ENERGY COMMISSION, GHANA

2017 ENERGY (SUPPLY AND DEMAND) OUTLOOK FOR GHANA

Final

April, 2017

Executive Summary

Energy Commission presents supply and demand forecasts for electricity, crude oil, petroleum products, natural gas and charcoal for the year 2016. Factors that could influence the demand and supply are also discussed.

Electricity

1. In 2016, the total electricity made available for gross transmission was around 13,700 GWh as against 11,692 in 2015 and 13,071 GWh in 2014; i.e. 2,008 GWh (about 17%) more than in 2015 and 629 GWh (about 5%) more than in 2014. The net grid electricity supplied[1] to the country was 12,705 GWh as against 11,678 GWh in 2015; about 9% more than that of the previous year and about 24% less than the projected minimum requirement for the 4% economic growth (*which was for VALCO operating even at one potline).* Consequently and as expected, the economic growth could not reach the government target but settled at about 3.7%[2].

2. Peak load on the transmission grid excluding export[3] was 1,997 Megawatts (MW); roughly 14% more than in 2015. The total (maximum including exports) peak on the transmission grid[4] was however 2,087 MW, which was about 8% more than in 2015.

3. For the year **2017** and with the significance improvement in power supply due to expanded thermal generation capacity, the Government is targeting a real GDP growth of **6.3%**. At this projected GDP growth for 2017, the total electricity required for the is expected to be as follows:

    a) **16,800-16,900 GWh** (*with VALCO constrained at only one potline*). The corresponding peak capacity demand would lie within **2,480-2,500 MW**.

    b) **18,100-18,800 GWh** (*with VALCO to operate at a maximum of two potlines*). Expected peak capacity demand required would lie within **3,000-3,500 MW**.

[1] Gross transmission –wheeled –exports.
[2] Ghana-IMF Three-year Programme report, February, 2016; Ghana Statistical Services December23, 2015; Trading Economics March 17, 2016 (http://www.tradingeconomics.com/ghana/gdp-growth-annual/forecast). However, Government in its 2016 Budget Statement projected 5.2% (without oil) and 5.4% (with oil).
[3] Referred to as Domestic Peak Load by some of the utilities
[4] Ghana Peak load + Exports

4. Both levels (a) and (b) are achievable provided the following are also accomplished:

   i. Planned capacity additions for this year are timely completed and there is also adequate financial resource to procure all the fuel needed to run the thermal power plants even at higher utilisation factors.

   ii. Average end-user-tariff is reduced from the current of **20-21** US cents per kWh to within **10-15** US cents per kWh.

5. The key hindrance to achieving the projected targets thus would depend on a cost competitive or affordable electricity tariff and adequate hydro and gas fuels for the plants.

6. On the other hand, with the existing relatively high tariff, what is achievable would be as follows:

   c) **15,615-15,700 GWh**[5] (*with VALCO constrained at one potline*). *Expected peak capacity demand required would be from **2,386-2,400 MW**. Average End-User tariff estimated at US cents 18-20 per kWh; i.e. a bit lower than the Business-as-usual.*

   d) **14,000-14,500 GWh** (*with VALCO constrained at one potline*) *Expected peak Capacity demand required would range from* **2,200-2,300 MW**. *Average End-User tariff estimated at US cents 20-21 per kWh; Business-as-usual.*

Levels (c) and (d) would improve the economic growth from about 3.7% in 2016 to over 4% but not enough to take the economic growth to the 6.3% target for 2017.[6].

[5] This range adapted from the joint Supply Plan with GridCo, VRA, Bui, ECG, NED and other power entities.
[6] Energy consumption is directly related to economic growth for developing and middle income developing countries.

Fuel for Power Generation

7. In 2016, total gas flow to power plants dropped to about 27 million MmBTU (26,962 mmscf), almost half of the supply of the previous year; only about 18% coming from Nigeria (44% in 2015) via the WAGP and the remaining 82% (56% in 2015) coming from the Atuabo gas processing plant.

8. For **2017**, we project the average WAGP gas flow to be 30 mmscfd, whilst an average of **80 mmscfd** is expected from the Atuabo gas. Additional gas is expected from the TEN fields during the third quarter of the year and that could boost average supply range to **90-110 mmscfd** during the last quarter of the year.

9. 1n 2016, the average delivery price of the WAGP gas was $8.45/MmBTU ($8.6/mscf) and that of the Atuabo gas was a uniform $8.84/MmBTU ($9/mscf) throughout the year[7].

10. For **2017**, we assume the same price for the Atuabo gas and that it would remain uniform at **$8.84/MmBTU ($9/mscf)** but that of the average annual delivery price of WAGP gas to VRA would increase to **$8.7/MmBTU ($8.86/mscf)** due to its indexation to price of oil[8].

11. However, since the Atuabo gas would be the dominant gas, we estimate that the total cost of gas required for **2017** would be about **$315 million**.

12. In 2016, LCO consumed by the thermal power plants for grid power production was about 3.9 million barrels compared to the estimated requirement of 5.9 million barrels.

13. For **2017**, we estimate the LCO required to be about **4.4 million** barrels, driven by the increased availability of indigenous gas.

14. In 2016, the average delivery price[9] of light crude (LCO) for power generation was $55 per barrel.

15. **For 2017**, we expect the delivery price of the light crude to remain about the same as in 2016. The total cost of LCO required would thus be about **$261 million**.

[7] Interesting to note that imported gas was cheaper than indigenous gas.
[8] We project that the average crude oil price to be higher in 2017 than it was in 2016.
[9] i.e. including transportation and treatment.

16. In 2016, total diesel consumed by the thermal power plants for grid power production as well as for starting and switching off the plants was about 400 thousand barrels compared to the estimated requirement of 1.5 million barrels.

17. For **2017**, we estimate the diesel required largely for the same exercise to drop to just about **250 thousand** barrels due to expected improvement in supply of cheaper alternative thermal fuels.

18. In 2016, the average delivery price of diesel was about $90 per barrel as projected.

19. For **2017**, we maintain the same delivery price and thus estimate the total cost of diesel required to be around **$22 million.**

20. HFO is the fuel being used by the Karpower Barge and the AKSA power plant for power production. In 2016, the Karpower plant consumed about 2.3 million barrels, a drop from the estimated requirement of 2.8 million barrels.

21. For **2017**, we estimate the HFO required to be about **4.9 million** barrels.

22. In 2016, we estimated the delivery price of HFO for the Karpower Barge to be about **$72** per barrel.

23. For **2017**, we maintain the same HFO delivery price bringing the total cost of supply to around **$360 million.**

24. In all, almost **$960 million** would thus be needed to procure **fuel** for grid or public electricity generation.

Crude oil and Petroleum products

25. In 2016, the average purchase price of Brent crude on the global market was $43.3 per barrel, a drop from $52 per barrel in 2015. Average price in 2014 was $99 per barrel.

26. For **2017**, the average price at which Ghana would source Brent crude is expected to increase from $46.5 per barrel in 2016 to **$52-58** per barrel. The average price for other light crudes for refinery operations would increase from $45 per barrel in 2016 to within **$48-52** per barrel. Average delivery price for light crude oil for power generation would range from **$55-60** per barrel as it was in 2016.

27. In 2016, crude oil from the Jubilee field was sold at an average price of $40 per barrel. Average prices in 2015 and 2014 were around $51 and $96 per barrel respectively.

28. For **2017**, average oil price from the Jubilee field is likely to recover from the $40 per barrel in 2016 to hit **$50-51** per barrel.

29. In 2016, total petroleum products pumped into the economy was around 3.32 million tonnes, a drop from 3.52 million tonnes in 2015. . There was one percent drop each for both diesel and gasoline consumption respectively. These could be attributed to the improvement in the grid electricity supply due to the return from the numerous private back-up gensets to the grid.

30. For **2017**, total petroleum products required would range from **3.7-3.9 million tonnes**, equivalent to **70,000-75,000** barrels per stream day refinery capacity. This amount of petroleum products would be necessary to enable the country improve upon her 2016 economic growth. It would largely comprise gasoline formulae of about 34-35% and diesels of about 54-55% (*excluding products directly destined for public or grid power generation*).

31. However, to achieve the government target of 6.3% economic growth, **4.5-4.7 million tonnes,** equivalent to **85,000-90,000** barrels per stream day refinery capacity would be needed.

32. In 2016, crude oil production from the Jubilee field dropped to about 27 million barrels from 37.4 million barrels in 2015. Corresponding daily production averaged 94,200 barrels. It was 106,938 barrels and 105,935 barrels per day in 2015 and 2014 respectively.

33. For **2017**, average crude production from Jubilee is likely to remain about the same as in 2016, i.e. stay within to **90,000-105,000** barrels per day.

34. In 2016, LPG supplied was 281,500 tonnes, just about one percent slightly higher than in 2015. About 55% was imported and around 35% from local production.

35. For **2017** however, between **290,000- 300,000 tonnes** of LPG would be required for an economic growth higher than the 2016 economic growth of which over 40% is likely to come from the processing of the indigenous gas and imports drop to about a third. We do

not expect more than one-third of supply to come from TOR due to the likely shut down of it during some periods of the year to allow retrofitting and expansion works on-going at the facility to be completed.

36. The Government's 6.3% growth for the year **2017** however, would require **320,000-350,000** tonnes due to the growing demand for LPG as cooking fuel in the homes and particularly as transport fuel. Notwithstanding, the limited nation-wide storage capacity could as usual constrain the supply to not more than 300,000 tonnes.

Charcoal

37. In 2016, the average prices of charcoal in the country followed the historical increasing tread, for mini bag[10], it rose to a little over GH¢21 from about GH¢20 in 2015 whilst for the maxi bag, it was from about GH¢31 in 2015 to about GH¢34. The 2016 price increases however were just about 4-6% for the mini-bag compared to about 21% and about 10% compared to 24% for the maxi-bag respectively in 2015. The average percentage price increment of about 5% for the year was also far below the 30-35% we projected for the coastal zone in 2016. Greater Accra and the Savannah regions also experienced a moderate increase of about 8-10% compared to the 20-25% projected for the year. Relatively stable prices of transport fuels, especially diesel during the year is likely to have contributed to the moderate price growth.

38. Nonetheless and as usual, the high-price zone were along the coast and the Upper East Region. The low-price areas were also the transitional regions of Brong Ahafo, Northern and Upper West regions followed by the forest regions of Ashanti, Eastern and Western. Interestingly however, there was no price change in Eastern Region and for Central Region, average prices in 2016 rather dropped by about 8% for the mini bags.

39. For **2017**, we estimate that the average charcoal price increment to remain within 5-10% for both the mini and the maxi bags in the coastal areas of Central, Western and Volta Regions.

[10] See Annex 7

40. Greater Accra and the Savanna regions would experience a moderate price increment of 5-8% in 2017. Nationwide, we estimate an average price range to remain within 4-6% for the year due the likely availability of LPG which is an alternative or substitute fuel for charcoal in urban areas.

Recommended Actions

Ameliorating the overall power supply shortage

41. The Akosombo Hydropower plant would be required to operate six (6) units during the first quarter to make up for reduced thermal generation as a result of some scheduled plant outages which coincide with the cessation of gas supply from Ghana-Gas to enable the TEN tie-in works. The plan is to reduce the number of units to a maximum of four (4) for the rest of the year in order to maintain the reservoir level above the minimum operating level of 240 feet. It would be prudent to limit Akosombo operations to running not more than four (4) units in the second quarter and for the rest of the year. Failure to adhere to the plan for hydro could significantly compromise reservoir integrity for subsequent years.

42. One crucial requirement for reliable power supply is the availability of the required dependable plant capacities, quantities of fuel and funds to purchase the fuel in a timely manner.

43. Gas supply inadequacy and gas pricing remain the major risks to reliable electricity supply in Ghana. Installed capacity by end of the year is expected to reach about 4,500 MW capable of generating over 20,000 GWh, which is enough to meet the country's electricity requirement including supressed demand, should there be adequate and cost-competitive fuel. The challenges however are fuel availability and competitive grid electricity tariff.

44. The fuel supply challenge also has to do with funding besides technical constraints. It is therefore necessary to arrange to secure the needed funds to purchase the needed quantities of fuel on time.

45. Furthermore, there is also the need to pay off any indebtedness to gas suppliers so that the required gas volumes would be obtained for thermal generation.

46. To ameliorate the inadequate cost competitive fuel supply for power generation, investments in liquefied natural gas (LNG) as an alternative gas supply to augment the limited local and unreliable gas from the West Africa Gas Pipeline from Nigeria are being pursued vigorously. Licences have thus been issued and supply contracts already signed, nevertheless the LNG supply is more likely to be available the nearest future.

47. Every effort however, should be made to ensure that fuel for power generation are cost-competitive based on open bidding process rather than sole-sourcing, the latter which is a contributory factor to the current relatively high non-competitive grid electricity tariff regime. For instance, the higher delivery price of indigenous gas compared to that of imported gas has been attributed to the price build-up which needs an urgent revision.

Cash Waterfall Mechanism

48. Energy Sector arrears and debt situation along the power supply value chain was over $1 billion by end of 2016. Most of the debt were due to short term loan contracted by the power producers and the distribution utilities' inability to collect adequate revenue to cover their operations. In order to address the chronic debt challenges and to facilitate equitable distribution of all cash collected in the power sector value chain using the end user tariff as a basis, the Cash Waterfall Mechanism concept was instituted in 2016. It is expected to be carried out across the country, which would see the development of a formula, for adequate distribution of revenue to all stakeholders in the power sector value chain. However, the implementation of the CWM was deferred to 2017 because of delays in the aspects of the inter-utility debt and modalities for the implementation.

49. The Commission wishes to propose that a national bank is selected through open competitive bidding to implement the scheme.

Achieving 50% nationwide penetration of LPG

50. National LPG penetration rate increased from 6% in 2000 to 18% in 2010 and is currently around 23%. The sector ministry is targeting 50% penetration by 2020 but it is not likely to be achieved if limited distribution outlets nationwide remain the same.

51. This can however be achieved by implementing the measures to support and accelerate the supply and use of LPG outlined in the Energy Sector Strategy and Development Plan, and the LPG Policy Paper. These include:

(a) Deliberate government policy to make the LPG produced available for local consumption as against export;

(b) Removal of price distortions which has already been done.

(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.

52. In this light, the Ministry of Energy 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 centres in-country to increase access and consumption.

53. Besides, processing of indigenous gas from Jubilee makes available LPG which could provide adequate volumes to meet the 50% target by 2020. However, LPG supply from Atuabo, would have some challenges if sent directly to the domestic market without paying attention to its peculiar nature. Atuabo LPG is a natural gas refining product and thus would have different characteristics from that of TOR since the latter is a crude oil refining product in terms of propane-butane composition. Further, natural gas by its

nature is odourless and so its LPG is relatively of less odour compared to that from crude oil processing. Deodorisation of Atuabo–based LPG to the same odour as LPG from the conventional sources is thus critical.

54. Higher penetration of the Atuabo LPG in the domestic market therefore would require more attention in terms of safety and standardization and also more public education to avoid potential fire hazards in homes.

Expanding Crude Oil Strategic Reserve

Fuel supply security and erratic fuel prices have compelled countries to set up strategic stocks both for crude oil and refined products. Crude oil storage however, has the comparative advantage of far longer lifespan and could even be indefinite depending upon the blend and state. With the prevailing low global oil prices therefore, many developed countries have taken the opportunity to expand their crude oil reserves.

55. In the same respect, the global low oil price regime is an opportunity for BOST to include crude oil stock in the existing oil reserve stock of the country before the opportunity eludes the country once again.

Expanding crude refining operations

As indicated earlier, equivalent of 70,000-75,000 barrels per stream day refinery capacity would be required to enable the country meet its projected economic growth for 2017. Even though, it costs less to import crude oil for refining locally than importing the finished product, capacity utilisation at Tema Oil Refinery (TOR) had worsened from about 64% in 2011 to just around 3.1% in 2015 compared to a minimum capacity utilization of 70% to break even in this current global low oil price environment.

56. In the light of this, providing input crude of at least **1.5 million tonnes** for the refinery during the year, could help the refinery break-even, even though still dependent on the production configuration. Profit could start emerging as the capacity utilisation increases.

Foreword

ENERGY COMMISSION has the mandate to prepare, review and update periodically indicative national plans to ensure that reasonable demands for energy are met in a sustainable manner. In addition, the Energy Commission is mandated to secure and maintain a comprehensive data base for national decision making for the efficient development and utilisation of energy resources available to the nation. Energy Commission's jurisdiction include promoting and ensuring uniform rules of practice for the production, transmission, wholesale supply, distribution and sale of electricity and natural gas.

In fulfilment of its mandates, the Commission has been preparing annual energy demand and supply outlook to provide guidelines to the energy sector operators and potential investors as well as the wider business community wishing to operate in the country. The purpose of the 2016 Annual Energy Outlook therefore is to give government, industry and business, indications of the levels/quantities of electricity, liquid and gaseous fuels that would be required to be provided by the energy producers for this year.

This document covers demand and supply of electricity, crude oil, petroleum products, natural gas as well as charcoal.

In the document, 'Demand' is used when referring to gross fuel or energy required by a demand sector, e.g. Residential, Commercial, or Industry. 'Supply Requirement' is Supply or Generation/Production plus transmission/transport losses.

For further elaboration, please refer to Annex 1 of the document for a schematic overview of Ghana's Energy Demand and Supply System.

This report was prepared by the Strategic Planning and Policy Directorate of the Energy Commission.

General questions about the report should be referred to Dr. A.K. Ofosu-Ahenkorah, (oahenkorah@energycom.gov.gh, ahenkorah@gmail.com) the Executive Secretary. Specific questions about the content may be directed to Dr. Joseph Essandoh-Yeddu (essandohyj@energycom.gov.gh, jeyeddu@gmail.com), Acting Director of Strategic Planning and Policy Directorate.

Your comments are most welcome.

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Executive Secretary

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Acronyms

GDP	Gross Domestic Product; *measure of wealth of an economy of a nation.*
LPG	Liquefied Petroleum Gas
Solar PV	Solar Photovoltaic; *panel technology for electricity via solar or sunshine*
GWh	Gigawatt-hour, i.e. *million units of electricity*
kWh	Kilowatt-hour, i.e. *one unit of electricity*
MWh	Megawatt-hour, i.e. thousand unit of electricity
NG	Natural Gas
LNG	Liquefied Natural Gas; *natural gas liquefied about 600 times*
mmBTU	Million British Thermal Unit; *an energy unit for gas flow*
mscfd/mcfd	Thousand standard cubic feet per day/ Thousand standard cubic feet per day; *a volumetric unit for gas flow*
mmscfd/mmcfd	Million standard cubic feet per day/ Million standard cubic feet per day; *a volumetric unit for gas flow*
bscfd/bcfd	Billion standard cubic feet per day / Billion standard cubic feet per day; *a volumetric unit for gas flow*
Tcf/tscfd	Trillion standard cubic feet per day / trillion standard cubic feet per day; *a volumetric unit for gas flow*
IPP	Independent Power Producer
BOST	Bulk Oil Storage and Transport company, a state company supposed to manage the country's strategic reserve
ECG	Electricity Company of Ghana, a public power distributor
TAPCO	Takoradi Thermal Power Company, a public power generator
TICO	Takoradi International Company, a public power generator
TOR	Tema Oil Refinery, the only crude oil and public refinery in the country.
VRA	Volta River Authority, a public power generator
VALCO	Volta Aluminium Company, a smelting company
WAGP	West African Gas Pipeline
WAGPCo	West African Gas Pipeline Company

1.0 Power Subsector

1.1 Overview of Grid Power Supply in 2016

Installed generation capacity operational and available for grid power supply as at the end of 2016 was about 3,775 Megawatt (MW), about 19% expansion over previous last year's compared to 12% increment from 2014 to 2015 (*see Table 1*).

