REPUBLIC OF GHANA

2019

Electricity Supply Plan

for the Ghana Power System

2019 Power Supply Outlook with Medium Term projections

2019 ELECTRICITY SUPPLY PLAN FOR GHANA

An Outlook of the Power Supply Situation for 2019 and Highlights of Medium Term Power Requirements

ACKNOWLEDGEMENT

We hereby wish to express our deepest appreciation to the Supply Plan Committee which is made up of experts from Energy Commission, GRIDCo, VRA, BPA, ECG and NEDCo as follows:

Frederick A. Okang	–	Ghana Grid Company Limited
Frank Otchere	–	Ghana Grid Company Limited
Kassim Abubakar	–	Ghana Grid Company Limited
Monica Debrah (Mrs.)	–	Ghana Grid Company Limited
Abdul N. Wahab	–	Volta River Authority
Afua A. Thompson (Mrs.)	–	Volta River Authority
Dr. Joseph Essandoh-Yeddu	–	Energy Commission
Godfred Mensah	–	Electricity Company of Ghana
Ebenezer Baiden	–	Electricity Company of Ghana
Mohammed Aminu	–	Electricity Company of Ghana
Elvis Demuyakor	–	Northern Electricity Company Limited
Mohammed T. Tampuri	–	Northern Electricity Company Limited
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EXECUTIVE SUMMARY

The Electricity Supply Plan (ESP) for 2019 is being submitted by the Electricity Supply Plan Committee as per the requirement of the Ghana Electricity Grid Code.

The 2019 ESP presents an outlook of power demand and supply for 2019 taking into consideration all the committed projects and existing generation sources. It assesses the available hydro generation taking into consideration low reservoir elevations at Akosombo and Bui. Additionally, it presents fuel requirements and associated cost to meet electricity demand in 2019 and evaluates the associated power evacuation requirements to ensure reliable power supply. The 2019 ESP, further highlights the anticipated challenges in meeting the 2019 electricity demand and makes recommendations on the best course of action to be taken to ensure reliable power supply in 2019. Finally, it further provides an outlook of electricity demand and supply for the next five years.

Review of 2018 Performance

Peak and Energy Demand

The projected Ghana peak demand for 2018 was 2,523.49 MW. However, by the end of the year, the power system had recorded a maximum coincident peak demand of 2,525.0 MW. This occurred on December 17, 2018. The 2018 peak represents an increase of 367.0 MW or growth of 17.01% over the 2017 peak of 2,158.0 MW.

The total energy consumption including losses was 15,960.36 GWh as against the projected of 16,302.09 GWh. A total of 14,308.08 GWh was consumed during the same period in 2017, thus, the consumption in 2018 represented a growth of 11.55% or 1, 652.28 GWh increase over that of 2017.

Energy Supply

The total energy supplied (including imports from Côte d'Ivoire) over the period was 15,960.36 GWh. It comprised 6,017.36 GWh from hydro, 9,803.15 GWh from thermal and 139.70 GWh of Imports. The generation mix at the end of the period was therefore 39.60% hydro, 58.14% thermal and 2.26% import.

Transmission Losses

The total system transmission losses recorded during the period was 707.33 GWh which is 4.43% of total transmitted energy of 15,960.36 GWh, representing 19.01% increase over the projected transmission losses of 594.30 GWh.

In 2017 on the other hand, the network recorded total transmission losses of 587.11 GWh. The 2018 figure thus represents 1.2 % increase over the 2017 figure.

Transmission Lines and Feeder Availability

The Average Feeder Availability (AFA) in 2018 was 99.84 % and the System Average Availability (SAA) for the transmission grid was 99.58%. The System Average Availability (SAA) for the transmission grid was 99.48 % in 2018

2019 Demand Outlook

The projected system peak demand for 2019 is 2,665.68 MW. The Committee also considered a high case scenario and projected 2,796.92 MW for the high case scenarios. The projected 2019 reference peak of 2,665.68 represents an increase of 140.68 MW or in percentage terms, a growth of 5.54 % over the 2018 peak demand of 2,525 MW which occurred on December 17, 2018.

