December 2017

FONDAZIONE ENI ENRICO MATTEI

Report

Ghanaian Energy Markets and the Role of Natural Gas for Local Development

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Abstract

The Ghanaian economy is one of the most successful of Sub-Saharan Africa. Over the last two decades it has undergone a process of structural change with shifts from agricultural activities to services. This report presents the most recent figures on Ghanaian energy markets with a focus on the role that natural gas could play for the development of the power sector and the national economy. The use of national gas instead of imported light crude oil in thermal generation would increase the reliability of electricity supply, which has long been considered one of the main obstacles to economic growth. The power sector is not the only sector in which natural gas could play a pivotal role. The financial resources dedicated to imported oil could be directed towards investments in generation capacity, while the emission profile of the country would also stand to gain.

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Executive Summary

Ghana is one of the most successful economies of Sub-Saharan Africa, with an average GDP and GDP per capita growth rate of more than 6.7% and 4.2% respectively between 2006 and 2016. The Ghanaian economy has also been undergoing a process of structural change over the last two decades with substantial shifts from agricultural activities to service

Electricity demand has been growing at an average yearly rate of 5.4% between 2006 and 2015, while over the same period electricity supply grew only of 4.1%. Energy crisis have become a recurrent feature of the Ghanaian economy, costing around 2% of GDP.

Electricity still represents a small share of final energy consumption, although there has been a relevant shift from biomasses to petroleum products. The industrial sector is main consumer of electricity, followed by the residential sector, with the ten biggest load centres in the country accounting for more than 70% of electricity consumption.

Hydropower still represents the main generation technology in the country but its relevance has been decreasing over the last ten years, with natural gas generation becoming ever more relevant. This is shift is strongly connected to the discovery of domestic oil and gas resources in 2007.

With almost 60 bcm of endowment in its three main fields, natural gas holds a great potential for the development of the Ghanaian economy. The most immediate benefit would accrue to the power sector, which has long been suffering from the unavailability of Nigerian gas for which contracts have been in place since 2009. Solving the power crisis has long been a priority in the country and domestic gas will undoubtedly play a central role.

The power sector is not the only sector in which natural gas could play a pivotal role. Netback analyses carried out over the last few years show that both the construction sector (cement) and the transport sector (as substitute to gasoline and diesel) are potentially relevant consumers of natural gas, with a promising outlook also present in industrial heating application. Other sectors which might contribute to gas demand are also fertilizing and aluminium and steel smelting.

General Facts and Figures

GDP: $42.689,78 million, 7th in Sub-Saharan Africa (World Bank, World Development Indicators).
GDP per capita: $1.513,5 , 12th in Sub-Saharan Africa (World Bank, World Development Indicators).
Population: 28.206.73, 10th in Sub-Saharan Africa (World Bank, World Development Indicators)
Electrification rate: 72%, 3rd in Sub-Saharan Africa (World Energy Outlook 2016)
Main economic activities: Mining, lumbering, light manufacturing, aluminium smelting, food processing, cement, small commercial ship, building, petroleum (CIA World Factbook)

GDP by sector	
Agriculture, Forestry, Fishing and hunting	20,0%
of which fishing	*1,1%*
Mining and quarrying	4,6%
Manufacturing	4,4%
Electricity, gas and water	1,5%
Construction	15,1%
Wholesale and retail trade; Repair and Vehicles; Household goods; Restaurant and hotels	13,7%
of wich Restaurant and hotels	*6,7%*
Transport, Storage and communication	16,8%
Finance, real estate and business services	9,3%
Public administartion and defence	5,3%
Other services	9,3%

Source: African Economic Outlook 2017

01 Introduction

Ghana has been rightfully described as one of the most successful economies of Sub-Saharan Africa for almost a decade. Boosting an average GDP and GDP per capita growth rate of more than 6.7% and 4.2% respectively between 2006 and 2016, the Ghanaian economy has also been undergoing a process of structural change over the last two decades. In 1996 the shares of agriculture, industry and services value added in GDP were respectively 43.88%, 26.56% and 29.56%; twenty years after (2016) the same shares are respectively 19.6%, 28.16% and 52.24% (see Fig.1, World Bank). One of the consequences of these sustained growth rates and of the relevant shift from agriculture to services and (to a lesser extent) industry is that electricity demand has also been growing at an average yearly rate of 5.4% between 2006 and 2015. On the other hand, electricity supply has been growing only at a yearly average of 4.1% (Energy Commission of Ghana 2016a).

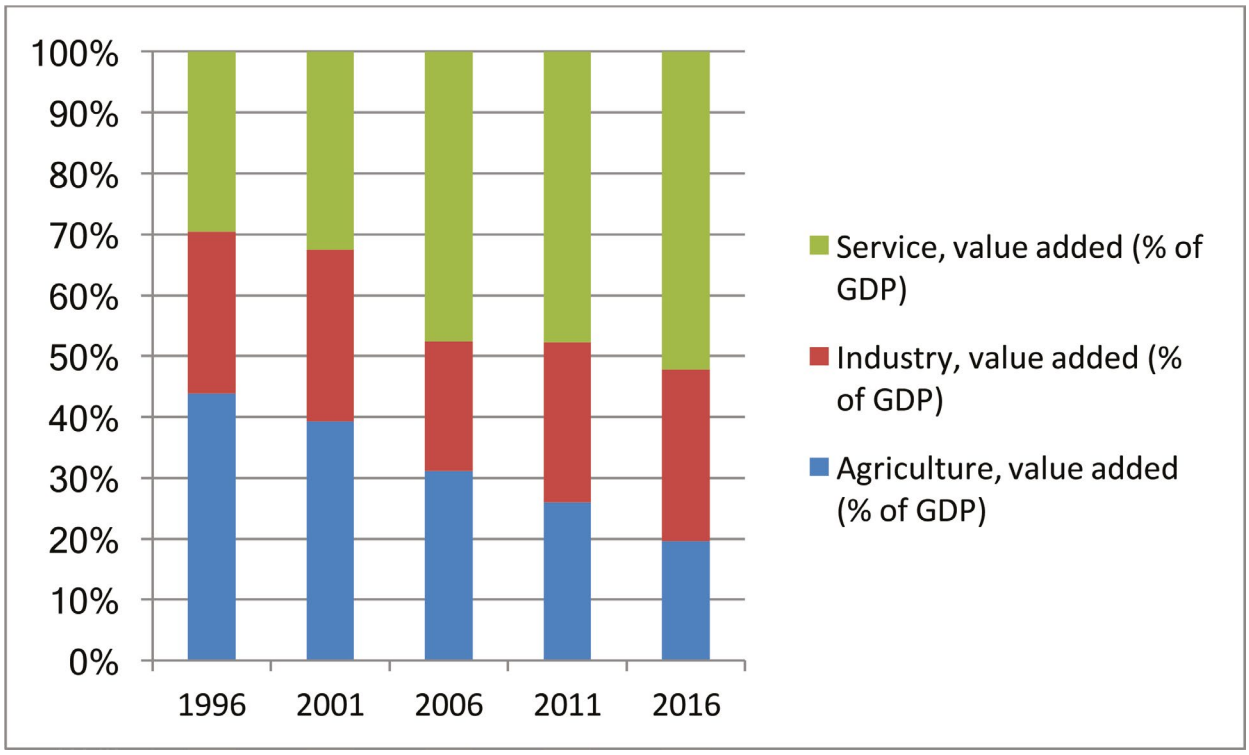

Figure 1. *Value added of agriculture, industry and services as % of GDP - Source: World Bank Development Indicators.*

These differences between the last two figures already give a first approximation of why electricity crises have become a recurrent feature of life in Ghana in the last decade. The cost of these crises has been estimated to range between 2 and 6% of GDP in 2010 (PSEC-GRIDCo 2010), while more recent estimates put the figure at more than $800 million per year which again translate to around 2% of GDP (ISSER 2015). Although an insufficient pace of investment in new generation capacity is surely one of the main reasons for the current state of affairs, at least two others have to be quoted. Firstly, the water levels at the Akosombo Hydro Plant, the biggest power plant of the country, have been decreasing from 2011 onwards; secondly, the supply of natural gas from the Western African Gas Pipeline, vital to power the almost 1800 MW of gas fired power plants, has never met the contractual amount since the pipeline became operational in 2009.

Indeed the status of the electricity supply was one of the main determinants of the election loss of John Mahama, who was nicknamed "Mr. Dumsor" ("Mr Power cut"), to Nana Akufo-Addo in last year's election. The promise to use domestic gas production to solve the power crisis and to spread more widely throughout the economy the gains accrued through oil and gas production was pivotal in attracting votes to the New Patriotic Party, and Ghanaians are now waiting for the president to deliver on his promises. It is with this background in mind that we proceed to the analysis of the current situation in the Ghanaian energy markets. The remainder of the report is organised as follows: section 2 describes the current trends in the Ghanaian markets; section 3 covers the institutional setting and the most recent policies with particular focus on those connected to the petroleum sector; section 4 analyses how the development of the gas sector can impact the electricity markets and the wider economy while section 5 concludes.