Table 1: Installed Grid Electricity Generation Capacity operational as of December 2016.

GENERATION PLANT		FUEL TYPE	CAPACITY (MW)				TOTAL GENERATION	
			Installed (name plate)	% *Share*	Average Dependable	Average Available	GWh	% *Share*
Hydro Power Plants	Akosombo	Hydro	1,020		1,000[11]	460	3,853	
	Bui	Hydro	400		360	345	944	
	Kpong	Hydro	160		148	105	763	
		Sub-Total	***1,580***	***42.9***	***1,508***	***910***	***5,560***	***42.84***
Thermal Power Plants[12]								
Takoradi Power Company (TAPCO)		Oil/NG	330		300	185	1,192	
Takoradi Inter. Company (TICO)		Oil/NG	340		320	240	1,903	
Sunon–Asogli Power (SAPP1)		NG	200		180	180	373	
Sunon–Asogli Power (SAPP2)		NG	180		170	0	0	
Kpone Thermal Power Plant (KTPP)		Oil/DFO	220		200	200	199	
Tema Thermal Plant1 (TT1P)		Oil/NG	126		100	100	178	
Tema Thermal Plant2 (TT2P)		Oil/NG	50		45	30	26	
CENIT Energy Ltd (CEL)		Oil/NG	126		100	100	418	
Mines Reserve Plant (MRP)		Oil/NG	80		70	30	3	
AMERI		NG	250		240	230	1,204	
Karpower		HFO	225		220	220	1,855	
Trojan*		Diesel/NG	25		22	12	39	
Genser*		Coal/LPG	20		18	0	0	
		Sub – Total	***2,172***	***57.5***	***1,985***	***1,527***	***7,390***	***56.94***
Renewables*	VRA Solar	Solar	2.5		1.5	1	2.5	
	BXC Solar	Solar	20		10	9.5	26.3	
	Safisana Biogas	Biogas	0.1		0.1	0.5		
		Sub – Total	22.6	***0.6***	11.6	11	***28.8***	***0.22***
Total			**3,774.6**		**3,304.6**	**2,448**	**12,978**	

*NG is Natural gas. * Sub-transmission connection. EC implies Energy Commission.*

[11] 2017 Electricity Supply Plan chaired by GRIDCo indicated 1000MW but EC estimates it to be 900-960MW

[12] TAPCO is Takoradi Power Company, a combined cycle (CC) thermal plant; TICO is Takoradi International Power Company, a single cycle (SC) thermal plant.

The Genser power plant even though commissioned during the year was not ran, due to un-concluded negotiations between the operator and the off-taker before the year ended.

The 20 MW BXC Solar is an embedded generation plant, likewise the Trojan and the Genser power plants but included here owing to their significant sizes.

The 100 kW Safisana Biogas Power is included just because it is the first of its kind in the country.

The gross generation in the country in 2016 was 12,978 Gigawatt-hours (GWh), about 13% more than in 2015, comprising 42.8% hydro, 56.9% thermal and about 0.2% solar power.

Total grid electricity supplied was about 13,722 GWh comprising about 5% imports (744 GWh), 94.6% conventional large hydro and thermal and just about 0.2% solar or renewables.

Grid electricity made available for gross transmission[13], during the year however was around 13,700 GWh[14] consisting of about 5,561 GWh (41%) from hydro generating, 7,380.40 GWh (54%) from thermal generation and about 744 GWh (5%) of import. It was almost 13% improvement over 2015 just as for gross grid electricity generation.

A total of 410.46 GWh of electricity was transmitted to Togo and Benin (CEB), comprising 186.52 GWh power exports from VRA and 223.94 GWh wheeled from CIE.

The net grid electricity supplied[15] to the country was almost 12,705 GWh; about 24-33% less than the minimum projected requirement for *achieving a marginal economic growth of **4.0-4.5%** in 2016.* The deficit was equivalent to about 550 MW net and just as in 2015, could contribute to the relatively low economic growth[16] for the year.

Peak load on the transmission grid excluding export[17] was 1,997 Megawatts (MW); roughly 14% more than in 2015. The total (maximum) peak on the transmission grid[18] was however 2,087 MW, which was about 8% more than in 2015.

Total power transmission loss in 2016 was 4.4% of gross transmission, 0.6 percentage point higher than in 2015 after a slight improvement that year, of which the utilities had largely attributed it to lack of adequate generation to allow for a geographical flexibility and balance in generation in operation at all times. Congestion in some portions of the transmission network was also cited as a culprit (*see Table 2*).

[13] Does not include imbedded generation and from solar since the latter is at the distribution grid level.
[14] 13,685 GWh
[15] Gross grid electricity less wheeled less exports less transmission loss.
[16] Real GDP growth estimated between 3.6-3.9% for 2016. Sources: African Development Bank, Ministry of Finance Supplementary Budget.
[17] Referred to as Domestic Peak Load by some of the utilities
[18] Ghana Peak load + Exports

Table 2: Grid Power Transmission losses since 2008.

Year	2008	2009	2010	2011	2012	2013	2014	2015	2016
Transmission losses as % of gross transmission	3.7	3.8	3.7	4.7	4.3	4.4	4.3	3.8	4.4

1.1.1 State of the Generation Sources in 2016

The Hydro generation[19]

Akosombo and Kpong

Akosombo was made to produce about 3,853 GWh against projected supply of 3,285 GWh; about 17% more than estimated.

The Volta Lake started the year 2016 at an elevation of 242.65 feet (ft) against its minimum operating level of 235ft. Due to this low reservoir level and in order to ensure system stability by not dropping below the minimum operating level, it was recommended[20] to operate not more than three (3) units throughout the year. However, fuel supply challenges for the alternative and complementary thermal generation made it impossible to adhere to the plan for the year. The plant started operating three (3) to four (4) units in February and then increased to four (4) to six (6) units' operation from March. This thus made the reservoir level drop to a minimum of 235.01 feet which was just 0.01ft above the Extreme Minimum Operating level (*see Figure 1*).

The 2016 inflow season for the Volta Lake ended with the reservoir attaining a maximum elevation of 253.05 feet. This resulting reservoir rise of about **18ft** is thus what is to be managed this year 2017 until about beginning of second quarter of the year when the next rains start upstream.

Kpong GS produced about 763 GWh in 2016; 22% more than projected. Kpong GS operated three units throughout of the year since the fourth unit was undergoing retrofitting. This has reduced the total average available capacity of the dam from 140 MW to 105 MW.

[19] Unit has been maintained in feet because VRA maintains the imperial measurement.
[20] See 2016 Energy Outlook and 2016 Power Supply Plan.

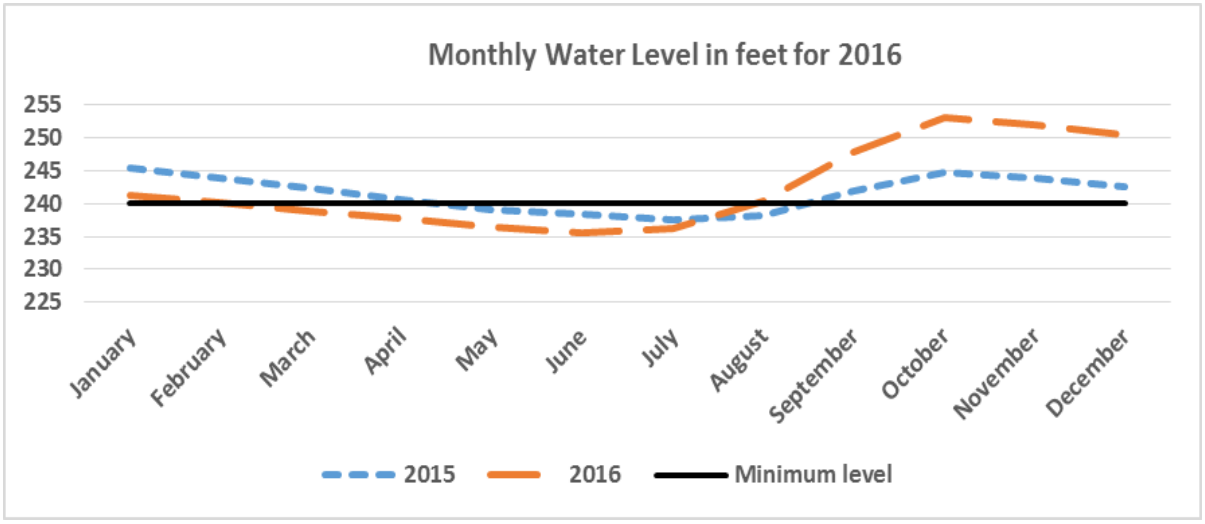

Figure 1. Monthly Water level at Akosombo Reservoir in 2016

Bui Hydro

Bui reservoir started the year at about elevation 178.59m and dropped to 168.31m in May 2016. From January to May 2016, the Bui Generating Station operated one (1) unit during off-peak and two (2) to three (3) units during the peak period. The Bui reservoir trajectory for 2016 is shown in Figure 2.

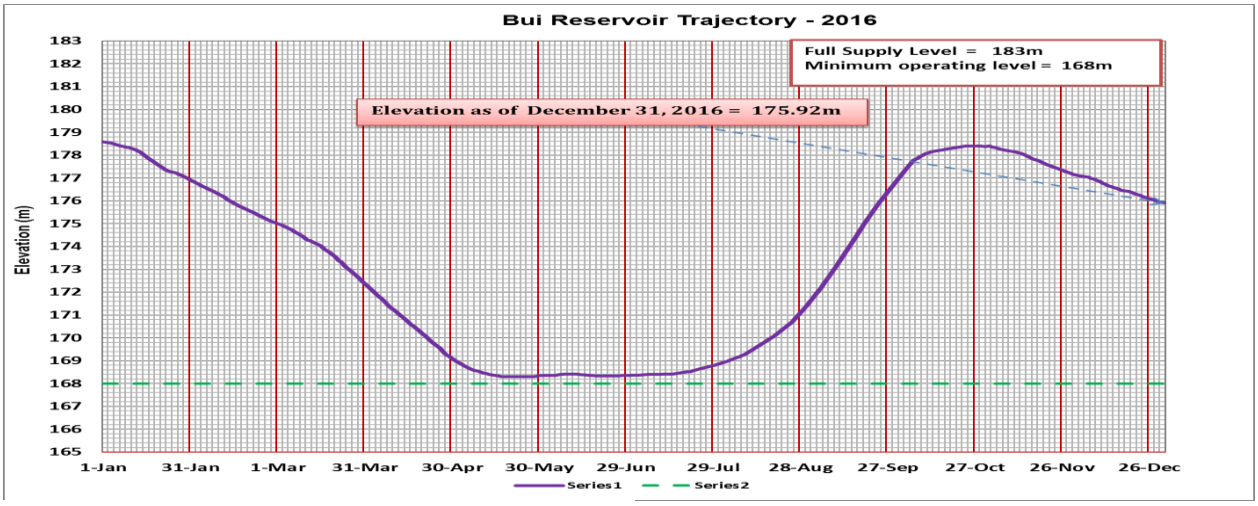

Figure 2. Bui Dam reservoir trajectory in 2016

The reservoir operation regime changed to only one (1) unit at peak period when the state of the reservoir worsened, depleting to almost the minimum operating level but by November, the reservoir had improved, risen to elevation of 177-178m, about **9.16m** above the minimum operating level and thus the column of water to be managed until the next rainy season starts at the end of the first quarter this year 2017.

The Thermal Generation

Total installed thermal generating capacity as at end of 2016 was about 2,172 MW of which 1,985 MW was dependable (see Table 1). The gross available capacity however fell to about 1,500 MW mainly because some of the capacities of the plants like TT2PP and MRP dropped due to technical faults.

Grid electricity generated from the thermal plants was 7,390 GWh which was about 56% less than the projected available grid power generation for 2016 and this was attributed to inadequate gas supply from the WAGP and Ghana Gas coupled with the inability of the thermal entities to purchase adequate liquid fuels to run the thermal plants *(see Figure 3).*

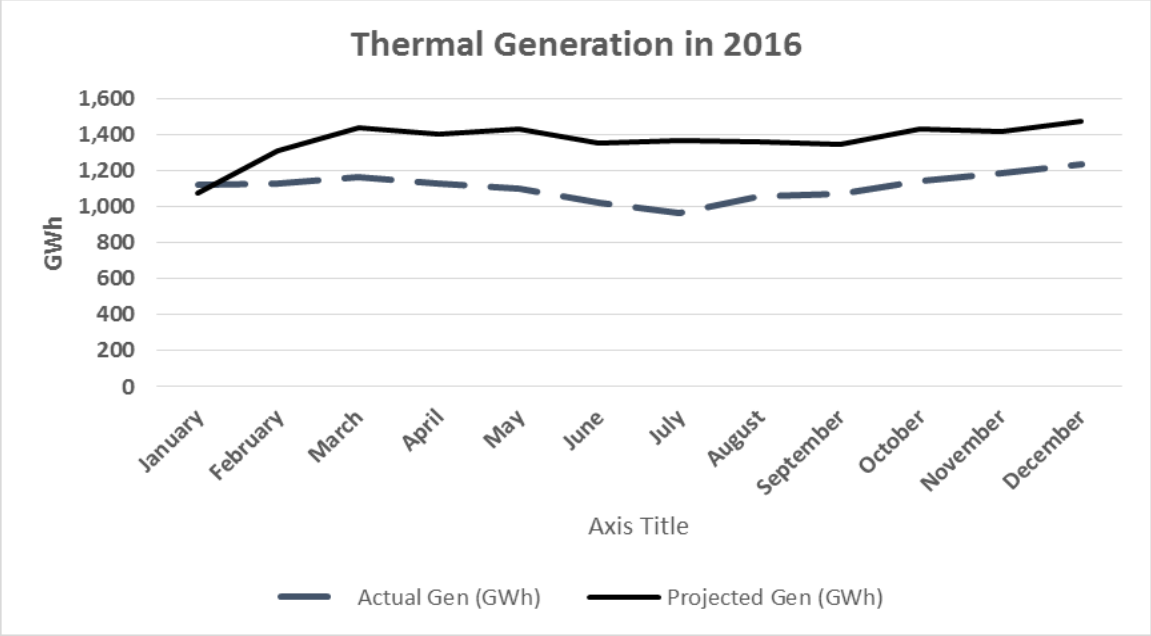

Figure 3. Total Electricity Generation from Thermal Power Plants in 2016

Total gas from Jubilee field through Atuabo (Ghana Gas) was 22,960,056 mmBTU in 2016, about 12.6% drop from 2015 supply (*see Table 3*).

Average daily gas flow from the Jubilee field through Atuabo (Ghana Gas) dropped from 72 mmscf in 2015 to about 60 mmscf in 2016 (*see Table 3*). Whilst flow averaged 73 mmscf in January, it exceeded 100 mmscf during the second half of the month. There was however a week of no flow in the middle of January. The gas flow resumed in the last week of January then peaking to an average of about 100 mmscfd but started to decline levelling around 70-80 mmscfd from February till the end of March when supply stopped. The Atuabo plant was shut down for maintenance in April and for that matter there was no gas flow during that month. The gas flow returned in May but with a far lower average flow rate until October when it averaged the February flow and was maintained for the rest of the last quarter.

Total gas flow from WAGP worsened in 2016, it dropped from 20,625,393 mmBTU in 2015 to just about 4,000,000 mmBTU and compared to 22,541,001 mmBTU in 2014 (*see Table 3*).

Table 3: Monthly and Daily Natural Gas Supply in 2016

Month	Ghana Gas Supply		WAGP Supply		Daily flow in mmscf	
	Monthly flow in mmBTU	Daily flow in mmscf	Monthly flow in mmBTU	Daily flow in mmscf	Takoradi Enclave	Tema Enclave
January	2,565,304	73.30	1,029,209	32.17	**53.95**	**30.02**
February	2,721,712	78.56	685,094	22.07	**75.71**	**21.86**
March	1,705,592	80.40	642,215	19.90	**71.87**	**19.41**
April	0	0	575,055	18.38	**0.00**	**16.69**
May	1,309,784	44.56	373,578	13.81	**41.13**	**12.20**
June	1,644,944	46.30	84,404	9.86	**43.08**	**7.80**
July	2,200,352	61.52	0	0	**60.40**	**0.00**
August	2,429,112	69.28	0	0	**64.99**	**0.00**
September	1,781,136	66.95	0	0	**63.44**	**0.00**
October	2,554,664	73.70	0	0	**68.20**	**0.00**
November	1,657,712	50.17	30,989	19.12	**44.46**	**16.12**
December	2,389,744	68.57	582,138	20.55	**59.62**	**18.91**
Total	***22,960,056***		***4,002,682***			
Average	***2,087,278***	***59.70***	***500,335***	***12.99***	***53.90***	***11.92.***

Average flow from WAGP on the other hand was less than half that of the GhanaGas supply beginning January and continued with a downward trend until July when the flow practically ceased. It resumed in December but the story was not different. The average daily rate throughout the year was about 13 mmscf, barely enough to fire a 50 MW thermal plant.
The WAGP supply was largely destined to the Tema enclave whilst the GhanaGas supply was to the power plants located at the Takoradi power plants enclave.

1.2 2016 Forecast and Actuals

For 2016, we projected that all things being equal, the total electricity required would have ranged as follows:

(1) **16,798-16,900 GWh** *with VALCO operating at one potline*; to improve the economic growth to an average range of 4-4.5% with capacity demand requirement estimated at **2,486-2,500 MW**.

(2) **18,158-18,398** GWh *with VALCO to be operating at most two potlines*; to raise the economic growth above 4.5% with the required capacity demand falling within **3,979-4,076 MW**.

(3) **20,146-20,698 GWh** for VALCO to be operating more than two potlines to further raise the economic growth over 5%. Capacity demand requirement would have ranged from **4,260-4,357 MW**.