The projected energy consumption including transmission system losses for 2019 is 17,237.79 GWh and 18,013.96 GWh for base and high case respectively. The base case consumption for 2019 compared to the 2018 actual consumption of 15,960.36 GWh represents a growth of 8% (1,277.43 GWh).

2019 Supply Outlook

Hydro Power Generation for 2019

The total projected hydro generation for 2019 is 5,670 GWh. This would be made up of 4,258.44 GWh, 811.50 GWh and 650 GWh for Akosombo, Kpong and Bui Generating Stations respectively.

Akosombo Hydro Elevation

The recorded maximum lake elevation at the end of 2018 inflow season was 263.67 feet, a rise of 23.67 feet above the minimum operating level of 240 feet. The total net inflow recorded in 2018 was 40.01 MAF, which implies that an above average inflow was obtained in 2018.

NB: the average inflow is 25 MAF.

Bui Hydro Elevation

With a year-start elevation of 176.97 MASL in 2019, and the total estimated total energy production of 600 GWh for 2019, the year-end elevation is projected at 175.21 MASL.

Thermal Power Generation for 2019

The Projected Dependable Thermal Capacity for 2019 is 3,456 MW. This is made up of 2,906 MW from existing and 550 MW of committed Thermal Plants. The projected total thermal energy generation for 2019 is 11,460.11 GWh from VRA Plants and IPPs.

Renewable Energy (RE) Generation for 2019

The total RE (currently only Solar PV) generation for 2019 is projected at 42.64 GWh. This is made up of VRA (Navrongo), BXC (Winneba) and Meinergy (Saltpond) as shown in the Table below.

All of these utility-scale Solar PV Plants are connected on the Medium Voltage Distribution System.

Imports

In 2019, no programmed import is expected apart from the usual inadvertent exchanges between the two utilities, CIE and GRIDCo.

Existing and Committed generation capacity for 2019

Plants	Installed Capacity (MW)	Dependable Capacity (MW)	Fuel Type
Akosombo GS	1020	900	Hydro
Kpong GS	160	105	Hydro
TAPCO (T1)	330	300	LCO/Gas
TICO (T2)	340	320	LCO/Gas
TT1PP	110	100	LCO/Gas
TT2PP	80	70	Gas
KTPP	220	200	Gas/ Diesel
VRA Solar Plant	2.5	0	Solar
TOTAL VRA	**2,263**	**1,995**	
Bui GS	404	360	Hydro
CENIT	110	100	LCO/Gas
AMERI	250	230	Gas
SAPP 161	200	180	Gas
SAPP 330	360	340	LCO/Gas
KAR Power	470	450	HFO
AKSA	370	350	HFO
BXC Solar	20	0	Solar
Meinergy Solar	20	0	Solar
Trojan	44	39.6	Diesel/Gas
Genser	22	18	Gas
CEN Power	360	340	LCO/Gas
Amandi	190	190	LCO/Gas
TOTAL IPP	**2,820**	**2,598**	
TOTAL (VRA, Bui & IPPs)	**5,083**	**4,593**	

Natural Gas Quantities and Availabilities

Two main supplies of natural gas were considered as follows:

Nigeria Gas – Average supply of 60 mmscf/day is assumed from January to December 2019

Ghana Gas

- ✓ Jubilee Fields- a maximum of 73 mmscf/day in 2019.
- ✓ TEN Fields –a maximum of 24 mmscf/day in 2019.
- ✓ Sankofa Fields –a maximum of 180 mmscf/day in 2019.

Distribution Outlook in 2019

ECG Network

Based on sub-transmission reliability studies undertaken by ECG, a number of interventions and projects were initiated in 2018 and are expected to be completed in 2019 to resolve various constraints of *low voltages, feeder and transformer overloads during firm and non – firm conditions*. Some of the key projects under construction are the following:

- ✓ Installation Voltage of Regulators at Nsawam, Mampong and Aburi to improve voltages
- ✓ Construction of the Pokuase BSP, this project is under construction- Upon completion it will boost voltage support to Dodowa, Mampong, Aburi and Ofankor. it will also improve reliability by serving as an alternative BSP to Achimota and Afienya BSPs.
- ✓ Construction of Afienya BSP- this will boost voltage at Dodowa, Mampong and Aburi

