011, the Parliament of Ghana to further show its commitment in enhancing the development of renewable energy in the country, approved the renewable energy act (REA) with the mandate to regulate and license all activities in the Renewable Energy sub-sector. REA also created an environment capable to attract investment into the renewable energy sector by incentivizing businesses, households and communities to adopt renewable energy technologies and increase their use in their energy mix.

- **A. Solar PV**

Ghana sits itself between 15° and 35° North and South parallels, which is the portion of the globe with greatest solar radiations (Codjoe, 2004). Moreover, the average duration of sunshine varies from a minimum of 5.3 h per day in the cloudy semi-deciduous forest region to 7.7 h per day in the dry savannah regions. Thus, making Ghana a particularly suitable country for solar energy.

Ghanaian suitable position has incentivized external funding and donations, specifically in solar PV projects starting in the 1990s and increasing thereafter.

Atsu et al. (2016) show that since 2009, a total of 9536 solar systems have been installed in remote off-grid communities in over 70 districts nationwide. The installation of solar systems in rural areas has received investment in the form of donations from the World Bank, the Spanish government and the Japan International Cooperation Agency.

Two projects fostering the development of solar PV are still ongoing, which are respectively:

a) e-CARE project (standing for E-commerce and Renewable Energy Project) which started in 2003. Its objective is to accelerate access to Renewable Energy-enabled ICT services in rural and peri-urban communities in Ghana. The project is funded jointly by UN Development Program (UNDP), the UN Environment Program (UNEP), Kumasi Institute of Technology and Environment (KITE) and the German Technical Cooperation (GTZ).

b) Elecnor Foundation of Spain, which started in 2011 with financial support from Spanish Ministry of energy. Its goal is to provide solar back-up systems to various facilities around the country.

- **B. Micro-grids**

Micro-grids have been widely adopted by high income economies during their transition economic process. However only recently they have been considered as an instrument for developing countries to meet their targets of global energy access. Micro-grids are therefore expected to play a crucial role in order to invert the growing trend of household without access to modern form of energy, therefore meeting the goal of universal energy access by 2030.

IEA (2013) reckons that micro-grids are a least-cost and timely option for more than 120,000 villages and towns in Sub-Saharan Africa.

As previously shown Ghana has been remarkably successful in providing electricity access in urban areas (90.8% in 2014) and rural (63% in 2014). Thus, proving the government's commitment. However, the challenge remains in bringing electricity to the communities living on islands in Lake Volta and in isolated lakeside locations.

It has been estimated that about two million people live in isolated areas where grid is unlikely to reach within next 10 years due to difficulties associated with the extension of conventional grid electricity. Reaching those two million people living in four island communities situated in Lake Volta poses today the most difficult task for Ghana's government. To this extend the World Bank funded the Ghana Energy Development and Access project (GEDAP) whose objective is to explore the option of micro-grids to allow the isolated communities in Lake Volta the access to energy.

An alternative to allow those remote populations to access to electricity is constituted by off-grid technologies. Off grid systems might serve as a solution for isolated communities who will never receive a central grid for a reliable power supply. Therefore, in order to deal with the expanding demand of electricity (due to the population growth) it is crucial to have an efficient combination of grid extension and off-grid systems. The government should regulate in order to guarantee both the extension of micro-grid and off-grid systems. Moreover, the government should also intervene in order to preserve interests of investors in micro-grid system when the rural areas have access to the central grid. When micro-grids powered by renewable energies are constructed in off-grid areas, the necessary investments are considerable and should also consider the uncertainty that the grid will come at some point, possibly before the break-even. This from one side may discourage investments in such solution, while on the other side could crowd-out mini-grid providers, when the main grid comes. A regulation that explicitly takes into account the integration between the micro-grids to the central grid is essential.

5.2 Modern Fuels and Technologies for Cooking

In general, the policies implemented at the national level which aim to improve cooking strategies and to avoid health problems related to high exposure to indoor air pollution (IAP) have followed three main strategies. The first tried to promote cleaner fuel adoption by replacing biomass with kerosene and liquefied petroleum gas (LPG). This has been the case for Ecuador and Indonesia, where poor households could benefit from subsidized kerosene for cooking (Barnes and Halpern, 2000). However, drawbacks emerged such as the high cost of kerosene and LPG together with difficulties in supplying them in remote areas, given poor infrastructure. More recently, a second practice has seemed to prevail: the development and promotion of ICS which use wood and biomass in a more efficient way while reducing exposure to air pollutants through the introduction of a chimney. The important pros of the substitution of cookstoves rely on the fact that the technology is relatively easy to up-scale using local materials and producers (which may lead to job creation in the area and use of local materials), prices are affordable even for poor households and the final product is similar to traditional cookstoves, allowing the reduction of the cultural "gap" arising from the introduction of a new technology. A third option is the introduction of small scale bio-digesters for the production of biogas at the community and household level, though a wide diffusion of such technologies has been slow in several developing countries.