The net grid electricity supplied[21] to the country was around **12,705 GWh**; about 24% less than the scenario (1), i.e. the minimum projected requirement for *achieving a marginal economic growth of **4.0-4.5%** in 2016.* The deficit was equivalent to about 550 MW net and just as in 2015, could contribute to the relatively low economic growth[22] for the year.

As indicated in the past years[23], Ghana's real Gross Domestic Product (GDP) growth has been dropping since 2012. The GDP was about 3.9% in 2015, a drop from 4.0% in 2014, a drop from 7.1% in 2013 and 8.8% in 2012[24] GDP growth for 2016 was estimated at **3.7-3.8%**[25]. As has been the case in the previous years, the projected marginal dip in the GDP growth is attributed to the negative growth in the Manufacturing subsector and Industry in general [26].

[21] Gross grid electricity less wheeled less exports less transmission loss.
[22] Real GDP growth estimated between 3.6-3.9% for 2016. Sources: African Development Bank, Ministry of Finance Supplementary Budget.
[23] 2015, 2016 Energy Outlooks, Energy Commission, www.energycom.gov.gh/DataCenter
[24] Ghana Statistical Service (GSS), March, 2015.
[25] http://www.tradingeconomics.com/ghana/gdp-growth-annual.
[26] http://www.statsghana.gov.gh/gdp_bulletin.html.GDPQuarterlyBulletin,December2016

Impact of Electricity Tariff on Demand

The drop in the GDP could largely be due to the relatively high electricity tariff which dipped sales during the year[27]

Prevailing electricity tariff moves Ghana from once among less expensive countries to very expensive grid tariff regimes among middle-income developing countries (*see Table 4*).

Table 4. Comparing Average End User Tariff ranges of Ghana and Selected Middle-Income Developing Countries and Region spanning 2014-2016

Country/Region	Ghana	South Africa	India	China	SouthEast Asia
US cents/kWh	15-21	8-10	8-9	7-8	4-7

Source:[28]

Ghana could lose its competitiveness as an investment destination since her average grid electricity pricing is about twice higher than in South Africa, China and India. The average tariffs in Africa are also much higher than in other developing regions. For instance, the average effective tariff in South Asia was US $0.04/kWh, while that for East Asia was US $0.07/kWh (*Table 4*). These are countries and regions that have direct trade links with Ghana and where most finished products and light industrial materials are imported from.

Most heavy industries including the mines would require on the average tariff less than 6 US cents per kWh to stay competitive with similar products imported. Light industries could go as high as 10 US cents per kWh to survive. Thus for current energy tariffs for industries ranging from 18–26 US cents per kWh, excluding service charges means they are on the very high-side[29].

We reiterated as in 2015, that for non-residential or Commerce/service customers, for a tariff range of 26-43 US cents per kWh for initial consumption of 300 kWh in a month, it would be cheaper running own diesel alternative if available, except for convenience. Running a back-up generator at the current retail diesel price in the country would produce electricity at an average cost of 27 US cents per kWh. As if some service sector consumers have already realised it, they are switching to their back-up gensets during the last two weeks of the month

[27] 2017 National Energy Statistics, Energy Commission, www.energycom.gov.gh/DataCenter
[28] Adapted from 2016 World Energy Outlook, International Energy Agency; National Energy Statistics 2016, by Energy Commission.
[29] Low or less expensive tariff: 2-9 US cents/kWh; medium expensive tariff: 10-15 cents/kWh; High or very expensive 18-25 US cents. 26-35 US cents/kWh most expensive.

during operation, or for some hotels, they switch to diesel generation, when occupancy is above 80%[30]. Others are also investing heavily in solar PV power generation facilities.

Increasing Reliance on Alternatives to the Grid impacted on Demand

Long period of load shedding spanning 2012–2015 apparently made it attractive for a section of consumers particularly large and commercial entities to invest in conventional gensets and that have facilitated the flexibility to switch supply from the grid in order to avoid entering the high grid tariff classes.

The prevailing high relatively electricity tariff *(see Table 5)* also make it cost competitive and attractive for some consumers to opt for solar electricity (*having feed-in tariff of **18.24 US cents per kWh** equivalent for systems without back-up storage and **20.14 US cents per kWh** equivalent for systems with back-up storage[31]).* About 571 units totalling 334 kWp had been installed as of December 21, 2016 under the National Rooftop Solar Programme[32]. Private individuals and institutions as well as some government agencies on their own also embarked on solar power projects independent of the Rooftop national programme to supplement their grid supply during the year.

Table 5: Non-Residential Electricity Tariff for 2014, 2015 and 2016.

CONSUMPTION CLASS	RATE					
	Gp per kWh			US cents per kWh		
Year	2014	2015	2016	2014	2015	2016
0-300	45.2	60.79	96.79	16.99	16.00	25.47
301-600	48.1	64.69	102.99	18.08	17.02	27.10
601+	75.9	102.08	162.51	28.53	26.86	42.77

US cent 1 = 2.66 Ghana pesewas average in March, 2014.
US cent 1 – 3.80 Ghana pesewas average in March, 2015
US cent 1 – 3.80 Ghana pesewas average in March, 2016

All these contributed in the drop in demand from the national grid. .

[30] Energy Commission industrial field survey, 2016.
[31] US cent 1 = 3.1986 Ghana pesewas average as at September 30, 2014 when the tariff were set.
[32] 200,000 Solar Rooftop Programme being spearheaded by the Energy Commission.

Fuel Supply Issues

There were fuel supply challenges in 2016: For instance, Sunon Asogli phase II Thermal (180 MW) Power Plant was commissioned on gas but there was no gas to run the plant. The KTTP (220 MW) Plant was also commissioned on gas, but could not be operated as planned due to lack of gas. The gas shortage was largely due to supply curtailment from the West African Gas Pipeline due to non-fulfilment of financial obligations by VRA and the government.

Gas supply from the Jubilee Field through the GhanaGas was irregular due to some technical challenges with the FPSO during the year.

There were prolonged periods when there were inadequate stocks of liquid fuels (LCO and diesel) at the thermal Plants in Tema and Takoradi, largely due to the inability of the generating entities to finance purchases. This often necessitated frequent undesirable switching between firing thermal units on oil and gas which incidentally led to 'coking' on some of the thermal plant generating units with consequential reduction in output of the thermal plants.

Average WAGP gas flow in 2016 was 13 mmscfd (*19 mmscfd if considering the periods of flow only*) compared to minimum of 50 mmscfd projected for the year. Above average supply occurred only during the first quarter of the year *(see Table 3*).

Average WAGP delivery gas price to VRA the foundation customer was $8.05 per mmBTU in 2016; it averaged $8.13 per mmBTU for the first half of the year but dropped to an average of $7.96 per mmBTU during the second half. Final delivery cost however was $8.75 per mmBTU compared with $8.75 per mmBTU in 2015.

Lack of gas meant over 6 million barrels of LCO were needed but only about 3.8 million could be supplied (*see Tables 6*). Only one-third of the diesel requirement amounting to about 370 thousand barrels could be met. HFO supply was almost within the Karpower plant needing it.

Light crude oil (LCO) purchased purposely for power generation averaged $55 per barrel during the year which was $5/bbl lower than our forecast for the year (*see Table 6*).

Table 6: Grid Electricity and associated fuels: Forecast and Actuals for 2016.

		2015	2016	
			Forecast	Actual
Ghana's Electricity requirement (GWh)				
VALCO at one potline		*14,150-14,730*	*16,798-16,900*	
VALCO at 2 -3 potlines		*15,408-16,398*	*18,185-18,737*	
Total Grid Electricity available *(i.e. Including imports)* GWh		11,692		13,722
Grid Electricity generation available *(i.e. excluding imports)* GWh		11,678		12,978
Percentage hydro of generation (%) *(GWh)*		50.9 *(5,845)*	29.5 *(4,836)*	42.8 *(5,560)*
Ghana System Peak *(Domestic peak)* MW		1,933	2,325	2,105 *(1,997)*
GRIDCO Transmission System Peak/Maximum Demand MW *(Ghana/CEB System peak)*		2,118	2,477	2,087 *(2,405)*
Average WAGP gas flow (mmscf per day)		56	50-70	13 (*all year*) 19 (*for supplied period only*)
Average Jubilee/Atuabo gas flow (mmscf per day)		72	80-100	60
Delivered WAGP gas price * US$ per MmBTU *($ per mscf)*		8.25-8.92 *(8.4-9.09)*	8.3 *(8.4)*	7.9-8.13 *(8.05-8.28)*
Delivered WAGP gas price *(VRA receipt +other charges included[#])* US$ per MmBTU *($ per mscf)*		8.40-9.17 *(8.56-9.34)*	8.7 *(8.9)*	8.45 *(8.61)*
Delivered GhanaGas gas price * *(other charges included)* US$ per mmBTU *($ per mscf)*		8.84 *(9.00)*	8.84 *(9.00)*	8.84 *(9.00)*
Oil required (Million barrels)	LCO	5-7 *(LCO)*	5.9	
	Diesel		1.5	
	HFO		2.8	
Oil consumed (Million barrels)	LCO	1.7 *(LCO)*		3.9
	Diesel			0.4
	HFO			2.3
Average delivered light crude oil price *dedicated for power production* $ per bbl *($ per mmBTU)*		60 *(10.31)*	60-65 *(10.31-11.17)*	*55 (9.45)*

** Actual data in $/mmBTU courtesy of WAPCo. Low-side for Foundation customers and high-side for Standard customers. Other charges include delivery fee, ELPS transport fees, insurance, etc.*

***Prices indexed to LCO and negotiated between the buyer and supplier and reviewed every six months. Actual data in $/mmBTU courtesy of WAPCo. Low-side for Foundation customers and high-side for Standard customers.*

[#]VRA indicates that it adds administrative charges to the delivered gas price from WAPCo.

1.3 Forecast for 2017

1.3.1 Electricity Requirement of the Economy

The real GDP growth for **2016** was estimated to be 3.7%[33] (3.5-3.9%)[34] against the backdrop of the worsened power crisis and fiscal consolidation. Thus about the same level of 3.8-3.9% in 2015 but still a decline from 4.0% in 2014 and from 7.3% in 2013[35].

The GDP growth was ideally expected to increase from about 3.8-3.9% in 2015 and to 5.2-5.4% in 2016 [36] but the improving power situation was not enough to achieve the target.

As indicated in the 2015 Outlook, the World Bank[37] has established that electricity is the second most important constraint to business activities in the country and that Ghana lost about 1.8% of GDP during the 2007 power crisis.

Also, ISSER[38], in its 2014 study[39] which it is updating, indicated that on the average, the country is losing production worth about US$ 2.1 million per day (or, US$ 55.8 million per month) through the power crisis alone. As an example, the country lost about US$680 million in 2014 translating into about 2% of GDP due to the power crisis. It further indicated that firms that do not have access to sufficient electricity have lower output/sales, and that not having sufficient electricity lowers a firm's annual sales by about 37-48%.

As indicated in the earlier Outlooks, stable and sufficient electricity supply is thus undoubtedly a key input to firm growth, expansion and development. Ghana's annual electricity consumption per capita except for 2016, has been averagely below **400 kWh** since 2010 compared to the global minimum average of **500 kWh** for lower middle-income developing countries.

With the significance improvement in the power crisis due to expanded thermal generation capacity, the new Government projects the real GDP growth to improve from 3.7-3.8% in 2016 to **6.3%** in **2017**[40].

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[33] Annual Gross Domestic Product-Ghana Statistical Service, 2016 Edition
[34] Ghana-IMF Three-year Programme report, February, 2016
[35] Bank of Ghana Statistical Bulletin, January ttps://www.bog.gov.gh/Statistical Bulletin
[36] Ghana-IMF Three-year Programme report, February, 2016; Ghana Statistical Services December23, 2015; Trading Economics March 17, 2016 (http://www.tradingeconomics.com/ghana/gdp-growth-annual/forecast). However, Government in its 2016 Budget Statement projected 5.2% (without oil) and 5.4% (with oil).
[37] World Bank, Energizing Economic Growth in Ghana: Making the Power and the Petroleum Sectors Rise to the Challenge, February, 2013
[38] ISSER is Institute of Statistical Social and Economic Research
[39] Electricity Insecurity and its impact on Micro and Small Businesses in Ghana, Charles Ackah, Senior Research fellow, ISSER, University of Ghana, 2015.
[40] Ghana-IMF Three-year Programme report, February, 2016; Ghana Statistical Services December23, 2015; Trading Economics March 17, 2016 (http://www.tradingeconomics.com/ghana/gdp-growth-annual/forecast). However, Government in its 2016 Budget Statement has projected 5.2% (without oil) and 5.4% (with oil).

At this projected **GDP growth rate of 6.3% for Ghana for 2017**, the convention is that the total electricity required for the expansion of the country's economy is expected to be as follows:

1) **16,800 -16,900 GWh** (*with VALCO constrained at only one potline*). Expected peak capacity demand required would lie within **2,480-2,500 MW**. *Average End-User tariff to make it realized is estimated at US cents 15 per kWh.*

2) **18,100-18,800 GWh** (*with VALCO to operate at most, two potlines*). Expected peak capacity demand required would lie within **3,000-3,500 MW**. *Average End-User tariff estimated at US cents 10 per kWh.*

Both levels (1) and (2) are achievable provided the following are accomplished:

iii. planned capacity additions for this year are timely completed and there is also adequate financial resource to procure all the fuel needed to run the thermal power plants even at higher utilisation factors

iv. Fuel secured is largely gas or the existing average end-user-tariff is reduced from the current of **20-21** US cents per kWh to within **10-15** US cents per kWh.

The key hindrance to achieving the projected targets thus would depend on a cost competitive or affordable electricity tariff and adequate hydro and gas fuels for the plants.

On the other hand, with the existing relatively high tariff, what is achievable would be as follows:

3) **15,615-15,700 GWh**[41] (*with VALCO constrained at one potline*). *Expected peak Capacity demand required would be from **2,386-2,400 MW**. Average End-User tariff estimated at US cents 18-20 per kWh; i.e. a bit lower than the Business-as-usual.*

4) **14,000-14,500 GWh** (*with VALCO constrained at one potline*) *Expected peak Capacity demand required would range from* **2,200-2,300 MW**. *Average End-User tariff estimated at US cents 20-21 per kWh; Business-as-usual.*

Levels (3) and (4) would improve the economic growth from about 3.7% in 2016 to 4-4.5% but not enough to take the economic growth to the 6.3% target for 2017.[42].

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[41] This range adapted from the joint Supply Plan with GriDCo, VRA, Bui, ECG, NED and other power entities.
[42] Energy consumption is directly related to economic growth for developing and middle income developing countries.

1.3.2 The 2017 Electricity Demand Outlook

We do not envisage major load-capacity expansion in existing industrial set-up. However, key spot loads identified for 2017 load demand growth are the following:

i. Enclave Power Company 30 MW

ii. The Mines -75 MW,

iii. Drillworx, a new mining company in Konongo, Ashanti- 5 MW,

The numerous rural electrification projects earmarked for commissioning in 2017 are anticipated to increase demand in both the ECG and NEDCO operational areas. Besides, on-going network expansion works and measures to improve the quality of distribution services by ECG and NEDCO would further allow the connection of new loads which would culminate in an increase in demand in the residential, commercial and industrial sectors.

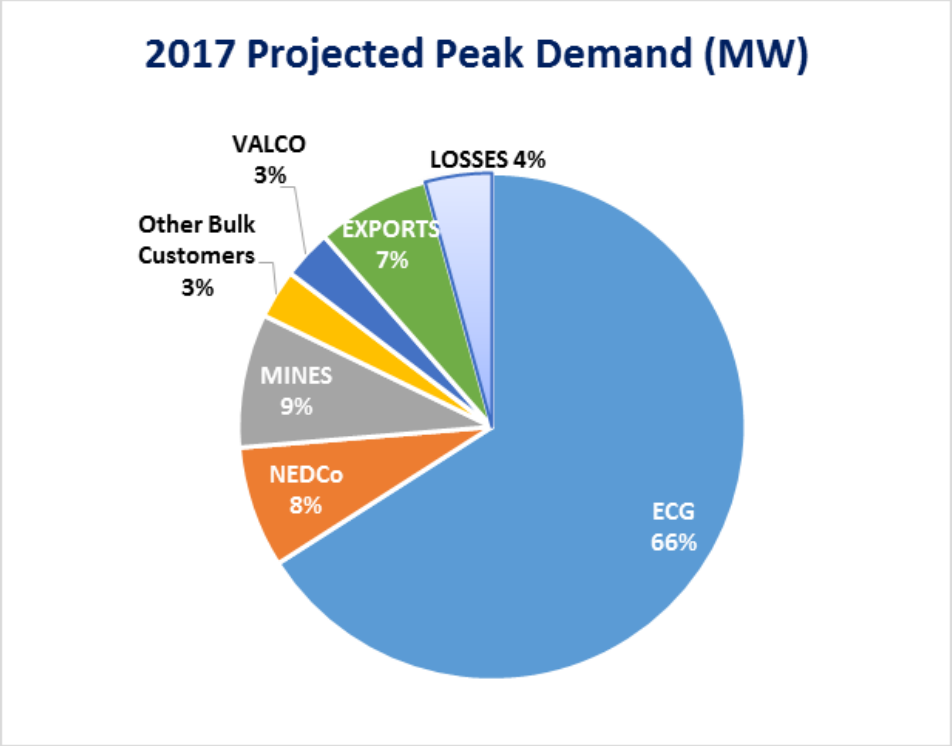

Figure 4: System Peak Demand by Major Customers for 2017[43]

[43] Source: 2017 Electricity Supply Plan; jointly prepared by GridCo, VRA, Bui Authority, ECG, NED and Energy Commission, January, 2017. .

Figure 4[44] shows coincident system peak demand for 2017 by customer class. ECG's demand constitutes 66% of the total system peak followed by the Mines with 9%. At plotline, VALCO's demand of 75 MW constitutes 3%, NEDCO 8%, other bulk consumers 3%. Exports to CEB and SONABEL account for 7% of the total system demand.

1.4 Available Electricity Supply for 2017[45]

1.4.1 Generation Sources

The sources of generation considered are mainly from the existing generation and the new committed projects expected to come online during the first quarter of 2016.

Existing Generation Sources – Hydropower

Akosombo and Kpong Hydro

The elevation for the Akosombo reservoir at the beginning of 2017 was 250.47 feet; about 10.47 feet above the Minimum Operating level of 240 feet. With this limited elevation, running three (3) units off peak and five (5) units at peak is recommended for 2017 at Akosombo Hydro power station (GS) is therefore highly recommended in order to maintain the reservoir elevation above 240 feet before the onset of the inflow season.

Nonetheless, existing challenges with gas supply and on-going maintenance activities on thermal units at the Aboadze enclave would necessitate running six (6) units during peak periods in the first quarter of 2017. The station should revert to three (3) units operation during off-peak and a maximum of five (5) units at peak for the rest of the year.