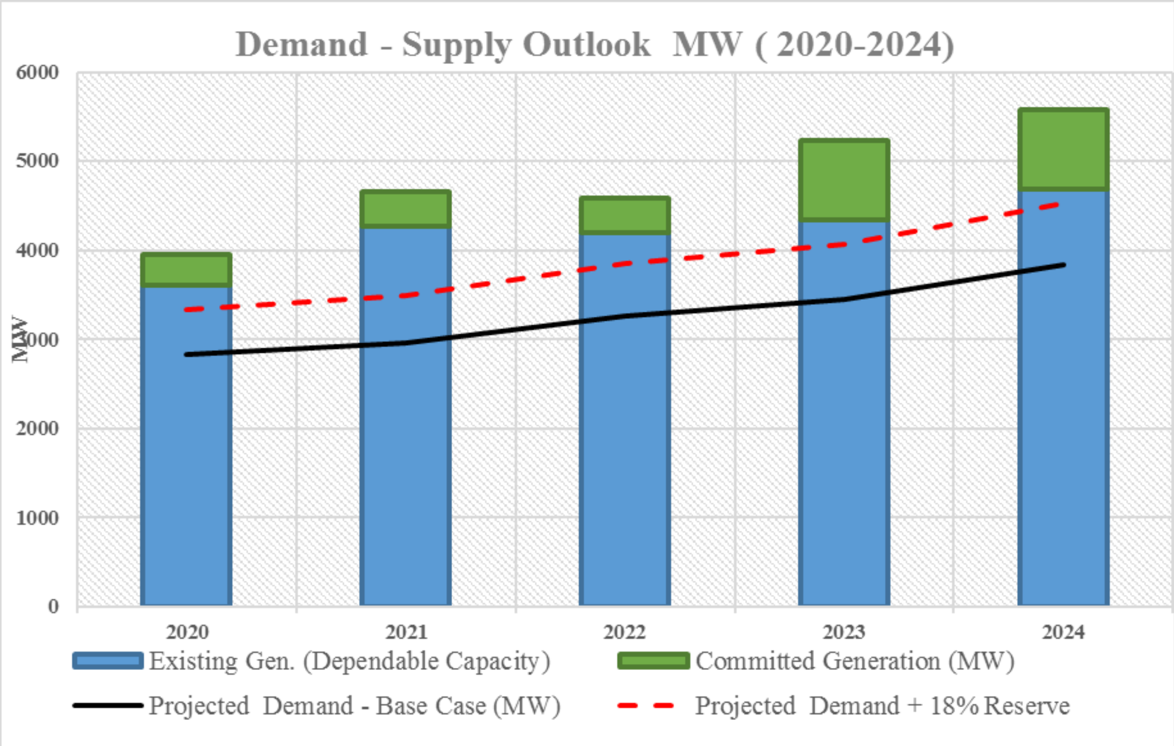
The completion of these Projects is expected to improve supply reliability to the various ECG customers.

NEDCo Network

Power supply reliability in NEDCo Areas is generally good. However, reliability in some areas of the network has been lower than expected due to over extension of these lines and over-ageing resulting in high technical losses. Some of these lines have been extended, as part of Self Help Electrification Program (SHEP) implementation, beyond technically allowable distances. Some interventions, however, have been made on some of these lines resulting in improved supply reliability on them.

Medium-Term (2020 – 2024) Demand and Supply Outlook

The Medium-Term (2020-2023) Demand and Supply Outlook as shown in the Figure below suggests that there will be adequate generation to meet demand for the period 2020-2023 for the high case growth scenario. However, an additional generation capacity of about 130 MW is required to be procured, installed and commissioned into service by January, 2024 to meet the demand and the 18%.reserve margin requirement.



Gas Supply Outlook

By the end of 2019, the infrastructure bottlenecks in the gas supply are expected to be resolved. Gas supply is therefore expected to revert to committed levels as shown in Table 36. In addition to the existing supply sources, two LNG projects are expected to add additional 430 MMscfd by 2022.