02 Current trends in the Ghanaian energy markets

As explained in the introduction, the sustained development of the Ghanaian economy, combined with a process of structural transformation that has seen a decreasing contribution of agriculture to total output, has had a relevant impact on electricity demand.

Adding to a higher demand from richer households and growing firms, population and urbanisation trends have also played a role in increasing the electricity output required by the economy.

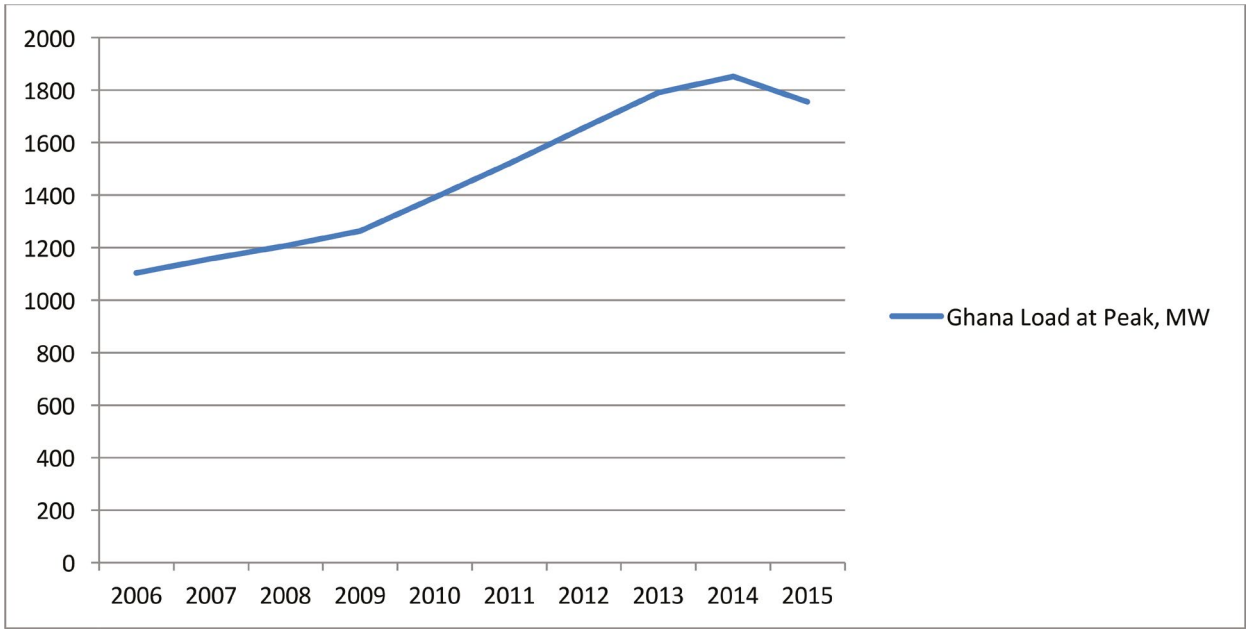

Figure 2. *Ghana load at peak (MW), 2006-2015 - Source: Energy Commission of Ghana 2016a.*

It must though also be noted that the growth in electricity demand has not led to a relevant change in the share of electricity in final energy consumption: it was 12% in 2006, 10.8% in 2010 and 11.6% in 2015. Under this point of view, the most relevant change has been the growth in the share of petroleum products, which overtook biomasses as the main source of consumed energy in 2009 (see Fig.3). The decreased importance of biomasses can also be seen in their 11% drop in the share of primary energy supply (Fig.4), which is coherent with the shift to more modern energy sources which normally accompanies a process of structural transformation. This can especially be seen in increased reliance of the urban residential sector on petroleum products, especially LPG, for cooking needs, with the cost and unreliability of the electricity supply over the last period disincentivising the switch to electric cookers (Mensah et al. 2016).

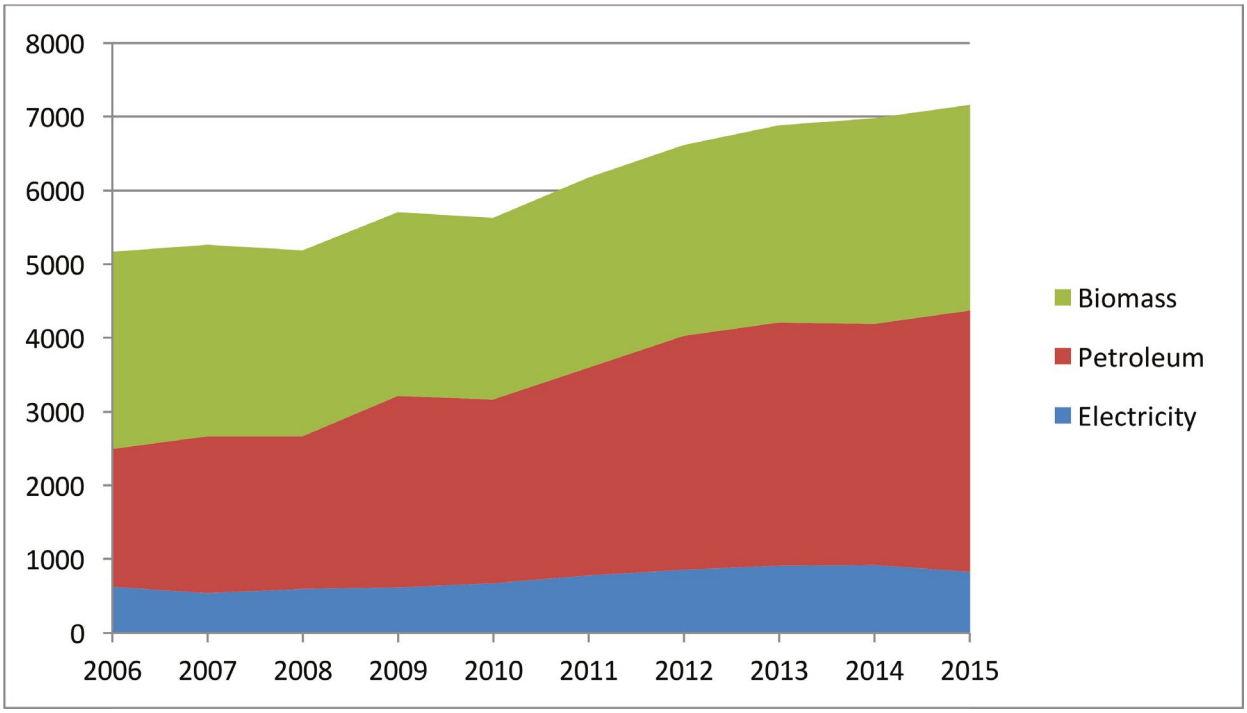

Figure 3. *Ghana final energy consumption (ktoe), 2006-2015 - Source: Energy Commission of Ghana 2016a.*

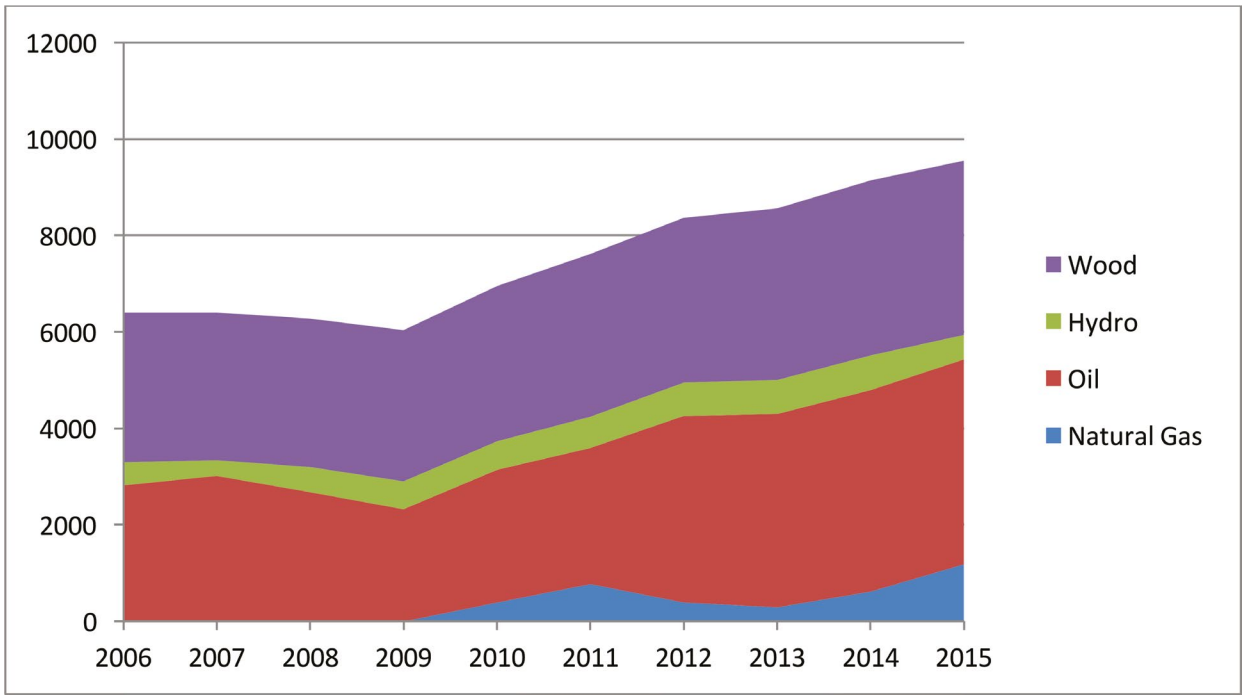

Figure 4. *Ghana Primary Energy Supply (ktoe), 2006-2015 - Source: Energy Commission of Ghana 2016a.*