Kpong GS which is at present undergoing retrofit would have three (3) units out of the total four (4) units available. Hence, the total average capacity at Kpong GS would be 105 MW. As a result, total projected annual hydro generation from Kpong and Akosombo generating stations is projected to be 4,400 GWh for the year.

The projected elevations for the Akosombo reservoir in 2017 based on the above recommended hydro generation are as shown in Figure 5.

[44] Source: A joint 2017 Electricity Supply Plan produced jointly by GridCo, Energy Commission, VRA, Bui Authority, ECG, and NEDCo, January, 2017.
[45] This work mostly adapted from a 2017 Electricity Supply report jointly produced with GridCo, VRA, Bui, ECG and NED, January, 2017.

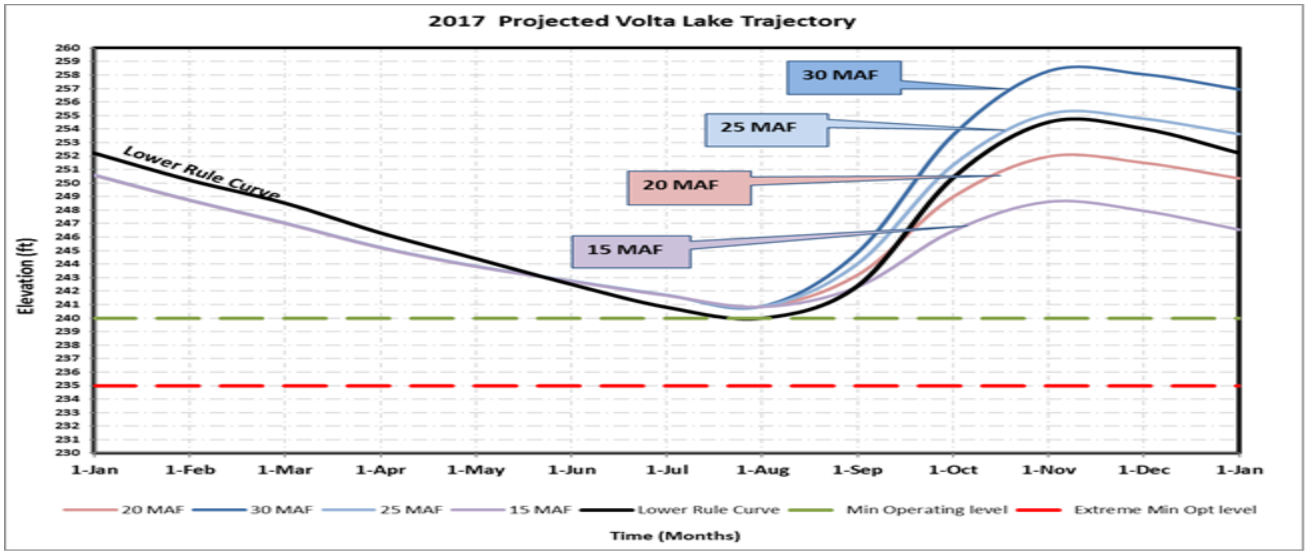

Figure 5: 2017 Akosombo Reservoir Projected Trajectory

Bui Hydro

In 2017, Bui GS would operate up to three (3) units based on system demand in the first quarter and then reduced to two (2) units at peak for the rest of the year. This mode of operation would lead to a projected annual production of 841 GWh.

Rainfall Pattern

With the rising sunspot activity of the sun, high precipitations associated with it are expected to bring in more rains beginning 2017 and projected to peak between 2019 and 2020 before starting to subside (*see Annex 2*). Strong sunspot activities imply that geophysical forces needed to push rainfall currents such as the inter-tropical boundaries from the coast far inland would increase and consequently releasing more precipitations at further distances from the equator and the coast.

For this reason, the hydropower dam catchment areas which are largely inland are likely to experience higher than expected average annual rainfall for this year and next, i.e. up to 2020[46]. This is evident in the catchment areas of the dam as shown in Figure 6.

[46] The 11 year sunspot cycle takes a sine shape; four-five years for the first arm of curve, one-three years to plateau or trough, and another four-five years to complete the full curve.

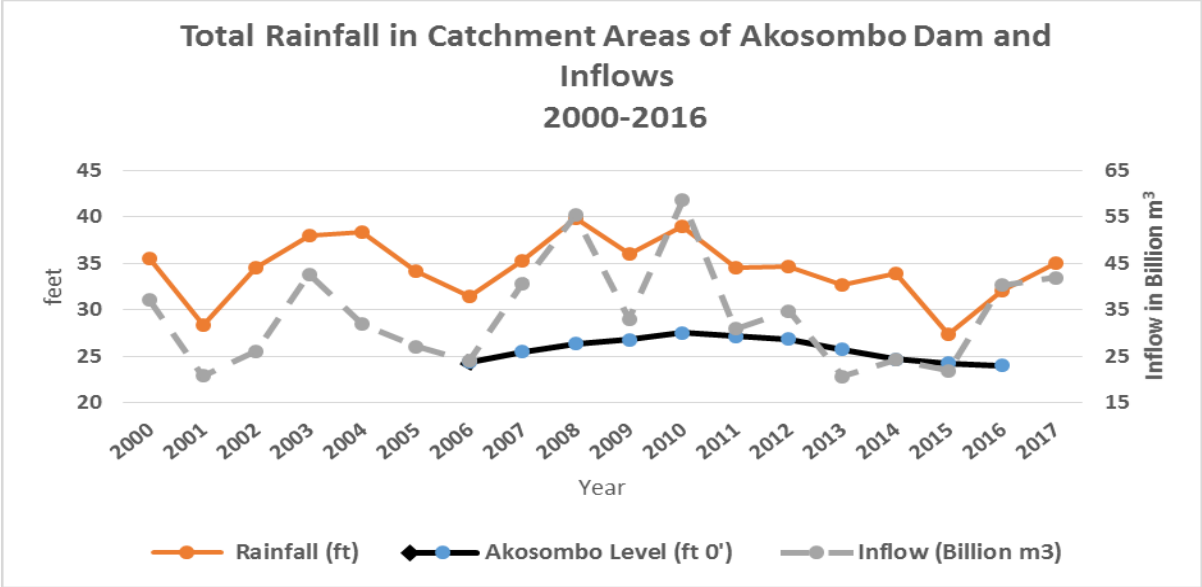

Figure 6: Total rainfall in key towns sited in catchment areas of the Akosombo hydrodam

Thus the precipitations and inflows indicate upward trend from 2015 to present. We should however be mindful that climate change could distort all these future predictions.

Existing Generation Sources – Thermal Power

Thermal

The total installed thermal generating capacity is 2,351.5 MW of which dependable capacity is 2,155 MW (*see Table 7*).

Table 7: Thermal Generation Sources available as at March, 2017.

PLANTS	Installed Capacity (MW)	Dependable Capacity (MW)	Fuel Type	Availability Factor (%)
TAPCO (T1)	330	300	LCO/Gas	85%
TICO (T2)	340	320	LCO/Gas	88%
TT1PP	126	100	LCO/Gas	88%
TT2PP	49.5	45	Gas	85%
***MRP**	*80*	*70*	*Gas*	*0%*
KTPP	220	200	Gs/Diesel	85%

Karpower	225	220	HFO	90%
AMERI	250	240	Gas	90%
SAPP	200	180	Gas	92%
SAPP2	360	340	Gas/LCO	85%
CENIT	110	100	LCO/Gas	92%
Trojan	25	22	Diesel/Gas	75%
Genser	20	18	coal	80%
TOTAL	**3,351.5**	**2,155**		

** VRA has written to Energy Commission to indicate that MRP is out of service for retrofit. Besides, operating licence for MRP has expired.*

Additional Generation Sources

In 2017, installation of additional generation resources totalling 801 MW of which 743 MW is projected to be dependable is expected to be completed and commissioned into operation. The details of installed and dependable capacities of on-going additional generation projects and their expected timelines are shown in Table 8. Construction of Cenpower plant is be completed by the end of 2017 but would be operational in 2018.

Table 8: Expected Additional Generation Sources in 2017.

Plants	Installed Capacity (MW)	Dependable Capacity (MW)	Fuel Type	Availability Factor (%)	Remarks
SAPP (2)	180	170	Gas	85%	*Awaiting Gas for commissioning*
AKSA	370	340	HFO	90%	*240 MW from June 2017, full capacity by September, 2017*
Karpower Barge 2	225	200	HFO	90%	*450MW to replace existing 225 MW. Hence, additional capacity of 225 MW from July, 2017*
TT2PP-X	36	33	Gas	85%	*Awaiting Gas for Commissioning*
TOTAL	**801**	**743**			

Planned Maintenance

The schedule of key maintenance activities planned to be undertaken in 2017 on generating units at the various power plants is shown in Table 9.

Table 9: 2017 Planned Maintenance for the Power Plants.

Plants	Planned Maintenance
Akosombo GS	• Each of the 6 units would undergo maintenance for separate months in the year Therefore, supply from Akosombo is not expected to be affected since 3 to 5 units are expected to be dispatched.
Kpong GS	• Kpong major retrofit is ongoing. Semi-annual inspection for 1 week would be carried out on 1 unit at a time in March, April and October 2017. In addition, there would be a post retrofit inspection on unit 2 in the month of August.
TAPCO (T1)	• ***Unit 1:*** Generator Rotor Repairs from March 20 – April 26, 2017. Hot Gas Path Inspection in the Month of October. • ***Unit 2:*** Major Inspection from January 8 to July 31, 2017. • ***Unit 3:*** Minor Inspection on steam turbine and generator from April 17 – May 18, 2017.
TICO (T2)	• ***Unit 2:*** Hot Gas Path Inspection and hardware upgrade from January 25 – March 25, 2017. • ***Unit 3:*** Major Inspection from January 25 to March 2, 2017.
TT1PP	• Unit scheduled for 3 days' outage. Maintenance would therefore not impact significantly on supply.
TT2PP	• Unit 1: Engine Swap; main gearbox overhaul, June 1 – June 21, 2017; • Unit 2: Engine Swap and main gearbox overhaul, June 24 – June 30, 2017; • Unit 3: Engine Swap and main gearbox overhaul, July 17 – August 9, 2017
VRA Solar Plant	• Maintenance will not impact on supply
SAPP	• No major maintenance activity is planned
CENIT	• No major maintenance activity is planned
Bui GS	• Maintenance would not impact on supply

Fuel Allocation, Requirements and Cost Implications

In 2017, natural gas, Light crude oil (LCO), diesel and Heavy fuel oil (HFO) are the types of fuel that would be required for firing thermal generating plants on the Ghana power system just as in the previous years. HFO, LCO and diesel are procured from the open market but are largely to come from Nigeria to save freight cost.

Natural Gas

Natural gas would however come from two sources; WAGP carrying gas from Nigeria; and the Atuabo pipeline carrying indigenous gas from the Jubilee field. Gas from the Jubilee field is being processed at the Ghana National Gas Company's Gas Processing Plant at Atuabo. Further supply to the plant is also expected from the TEN fields during the third quarter of the year. The Sankofa Field being operated by the ENI is set to supply gas from its Floating Production Storage and Offloading (FPSO) vessel in 2018.

We estimate the average WAGP gas flow in 2017 to be 30 mmscfd, whilst supply in the in the range of 80-100 mmscfd[47] is expected from GhanaGas at Atuabo. Supply in the beginning of the year had averaged 50 mmscfd. TEN fields supply tie-in work by GhanaGas and Tullow Oil scheduled for the first quarter of the year would result in cessation of gas supply to thermal plants in Aboadze. Supply would resume by end of the second quarter and with average supply within 80-100 mmscfd till end of the year. Additional gas is expected from the TEN fields during the third quarter of the year and that could boast average supply range to **90-110 mmscfd** during the last quarter of the year.

Based on the assumed volumes of natural gas supply from WAPCO and Ghana Gas, the total natural gas consumption is projected to be about **34.8** million MMBTU.

Average delivery price of the WAGP gas in 2016 was $8.45/MmBTU ($8.6/mscf) and that of Atuabo gas was a uniform $8.84/MmBTU ($9/mscf). Assuming the Atuabo gas price of $8.84/MmBTU ($9/mscf) as it was last year as the average delivery gas price for 2017, the total cost of gas required for **2017** would about **$315 million**.

In the light of the projected limited quantities of natural gas supply, fuel allocation at Tema and Takoradi power enclaves thus projected as follows:

[47] 110 mmscfd high will be reached occasionally but not likely to be in most cases.

Tema:

- *Nigeria Gas allocated to existing and new Sunon-Asogli power plants.*
- *TT1PP/CENIT operates on light crude oil (LCO); TT1PP operates on LCO but on standy from April to December.*
- *KTPP operates on diesel but in February during the TEN gas tie-in; thereafter operates as standby throughout the year.*
- *Karpower Barge operates on heavy fuel oil (HFO).*
- *MRP/TT2PP/TT2PP-X are on standby due to inadequate supply of gas.*

Takoradi:

- *Ghana Gas allocated to VRA/Ameri power plant and partly to T2 power plant.*
- *TAPCO would operate mainly on gas but switch to LCO as supplement.*
- *TICO would operate mainly on LCO with gas as supplement, i.e. when available.*

LCO

In 2016, Light crude was sold to Ghana at an average price of $55 per barrel. The average delivery price of the light crude (i.e. including transportation and treatment) for power generation was $60 per barrel. We expect the delivery price to remain about the same for 2017.

The total LCO requirement for 2017 is about 4.4 million barrels. Based on a cargo size of 405,000 barrels, a total of 11 cargoes of LCO would be required. The total cost involved would be **$261 million**.

HFO

HFO would be used mainly by the Karpower Barge and the incoming AKSA power plant. An estimated 4.9 million barrels would be required. This translates to 12.2 cargoes, assuming a cargo size of 405,000 barrels at an estimated delivery cost of about **$360 million** at $72 per barrel[48].

Diesel

As usual, diesel would be used mainly by the KTPP plant and for starting and shutting down all thermal plants. About **136,000 million barrels** (about one-third of a cargo size of 405,000 barrels) would be required by KTPP for power generation in February during the temporary shutdown of the Atuabo gas plant to allow the TEN-tie in. About **60,000 barrels** would be

[48] $72/bbl = 1.2 x LCO delivery cost.

required for starting and stopping all VRA thermal power plants. Another **50,000 barrels** of diesel is estimated to be used by IPPs for similar exercise. In all, around **250 thousand** barrels of diesel would be needed at a total delivery cost of about **$22 million** at $90 per barrel[49].

In all, almost **$960 million** would be needed for **fuel.** Summary of estimated amount of fuel needed and the cost involved are as presented in Table 10.

Table 10: Estimated Quantities of fuel needed and Cost involved for the Power Plants in 2017.

PLANT	LCO (Barrels)	Natural Gas (mmBTU)	DFO (Barrels)	HFO (Barrels)
TAPCO (T1)	612,808	6,507,602		
TICO (T2)	1,434,113	7,980,777		
TT1PP	411,060			
TT2PP + TT2PP-X				
MRPP				
KTPP			136,013	
CENIT	356,970			
AMERI		16,450,142		
SAPP		3,865,800		
SAPP PHASE 2	1,540,179			
Karpower Barge				2,369,862
AKSA				2,581,782
Starting and switching off plants			110,000	
TOTAL FUEL	**4,355,130**	**34,804,321**	**246,013**	**4,951,644**
Unit Delivery Cost (US$)	**60**	**9.05**	**90**	**72**
TOTAL FUEL COST (US$)	**261,307,800**	**315,000,000**	**22,140,000**	**356,518,368**

Fuel Supply Challenges

Hydro Risk

The Akosombo Hydropower plant will be required to operate six (6) units during the first quarter to make up for reduced thermal generation as a result of some scheduled plant outages which coincide with the cessation of gas supply from GhanaGas to enable the TEN tie-in works (which would lead to a temporary shutdown of the Ameri Plant). The plan is to

[49] $90/bbl=1.5 x LCO delivery cost.

reduce the number of units to a maximum of four (4) for the rest of the year in order to maintain the reservoir level above the minimum operating level of 240 feet. With the water level (249.22 feet as of January 25, 2017), it would be prudent to limit Akosombo operations to running not more than four (4) units in the second quarter and for the rest of the year. Failure to adhere to the plan for hydro could significantly compromise reservoir operations for subsequent years.

Thermal Fuel Risk

One crucial requirement for reliable power supply is the availability of the required dependable plant capacities, quantities of fuel and funds to purchase the fuel in a timely manner.

Whilst the issue with tariff has been discussed in ***section 1.2***, gas supply inadequacy remains one of the major risks to reliable electricity supply in Ghana. Thus, although, installed generating capacity is high, unavailability of fuel to run thermal units has rendered some thermal plants inoperable and consequently limiting the grid electricity supply likely to just about 15,000 GWh *(see Table 11).*

Table 11: Expected Production under the joint 2017 Electricity Supply Plan.

Power Plant	Installed Capacity (MW)	Supply (GWh)
Total VRA Hydro (Akosombo & Kpong GS)		4,400
Bui GS		841
TAPCO (T1)		1,258
TICO (T2)		1,983
TT1PP		177
KTPP		62
VRA Solar		4
SAPP (includes new plant)		1,477
CENIT		154
AMERI		1,619
Karpower Barge		1,802
AKSA		1,174
Trojan		19
BXC Solar		**32**
Total IPP Thermal Generation		**6,277**
Total VRA Supply		**7,884**
Expected Import		613
TOTAL PROJECTED SUPPLY		**15,615**

Installed capacity by end of the year is expected to reach about 4,500 MW capable of generating over 20,000 GWh (*see Table 12*), which is enough to meet the country's electricity requirement including supressed demand, should there be adequate and cost-competitive fuel. The challenge is fuel availability and competitive electricity tariff.

Table 12: Potential Grid Power Generation Capacity estimated for 2017

GENERATION PLANT		FUEL TYPE	CAPACITY (MW)				TOTAL GENERATION	
			Installed (name plate)	% *Share*	Average Dependable	Average Available	GWh	% *Share*
Hydro Power Plants	Akosombo	Hydro	1,020		1,000	460	3,627	
	Bui	Hydro	400		360	345	997	
	Kpong	Hydro	160		148	105	782	
		Sub-Total	***1,580***	***34.7***	***1,508***	***910***	***5,406***	***26.4***
Thermal Power Plants[50]								
Takoradi Power Company (TAPCO)		Oil/NG	330		300	185	1,192	
Takoradi Inter. Company (TICO)		Oil/NG	340		320	320	1,903	
Sunon–Asogli Power (SAPP1)		NG	200		180	180	373	
Sunon–Asogli Power (SAPP2)		NG	360		340	320	0	
Kpone Thermal Power Plant (KTPP)		Oil/DFO	220		200	200	199	
Tema Thermal Plant1 (TT1P)		Oil/NG	126		100	100	178	
Tema Thermal Plant2 (TT2P)		Oil/NG	50		45	30	26	
CENIT Energy Ltd (CEL)		Oil/NG	126		110	100	418	
Mines Reserve Plant (MRP)		Oil/NG	80	*This plant is being decommissioned*				
AMERI		NG	250		240	230	1,204	
Karpower		HFO	450		220	220	1,855	
AKSA		HFO	370		340	200		
Trojan*		Diesel/NG	25		22	12	39	
Genser*		Coal/LPG	20		18	0	0	
		Sub – Total	***2,947***	***64.8***	***2,655***	***2,335***	***15,008***	***73.4***
Renewables*	VRA Solar	Solar	2.5		1.5	1	2.5	
	BXC Solar	Solar	20		10	9.5	26.3	
	Safisana Biogas	Biogas	0.1		0.1	0.5		
		Sub – Total	*22.6*	***0.5***	11.6	11	***28.8***	***0.14***
Total			**4,549.6**		**4,174.6**	**2,448**	**20,442.7**	

*NG is Natural gas. * Sub-transmission connection.*

[50] TAPCO is Takoradi Power Company, a combined cycle (CC) thermal plant; TICO is Takoradi International Power Company, a single cycle (SC) thermal plant.