Medium Term (2020 - 2024) Gas Delivery Profile (MMscfd)

	2020	2021	2022	2023	2024
Jubilee FV	83	80	83	83	-
Greater Jubilee	-	-	-	-	80
TEN AG	26	26	26	26	26
Sankofa NAG	180	180	180	180	180
Aker	-	-	-	-	-
Takoradi LNG	-	-	180	180	180
Tema LNG	100	250	250	250	250
N-Gas	70	70	70	70	70
Total Gas Supply	**459**	**606**	**789**	**789**	**789**

Strategic Medium Term Transmission Infrastructure Requirements

The results of the extensive system network analyses carried out using the projected demand and supply scenario indicates that there would be the need for the following transmission line and equipment additions in the medium term to meet the required supply reliability indices, and this is in addition to the investment identified under Section 5. The following are the critical transmissions additions required:

- ✓ Upgrade of 161kV Aboadze-Takoradi-Tarkwa-Prestea
- ✓ Construction of a second 330 kV Prestea - Dunkwa – Kumasi line
- ✓ Upgrade of 161kV Aboadze-Mallam
- ✓ Construction of a second 330 kV Aboadze – A4 BSP circuit
- ✓ Construction of a double circuit 330 kV line from A4BSP to Kumasi
- ✓ Eastern Transmission Corridor Projects:
- ✓ 161kV Kpando – Juale Line
- ✓ 161kV Juale – Yendi Line
- ✓ Construction of a 330 kV substation at Dunkwa with a link to the existing 161 kV substation
- ✓ Construction of a third Bulk Supply Point in Kumasi

CONCLUSION

Demand and Supply Outlook

a) The 2019 total system demand is projected to be 2,665.68 MW (base case), representing a 5 % growth over the 2018 peak demand of 2,525 MW. The corresponding projected energy consumption for 2019 is 17,237.79 GWh of which:

b) Hydro supply will be 5,669.95 GWh representing 33% of the total energy supply;
   - ✓ Thermal supply will be 11,460.11 GWh representing 66.9% of total energy supply; and
   - ✓ Renewables supply will be 57.7 GWh representing 0.1% of total energy supply

c) Total projected energy exports are 915.81GWh for 2019.

d) VALCO is expected to operate on two pot lines with projected total consumption of 1,283.8 GWh.

e) There is the need to dispatch Akosombo and Bui Hydro Plants conservatively throughout 2019 to ensure that the two reservoirs are not drawn down below their minimum operating levels to guarantee sustainable operations in the coming years

f) In terms of fuel, the following quantities of the various fuel types are required;
   - ✓ Natural Gas - 80,241,689 MMbtu
   - ✓ HFO - 5,308,727 barrels

g) In terms of fuel cost, an annual total of approximately 1.04 billion USD is required, averaging a monthly total of some US$ 86.64 Million.

h) In 2019, Aboadze will be the largest generation enclave in Ghana with an installed capacity of 1,540MW

i) Under maximum west generation scenario with KarPower in the West, the autotransformers at Volta will become overloaded leading with low voltages in the East (Accra/Tema Area).

Requirements for Grid Reinforcement

a) The transmission system has inadequate available transfer capacity to meet the demand requirements of the major load centres (of Accra, Kumasi, Tarkwa, etc.) particularly at peak. This situation would result in low voltages, overloading of lines and increased overall transmission system losses.

b) For radial lines and single transformer stations, significant percentage of network loads could be islanded in the event of outage of such lines and transformers.

c) In normal operation, there would be congestion on the Volta –Accra East – Achimota - Mallam transmission corridor especially when there is high generation in the east.

d) Low voltages would be experienced at Kumasi, Accra and surrounding areas due to poor customer-end power factors.

e) A fair East-West balance in generation provide better system stability and minimal overall transmission system losses.

Distribution Systems

a) The commissioning of the Accra Central BSP has increased the level of reliability and distribution capacity to meet the growing demand within the ECG network in Accra. This has resolved the loading constraints on selected 33 kV feeders and reduce technical losses within the ECG Accra network.

b) In a bid to improve voltages in Nsawan and Aburi, ECG has installed a number of Voltage Regulators to improve on reliability and quality of supply. Furthermore, a number upgrade projects have either been commissioned into service or under construction. This is to increase distribution capacity and reliability of supply customers.

c) Power supply reliability in NEDCo Areas is generally good. However, reliability in some areas of the network has been lower than expected due to over extension and over-ageing resulting in high technical losses. Some interventions, however, have been made on some of these lines resulting in improved supply reliability on them.