A recent study from Mensah et al. (2016) analyses in some depth the drivers for the demand of different energy sources in Ghana, considering factors such as their prices, the changing structure of the economy, urbanisation trends and income divergences amongst different regions. Their results strongly point towards the relevance of urbanisation rate and economic growth for most energy sources (and especially electricity), while are also showing a high degree of inter-fuel substitutability amongst most households. The latter is particularly strong from gasoline, diesel and kerosene towards LPG, with strong consequences on the type of policies which can increase the adoption of LPG amongst households. This has long been an objective for policy makers in order to decrease the rate of deforestation and the incidence of pulmonary diseases, and it is the reason behind a substantial subsidisation of the fuel. However, it is becoming clearer and clearer that a sizeable proportion of the consumers of the subsidised product are vehicle operators and not household. and although there is an interest in developing a gas-based transport system this is not the priority given the current gas availability (see also Biscoff et al. 2012).

The shares of electricity consumption by customers class has also remained fairly stable over the period 2006-2015 (see Fig.5), with industry being the main consumer (accounting on average for 48.4%) followed by the residential sector (accounting on average for 32.8%). Although the figures start to be fairly outdated, the "Ghana Wholesale Power Reliability Assessment 2010" (PSEC-GRIDCo 2010) shows how the ten biggest load centres in the country (see Fig.6) accounted for more than 70% of total electricity consumption in 2009. These centres are either big urban areas (such as Accra, Tamale and Kumasi, which account together for 49% of national peak demand) or sites of heavy industries, with the four biggest mines in the country accounting for 12.5% of peak demand (see Tab.1).

It must also be noted that although Ghana as of 2016 has the third highest electrification rate in Sub-Saharan Africa (72%, World Energy Outlook 2016), there are still at least 8 million people without any access to electricity. The objective stated in the National Electrification Scheme of 1989 is to complete the electrification of the country by 2020, however there has been a significant slowdown in the expansion of access since the 2000s. This is due to both a growing gap between available electricity supply and already existing demand and to the remoteness and lack of political and economic relevance of the communities yet to be reached by the grid (Fristch and Poudineh 2015).

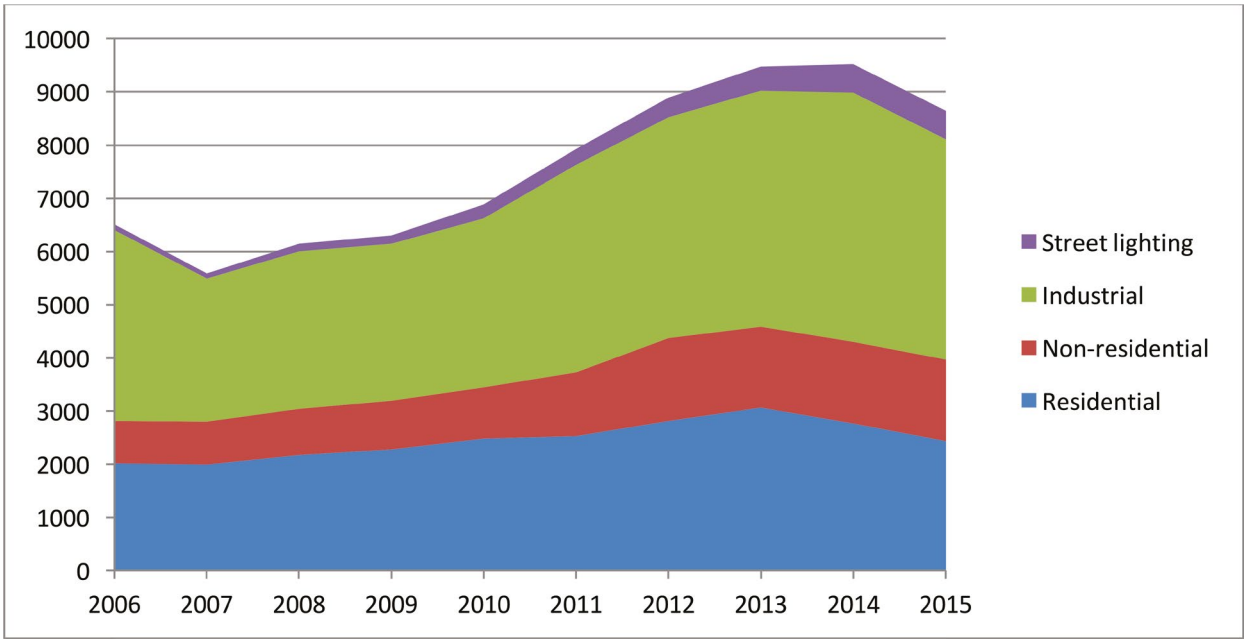

Figure 5. *Electricity consumption by customer class (GWh), 2006-2015 - Source: Energy Commission of Ghana 2016a.*

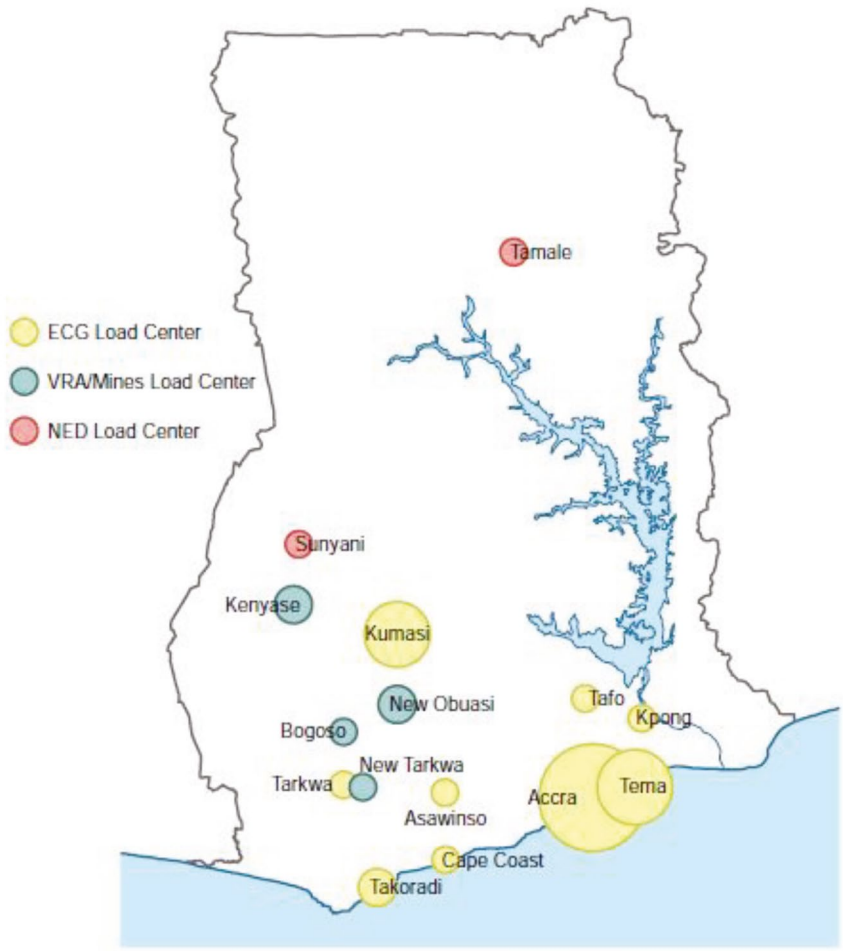

Figure 6. *Peak demand of major load centres by service provider, 2009 - Source: PSEC-GRIDCo 2010*