The fuel supply challenge also has to do with funding besides technical constraints. It is therefore necessary to arrange to secure the needed funds to purchase the needed quantities of fuel on time. Furthermore, there is the need to pay off any indebtedness to gas suppliers so that the required gas volumes would be obtained for the thermal generation.

1.4.2 Transmission System Performance

State of the NITS

The National Interconnected Transmission System (NITS) consists of approximately 5,207.7 circuit kilometres (km) of high voltage transmission lines which connect generation plants at Akosombo, Kpong, Bui, Tema and Aboadze enclaves to sixty four (64) Bulk Supply Points across the nation.

The transmission lines consist of 364 km of 330 kV line, 4,636.6 km of 161 kV and 132.8 km of 69 kV lines. There is a 225 kV tie-line which interconnects the Ghana grid with that of Cote d'Ivoire and two 161 kV tie-lines that interconnect Ghana grid with that of Togo. In addition, there is a single circuit 225 kV tie-line of 74.3 km linking the country's network with that of Cote d'Ivoire.

The network has 123 transformers installed at various load centres across the country with a Total Transformer Capacity of **4,598.86** MVA.

It also has 636 MVAr of static capacitor and a 40 MVAr Static Var Compensator (SVC) which provide reactive power compensation on the NITS, in order to maintain good voltages and minimize transmission losses on the Ghana Power System.

Ghana Grid Company (GridCo) is the operator of the NITS and is responsible for the real time dispatch (monitoring, coordination and control) of power system operations on the Ghana Power System as well as cross-border power exchanges with neighboring countries.

Transmission Line, Feeder and Substation Availability

In 2017, all existing transmission lines are expected to be in service for the transmission of electricity generated at the power plants to bulk supply points across the nation and as well to enable the execution of power exchange programmes with neighboring countries.

Maintenance work on transmission lines and substations are not expected to significantly affect power supply to customers except for single transformer substations and consumers served on single radial lines. Most transformers in operation on the NITS are designed with a capability of 100% continuous loading; 100% Transformer Utilization Factor (TUF). Indications from GridCo therefore suggests that there is adequate transformer capacity on the NITS for the supply of power under normal operating conditions[51].

[51] 2017 Electricity Supply Plan; joint work with GridCo, VRA, Bui Authority, ECG and NEDCo.

2.0 Petroleum Subsector: Oil

2.1 Overview of Petroleum Supply in 2016

Saltpond field

There was no production from the Saltpond field since it has apparently been closed.

Jubilee field

Total oil production from the Jubilee field in 2016 on the other hand was around 26.9 million barrels compared with 37.4 million barrels in 2015 and 37.2 million barrels in 2014.

Average daily oil production from the Jubilee field dropped from about 106,938 in 2015 to around 94,200 barrels in 2016, unable to reach the target of 120,000 barrels per day as projected by the industry since 2012 (*see Figure 6*).

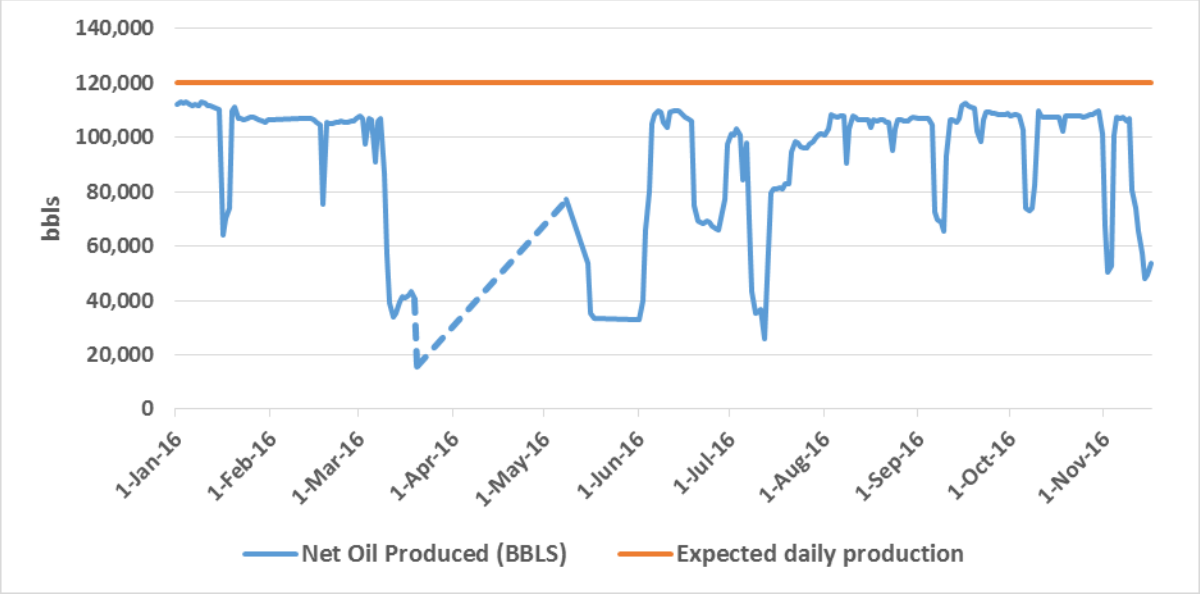

Figure 7: Jubilee field daily oil production in 2016

Mean daily production was fairly stable averaging over 100,000 barrels from the beginning of the year until April when field operation was shut down for maintenance. It returned in late May with daily production unstable until September when the production returned to pre-maintenance levels of over 100,000 barrels.

Crude Prices

In 2016, crude oil from the Jubilee field was sold at an average price of about $40 per barrel compared with about $51 per barrel in 2015. It started at an average price of about $30 per in barrel January and reached the highest of $56 per barrel in June then started to fall again till August when TEN[52] fields produced its first oil. It then averaged $46 per barrel till the end of the year with Jubilee field oil accounting for about 84% of the sales.

Average price of crude oil sourced by Ghana in 2016 for the refinery was about $46.5 per barrel compared to $54.5 per barrel in 2015 (*see Table 13*).

The annual average for power generation however was about $55 per barrel.

Table 13 compares the Ghanaian sourced oil prices to those of West Texas Intermediate (WTI) representing the United States and the London Brent representing Europe.

Table 13: Average crude oil prices in Ghana, United States (Gulf Coast), and Europe (the North Sea).

Year	Ghana	WTI Gulf Coast/ United States	Brent Crude North Sea/ United Kingdom
	U.S dollars per barrel		
2010	80	79.4	70
2011	111	94.9	111
2012	113	93.3	112
2013	109	97.9	109
2014	99	93.3	99
2015	54.5 (60)*	48.7	52
2016	46.5 (55*)	43.3	43.7

**for power generation.*
Source: Bank of Ghana, LondonGasPrice.com, tradingnrg.com; www.statistica.com

Global Scan

The global economy growth is projected to pick up from below about 2.4% in 2016 to 2.7% in 2017 amid a pickup in manufacturing and trade, rising confidence, favourable global financing conditions, and stabilizing commodity prices. Average growth in advanced economies is also expected to improve from 1.7% in 2016 to 1.9 percent in 2017 after a drop from 2.1% in 2015. Growth in emerging market and developing economies would equally recover from an average of 3.5% in 2016 to 4.1% in 2017 after a drop from 3.6% in 2015[53].

[52] Tweneboa, Enyenra & Ntomme oil fields. The TENS lie in the Deepwater Tano offshore of Ghana.
[53] Global Economic Prospects, 2017, The World Bank.

Average growth in Sub-Saharan Africa was projected to be 3.3% for 2016 but sharp deceleration to 1.3% for the year. It is however expected to recover to 2.6% in 2017. The upturn reflects recovering global commodity prices and improvements in domestic conditions. Most of the rebound would come from the continent's two largest oil exporters - Angola and Nigeria[54]. Growth in Sub-Saharan Africa had earlier dropped from 4.6% in 2014 to about 3.1% in 2015 and this was attributed to the fall in oil prices and other primary commodities.

East Africa remains the fastest growing region, with an estimated growth of 5.1% in 2016 projected to grow by 5.4% in 2017[55].

For West Africa dominated by Nigerian's oil production, average growth in the region was severely constrained at 0.4% in 2016 due to largely the economic downtown of that country[56]. However, with improvements in oil production in Nigeria and rising global commodity prices as well strong economic gains made largely in the francophone countries West Africa is expected to record improvements in growth from the 0.4% in 2016 to 2.5% in 2017.

Domestic consumption and stocks in 2016

Crude oil imported for domestic consumption increased from about 310,000 tonnes (~2.1 million barrels) in 2015 to about 1.45 million tonnes (~10 million barrels) in 2016 after a drop from 693,000 tonnes (~4.85 million barrels) in 2014. Thus a return to levels of consumption before 2014.

Electricity production accounted for about 32% (*compared to 80% in 2015*) of the crude oil consumption whilst primary refinery operations accounted for the remaining 68%.

Total products supplied in 2016 however dropped to 3.3 million tonnes (*a little over the same level in 2014*) from around 3.5 million tonnes in 2015. This had been attributed to the significant improvement or elimination of the load-shedding which consequently led to the decreased gasoline and diesel consumption, fuels largely used by individual back-up genset.

The great product movers were Premix, ATK and Kerosene (*see Table 14*).

LPG supplied increased slightly over the previous year and largely coming from significant increase in local production. Import was slightly lower than last year. LPG production is being boasted by the Atuabo gas processing plant which is churning out more LPG as by-product of processing wet/rich associated gas to dry/lean gas for power production (*see Table 15*).

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[54] Global Economic Prospective: Sub-Saharan Africa, 2017, The World Bank.
[55] African Economic Outlook, 2017, African Development Bank.
[56] Nigeria accounts for 72.4% of the region's overall GDP but contracted by -1.5% in 2016. African Development Bank, Africa Economic Outlook 2017.

Table 14: Petroleum products supplied to the Economy for 2013-2016.

PETROLEUM PRODUCT	2013	2014	2015	2016	CHANGE		
					b/n 2013 & 2014	*b/n 2014 & 2015*	*b/n 2015 & 2016*
	1000 tonnes				*Percentage*		
LPG	251.8	241.5	279	281.5	*-4.1*	*15.5*	*0.9*
Gasoline	1,080.6	1,102.3	1,163.2	1,069.2	*2.0*	*5.5*	*-8.1*
Premix	53.4	56.2	47.2	56.0	*5.2*	*-16*	*18.6*
Kerosene	27.8	9.3	6.9	8.1	*-66.5*	*-25.8*	*17.4*
ATK	131.9	113.9	112	132.2	*-13.6*	*-1.7*	*18.0*
Gas oil/diesel	1,722.6	1,713	1,902.7	1,765.0	*-0.6*	*11.1*	*-7.2*
RFO	39.3	26.8	13.4	12.9	*-31.8*	*-50.0*	*-3.7*
Total	**3,307.4**	**3,263.1**	**3,524.4**	**3,324.8**	***-1.3***	***8***	***-5.7***

Source: National Petroleum Authority, 2017.

Table 15: Petroleum products produced locally, imported and Exported from 2013-2016.

PETROL PRODUCT	2013			2014			2015			2016		
	1000 tonnes											
	Pro	**Imp**	**Exp**	**Pro**	**Imp**	**Exp**	**Pro**	**Imp**	**Exp**	**Pro**	**Imp**	**Exp**
LPG	25.3	203.9	0	3.3	236.4	0	2.0	197.7	0	114.2	177.9	25.1
Gasolines	167.3	1017	36	40.4	1254	10.2	31.8	1182	9.9	244	1235.7	271.6
Kerosene	14.6	0	0	4.5	0	0	0.2	0	0	24.5	0	0
ATK	59.8	41.4	122.3	9.4	112.4	105.6	18.2	109.1	101.9	37.6	112.7	115
Gas oil	113.3	1639	51.8	27.8	1742	10.8	28	2161	10.3	254.7	2161	170.1
RFO	43.5	44.3	3.7	43.7	48.6	0	8.9	0	0	64	20.6	69.8
Total	**424.2**	**2946**	**213.8**	**129.2**	**3394**	**126.6**	**89.1**	**3650**	**122.1**	**739**	**3266.7**	**651.6**

Pro refers to production at the TOR and Atuabo; **Imp** refers to imports while **Exp** refers to exports. NB: *Diesel export is largely sales to international bunkers. ATK export is sales to international aviation bunkers. Gasoline export is largely heavy gasoline.*

*Source: Tema Oil Refinery and National Petroleum Authority***.**

2.2 2016 Forecast and Actuals

Average Brent price for refinery operations was $46 per barrel falling within our forecast; faring better than global projections made elsewhere.

LCO however for power operations was on the high side as usual, averaging $55 per barrel for the year (*see Table 16*).

Table 16: Yearly average crude oil prices for 2016: Forecast and Actuals.

	Ghana		WTI & NYMEX Gulf Coast/ United States	Brent Crude North Sea/ United Kingdom
	Brent	**LCOs***	**LCOs**	**Brent**
Forecast	45-50	40-45	34	37
Actual	46.5	45#	43.3	43.7

** Other light crudes / U.S refiner*
 # largely influenced by power generation requirements
Source: Bank of Ghana, U.S EIA Short Term Energy Outlook, 2016, 2017

Crude oil for refinery at Tema Oil Refinery (TOR) was about 989 thousand tonnes accounting for almost 68% of the total crude oil imported in 2016. Thus gradually approaching pre-2011 refinery levels even though still below half of TOR refinery capacity of about 2 million tonnes per annum *(see Table 17).*

Table 17: Operating performance of Tema Oil Refinery with and without the RFCC[57].

	Without RFCC		With RFCC	
	Tonne per year	**Weight %**	**Tonne per year**	**Weight %**
Technical operational capacity in tonnes	1,995,000	100	1,995,000	100
Products				
LPG	26,136	1.3	114,944	5.8
Gasoline	300,273	15.1	580,615	29.1
Naphtha	38,595	1.9	0	1.9
ATK/kerosene	270,629	13.6	270,629	13.6
Diesel	716,206	35.9	798,034	40.0
Fuel Oil	582,994	29.2	71,575	3.6
Consumption/Losses	*60,379*	*3.0*	*119,930*	*6.0*

Adapted from Tema Oil Refinery data

The Tema Oil Refinery (TOR) comprises a Crude Distillation Unit (CDU) with a production capacity of 45,000 barrels per day (bpd) and a 14,000 bpd Residual Fluid Catalytic Cracker (RFCC) unit to process the Residual Fuel Oil (RFO), which is a by-product of crude oil processed by the CDU, into more diesel, gasoline and LPG *(see Table 17).*

[57] RFCC is Residual Fuel Catalytic Cracker.

Crude oil in stock would still have to be refined into usable end products. With the commercial oil production, Ghana stands to gain immensely if immediate steps are taken to expand the refinery capacity of the country. All things being equal, it costs less to import crude oil for refining locally than importing the finished products.

A new crude oil furnace is currently being installed at the TOR, which is expected to increase the production capacity of the Crude Distillation Unit (CDU) to 60,000 barrels per stream day. It could not be completed in 2016 as originally scheduled but more likely by close of 2017.

The supply of all petroleum products with the exception of ATK were below the low economic growth projections of 4-4.5% for 2016. The total product deficit was about 275 tonnes (*see Table 18*). This contributed to the lower than expected GDP growth in 2016.

Table 18: Comparison of major petroleum products consumption in Ghana in 2015 and 2016[58].

PRODUCTS	2015 CONSUMPTION			2016 CONSUMPTION		
	1000 Tonnes			1000 Tonnes		
	Forecast	**Actual**	**Net /shortfall***	**Low-side Forecast *4-4.5%***	**Actual**	**Net /shortfall***
Gasolines	1,150-1,200	1,210.4	10.4	1,300-1,400	1,125	(175-275)
Diesel	1,760- 1,850	1,902.7	52.7	2,000- 2,100	1,765	(235-335)
Kerosene /ATK	240 - 250	118.9	(121.1-131.1)	125 - 136	140	4
LPG	300 - 350	279	(21-71)	290-300	282	(8-18)
Total	***3,450 3,650***	***3,511***	***(71-139)***	***3,450 3,650***	***3,312***	***(4-275)***

NB: Total diesel consumption includes sales to the mining companies and bunkering.
Total gasoline consumption includes premix and other premium formulations.
Petroleum supply shortfall in brackets ( )
** Low-side implies high efficient fuel consumption.*

ATK supply has continued to drop since 2014 and this has been attributed to its relatively high cost in the country. ATK supply shortfall in the country in 2013 compelled a number of foreign airlines to make alternative refuelling arrangements with neighbouring countries before landing or taking off in the country. The shortfall in kerosene has largely been due to the shifts from its usage for lighting and cooking to better options.

LPG supply improved slightly though still below forecast. This was largely due to the operations of the Atuabo Gas Processing Plant which is producing LPG as by-product from processing the wet associated gas from the Jubilee Field into dry gas largely for electricity generation. Import however still dominated; about 56% of the total stock. Some LPG was exported for the first time since 2009 though just about 8% of the total stock.

[58] In this analysis, products supplied to the economy were assumed to be consumed.

2.3 Forecast for 2017

For 2017, we project the average oil production at Jubilee field to stay within **90,000-105,000** barrels as global crude oil prices increase to within $50-56 during the year.

Further, we forecast that average Brent crude oil that Ghana buys would lie within **$53-58** per barrel and **$48-52** per barrel for other light crudes for refinery operations (*see Table 19*). Average delivery price of light crudes for power production would be within **$58-60** per barrel.

Table 19: Forecast for average light crude oil prices for 2017.

FUEL BRAND	Ghana	United States EIA (WTI and NYMEX)	Europe[59] (UK & Holland)
	US dollars per barrel		
Brent crude	53-58	52.4	51-55
Other light crudes/ U.S refiner	48-52	49.7	49-53

Jubilee field oil was exported at an average price of $40 per barrel in 2016. We project the average price in **2017** to increase to **$50-51** per barrel due to the rising crude oil prices on the global market.