Medium Term Supply

a) For the high case growth scenario, it is expected that with the deployment of the committed generation capacity, there would be adequate dependable generation capacity to meet projected demand for the period 2020 - 2023 with a maximum reserve margin of 39%.

b) The system peak demand for high case growth scenario is projected to be 4,394 MW by 2024 and a corresponding dependable generation capacity of 5,058 MW. Hence, to meet the reliability requirement of the Ghana power system, an additional reserve margin of 18% representing 791 MW is required. This adds up to a total required supply capacity of 5,185 MW. This compared to the projected supply capacity implies a deficit of about 130 MW. Thus, there is the need to procure an additional generation capacity of 127 MW in time for commissioning by January, 2024.

RECOMMENDATIONS

Based on the above conclusions, the following recommendations are made:

a) The ongoing transmission expansion projects should be expedited and completed in 2019 to ensure that the peak demand can be supplied. These are
   - ✓ Volta – Achimota – Mallam Transmission Line Upgrade Project
   - ✓ Aboadze – Prestea - Kumasi 330 kV Transmission Line Project
   - ✓ Kumasi – Bolgatanga 330 kV transmission line Project

b) GRIDCo should explore the possibility of installing the 3rd autotransformer at Volta Substation

c) A well-coordinated maintenance programme should be pursued by both GRIDCo and the Generating Companies (GENCOs).

d) Fuel supply security and adequacy remains the single most important risk to power supply reliability in Ghana. In this vein, it is strongly recommended that all the relevant sector agencies stakeholders work conscientiously together to ensure that fuel supply is adequate and secure at all times.

e) For the medium term, the reserve margin for the 2024 falls short of the required reserve margin of 18% (for reliability of supply). Therefore, additional generation capacity would need to be procured in time for commissioning by the beginning of 2024.

f) In order to meet the transmission reliability indices, the following are the critical transmissions additions and upgrades are required:
   - ✓ Upgrade of 161kV Aboadze-Takoradi-Tarkwa-Prestea
   - ✓ Construction of a second 330 kV Prestea - Dunkwa – Kumasi line
   - ✓ Upgrade of 161kV Aboadze-Mallam transmission lines
   - ✓ Construction of a second 330 kV Aboadze – A4 BSP circuit
   - ✓ Construction of a double circuit 330 kV line from A4BSP to Kumasi
   - ✓ Construction of a 330 kV substation at Dunkwa with a link to the existing 161 kV substation

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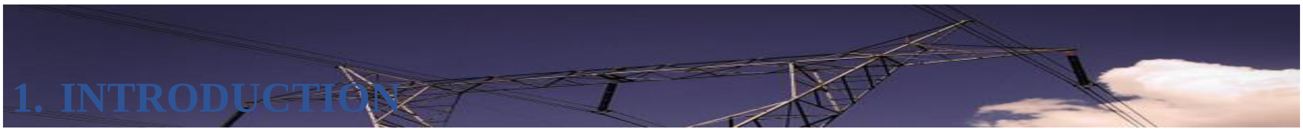


1. INTRODUCTION

The 2019 ESP presents an outlook of power demand and supply for 2019 taking into consideration all the committed and existing generation sources. It assesses available hydro generation sources taking into consideration reservoir elevations at Akosombo and Bui. It also looks at thermal generation and its fuel requirements and associated costs. The anticipated challenges to meeting the 2019 demand is presented and appropriate recommendations made to ensure reliable power supply situation in 2019.

2. SYSTEM PERFORMANCE REVIEW FOR 2018

The review of the 2018 Ghana Power System performance includes amongst others, the comparison of the actual peak demand, consumption and energy generation against the projection made for the period. It also assesses the performance of the power system with respect to voltages, system frequency and transmission losses.

2.1 Peak Demand

In 2018, it was projected that the maximum coincident peak demand would be 2,523.49 MW. However, by the end of the year, the power system had recorded a maximum coincident peak demand of 2,525.0 MW. This occurred on December 17, 2018. This value represents an increase of 1.51 MW or 0.0598 % over the projected for the year. Compared to the 2017 coincident peak, the 2018 peak of 2,525 MW represents an increase of 367.0 MW or 17.01% over the 2017 peak of 2,158.0 MW.