Rank	Load Centre	Bulk Power Service Provider	Peak Load (MW)	Energy (GWh)
1	Accra (Achimota+Mallarm)	ECG	380,2	2896
2	Tema	ECG	183	1215,9
3	Kumasi	ECG	154,4	1051,4
4	New Tarkwa (G.G.L.))	VRA/MINES	56,8	308,3
5	New Obusai (A.G.C.)	VRA/MINES	53	458
6	Takoradi	ECG	44,7	343,9
7	Tarkwa	ECG	37,7	350,3
8	Sunyani	NED	30,5	226,3
9	Kenyase (Newmont)	VRA/MINES	30,2	251,9
10	Asawinso	ECG	29,8	171,7
Total % Of 2009 System Peak Load or Energy			1000,3 70,30%	7273,5 71,90%

Table 1. *Peak demand of major load centres by service provider, 2009 - Source: PSEC-GRIDCo 2010*

With regards to electricity supply, the installed capacity has grown from 1730 MW in 2006 to 3656 MW in 2016, with an average yearly growth of 9.13%. As of August 2017, the installed capacity has reached 4223 MW, of which though only 3842 MW are considered as dependable. The majority of this capacity is managed by the Volta River Authority (2288 MW), although the capacity managed by IPPs, standing at 1935 MW, has almost reached that of the public utility. With regards to generation technology, the relative majority of installed capacity, both total and dependable, relies on hydropower (37.4% and 35.9% respectively), followed by gas generation (13.5% and 14.5%). However, if we also consider gas turbines able to run on other fuels (either light crude oil or heavy fuel oil), the order is inverted, with "gas plus other fuels" representing 45.4% of installed capacity and 46.7% of dependable capacity (see Tab.2). Regardless, electricity generated from hydropower plants still prevails over that generated from thermal power plants, with the first accounting for 50.8% of total generation in 2015 and the second for 49.1% (with the remainder coming from renewable sources). However, it must be noted that the share of hydro generation has decreased from an average of 68% in the period 2006-2010 to an average of 62.8% in the period 2011-2015, with a concurrent increase in the share of thermal generation from 32% to 37.1% in the same period (see Fig.7).

Plant	Installed Capacity (MW)	Dependable Capacity (MW)	Fuel Type
Volta River Authority			
Akosombo Hydro Plant	1020	900	Hydro
Kpong Hydro Plant	160	140	Hydro
TAPCO - T1	330	300	LCO/Gas
TICO - T2	330	320	LCO/Gas
Mines Reserve Plant (MRP)	80	70	Gas
Tema Thermal 1 Plant (TT1P)	110	100	Gas/LCO
Tema Thermal 2 Plant (TT2P)	49.5	45	Gas
Tema Thermal 2 Plant Expansion (TT2PP-X)	38	32	Gas
Kpone Thermal Power Plant (KTPP)	220	200	Gas/DFO
VRA Navrongo Solar Plant	2.5	-	Solar
IPPs			
Bui Hydro Plant	400	340	Hydro
Kar Power Barge 1	235	225	HFO
Sunon Asogli Phase 1	200	180	Gas
Sunon Asogli Phase 2 Stage 1	180	160	LCO/Gas
Sunon Asogli Phase 2 Stage 2	180	160	Gas/LCO
CENIT Power Plant	110	100	LCO
Ameri Power Plant	250	230	Gas
BXC Solar	20	-	Solar
AKSA	360	340	HFO
Total Capacity	4223	3842	

Table 2. *Total and dependable installed capacity as of August 2017 - Source: Volta River Authority.*

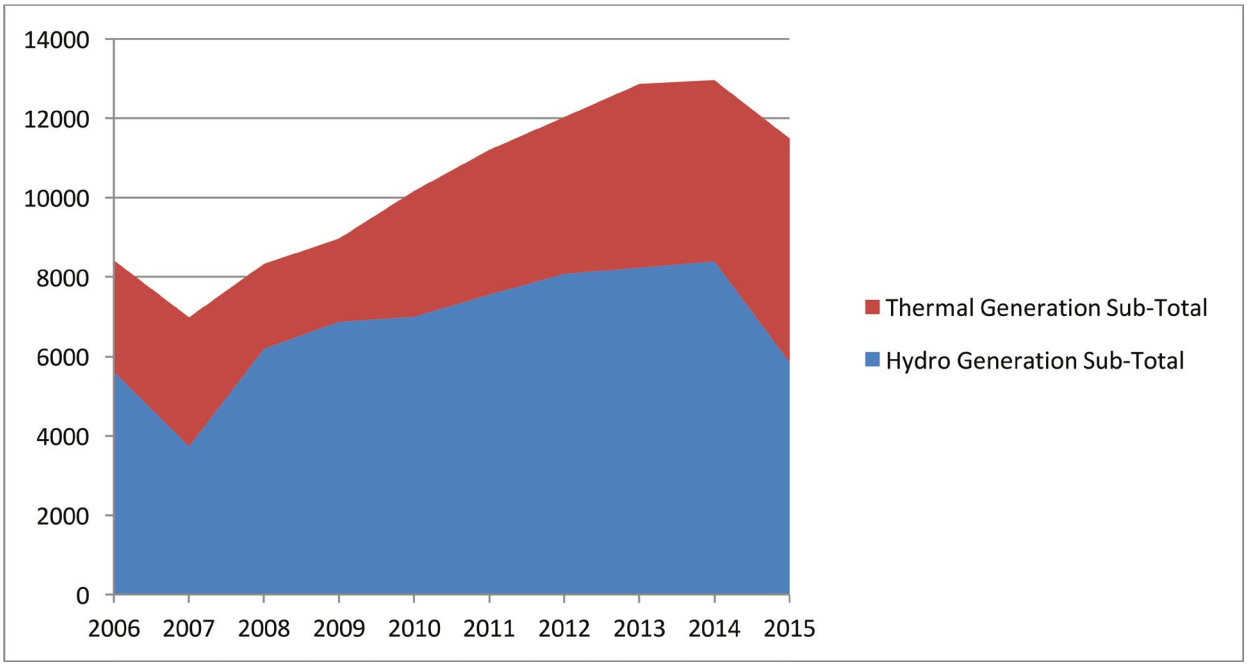

Figure 7. *Hydro and thermal generation (GWh), 2006-2015 - Source: Energy Commission of Ghana 2016a.*

The discovery of the Jubilee field in 2007, which entered the production stage in 2010, represented a significant boost to the Ghanaian oil and gas sector. In the previous decade oil production was taking place only in the recently rehabilitated Saltpond Field near Takoradi: its peak production of 213,730 barrels in 2008 was less than a fifth of the output of the Jubilee field in its first year of operation (1,27 million barrels). Since then, production from the Jubilee field has increased substantially, reaching almost 39 million barrels in 2015 (see Fig.8). Tullow Oil, the operator of the Jubilee field, has also been responsible for the development of the offshore Tweneboa, Enyenra, Ntomme (TEN) fields, which entered production in August 2016 and which might achieve a production of 80,000 barrels per day once the resolution of a border dispute with Cote d'Ivoire will allow Ghana to develop new productive wells (see Fig.9). The Tema Oil Refinery, with nameplate capacity of 45,000 barrels per day, is the only refining plant of the country and has been running below capacity for years due to a series of problems connected to old equipment.

Ghana also possesses relevant gas resources in the form of associated gas in both the Jubilee and the TEN fields and in the form of non-associated gas in the Offshore Cape Three Point, including both the Sankofa and the Gye Nyame fields. While gas production in the Jubilee Fields started in 2015, the production of gas from TEN field is expected to start in the summer of 2017 and production from Sankofa is expected in 2018 (see Section 4 for a more in depth discussion of the role of natural gas in the Ghanaian economy).