Key features of successful programs include both supply- and demand-side aspects combined with the development of enabling institutional and market environments. From the supply-side, product design aspects such as the compatibility with household needs, housing, cultural and environmental conditions have shown crucial factors for large-scale product take-up (Lewis and Pattanayak, 2012). Quality and durability of cookstoves are critical conditions to realize sustained improvements in efficiency and/or IAP reduction. From the demand side, efforts in filling households' information gaps about the advantages of ICS take-up through information campaigns and social marketing as well as innovative financial solutions to overcome credit constraints are key drivers of success. Enabling institutional and market conditions at the local level include the involvement of local institutions, the development of the supply chain for production and after sale services, and the use of robust independent monitoring and evaluation tools. A useful illustration of the drivers of success and failure of large-scale national programs for ICS adoption is represented by the Chinese National Improved Stove Program (Smith et al., 1993; Sinton et al., 2004) and the National Program on Improved Chulhas in India (Venkataraman et al., 2010), respectively.

- **Challenges to LPG diffusion**

The model implemented by the Government in order to increase the penetration of LPG in the population and meet the objectives, faces major challenges.

First, the evidence suggests that LPG subsidies have been successful in promoting energy transition, hence should be sustained. However, policy-maker should find solution to avoid dispersion of public resources which would reach unintended target s. This is the case for commercial services, like drivers, who make use of subsidized LPG for their business activities Biscoff et al. (2012).

Second, on the distribution side, access to LPG implies people owning an empty cylinder to a fuel depot, itself requiring a private car or taxi, with a nontrivial risk that the depot will not have replacement fuel when they arrive there. From an analysis conducted by Karimu et al. (2016), it turns out that the presence of filling station in the country is insufficient to meet the increasing needs and are very unevenly distributed across the country (see figure 17), with particular shortage in the Northern regions, where the density of stations is one over 400,000 people, whereas in Greater Accra one finds one LPG station every 50,000 inhabitants.

Third, the crucial role played by LPG shortage in impeding the complete switching to modern cooking fuels requires that constraints to supply of LPG need to be urgently addressed, by adequately increasing the investment in the distribution infrastructure.

Possible solutions may imply to change the distribution mode implying centralized filling depots and bottles owned by the companies and re-circulated. Moreover, the LPG subsidy should be better targeted for the domestic usage, for example by supporting the end-use equipment for cooking.

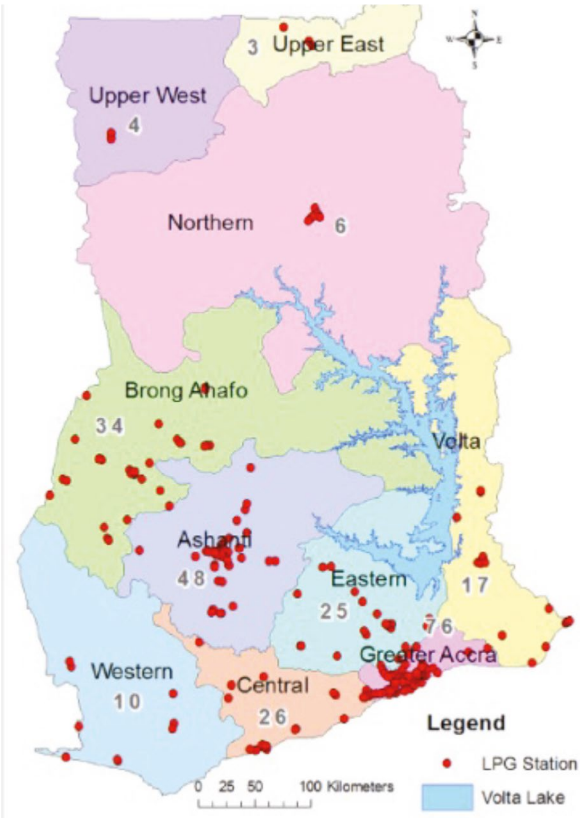


Figure 17. *LPG stations in Ghana - Source: Karimu et al. (2016)*

- **Barriers to the adoption of modern cook stoves**

Some recent works have tried to investigate the role of the barriers which prevent adoption, daily use and maintenance of ICS, through regression analysis of the drivers of demand. The main drivers associated with ICS adoption are related to socio-economic status: income, education and urban location are positively associated, whereas socially marginalized status is negatively related to purchase and use. Price of firewood also seems to be a key factor. In some contexts, existing models of ICS do not seem to respond to local needs and preferences (Lewis and Pattanayak, 2012).