For **2017**, the total petroleum product requirement would as usual depend upon the performance of the economy and it is projected as found in Table 20.

3.7-3.9 million tonnes, equivalent to 70,000-75,000 barrels per stream day refinery capacity, (*12-18% more than in 2016*) would be required to enable the country's economy perform better than in 2016.

The requirement for diesel (gas oil) includes demand by the mining and the petroleum upstream industries. Diesel constituted about 53% of the total products demand in 2016. Improvement and normalisation of grid power supply however is likely to reduce diesel demand by 1% or remain same keep it same as last year. Gasoline demand is however likely to inch up by 1%.

However, to meet the target of the **6.3% economic growth for 2017**, it would require at least 4 million tonnes of products with gasoline and diesel having an average share of 35% and

[59] London and Rotterdam trading for Brent averaged $51-53 for 2017. www.tradingeconomics.com World Bank forecasts $55 per barrel and IMF forecast $49 per barrel or 2017.

54% respectively due to the expected growth of the Agricultural and Service sectors of the economy (*see Table 20*).

Table 20: Forecast for petroleum product requirement for 2017.

PRODUCT	National supply requirement 1000 Tonnes	
	For marginal economic growth >4%	**For economic growth ≤6.3%**
Total Gasolines	1,300 -1,400	1,700-1,800
Total Diesel	2,000 - 2,100	2,300-2,400
Kerosene	10-15	16-20
ATK	140-160	200 – 220
LPG	290 – 300	320 – 350
Total	***3,740-3,975***	***4,516-4,790***
Equivalent refinery capacity	***70-75 per day***	***85-90 per day***

For LPG, at least half of the total LPG requirement is expected to come from local production. Less than a third is likely to come from TOR due to the on-going retrofit and expansion works at the facility.

To achieve a 50% nationwide penetration of LPG, the consumption would require an LPG supply of at least 450,000 tonnes by 2020 based on an estimated population of 31-32 million by the end of the decade.

Increasing refinery capacity and revamping of TOR would also increase its production of LPG.

The total national LPG storage capacity coverage is however a challenge, since the distributions are largely found in coastal to middle Ghana. National LPG penetration share of households increased from 6% in 2000 to 18% in 2010 and 22.3% in 2013[60]. Government is targeting 50% penetration by end of 2020 but it is not likely to be achieved if the existing limited distribution outlets nationwide remain the same. The limited storage capacity nationwide would thus continue to constrain the local distribution and access.

Government measures put in place to support and accelerate the supply and use of LPG include:

[60] 2010 Population Census, Ghana Statistical Services. 2013 data is from GLSS 6, 2014, Ghana Statistical Services.

- Re-capitalising the Ghana Cylinder Manufacturing Company (GCMC) to expand production capacity and focus on the production of small sized cylinders that would be portable and affordable to households in rural communities.
- Constructing LPG storage and supply infrastructure in all regional and district capitals in the long term.

About 50% LPG supplies could come from the Atuabo gas facility processing the wet associated gas from the Jubilee field. For instance, processing 100 mmscfd of the wet gas would provide at least additional 500 tonnes of LPG a day, which would be enough to meet the country's projected short to medium term demand of 400,000-450,000 tonnes per annum by 2020[61]. Ability to meeting this supply requirement would translate into achieving the country's target of **50%** penetration by 2020.

However, LPG supply from Atuabo, would have some challenges if sent directly to the domestic market without paying attention to its peculiar nature. Atuabo LPG is a natural gas refining product and thus would have different characteristics from that of TOR since the latter is a crude oil refining product.

For instance, the propane level in the Atuabo LPG is said to range from 50-70% whilst butane constitutes the remaining depending on the blend for the consignment.

LPG from TOR is processed to constitute is a mixture of about 20% propane and 80% butane and this ratio has also been used to regulate the import market.

Besides, natural gas by its nature is odourless and so its LPG is relatively of less odour compared to that from crude oil processing.

Higher penetration of the Atuabo LPG thus would require more attention in terms of safety and standardization and also more public education to avoid potential fire hazards in homes.

Refinery capacity

The Tema Oil Refinery (TOR) was supposed to refine all the crude oil needs of the country with the exception of the consignments meant for power generation. The country's annual petroleum requirement has however exceeded the capacity of TOR by more than 50% assuming TOR is operating even at 90% capacity utilisation.

Capacity utilisation at TOR was about 37% in 2016. However worsened from about 5% in 2013 to just around 3.1% in 2015. Based on international standards, at least 90% capacity utilization is required for refineries to achieve economic viability.

[61] Assuming short term is 1-2 years; 2015-2016 and medium term; 2015-2020.

On the other hand, the prevailing low global oil price regime is an incentive for the refinery to make profit perhaps for the first time in many years; all things being equal and in a de-regulated market, the lower the input (crude oil) price the higher the profit margins on the outputs (products).

Thus, providing at least **1.5 million tonne (about 11 million barrels**) for the refinery, *(i.e. at least 70% equivalent to about 30,000 barrels per stream day*) during the year could help break-even for TOR operations, depending upon the production configuration.

Strategic reserves

Fuel supply security and the erratic prices of fuel have advised countries to set up strategic stocks for both crude oil and refined products. Most developed countries, for instance, the OECD[62] members have agreed on a minimum of six months of strategic stocks. However, with the prevailing low global oil prices, many of them had taken the opportunity to expand their crude oil reserves beyond the minimum to years.

Ghana decided on a similar measure in the 1990s and is supposed to maintain three weeks of strategic stocks of refined products on the average. However, most gasoline formulas when bought from open market are cracked petroleum products, meaning coming from the cracker units of refinery instead of straight-runs. Cracked gasoline and products have relatively short lifespan, usually not more than three months compared to straight-run products. This also means such cracked products must be used within three months of their storage to avoid gum formation. Straight-run gasoline and products last longer but more expensive, even then just a couple of years. Crude oil storage however, has the comparative advantage of far longer lifespan and could even be indefinite depending upon the blend and state. Among the long term strategy recommended under the SNEP 2006-2020 therefore was to expand the strategic stock to include crude oil.

Energy Commission reiterates that just as with the OECD countries, the global low oil price regime is an opportunity for BOST to implement and include crude oil in its existing strategic stock for the country.

[62] OECD is Organisation for Economic Cooperation and Development.

3.0 Petroleum Subsector: Natural Gas

3.1 Overview of Natural Gas Supply in 2016

Total gas flow in 2016 was 26,960,056 mmBTU (26,960 mmscf) and it was almost half that of 2015[63]. About 15% (*44% in 2015*) was from Nigeria via the WAGP and the remaining 75% (*56% in 2015*) coming from the Atuabo gas processing plant.

About 26% (*51% in 2015*) of the gas was supplied to the Sunon-Asogli thermal plant in Tema and the remaining 74% (*49% in 2015*) comprising largely indigenous gas (i.e. the Jubilee field) went to the VRA thermal plants at Takoradi.

3.2 2016 Forecast and Actuals

Average gas flow from the WAGP was 13 mmscfd which was far below the projected 50-70 mmscfd. The very low flow was due to non-payment of gas by the Ghana side.

Average gas flow from the Jubilee field was 60 mmscfd compared to the projected 80-100 mmscfd. The deficit was largely due to limited gas supply at the source (well-head) at the Jubilee field.

The WAGP delivery gas price averaged $8.13/mmBTU ($8.28/mscf) for foundation customers during the first half of the year (*see Table 21*). It was about 9% drop from 2015.

Table 21: Pricing Component for WAGP Delivered Gas for Foundation Customers in 2016

Details	Customer Price		
	2015	Jan-Jun 2016	Jul-Dec 2016
	$/mmBTU		
Gas Purchase	1.6171-2.2901	1.4870	1.2582
ELPS Transport	1.2959	1.2983	1.2983
WAGP Transport	5.0265	5.0330	5.0330
WAGP Credit Support Charge*	0.1299	0.9765	0.9765
WAGPA Charge	0.0600	0.0600	0.0600
Pipeline Protection Zone Charge	0.0250	0.0250	0.0250
Shipper Fee	0.1000	0.1000	0.1000
Fuel Charge**	0.0583-0.0717	0.1308	0.1823
Delivered Gas Price ($/mmBTU)	**8.2544-8.9274**	**8.1341**	**7.9568**

Note: **Credit Support Charge is a monthly lump sum charge and NOT an actual charge per MmBTU. The $0.9765/MmBTU shown above is a calculated average charge based on the average monthly throughput from January to December 2016*

[63] Total gas flow in 2015 was 46,911,854 mmBTU (46,912 mmscf).

The WAGP delivery gas price further dropped to $7.96/mmBTU ($8.11/mscf) for foundation customers and during the second half of 2016 due to its indexation to prevailing oil price *(see Table 21).* The second half of the year's price was thus about 4% drop from 2015.

The delivery prices were however below our projections for 2016[64] but the supply was far below what was projected and for that matter made the price gains insignificant.

The Jubilee gas delivered price was as usual uniform at $8.842/mmBTU ($9.01/mscf) throughout the year *(see Table 22).*

Table 22. Jubilee-Atuabo Delivered Gas Price in 2016.

Details	Customer Price for 2017
Gas commodity price	2.9
Gathering, Processing & transportation	5.28
PURC levy	0.66
Delivered Gas Price ($/mmBTU)[65]	**8.84**

Energy Commission, 2016.

Comparatively, average spot (Henry Hub) price in the United States in 2016 was $2.51/mmBTU ($2.75/mscf) which was above the global projected price of $2.25 per mmBTU ($2.47 per mscf) [66].

Average gas price in the European Union (EU) fell from about $7.26/mmBTU ($7.39/mscf) in 2015 to $4.56/mmBTU ($5/mscf) in 2016[67]. The EU Natural Gas Import Price dropped from $5.35/mmBTU ($5.86/mscf) beginning of 2016 to around $4.10/mmBTU ($4.50/mscf), by mid-year, then started climbing again to $5.50/mmBTU ($6/mscf) by close of the year[68].

3.3 Forecast for 2017 and beyond

For **2017**, we maintain the projection made for 2016; we expect the annual weighted average delivery price of gas to VRA to remain within **$8.7-8.75/mmBTU** ($9.53-9.59/mscf)**[69].** We project the foundation price to remain within **$7.96-8.13/mmBTU** ($8.11-8.28/mscf) during first half of the year but would increase to **$8.25-8.30/mmBTU** ($8.40-8.45/mscf) during the second half**.**

[64] For 2016, we projected the WAGP delivery price to VRA as $8.25-8.30/mmBTU ($8.40-8.45/mscf) during the first half of the year but increase to $8.50-8.55/mmBTU ($8.66-8.71/mscf) during the second half. Annual average price to be 8.7/mmBTU.

[65] Delivered gas price is not necessary an absolute sum of the listed charges.

[66] Spot prices usually do not include transportation cost.

[67] Projected price for 2015 was $3.50-4.20/mmBTU.

[68] https://ycharts.com/indicators/europe_natural_gas_price, March,2017.

[69] WAPCo delivers the gas at a lower price to VRA but the latter apparently adds administrative and other costs.

The delivery price of the Jubilee gas on the other hand is expected to remain at **$8.84/MmBTU** ($9.01/mscf) throughout the year.

The average US spot price for gas is projected to increase further from the $2.51/mmBTU ($2.75/mscf) in 2016 to about **$3/mmBTU** ($3.3/mscf) for **2017**.[70] Comparatively, the EU gas import price would range between **$5.4-5.5/mmBTU** ($5.48-6.03/mscf) and largely coming from Russia *(see Table 23).*

The market is nevertheless projected US LNG exports to Europe in 2016 but did not materialised due to the average delivery price estimated at $7-8/mmBTU and which is unlikely to withstand any potential price war with Gasprom of Russia, the latter being capable of coming down to as low as $3.5/mmBTU to price out any potential trans-Atlantic trade (*refer to Annex 3*).

Table 23: Average delivery gas prices in Ghana (WAGP), United States (Henry Hub), and Europe (the North Sea); 2011-2015 and projected prices for 2017.

Year	WAGP+Jubilee/ Ghana	Henry Hub/ United States	Northsea Europe/
	U.S dollars per mmBTU		
2011	6.56	3.59	8.70
2012	8.19	2.75	8.90
2013	8.27-8.38	3.71	10.63-10.72
2014	8.49	4.52	10.05
2015	8.80	3.00[71]	7.26
2017*	**8.7-8.75**	**3-3.1**	**4-5.5** ***(5.48-6.03)****

**forecast ;*
*** LNG forecast price range in bracket. Price range is an indication of where it is coming from.*
Source: Bank of Ghana, LondonGasPrice.com, tradingnrg.com

3.3.1 Gas Supply Challenges

A sustainable and relatively cost-competitive fuel supply to produce affordable power has been the weakest link in the electricity supply value chain. On the thermal side, gas on the average has been cheaper than oil. The key challenges however that have been experienced in the reliability of gas supply include:

i. Inadequate supply;
ii. planned and unplanned supply interruptions; and
iii. finance - domestic and international payment deficits.
iv.

[70] US EIA Short Term Energy Outlook, March, 2017.
[71] Estimates from US EIA Short Term Energy Outlook, 2017

Inadequate gas supply

With the number of thermal power plants currently installed and expected to be in operation by 2017, the supply requirement by the end of the year including potential demand by the power rentals is expected to be between **400-450 mmscfd**. However only about an average of 100 mmscfd would be available and provided the projected required amount of fuels are supplied. This translates into a deficit of **300-350** mmscfd.

Indigenous gas and LNG to the rescue

Even though, the country can boast of about five (5) trillion standard cubic feet per day (tscf) of proven gas reserves, exploitation would depend on the demand and the delivery cost to the market.

Besides the associated gas from the Jubilee field, more gas is expected from other neighbouring fields in the short to medium term. The most prominent being the TEN (Tweneboa-Enyenra-Ntomme) fields which commenced in 2013 produced its first oil during the third quarter in 2016 and with about 1.3bcf of gas. The TEN fields and is expected to produce an average gas supply of 63-70 mmscfd and between 30,000-50,000 barrels of oil a day. Gas production is expected ramp up in 2017 yielding an average of 90 mmscfd of gas for over 20 year operational lifetime.

The US$7.9 billion project - Sankofa and Sankofa East fields, another neighbouring fields to the Jubilee field presents the most significant proven non-associated gas discovery in recent times. Estimated yield is about twice the projected average yield from Jubilee; about 185 mmscfd. Wellhead price is estimated to be $6-9 per mmBTU[72].

First oil from Sankofa and Sankofa East fields estimated at 30,000 barrels per day is expected by end third quarter of 2017 whilst the gas phase is expected to be completed during the first quarter of 2018 with the first gas being delivered by the end of that quarter.

Production from these new fields would make available an average total of 300-500 mmscfd by 2020 if developments of the fields are carried out as planned [73].

Total gas supply however is not likely to exceed **500 mmscfd** though demand for power generation could go past **800 mmscfd** by 2020**.**

Thus, establishing the fact that the indigenous gas would still not be adequate to meet the gas requirements for the medium-to-long term requirements of the country, Ghana is therefore looking at supplementing the gas supply with LNG imports.

[72] Natural Gas Pricing Policy for Ghana, Final Report, World Bank, May 2012, consultant- R. Garcia Consultores S.A

[73] World Bank\ Energy Group report, June, 2013.

LNG Option

An estimated deficit of about **300-350 mmscfd** by 2020 is within the breakeven point for a typical 200-250 mmscfd LNG re-gasification facility.

LNG supply option (*see Annex 4*) however could be relatively expensive compared to local or the WAGP gas. Nonetheless, it has the potential to be cost-competitive and perhaps cheaper this time for possible shipments coming from the United States which for the first time in 2016 began shipment of LNG from its shores. Even though average base price of gas could average $2/mmBTU *(see Table 25)*, refrigeration into LNG averages $5/mmBTU and shipment could range between $1-3/mmBTU depending upon shipment location and the volumes involved.

Potential LNG supplies are also likely to come from cargos plying between Western African (Nigeria and Angola) and the European markets. LNG cargoes from Nigeria accounted for 3% of United States' LNG supply in the past but there has not been any shipment since 2014, prompting shippers to look for alternative markets such as the growing Asian market.

Ownership and financing arrangement would also have a significant impact on the cost of the delivered gas. Ownership can be Joint Venture - shared cost between a Ghanaian and foreign partners; Public or State Private Partnership (PPP); or facility wholly owned by a foreigner investor.

PPP through state participation by providing sovereign guarantee is likely to reduce cost further due to potential decrease in risk cost.

Table 24 presents a qualitative analysis of the likely cost range for the country if an LNG regas facility is built in the country.

Table 24: Estimated LNG cost range for potential cargo shipments to Ghana.

LNG Cargo Destination	**Ownership/Financing Arrangement in US dollars per MmBTU***			
	PPP	Joint Venture/ Shared Cost	Operator wholly owned	***Add*** Construction of off-loading/regas berth
Potential cargos from USA	6-7	7-8	8-9	1.0-2.0
Nigerian cargo originally destined to USA	6-7	8-9	9-10	
From Nigeria en-route to Europe	7-8	9-10	11-12	
Angolan cargo originally destined to USA	7-8	9-10	10-11	
From Angola en-route to Europe	8-9	11-12	13-14	

**Assuming operating life time of 5-10 years and minimum delivery volume of 200 mmscfd*

As mentioned previously, although most of the gas would be used for power generation, there would still be gas demand for industrial purposes such as heating and as feedstock but would also depend upon quantities available and the base price of the gas delivered. The resulting scenarios would thus likely be as follows

- Industrial use of gas is not likely to be realised until after 2020 and beyond.
- that a typical urea-fertilizer plant with a minimum capacity of 800,000 tonnes per year would require about 50 mmscfd but would not be available until after 2020, if construction is even to start in 2018. Also, it would require a delivered gas price of not more than $3/mmBTU on the average.
- that a typical methanol plant with a minimum capacity of 800,000 tonnes per year would require about 70 mmscfd but would not be available until after 2020, if construction is even to commence in 2018. Such a plant would require a delivered gas price of not more than $5/mmBTU on the average.

Progress of Planned LNG projects

The Ghana National Petroleum Corporation (GNPC)[74] in 2017 signed an agreement with a private company, Quantum Power for the latter to construct and operate a 500 mmscfd[75] floating LNG storage, regasification and delivery facility moored offshore Tema. The US$550 million facility is said to be on BOOT[76] basis with the assets said to be transferred to GNPC after 20 years of operation. The project is not likely to be operational this year as originally estimated but in 2018.

Interruptions both planned and unplanned

There had been some interruptions due to planned servicing and unplanned shutdown. Shutdowns at Jubilee fields would require back-up supply from WAGP gas Nigeria which currently is already inadequate and power imports from neighbouring la Cote d'Voire if available.