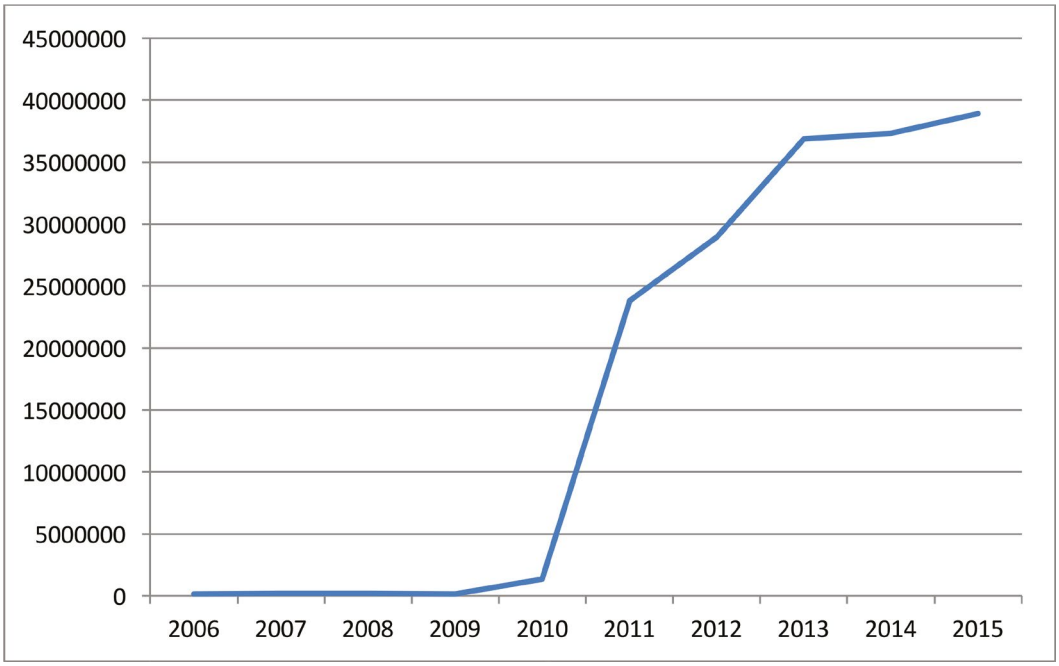

Figure 8. *Ghana oil production (barrels), 2006-2015 - Source: Energy Commission of Ghana 2016a.*

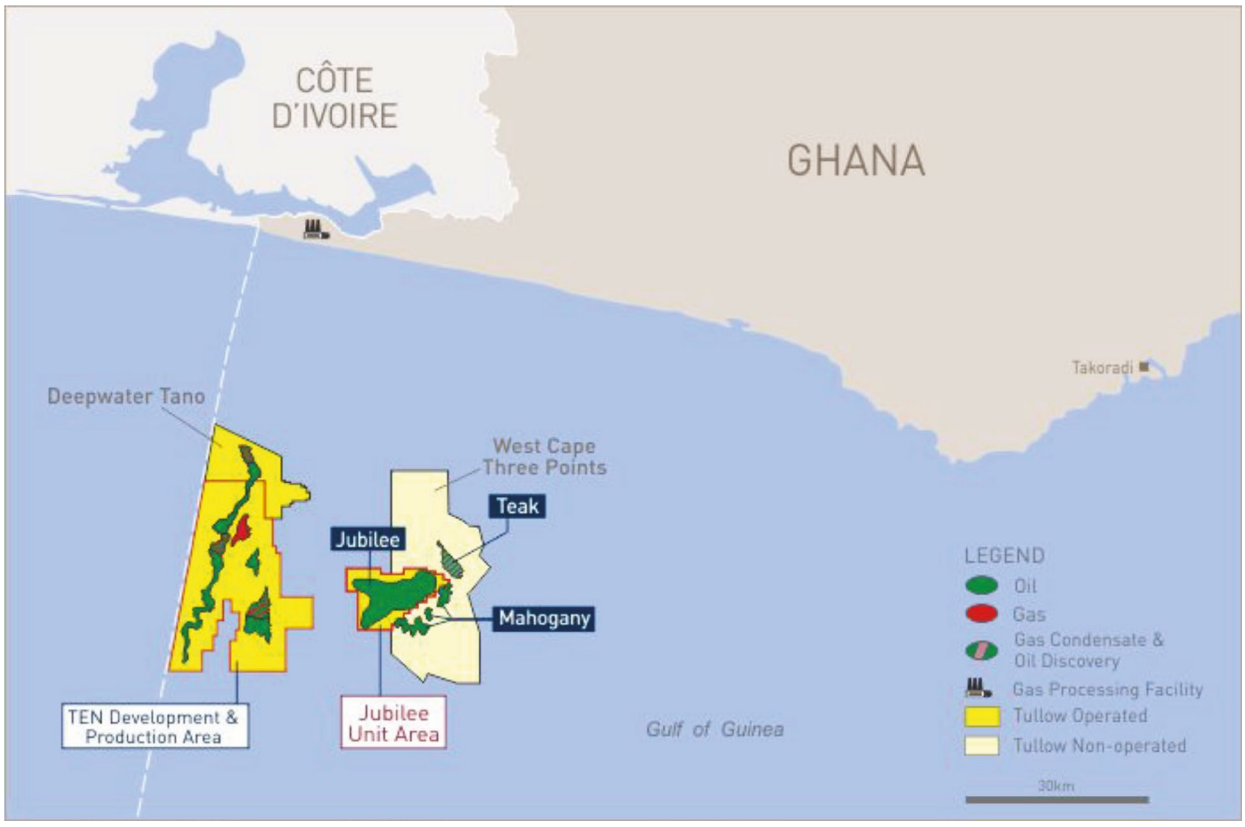

Figure 9. *Ghana oil field location - Source: Tullow Oil*

03 Institutional setting and policies

3.1 Most relevant institutions.

Volta River Authority (VRA): set up in 1961, is the dominant actor in electricity generation owning and operating 54.2% of the installed capacity in the country, amongst which the Akosombo and Kpong hydropower stations and the Takoradi thermal power plant. The company is further a minority stakeholder in the Takoradi International Power Company.

Bui Power Authority: established in 2007 to follow first the construction and the operation of the Bui hydropower plant, second power plant of the country by dimension after the Akosombo. The power plant was inaugurated in December 2013, and although it was initially thought of as a peaking power plant it is increasingly working as a base load plant.

Electricity Company of Ghana (ECG) and Northern Electricity Distribution Company (NEDCo): these are the two distribution companies in the country, the ECG serving customers in the southern regions while the NEDCo serves customers of the northern ones (see Fig.10). Both are suffering from significant distribution losses due to poor infrastructure maintenance and shortage of skills in the labour force.

Figure 10. *ECG (yellow) and NEDCo (red) distribution areas - Source: PSEC-GRIDCo 2010*

Ghana Grid Company (GRIDCO): is the owner and operator of the national transmission system. It is also mandated to follow the interconnection of the Ghanaian national grid with the regional transmission system currently developed within the framework of the Western Africa Power Pool.

Ghana National Gas Corporation (GNGC): created in 2010, it was originally responsible for the processing, the transmission and the commercialisation of all natural gas. In 2011 it launched the Western Corridor Infrastructure Project to bring gas from the Jubilee fields to the plant in Aboadze thermal power plant, with the China Development Bank as main financer.

However, shortly afterwards the Energy Commission of Ghana awarded the exclusive right for gas transportation to the Bulk Oil Supply and Transport Company (BOST, fully owned by the Ghanaian government), which is also responsible for operating and maintaining the pipeline, so that only the pipeline ownership has remained with GNGC.

Ghana National Petroleum Corporation (GNPC): funded in 1983 to support the government objective of reducing the country's dependence on oil import, the corporation is partner in all the country's petroleum agreements. The Government of Ghana has also individuated the GNPC as sole counterparty in all gas purchases agreements with IOCs despite initially giving the mandate to the GNGC.

Public Utility Regulatory Commission (PURC) and Energy Commission of Ghana: the two main regulators of the energy sector in Ghana, the first is an independent regulator tasked to supervise the provision of all public utilities, hence overseeing VRA, ECG, NEDCo and GRIDCO. The Energy Commission of Ghana has instead a more specific mandate to regulate the use of energy resources, especially granting licenses for transmission, distribution, wholesale supply and sale of both natural gas and electricity.

Western Africa Gas Pipeline Company Ltd. (WAPCo): headquartered in Accra, WAPCo is the owner and operator of the Western Africa Gas Pipeline (WAGP) which delivers gas from Nigeria to Benin, Togo and Ghana. The company is a joint venture amongst Chevron West African Gas Pipeline Ltd. (36.9%), Nigerian National Petroleum Corporation (24.9%), Shell Overseas Holding Ltd. (17.9%), Volta River Authority (16.3%), Societe Togolaise de gaz (2%) and Societe BenGaz S.A. (2%).

3.2 Most recent policies.

Energy Sector Strategy and Development Plan 2010: sets out the main objective for the energy sector, amongst which: achieving 50% of thermal gas based generation by 2015; prohibiting flaring and venting to maximise gas utilisation; discouraging re-injection when not needed for operational benefit; developing viable petrochemical industry; intensifying exploration, development production and utilisation effort and the Ghanaian participation in all these sectors; increasing LPG consumption in the residential sector to 50% by 2015 in the residential sector through investment in LPG infrastructure and pricing incentives, targeting especially rural and deprived areas.

LPG promotion strategy 2011: only an advisory paper, contains further elaboration of the recommendation included in the previous policy. Specifically, the paper suggests: to substantially reduce the cross subsidisation of LPG from petrol and diesel consumption as the uptake already took off; to increase the LPG supply and delivery infrastructure, so to increase competition, reduce prices and avoid re-switching back to fuel, possibly considering tax incentives for investment in LPG filling station in particular areas; to limit the use of LPG in the transport sector to vehicles with an LPG tank installation certificate.