In the particular context of Ghana, Mensah and Adu (2015) and Karimu et al. (2016) show that factors such as price, income, household level of education, household size, urban location and higher wealth indicators are relevant factors which are associated with household fuel decision, particularly in the adoption of LPG.

There are very few studies that assess the role of barriers to adoption of improved cookstoves (ICS) which are methodologically rigorous in the causal attribution exercise. Several of them confirm the crucial role played by prices and liquidity constraints in the decisions to buy, use and maintain ICS (Miller and Mobarak, 2013, 2014; Alem et al., 2014; Jeuland et al., 2014; Hanna et al., 2016); even despite relatively high subsidies, the percentage of uptake decisions remains relatively low (Mobarak et al., 2012).

Differences in preferences across households but also within households seem to explain differential ICS take-up rates. Miller and Mobarak (2013) find that propensity to adopt ICS differs for women and men: women have a stronger preference towards the new technology but lack sufficient authority and bargaining power within the household to impose their decision on men. Heterogeneity in user preferences for different stove features is an important predictor of take-up (Jeuland et al., 2014).

Others' decision to adopt ICS also seems to influence individual decision to adopt. For example, Miller and Mobarak (2014) highlight the role of opinion leaders and social networks in conveying information on the attributes of the new technology and decisions to adopt. Social influence and imitation through social network are also found to be an important driver for ICS take-up in Bonan et al. (2017), while Beltramo et al. (2015b) find no evidence of neighbors' adoption rates on individual decision to purchase. Social marketing and communication strategies can play an important role in favoring health preventive behavior and products (Evans et al., 2014). Investigating ICS adoption through social marketing lenses is the focus of a recent strand of research (Lewis et al., 2015). Levine et al. (2016) find that an offer combining a free trial period, time payments and the right to return the stove significantly increases the purchase of the product, compared to a traditional cash-and-carry offer. In a related study, Beltramo et al. (2015a) find that marketing messages conveying the benefits of ICS had no effect on willingness to pay (WTP).

Although ICS take-up is seen as a fundamental first step in climbing the energy ladder and fighting energy poverty, there are two conditions which make it possible, after take-up has occurred. The first is the quality, effectiveness and suitability of ICS: the product has to be durable and it has to fit customers' needs and preferences beyond their "improved" attributes. The second condition is the sustained use and maintenance of the product. ICS adoption cannot be intended as simple take-up, but has to be considered as a dynamic process involving the stacking of new and old fuels and stoves (Ruiz-Mercado et al., 2011). An example in which the two conditions are not met is given by Hanna et al. (2016) where stove breakages combined with insufficient investments in maintenance, inappropriate cleaning and use impeded sustained usage over time and eventually did not lead to the expected impacts.

Learning the drivers of adoption and diffusion and continuous use is of great relevance in order to strengthen evidence-based actions and policies. Further research should focus on the roles of household level decision-making, gender, cultural traits, liquidity and credit constraints, but also on behavioural factors to guide marketing interventions, through the involvement of local institutions and social networks (Foell et al., 2011). Testing different social marketing features would make it possible to shed more light on the role of information and preferences, whose impact on take-up is still under-researched.

Positive externalities in ICS adoption justify the introduction of subsidies or other ways to overcome households' liquidity constraints and relatively low WTP for ICS. However, such positive externalities occur only if households consistently use and maintain the products. This requires the introduction of innovative monitoring strategies which do not interfere with households' behaviour (Hawthorne effect) but which can provide a systematic and objective measure of their use. The introduction of sensors and IT-based stove use monitors can represent a scalable and cost-effective solution (Harrell et al., 2016).

The introduction of demand-side interventions, as proposed above, is likely to be effective only in the presence of a stable and accessible supply of ICS. Strengthening the supply chain appears to be an important prerequisite for the success of any attempt to diffuse ICS in developing countries (Lewis et al., 2015). More effort in the development of strategies and policies for the improvement of the supply chain is needed, perhaps involving local institutions (Pattanayak and Pfaff, 2009). More rigorous research on the supply side and on its causal role in enhancing the diffusion of ICS is required, although the attribution of causal impacts is far more difficult in such a context.

Given the important private and public benefits they can generate, innovative interventions should focus on financing mechanisms, coupled with demand-side considerations on household economic and behavioural constraints in climbing the energy ladder. This may imply the introduction of marketing interventions and post-sale services in order to maximize take-up and sustained usage over time. Once again, drawing on local social dynamics may support the diffusion process.

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