Shut downs at the Atuabo gas processing plant would require the two mentioned external reinforcements but also alternative supply arrangement when the Jubilee gas is available.

Plans are thus underway to install a spare overhead compression system in the course of the year, in order to minimise the downtime and to guarantee continuous plant operation. These would contribute to ensuring an uninterrupted supply of sales gas to the downstream consumers (*see Chapter 5.2*).

[74] The National Oil Company (NOC)
[75] 3.4 million tonnes of LPG per year.
[76] Build Own Operate Transfer

Finance – domestic and international payment deficits

Inadequate gas supply from Nigeria through the WAGP could not only be due to capacity challenges in Nigeria but finance as well *(see Annex 4).* Persistent untimely payment of gas delivered and the huge debt burdens of the off-takers most of the public entities are the bane or the weakest link along the electricity supply-distribution value chain. For instance, the Volta River Authority (VRA) has been indebted to N-Gas of Nigeria for gas supplied since 2016.

On the domestic side, VRA owes Ghana Gas Company for gas supplied from Atuabo, since 2016. GhanaGas in turn could not pay GNPC, the current national gas aggregator, because of the debt chain, considering that the aggregator is also currently experiencing revenue shortfalls due to the prevailing low prices of crude exports.

On the distribution or retail end, the Electricity Company of Ghana (ECG) is unable to settle its debts to the generation and the supply utilities because of untimely payments by mostly government and its agencies leading to legacy debts that have the potential of collapsing Ghana's power sub-sector. ECG itself by operation is also able to collect less than 70% of its revenue annually and consequently making the distribution subsector the weakest link in the electricity supply and distribution cycle or value chain. Notwithstanding, the ECG has signed a number of PPAs (Power Purchasing Agreements) with a number of Independent Power Producers (IPPs) with apparently not much due diligence to the price of the electricity to be supplied in terms of cost-competitiveness.

Whilst a mature, strong and transparent regulatory environment would generally offset the need for such guarantees especially for commercial risks, this is hardly the case in Ghana. For this reason, most of the incoming independent power producers (IPPs) have been demanding the government to guarantee ECG's payments through Government Consent and Support Agreement (GCSA) before proceeding to the construction stages of their capital investments. These GCSAs normally indemnify the investors against all manner of commercial as well as political risks.

However, owing to the current fiscal challenges facing the economy as well as to forestall the financial sustainability of the electricity supply-distribution value chain, the government is intervening with among many measures the, the following:

- In a major policy shift, either a Partial Risk Guarantee (PRG) or Put/Call Option Agreement (PCOA) is issued as a credit enhancement instrument in place of the GCSA[77]. Under a PCOA, the buyer, which in this case is the ECG and the government shall have a 'call option' over all the shares upon early termination of a PPA while the seller and its shareholders have a 'put option' over the shares upon

[77] Well illustrated in the February, 2016 edition of the Ghana Wholesale Electricity Market Bulletin - Market Watch, p7-8. Available at Energy Commission's website www.energycom.gov.gh/datacenter

early termination due to a breach of the PPA as may be duly specified in the agreement.

- ECG has been made to suspend signing new PPAs without authorisation from the sector Minister. A ceiling has also been imposed on the size of the power plant particularly with renewable power plant with all PPAs and/or quotations being subjected to tender to select the least cost and most favourable bidder. Millennium Development Authority (MiDA) is also providing support at looking into partial privatization of electricity distribution and retailing by inviting the private sector to participate in the operations and management of ECG.
- To safeguard the financial operations and assets of the Ghana Gas Company, the government ordered the GNPC to entirely takeover its management and operations. The process however still lingers on, with reasons being attributed to administrative and legal challenges, more so, when GhanaGas says its credit-worthiness has now improved significantly and now sustainable.

4.0 Woodfuel Subsector: Charcoal demand and prices

In 2016, the average prices of charcoal in the country followed the historical increasing tread, for mini bag, it rose to a little over GH¢21 from about GH¢20 in 2015 whilst for the maxi bag, it was from about GH¢31 in 2015 to about GH¢34. The 2016 increases however were just about 4-6% for the mini-bag compared to about 21% and about 10% compared to 24% for the maxi-bag respectively in 2015 *(see Table 25 and Annex 7).*

Table 25. Average price per bag of charcoal in the ten regions for 2015and 2016[78].

Region	**Mean Price per Mini bag in Ghana Cedi (GH¢)**			**Mean Price per Maxi bag in Ghana Cedi (GH¢)**			***Percentage change in mean prices 2014/2015***	
	2015	**2016**	***% change***	**2015**	**2016**	***% change***	***Mini***	***Maxi***
Ashanti	15.12	16.66	*10.2*	22.91	26.23	*14.5*	***19.00***	***18.54***
Brong Ahafo	12.15	13.61	*12.0*	20.27	22.48	*10.9*	***31.80***	***28.20***
Central	31.00	28.52	*-8.0*	39.03	41.44	*6.2*	***31.72***	***39.03***
Eastern	21.51	21.51	*0.0*	30.55	30.55	*0.0*	***29.46***	***25.54***
Gt. Accra	26.61	26.99	*1.4*	37.10	38.68	*4.3*	***26.61***	***22.62***
Volta	28.28	17.17	*-39.3*	49.50	28.16	*-43.1*	***36.83***	***35.90***
Western	21.68	22.75	*4.9*	32.96	36.67	*11.3*	***19.15***	***15.32***
Northern	15.79	15.66	*-0.8*	25.32	28.97	*14.4*	***22.56***	***14.33***
Upper East	23.00	30.83	*34.0*	34.45	53.74	*56.0*	***13.02***	***12.38***
Upper West	15.47	23.85	*54.2*	23.00	37.00	*60.9*	***30.43***	***26.05***
National	***20.14***	***21.67***	***7.6***	***31.35***	***33.92***	*8.2*	***20.88***	***24.03***

[78] The price survey was conducted in the district capitals and computed as average for each region.

The average percentage increment of about 5% for the year was also far below the 30-35% we projected for the coastal zone in 2016. Greater Accra and the Savannah regions also experienced a moderate increase of about 8-10% compared to the 20-25% projected for the year.

Nonetheless and as usual, the high-price zone were along the coast and the Upper East Region. The low-price areas were also the transitional regions of Brong Ahafo, Northern and Upper West regions followed by the forest regions of Ashanti, Eastern and Western. Interestingly however, there was no price change in Eastern Region and for Central Region, average prices in 2016 rather dropped by about 8% for the mini bags.

For **2017**, we estimate that the average charcoal price increment to remain within 5-10% for both the mini and the maxi bags in the coastal areas of Central, Western and Volta Regions.

Greater Accra and the Savanna regions would experience a moderate increase of 5-8% in 2017. Nationwide, we estimate an average price range to remain within 4-6% for the year due the likely availability of LPG which is an alternative or substitute fuel for charcoal in urban areas.

5.0 The Regulatory Regime

5.1 The Electricity Supply Industry

5.1.1 Licensing and Permitting

The Energy Commission in 2006 established a licensing framework for issuing licences to electricity service providers. The Licensing Manual for service providers in the Electricity Supply Industry was revised and published in 2012, setting the requirements and guidelines for entities desiring to acquire licences to operate in the electricity supply industry.

Under the Licensing framework, provisional and full licences have been issued to entities engaged in the various segments of electricity supply. Besides adding generating capacity to the existing capacity and enhancing service delivery to customers, the licensing regime enhances the Commission's authority to hold the licensees to the terms and conditions stipulated in the licence.

Licences and permits issued by the Commission so far are as follows:

i. Thirteen (13) Power Generation Companies have been issued with Operation Licences with a total capacity of 2,261.5 MW.
ii. Two Electricity Embedded Generation Licences were issued to Genser Power Limited, an IPP to distribute electricity to specific consumers in the distribution network, i.e. 5 MW at Tema and 30 MW at Chirano in the Western Region
iii. The following companies were also granted test and commissioning permits;
    a. Sunon Asorgli Power (Ghana. Ltd) Expansion of 360 MW Combined Cycle at Kpone in the Greater Accra Region;
    b. Ameri Power Limited 250 MW emergency power plant at Aboadze in the Western Region
    c. AKSA Power Limited 203 MW emergency power plant at Tema freezone area.
    d. Genser Power Ghana Limited 31.5 MW Gas Turbine Embedded Generation Plant at Tarkwa in the Western Region
    e. Genser Power Ghana Limited 25 MW Gas Turbine Embedded Generation Plant at Damang in the Western Region
iv. Construction permits have been issued to the following Power companies:
    a. Construction works on the 300 MW Cenpower Generation Plant is on-going and expected to be completed by the end of first quarter of 2018.
    b. Rotan Power Limited 660 MW Combined Cycle at Aboadze in the Western Region was issued in 2016.
    c. Marinus Energy Limited 80 MW Simple Cycle at Anochie near Atuabo in the Western Region.

v. Sixteen (16) Power Generation Companies have been issued with Siting Permits with total generation capacity of **4,555 MW**

v. Provisional Wholesale Electricity Supply licences have been issued to Forty Six (46) potential IPPs with a total capacity of **13,712 MW**,

vi. Sage Power Limited was issued with Electricity Brokerage License as well as Electricity Export Licence.

vii. Enclave Power Company was issued with distribution and sale licence to distribute and sell electricity to customers in Dawa Power Enclave (yet to be constructed) besides its existing operations at Tema.

viii. Bulk Customers of electricity operating in the deregulated Wholesale Electricity Market increased from 33 in early 2015 to 43 as at third quarter of 2017.

5.1.2 Codes of Practices and Regulations

The Commission developed and launched the ***National Electricity Grid Code*** in 2010 to govern the operation of the National Interconnected Transmission System (NITS). The Grid Code specifies in detail the technical operational rules, codes and procedures as well as obligations and liabilities of all players in the market. Complementary to the National Electricity Grid Code, the Energy Commission Board approved the ***National Electricity Distribution Code*** that sets in detail, the minimum acceptable technical standards for the development of the electricity distribution networks, provides guidelines and technical requirements for interconnection and evacuation of embedded generation and other relevant issues related to the safe and reliable management and operation of the Electricity Distribution Network.

The Commission has developed the Electrical Wiring Regulation 2011, L.I. 2008 to regulate electrical wiring in the country.

Pursuant to the above, a certification guideline has been developed. Furthermore, a curriculum for the certification examination was developed in conjunction with the Technical/Vocational Education Directorate of the Ghana Education Service in 2013.

In 2014, The Energy Commission in collaboration with the Technical Examinations Unit, of the Ghana Education Service conducted the first certification examination for potential and practicing electrician for certification as Certified Electrical Wiring Professionals (CEWPs). So far, seven (7) examinations have been conducted. As at third quarter of 2017, about 5,000 electricians had been certified as CEWPs and 84 as Certified Electrical Wiring Inspectors. The examinations are conducted twice in a year at 4 centres (Accra, Takoradi, Kumasi and Tamale).

The Commission also carried out public sensitization activities to create awareness in the general public on the provisions of the Regulations. In addition, the Commission has conducted training programmes in all the regional capitals for the CEWPs.

As part of its implementation, monitoring exercises are being carried out. CEWPs who were suspected to have violated provisions in the wiring regulations were first giving hearing by a Disciplinary Committee and those found culpable were penalized.

5.1.3 Establishment of Wholesale Electricity Market

The Electricity Regulation 2008 provides for the establishment of a competitive wholesale electricity market to facilitate wholesale electricity trading and the provision of ancillary services in the National Interconnected Transmission System (NITS). The Wholesale Electricity Market (WEM) in Ghana, the Electricity Transmission Utility (ETU) shall ensure the procurement and dispatch of electricity from any facility of a wholesale supplier to a bulk customer and distribution utility in a fair, transparent and non-discriminatory manner.

The Wholesale Electricity Market would allow for choice and competition in the wholesale supply of electricity and subsequently create an enabling environment to attract Independent Power Producers (IPPs) into the country.

Further incentive for private sector investment in the Wholesale Supply of electricity is Ghana's interconnection with some neighbouring West African countries, through which the market for electricity in those countries will be opened up to the IPP's in Ghana.

Such a market, in principle, requires to be guided by rules and regulations (backed by legislation) that should essentially reflect the government's broad policy objectives regarding the structure and administrative management and operation of the market.

The Market Oversight Panel (MOP) was thus set up in 2015 and members of the panel had been nominated by the appropriate institutions and had since been approved by the Ministry. The Commission is in communication with the sector Ministry for the inauguration of the MOP. Whilst awaiting the official inauguration, MOP has been publishing a monthly bulletin which is available on the Commission's website[79].

5.2 The Natural Gas Supply Industry

Electricity supply is heavily dependent on the availability of fuel to power the thermal plants. So far, natural gas supply from Nigeria through the West African Gas Pipeline (WAGP) has proven very limited and unreliable primary due to the country's indebtedness to WAGP and

[79] http://www.energycom.gov.gh/index.php/planning/ghana-wholesale-electricity-market-watch-monthly-bulletin

N-Gas[80] supply limitations. The Jubilee field gas is therefore mitigating the supply situation. Gas from the Jubilee field is processed at the Ghana National Gas Company's Gas Processing Plant at Atuabo, which used to experience shutdowns due to a mandatory 4,000hr maintenance of the overhead de-ethaniser compressor. Thus, during such times, there is no gas supply for power generation, hence leading to load shedding if alternative options are not available. To ensure continuous flow of gas, an Overhead Compression Unit was installed at the Atuabo processing plant in 2016 *(see Annex 6).*

5.2.1 Licensing and Permitting

A Licensing Manual for Natural Gas Supply Industry was developed by the Energy Commission in 2008 to serve as a guide for prospective natural gas service providers with regard to licensing requirements as well as assisting in ensuring compliance with codes and standards governing quality, health and safety in the industry as stipulated in the Energy Commission Act, 1997 (Act 541). The manual was reviewed in 2012 to facilitate the accelerated development of the natural gas industry. BOST has been formally licensed as the Natural Gas Transmission Utility Licence to operate the Natural Gas Interconnected Transmission System (NGITS).

The Energy Commission has thus further issued the following licences to players in the Natural Gas industry.

i. Eni is expected to renew its Construction Permit from the Energy Commission during the third quarter of the year to complete the construction of the Onshore Receiving Facility (ORF) at Sanzule, Western Region.
ii. Three (3) Natural Gas Bulk customer Permits were issued in 2016 for downstream offtakers.

As at end of the first quarter, only four (4) companies hold Provisional LNG facility licences. The rest have all expired and have not yet been renewed.

iii. The Commission issued a Natural Gas Wholesale Supply licence to Volta River Authority (VRA) for the importation of gas through the WAGP
iv. Continental Fuels Limited also holds a Provisional Natural Gas Wholesale Supply Licence.

5.2.2 Codes of Practices and Regulations

Since the natural gas industry is still new in Ghana and like any other energy industry, it is important that developers satisfy some basic requirements and comply with established regulation before the construction of facilities takes place. It is in this respect that the Energy Commission has developed the following Legislative Instruments (L.I.) with adopted Ghanaian Standards and which has been approved by Parliament:.

[80] owners of the commodity

i. Natural Gas Pipeline Safety Regulation (L.I. 2189)
ii. Natural Gas Distribution And Sale(Technical And Operational) Rules, 2007(LI 1911)
iii. Natural Gas Distribution And Sale (Standard of Performance) Regulations, 2007(LI 1912)
iv. Natural Gas Transmission Utility(Technical And Operational) Rules, 2007(LI 1913)
v. Natural Gas Transmission Utility (Standards of Performance) Regulations, 2008(LI 1936)

A ***Natural Gas Transmission Access Code*** to establish conditions for Natural Gas Service Providers to have fair, transparent and safe access to the Natural Gas Transmission Network in Ghana has also been developed in accordance with Sections 24, 27 and 28 of the Energy Commission Act, 1997 (Act 541). The Commission however is still developing an ***Occupational Health and Safety Regulation*** with adopted Ghanaian Standards.

5.3 Renewable Energy Update

As at March, 2017, 90 Provisional Wholesale Electricity Supply Licences had been issued to potential Independent Power Producers (IPPs) proposing to develop a total of about 5,000 MW of electricity from various renewable energy sources. 60 of the licences issued are for solar photovoltaic (PV) generation with a total capacity of about 3,000 MW. As at end of 2016, 15 licences were issued a total capacity of 961 MW compared with 29 with total capacity of 2,155 MW in 2014.

About 30 licensees have moved to the Siting Permit stage of the licensing process of which about 25 are for solar PV. However, only three (3) companies have been issued with Construction Permits to develop a solar PV project. A Construction Permit has also been issued for a 225MW wind project.

The Sector Ministry, through the Energy Commission begun the implementation of a Rooftop Solar Photovoltaic (PV) Programme in the country in February 2016. The primary objective of the programme is to provide 200 MW peak load relief on the national grid through solar PV technology in the medium term.

The first phase of the programme is targeted at the installation of 20,000 rooftop solar PV systems in residential facilities (homes) under a Capital Subsidy Scheme, where solar panels up to a maximum of 500 peak Watts (Wp) are given to prospective residential applicants after the prospective beneficiary has satisfied the following conditions:

i. Changed all lamps in his/her facility to LED lamps; and
ii. Purchased and installed the requisite Balance of System (BoS) components such as inverter, batteries, charge controllers, change over, etc. from an licensed solar vendor[81], whose products meet the minimum Technical Standards set by Ghana Standards Authority (GSA).

[81]Solar vendor licensed by the Energy Commission

As at end of 2016, over 2,000 applications had been received and processed, -and approvals have been given to over 800 applicants to install a maximum of 500Wp solar panels each out of which, about 440 installations have confirmed installation.

Also, the Energy Commission in collaboration with the Electricity Company of Ghana (ECG) has successfully piloted 33 net-meters equipped with automatic reading mechanism at various residential and commercial facilities. Implementation of the Net-Metering Scheme is expected to officially kick off during the last quarter of in the year.

The Government of Ghana in November 2015 published an invitation for pre-qualification for the procurement of 20 MWp solar PV power. During the first stage of the tender process, 18 bids were shortlisted to subsequently submit proposals. The proposals would be evaluated and ranked for award primarily based on least cost quotation. The award of contract is expected to be issued to BioTherm Pty, a South African based solar PV developer who offered the lowest bid of about 11$cents/kWh.

The Public Utility and Regulatory Commission (PURC) and the Energy Commission are yet to issue the Renewable Energy Purchase Obligations (REPO) to Distribution Utilities and Bulk Customers.

Annex1 – Schematic Overview of Ghana Energy Demand and Supply System

The integrated energy supply feeds the energy-demand economic sectors comprising Residential, Commercial & Services, Agricultural & Fisheries, Transport and Industries. The Energy Supply Sector of Ghana is thus: **Biomass, Petroleum and Power (Electricity),** whilst the Energy Demand sectors of the economy are the **Residential, Commercial & Services, Agricultural & Fisheries, Transport and Industries** (Figure A).