Natural Gas Pricing Policy 2012: which had the overall objective of achieving import parity pricing for gas in order to accumulate substantial revenue in the Gas Rent Fund, to be used to resolve the investment deficit in the power sector and eventually the subsidisation of the fertiliser industry and other strategic sectors. The principal characteristics of the policy are: fixing a purchase price for associated gas of no more than $1 per MMBtu plus the "aggregation tariff" and for non-associated gas of no more than the weighted average import price, anyhow assuring that the price covers the cost of production and reasonable return on investment; fixing a sale price equal to no less than the import price to all users, with customers free to negotiate prices with the aggregator above this level and with a bi-annual review of contracts in order to account for inflation and fluctuation in the exchange rate; it establishes a Gas Rent Fund derived from sales revenue through which subsidies will be directed to strategic sectors, with a small percentage of rent possibly used to extend gas infrastructure to communities for which there are no market incentives to do, while all rents accruing from sales to the power sector must be allocated to investments in the electricity sector.

Energy Sector Levies Act 2015: implemented in December of that year to face the debt incurred by power suppliers and by the Tema Oil Refinery, the act places levies on petrol, diesel and other fuels to be collected in an Energy Debt Service Account. The funds so collected will be used to service the debts incurred by the VRA and the Tema Oil Refinery as a result of non-payment from power suppliers and cost of development of infrastructure in support of power generation.

04 The gas sector and its potential for Ghana's development

With 13,9 bcm of associated gas in the Jubilee field (17,3 bcm if one considers the greater Jubilee), 10,3 bcm in the TEN fields and 31,4 bcm of non-associated gas in the Sankofa field, the gas sector holds a great potential for the development of the Ghanaian economy. The Gas Master Plan (GMP, Ministry of Petroleum of Ghana 2015), developed by the Ministry of Petroleum at the end of 2015, individuates in the lack of investment capacity of the VRA, ECG and NEDCo the main constraining factors for gas demand in the country, while also recognising that the pricing policy for natural gas agreed in 2012 needs to be updated and more fully implemented. This section presents the current status of the gas sector in Ghana and what are deemed to be the most promising ways to foster its development and its

contribution to the overall economy. Apart from the GMP itself, this section particularly relies on two recent studies: “Advisory Paper – Ghana Sector Master Plan” (Nexant 2010), “Energizing Economic Growth in Ghana: Making the Power and Petroleum Sectors Rise to the Challenge” (World Bank 2013).

4.1 Gas consuming sectors

The first sector which stands to gain from a successful development of the country’s gas resources is the power sector. Ghana has historically been reliant on hydroelectricity generation from the Akosombo Dam, but a series of years with lower than average rainfall in the second half of the 2000s (see Fig.11) combined with growing electricity demand made clear that more investments in thermal generation were needed. In fact, investments in thermal generation had already started in the late 1990s, with more than 1 GW of capacity installed between 1998 and 2013. While much of this thermal capacity was thought to be fired with gas, especially after the commercial discovery of the Jubilee fields in 2007, this fuel still plays a limited role in generation for two main reasons: first, there have been a series of issues with the delivery of Nigerian gas through the WAGP, which has never once reached the contractually agreed amount of 1.24 bcm per year (120 MMcfd, see Fig.12), secondly, while oil production from the Jubilee field started in 2010, production of the associated gas did not start until mid-2015, with the delay proving quite costly.

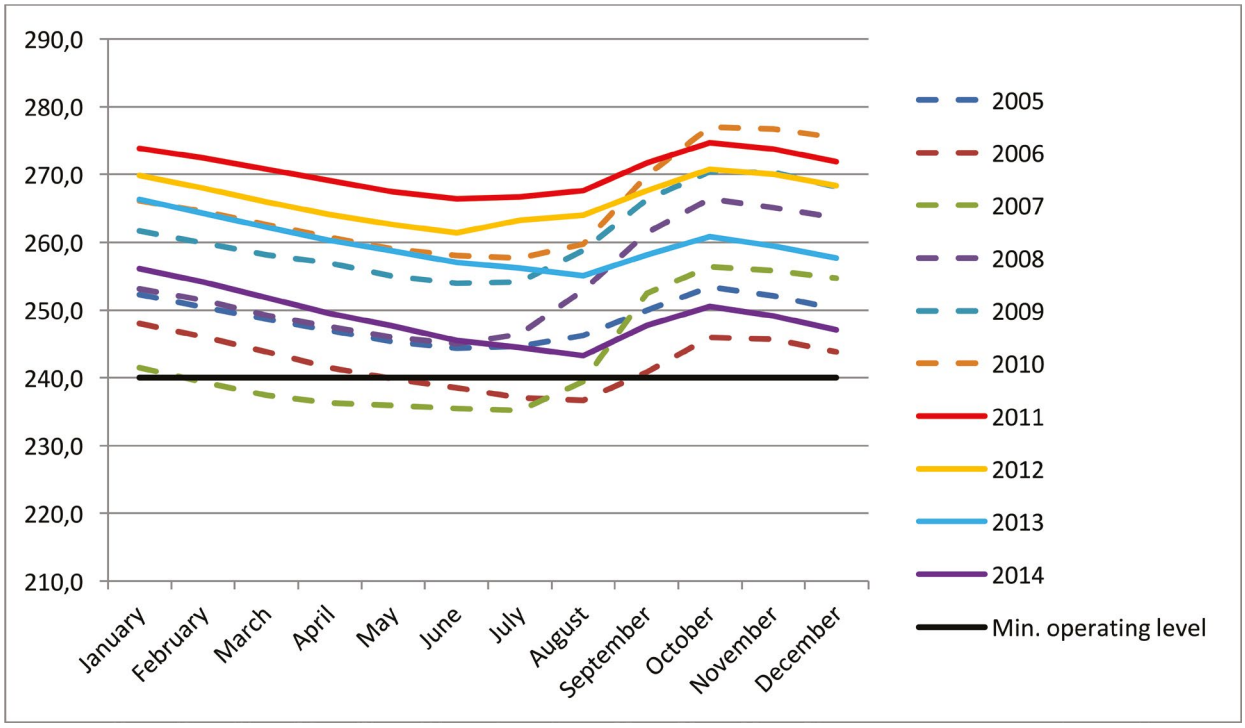

Figure 11. *Akosombo Dam average monthly reservoir level (feet), 2005-2014 - Source: Energy Commission of Ghana 2016a.*

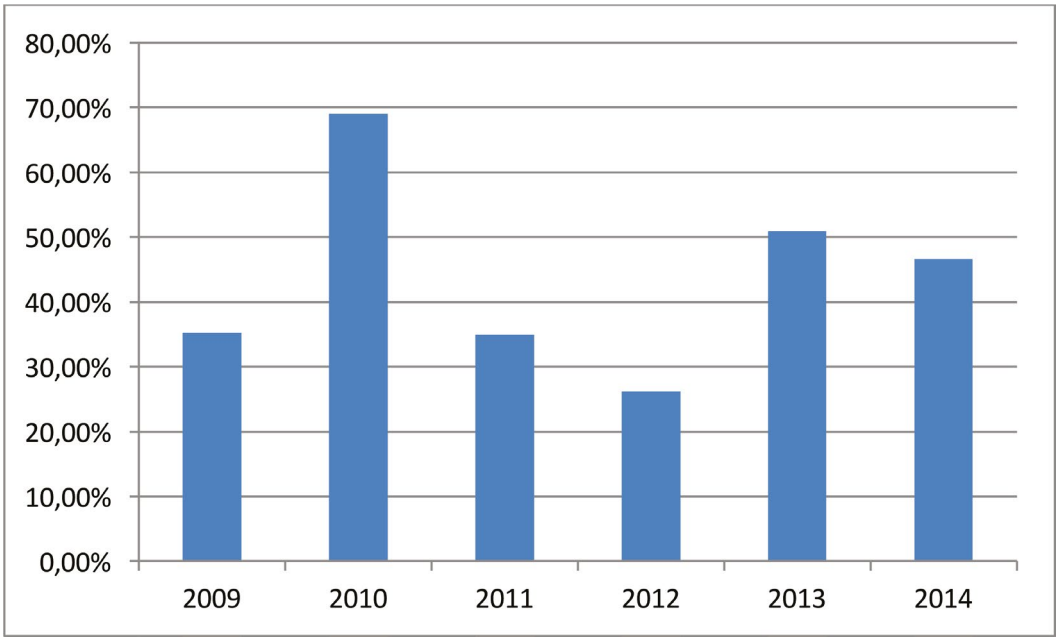

Figure 12. *Delivery through WAGP as percentage of contractual amount, 2010-2015 - Source: Author elaboration from Energy Commission of Ghana 2016a.*

The unavailability of gas for power generation has already costed much to the country in the form of oil import bills and power sectors fuel subsidies, and it would have costed even more if 70% of the gas-fired plants was not also able to run on light crude oil or distillate fuel oil. Moreover, the increased frequency of power outages, in which the interruption and shortages from the WAGP has played a relevant part, is consistently quoted as one of, if not the, main constraint on Ghana's economy. The World Bank study from 2013 compares the average prices for MMBtu from the different fuels used in thermal power generation in Ghana: the cost of delivery of associated gas to Takoradi was $2.25 MMBtu, the weighted average of all domestic gas (associated from Jubilee and non-associated from TEN and Sankofa) was $6.13 MMBtu, that of gas from the WAGP was $8 MMBtu while that of LCO, based on $100 per oil barrel, was $17.24 MMBtu. Even accounting for an oil barrel price roughly equal to a half of that used in the study, Ghana would still save $2.5 for each MMBtu that is produced with domestic gas, regardless of its provenience, instead that with LCO. It is interesting to note that domestic gas will remain competitive against all other fuels until 2021 in all scenarios developed in the Gas Master Plan (assuming that the price of the oil barrel will remain around $50).

If the development of all gas fields proceeds as planned and they all come on-line in 2018, Ghana should be able to cut oil imports by up to 12 million barrels, freeing resources which could be invested in more generation capacity while saving as much as 1.6 million tons of CO2. An increase in electricity supply could also allow for the satisfaction of a share of the unmet demand (with a gain in the range of $6.5-14.27/kWh), bringing Ghana a step closer to the enjoyment of electricity services worthy of a middle income economy. Moreover,

domestic supply from the currently discovered fields will terminate only around 2035, leaving more than enough time to secure other sources of supply and to develop the renewable potential of the country. Gas demand from the power sector has historically been the backbone for the development of a domestic gas market, and this will probably be the case also for Ghana. As shown in the second section, thermal generation is becoming increasingly relevant in the country and will soon become the main source of electricity. Given that natural gas remains cheaper than oil and its derivatives and that more than 70% of Ghana's thermal plants is gas-fired, it does not come as a surprise that gas demand from the power sector could remain as high as 80% of overall gas demand until 2040. Most of the thermal power plants are located along the coast nearby Tema, Accra and Takoradi and are served by the "Western Corridor Gas Infrastructure", feeding gas from the Jubilee field to the processing plant in Atuabo and the plant in Aboadze (Takoradi), and by the WAGP, serving Tema and Accra but also reaching Takoradi. Given the frequent problem with gas delivery from Nigeria, there have long been talks of building further infrastructure to allow for reverse flow on the WAGP between Takoradi and Tema, and after a dispute between BOST and GNGC on who had the right to build and operate it was resolved in favour of the latter, construction work started at the end of 2016.

Although the recent issues in the Ghanaian electricity market makes power generation the clear priority for the utilisation of domestic gas, possible demand from other sectors has also been the object of analysis from the Ghanaian government. The most attractive industrial uses which might substantially contribute to gas demand in the medium-long term (assuming a cost of delivered gas of $8-9 in the medium term and a maximum cost of $12 in the long term) have been individuated in cement production, transportation (substituting gasoline and diesel), methanol and urea for fertiliser (see Fig.13). Especially the cement sector possesses an attractive netback, given a willingness to pay (wtp) for fuel of around $15/MMBtu, principally due to the high cost of imported clinker which leads to an average price substantially higher than in the MENA region. CNG for transport also offers a potentially high netback value given a wtp for fuel of $14.6/MMBtu for gasoline fired vehicles and of $9.7/MMBtu for diesel fired ones. However, these results are fairly sensitive to the conversion costs assumed and to the annual vehicle mileage. In addition, the absence of infrastructure for refuelling and the fiscal consequences for fuel switching have not been comprehensively assessed, so that a pilot study for public transport in Greater Accra is suggested before moving ahead with more substantial plans.

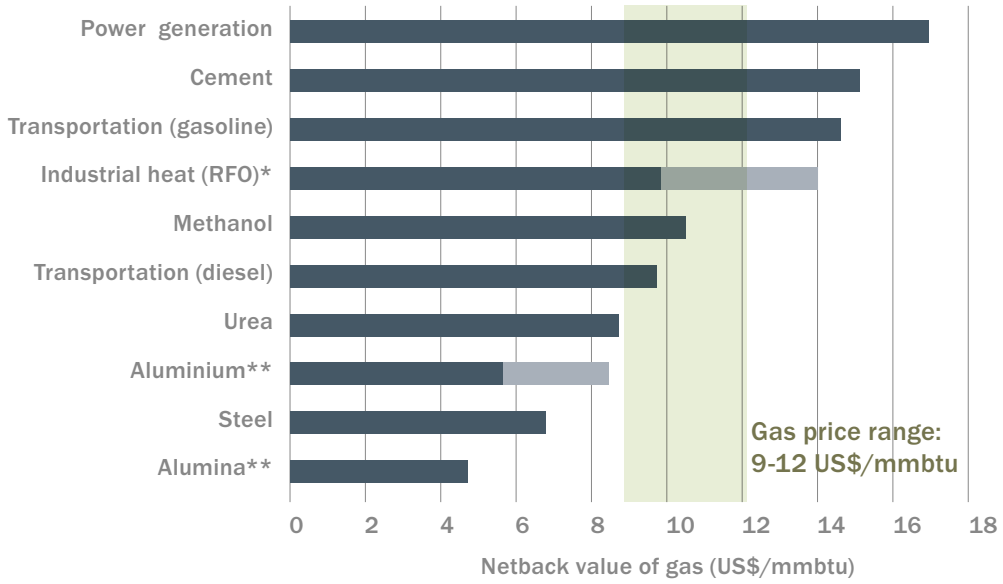

Figure 13. *Netback Values in Various Sectors - Source: Ministry of Petroleum of Ghana 2016*

The netback value of the utilisation of gas in industrial clusters around Tema and Takoradi, especially for heat, is also promising at a level of $9.8/MMBtu, calculated from a regulated cost of $0.47/ litre for residual fuel oil and a conversion cost of $45,000 for the boiler over a repayment period of 10 years. Furthermore, this result is extremely robust to different conversion costs, making the incremental development of industrial demand in sites nearby gas supply terminals particularly attractive, especially once the likely significant employment benefit has been taken into account. Although with a much more marginal netback value, methanol and urea are also industries which could positively contribute to gas demand if the condition in their volatile international markets are favourable. The former has a maximum netback value for gas of $10.5/MMBtu conditional to the construction of a world-scale production plant to serve export markets, which would require significant capital investment. However, given production costs faced by most competing nations, Ghanaian methanol would be at a significant disadvantage vis-à-vis MENA and North America, diminishing the attractiveness of the industry as utilization option. Much of the same reasoning can also be applied to urea production for fertilisers: the netback value of $8.7/MMBtu is reasonable in itself but its realisation would require the construction of a world scale plant to serve very volatile export markets in which other countries have recently postponed plans to expand capacity due to low prices.

4.2 Gas infrastructure development plan

The last infrastructure plan that explicitly addressed investment in gas transmission and distribution infrastructure was the 2007 “Natural Gas Transmission and Distribution Infrastructure Plan for Ghana” by the Energy

Commission. Recognising the development which has taken place since, the Gas Master Plan considers a few different options for the expansion of the existent infrastructure. The majority of the current infrastructure (see Fig.14) is comprised in “Western Corridor Gas Infrastructure”, which was developed to deliver the gas from the Jubilee field to the Ghanaian market and achieved commercial operation in 2015. The corridor includes a 59 km gathering pipeline connecting the Jubilee field to the Atuabo Gas Processing Plant, with the latter having the capacity to process 4.3 million m^3 of raw gas per day into NGL and lean gas, which is then transported to the thermal power plants at Aboadze (Takoradi) through a 110 km onshore pipeline.

The other principal existing infrastructure is the WAGP, which reaches Takoradi passing through Tema. Since the discovery of domestic gas and given the inconsistency in the delivery of Nigerian gas, the demand in the west of the country has been almost exclusively met with indigenous gas, with gas from the WAGP being materially restricted to Tema. This has left the Takoradi-Tema section of the pipeline lying vastly unutilised and has opened up talk for investing in the infrastructure required to connect the WAGP to the western corridor so as to allow for reverse flow in the segment and use the surplus gas from Atuabo to serve the eastern demand centres. The Government of Ghana has already approved the interconnection between the two pipelines and construction should start as soon as the last contractual details about the tariff for transmission of Ghanaian gas are resolved.