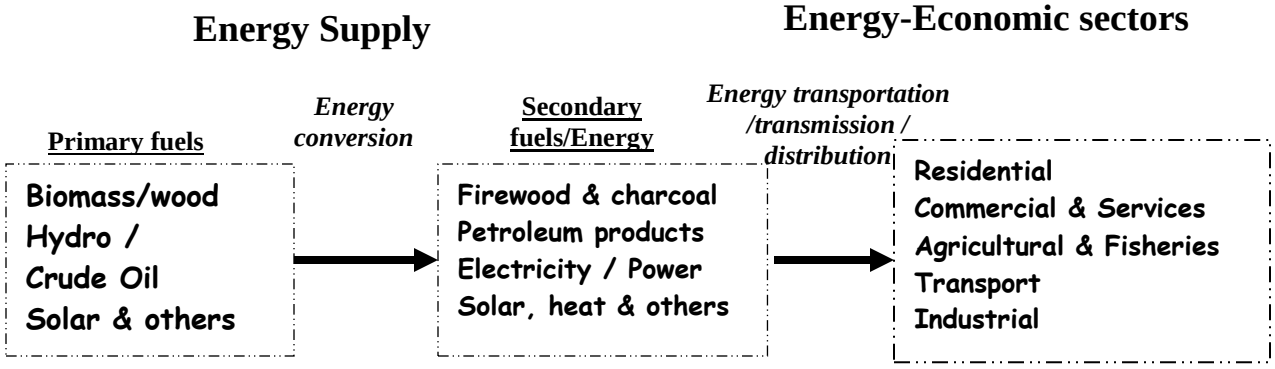

Figure Annex A1. Energy supply continuum

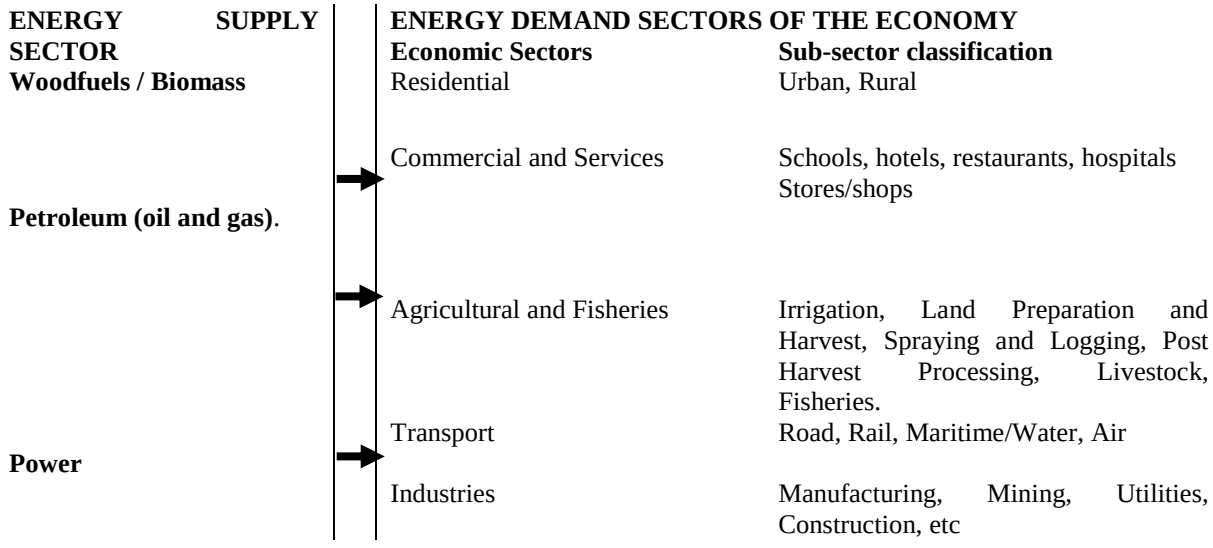

Figure A2. Energy supply continuum

Annex 2 – Eleven year Sunspot Cycle

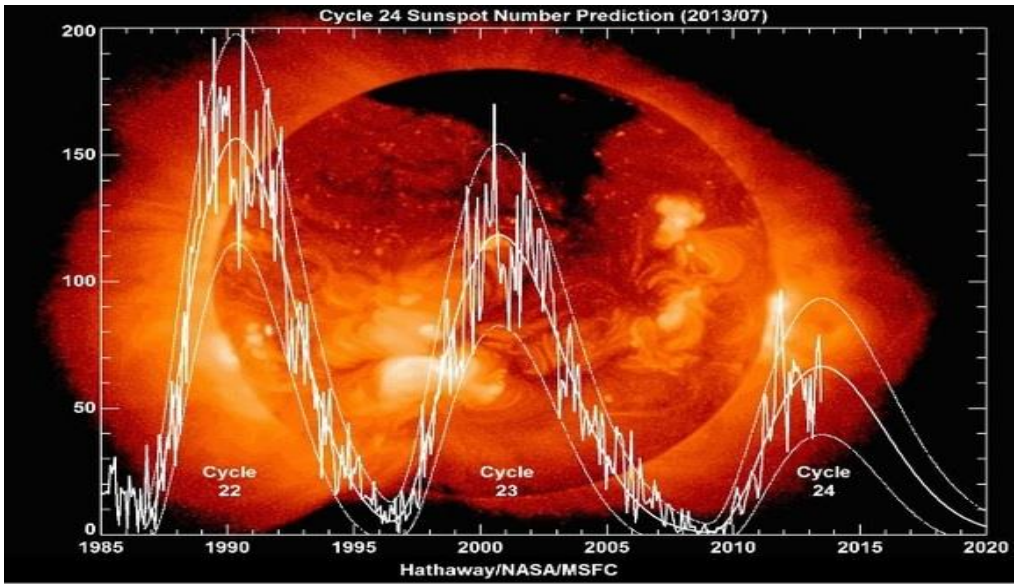

Figure A3. Sunspot Cycle from 1985-2020

Annex 3 – Can U.S. LNG Really Challenge Russian Gas in Europe?

The first cargo of U.S. liquefied natural gas (LNG) is expected to reach Europe in 2017. This is because the U.S. gas industry has been quick to take advantage of its abundant shale gas output and the growing LNG demand and to join the global LNG trade. Europe is a natural focus, not just because of stable demand, but because of the European Union (EU)'s energetic drive to diversify its sources of energy away particularly from Russia; Gazprom holds a third of the EU gas market.

LNG imports from the US is however most likely target countries, particularly at loggerheads with Russia or desiring to break their energy dependence on Russian (Gazprom) gas.

Securing gas at an attractive price however, is the key component in any deal, although diversification of sources has been shown to give customers increased bargaining power with supplier.

For the suppliers of US LNG, it is thus a question of securing the best price in whatever market is available. Thus since the start of US LNG supplies in February 2016 the vast majority have gone to more premium markets in the Americas and Northeast Asia.

In any case, Russian gas is still the most competitive and relatively abundant to Europe and buyers, particularly in Eastern Europe would be unlikely to turn down gas that makes economic sense, regardless of politics. Gazprom is not unaware of this as it is also not unaware of the European Union's ambition to diversify away from it. This has already prompted the Russian giant to substitute long-term gas supply contracts with shorter ones, and make its pricing more flexible. Chances are that the more the EU works to reduce its dependence on Russian gas, the more Gazprom will work towards making this gas competitive. After all, Europe is a core market for the company.

Indeed, the average price for U.S. LNG bound for Europe suggest that it is about **US$1-2** above northwestern European benchmark gas prices, which does make it uncompetitive. Yet this is the way things stand now unless if the buyer and the supplier are willing to make mutually beneficial compromises, which they seem to be. In the end, however, things would likely boil down to which gas is cheaper.

This could be a challenge for U.S. producers, despite the EU's eagerness to buy US LNG. In the end, it will all come down to how low Gazprom could make its prices without incurring serious losses, and how much and for how long European countries are willing to pay for more expensive U.S. LNG.

Annex 4 – Liquefied Natural Gas Regas Terminal Technologies

LNG could be delivered through the following terminal technologies:

- Temporary or stop-gap through "Energy Bridge Re-gasification Vessels" (EBRVs)
- Floating Re-gasification plants using grounded LNG vessels which have retired from services.
- Permanent LNG re-gasification plants.

Energy Bridge Regasification Vessels

Energy Bridge Regasification Vessels, or EBRVs™, are purpose-built floating storage re-gasification units (FSRU) LNG tankers that incorporate on-board equipment for the vapourisation of LNG and delivery of high pressure natural gas. It is the technology that can be delivered in the shortest possible time; i.e. **within a year**. These vessels load in the same manner as standard LNG tankers at traditional liquefaction terminals, and also retain the flexibility to discharge the gas in two distinct ways. These are:

- Through the EBRV's connection with subsea buoy in the hull of the ship; and
- through a high pressure gas manifold located in front of the vessel's LNG loading arms.

The maximum rate of discharge of the natural gas from an EBRV into the deepwater port is determined by a combination of the availability of capacity on downstream pipelines and the regasification capabilities of the facilities located on-board each EBRV.

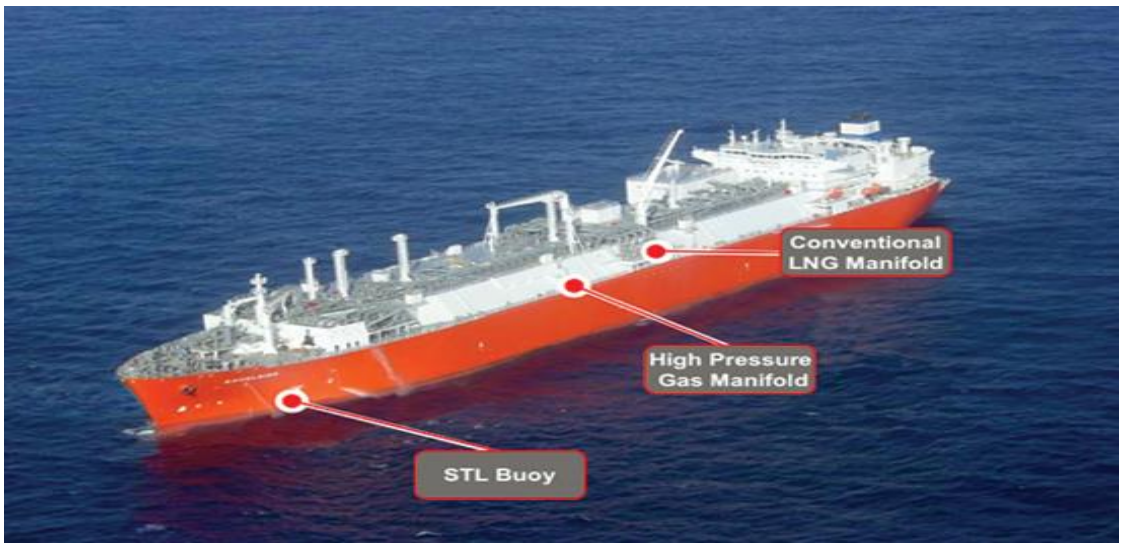

Figure A4: LNG Energy Bridge Regasification Vessel

LNG Floating, Storage and Re-gasification plants

Average lifetime of most LNG vessels is 25 years. This means LNG vessels built more than 25 years ago have become less competitive for transport services. Such an LNG ship is retired and reconfigured as floating storage LNG re-gasification unit or facility (FSRU). Typical LNG ship has capacity of 120,000-125,000 liquid cubic metres (lm^3). The larger the containment the greater the application for floating storage and regasification

applications[82]. Some 59 ships built worldwide before 1983 with containment between 122,000-133,000 liquid cubic metres are due for retirement. Construction of floating regas terminals has rapidly increased since 2005 when the first one was built in Louisiana, USA. Four units were commissioned between February 2007 and August 2008.

Floating Regas facility would take between **one and half-to-two years** to build if a project is approved and money is readily available today, otherwise **up to two and half years** to allow for initial paper work.

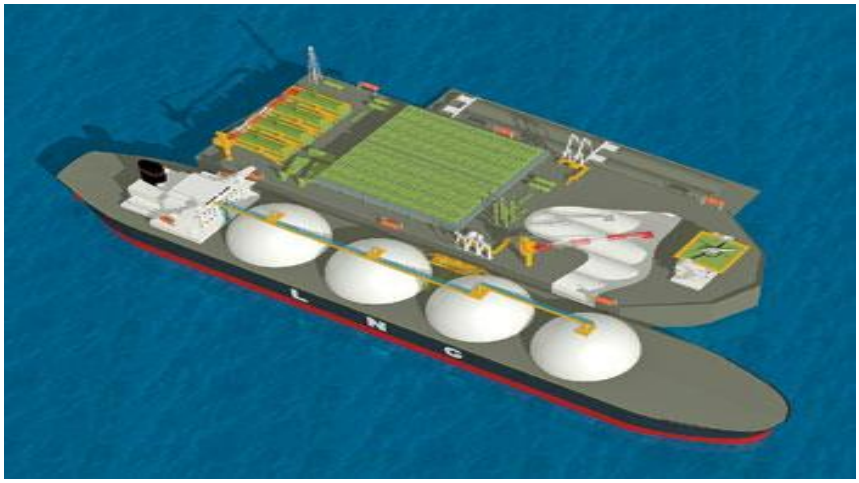

Figure A5: LNG Floating, Storage And Re-Gasification Plant

Permanent LNG discharge/re-gasification terminal

Contrary to FSRU, this is permanently fixed as the name implies and it is usually a specialised or dedicated harbour. Development of permanent LNG re-gasification plant of say 100-200 mmscfd capacity would require at least **3-4** years even if a project is approved and money is available today.

Figure A6: **Permanent LNG Re-Gasification Terminal**

[82] Zeus Liquefied Natural Gas Report, January 28, 2009

Annex 5 – Nigeria Gas Supply Challenges

Ghana has been expecting much of its natural gas to come from Nigeria. However, there are over 23 grid-connected generating plants in operation in the Nigerian Electricity Supply Industry (NESI), with a total installed capacity of about **12,000 MW** and dependable capacity of about **6,800 MW**. Most generation is thermal based, with an installed capacity of about 9,000 MW [83].

Nigeria had projected to expand its installed capacity to about 13,000 MW by 2016 but reached 12,000 MW. Available capacity has ranged between 3,000-5,000 MW. The target is to hit 15,000 MW by 2020 against an estimated demand of 26,651 MW by the end of the decade[84].

This ambition puts a greater strain on the existing gas supply situation as the country struggles to achieve its domestic gas supply and export plans. Supply requirement totals about **5 billion cubic feet per day (bcfd)** for domestic consumption, LNG contractual shipments and WAGP commitments. Despite, the country is currently only able to produce about **4 bcfd,** of which about **2.8-3.0 bcfd** is for the production of the **22 million tonnes of LNG** the county exports annually. Existing power plants require at **least 1.5 bcfd,** which translates into very little or no gas for pipeline export to WAGP partner. The supply to the WAGP partner however ramps up only when a local power plant trips or is offline for maintenance. The country thus needs to develop new fields to meet the projected demand but industry experts estimate that to happen within 2017-2018, provided the existing schedule is executed as planned.

The current policy of the Nigerian government somehow seems to be to meet local gas demand first before considering exports to neighbouring countries. For this reason, there is a policy in place compelling all major gas shippers including N-Gas that ship gas to Ghana through the West African Gas Pipeline (WAGP) to meet local supply quota first before export. As at the end of 2013, most shippers were finding it difficult to meet the local quota obligation. Besides, the sabotaging of oil and gas facilities in the Delta region still remains a challenge[85]. These are contributing to the relatively low average supplies to the WAGP, aside untimely payments by off-takers particularly in Ghana for gas supplied.

The country has done well in reducing gas flaring over the years from 2 bcfd in 2015 to about 750 mmscfd, this still equates to burning $700 million annually or wasting fuel that could have been used to generate nearly 3,000MW of electricity.

Thus for N-Gas of Nigeria to limit gas supply to WAGP at the contracted volume of 123 mmscfd instead of the full capacity of 440 mmscfd as originally agreed in the supply contract is of concern but not hopeless[86]. The supply balance of 312 mmscfd reinforces the opportunity for the development of a viable alternative supply option such as an LNG terminal along Ghana's coast.

[83] http://www.nipptransactions.com, 2016
[84] Power Generation: Status and Outlook, a presentation by Presidential Task Force on Power, at Electric Power Investors ' Forum by Bureau of Public Enterprises,
[85] Orient Energy Review, Vol.5 No. 02/03 Feb-March, 2016.
[86] Energy Commission source.

Annex 6 – Provision of Overhead Compression in the Atuabo Gas Processing Plant

The Gas Processing Plant (GPP) at Atuabo commenced commercial operations after the Energy Commission issued an Operating Licence to the Ghana National Gas Company on the 31st of April 2015. The GPP is composed of the following modules:

- Inlet Separation
- Inlet Filtration
- Fuel Gas Conditioning
- Gas Chilling and Deethanization
- Deethanizer Overhead Compression
- Fractionation
- Glycol Regeneration
- Heat Medium System
- Flare & Closed Drain System

Raw gas is received at the Inlet Separation at about 130–140 barg. After processing, pipeline pressure generally rides on the exit or operating set pressure of the Low Temperature Separator (LTS) which is usually set at 51 barg.

The first phase of the Western Corridor Gas Infrastructure Project involves the use of a Joule-Thomson valve for inlet separation at the LTS. This means that complete separation of lean gas at the LTS is not possible. Residual gas separation takes place at the Deethanizer at about 33.5 barg. Residual gas separated at the Deethanizer has to be compressed to about 51 barg to meet sales gas pressure.

The above description depicts the Deethanizer Overhead Compression a vital module of the GPP. The overhead compressor is a reciprocating engine with a mandatory maintenance of 4,000 man-hours, meaning that anytime it has to undergo mandatory maintenance, the entire GPP has to be shut down. The installation of a spare Overhead Compression System is therefore critical to minimizing downtime and guaranteeing continuous plant operations to ensure an uninterrupted supply of sales gas to downstream consumers.

Annex 7 – Woodfuel

Firewood/fuelwood	1 Tonne	0.30 - 0.36 TOE
Charcoal	1 Tonne	0.68 - 0.88 TOE
Sawdust/sawmill residues/wood chips	1 Tonne	0.20 - 0.30 TOE

Low side reflecting average dry wood and corresponding Charcoal in the forest zones and the high side reflecting average dry wood and corresponding charcoal in the savannah zones of the country.

Charcoal production is based on the fact that between 4 – 5 mass units of wood have been used to produce one mass unit of charcoal in the country

Charcoal Source	Average Weight (kg) of Charcoal		
	Mini Bag	Maxi Bag	Moisture Content
Sawmill residue	21 – 22	44 - 45	Up to 40%
Savannah wood	30 – 32	55 - 60	Up to 20%
Acacia plant	31 – 32	57 - 63	Up to 20%
All other woods	25 – 27	50 - 55	Up to 25%