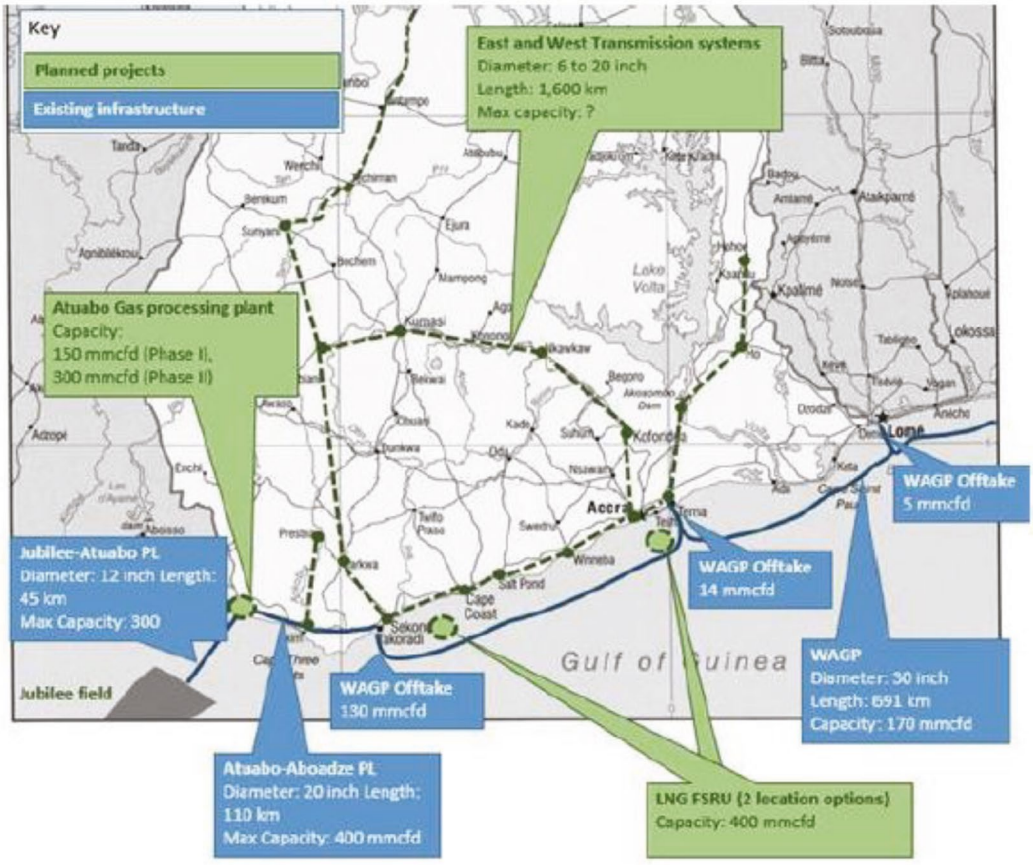

Figure 14. *Current transmission and distribution infrastructure in Ghana - Source: Ministry of Petroleum of Ghana 2016*

Given that the coastal area spanning from Takoradi to Tema, which also hosts the main industrial hubs of the country, will remain the main centre for gas demand in the medium term, the option to further expand the gas infrastructure in the region, namely a second pipeline from Takoradi to Tema, has been the first to be considered. The main argument in favour of building a twin pipeline to the WAGP relies on two main points: first, this will allow covering other major population centres between the two cities which are currently not served by the WAGP; second it will put more pressure on the WAPCo to increase the reliability and quantity of its supply and to offer a more competitive transmission tariff. While everyone recognises that the cost of such an infrastructure will be significant (a 2007 study estimated it at more than $630 million) and that if the delivery from WAPCo could reach its contractual amount a second pipeline will only really be useful in the long term, the current situation of the power system makes the benefit from an increased security of supply outweigh the costs.

Another matter of debate is the opportunity to construct a pipeline connection to Kumasi, second city of the country and capital of the Ashanti region, and more in general to the Northern region, with the alternative option represented by a power transmission infrastructure. With regard to the connection to Kumasi, this could happen either through Takoradi or through Accra-Tema, with the former being preferred despite the slightly higher cost due to the higher potential for uptake along the pipeline. However, gas prices in Kumasi will need to be higher than along coastal cities given the necessity to cover the transmission cost, and given that gas demand in the area is not expected to exceed 0,8 bcm until 2030, strengthening grid services would be much more economical than building a pipeline ($39 million instead of $178 million). Further connection towards the north of the country along the direction of Kumasi-Sinyani (140 km), Sinyani-Tamale (Ghana's fourth largest city, 304 km from Sinyani) and Tamale-Bolgatanga (northernmost big city in the country, 158 km from Tamale) will require an investment of at least $650 million does not currently seem justifiable given the absence of anchor buyers in the form of power facilities or gas-demanding industries.

The country has also been considering for some time the construction of an LNG terminal, with an earlier study suggesting Aboadze as the best location but a later one indicating Tema as a better candidate. The latter would be preferred due to the already quoted insufficient and irregular supply from the WAGP, which is of much less concern for the west of the country given the location of the national reserves. LNG would be especially beneficial in the short term (before production from the Sankofa field picks up) and then in the medium-long term (after 2024 when gas demand is reaching its maximum), leaving open two different options for the best way to address the infrastructural need. The first is the initial construction of a small facility (around 2.8 million m^3 per day), which should suffice for the short term need, to be later complemented by a second facility to address the long term requirements; the second is developing straight away a bigger facility (around 7.8 million m^3

per day) to exploit the economy of scale in LNG terminal construction knowing that it will be underutilised until the second half of the 2020s. Although the second option has a higher capital expenditure requirement than the first and a longer construction time, the possibility of a higher unmet demand in the medium term than what initially expected makes it slightly preferable.

05 Conclusions

This study has presented the most recent figure about the Ghanaian energy markets with a particular focus on the role that natural gas can play for the development of the power sector and the national economy. Over the last few years Ghana has faced significant power shortages, partially related to insufficient investments in generation capacity and to volatile rain patterns/increased evaporation rates influencing hydropower generation but also influenced by unreliable delivery of gas through the WAGP. The necessity to acquire more expensive fuels for thermal power plants, becoming increasingly relevant in the generation portfolio of the country, has put further strain on the financial stance of many actors in the electricity markets.

In this light, the development of the national gas resources discovered in the late 2000s becomes even more significant than before. The use of national gas instead of imported light crude oil in thermal generation can play a very relevant role in increasing the reliability of electricity supply in the country, which has long been considered one of the main obstacles to a faster rate of economic growth. Furthermore, the financial resources previously dedicated to imported oil could be directed towards greater investments in generation capacity, while the emission profile of the country also stands to gain. The possible domestic uses for natural gas exceeds though that in the power sector, with attractive netback values present especially in the cement and transport sector and in industrial heating. However, all the figures reported in this study are taken either from analyses developed during a period in which the oil price was around $100 per barrel (Nexant 2010, World Bank 2013), or from the Ghana Master Plan, which also assumed an oil barrel price of $100. Although the repetition of the netback analysis is outside the scope of the current work, it must necessarily be noted that given the current price and trends of the oil market the reported netbacks are likely to be a substantial overestimate of the realisable one.

Acknowledgments

This research report was written thanks to Eni's support and contribution within the activities of FEEM's project *Pathways to Sustainability in Africa*. This multifaceted project is focused on the in-depth multidisciplinary analysis of the main energy, economic and environmental issues of the African continent, and of the Sub Saharan area in particular.

The main contributors to this report are Giovanni Occhiali – researcher of FEEM's *Energy Scenarios and Policy (ESP)* research program - and Manfred Hafner, ESP program coordinator.

References

Biscoff, R., Akple, M., Turkson, R. and Klomegah, W. (2012) Scenario of the emerging shift from gasoline to LPG fuelled cars in Ghana: a case study in Ho Municipality, Volta Region Energy Policy 44, pp. 354-361

Energy Commission of Ghana (2016a) National Energy Statistics 2006-2015

Energy Commission of Ghana (2016b) 2016 Energy (Supply and Demand) Outlook for Ghana

Fristch, J. and Poudineh, R. (2015) Gas-to-power market and investment incentive for enhancing generation capacity: an analysis of Ghana's electricity sector, Oxford Institute for Energy Studies EL13.

Institute for Statistical, Social and Economic Research ISSER (2015) Annual Report 2014-2015

Mensah, J.T., Marbuah, G. and Amoah, A. (2016) Energy demand in Ghana: A disaggregated analysis Renewable and Sustainable Energy Reviews 53, pp. 924-935

Ministry of Petroleum of Ghana (2015) Gas Master Plan

Nexant (2010) Advisory Paper – Ghana Sector Master Plan

PSEC-GRIDCo (2010) Ghana Wholesale Power Reliability Assessment 2010

World Bank (2013) Energizing Economic Growth in Ghana: Making the Power and Petroleum Sectors Rise to the Challenge

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