The summary of projected and actual monthly peak demands for 2018 is presented in Table 1.

Table 1: System Projected and Actual Peak Demand for 2018

Month	*Projected Demand(MW)*	*Actual Demand (MW)*		*Difference*
		System	Domestic	(Projected-System)
Jan-18	2,305.77	2,198.17	2,067.00	107.6
Feb-18	2,337.62	2,269.00	2,137.00	68.62
Mar-18	2,401.94	2,278.00	2,153.00	123.94
Apr-18	2,509.01	2,433.00	2,248.00	76.01
May-18	2,496.88	2,406.00	2,270.00	90.88
Jun-18	2,415.89	2,290.00	2,127.00	125.89
Jul-18	2,338.78	2,349.00	2,125.00	-10.22
Aug-18	2,341.97	2,296.00	2,094.00	45.97
Sep-18	2,414.76	2,402.00	2,184.00	12.76
Oct-18	2,487.23	2,471.00	2,231.00	16.23
Nov-18	2,512.83	2,496.10	2,201.00	16.73
Dec-18	2,523.49	2,525.00	2,371.00	1.51

As shown in Table 1, there were wide deviations between the Projected and the Actual Peak Demands for the first half of the year. These were due to delays by VALCO in operationalizing the second Pot line of 75 MW and the late energization of the 225 kV Bolgatanga – Ouagadougou line to export about 50 MW to SONABEL (Burkina).

VALCO started operating the second Pot line on June 1, 2018 and its demand by the end of 2018 had reached 120.5 MW. The Ghana – Burkina Interconnection was also commissioned on June 27, 2018 and SONABEL has since imported an average of 46.46 MW and a maximum of 101.38 MW from Ghana.

The highest domestic peak demand recorded during the period was 2,270.0 MW and this occurred on May 24, 2018. This value represents an increase of 193.0 MW or 9.3% over that of 2017 of 2,077.0 MW which occurred on April 19, 2017.

2.2 Energy Consumption

The period under review registered a total energy consumption including losses of 15,960.36 GWh as against the projected total energy consumption of 16,302.09 GWh. The actual energy consumed was lower than projected by 2.10% or 341.73 GWh compared to the projected. A total of 14, 308.08 GWh was consumed during the same period in 2017, thus, the 2018 figure represents an 11.55% or 1, 652.28 GWh increase over that of 2017.

The summary of 2018 and 2017 projected and actual energy consumptions for the second quarter is presented in Table 2.

Table 2: Summary of Energy Consumption for 2018, actual vs. projected

Customer	Projection (GWh) 2018	Actual (GWh)	Actual (GWh)	% Growth
		2018	2017	(2018-2017)
ECG	10,588.86	10,869.87	9,922.61	9.55%
NEDCo	1,373.10	1,326.93	1,236.44	7.32%
Mines	1,495.41	1,090.78	1,150.65	-5.20%
VALCO	1,154.19	815.19	631.24	29.14%
Export	669.27	739.50	376.74	96.29%
Direct Cust.	426.96	401.95	395.53	1.62%
Network Usage/Losses	594.30	716.14	594.88	20.38%
Total Energy Transmitted	16,302.09	15,960.36	14,308.09	11.55%

The details of the peak demand and energy consumption per Bulk Supply Points are in Appendix A.

2.3 Losses

The total transmission losses recorded during the period was 707.33 GWh which is 4.43% of the total energy transmitted of 15,960.36 GWh, representing 19.01% increase over the projected transmission loss of 594.30 GWh

2.4 Energy Exchanges (Export and Import)

A maximum of 45 MW and an average of 15 MW of power was exported to CIE (la Côte d'Ivoire) whilst import from CIE reached a peak of 135 MW during the same period. On the other hand, a maximum of 141 MW and 101.38 MW were exported to CEB (Togo/Benin) and SONABEL (Burkina) respectively.

In energy terms, a total of 384.95 GWh and 277.07 GWh were exported respectively to CEB and SONABEL. A net of 217.17 GWh was also exchanged between Ghana and Côte d'Ivoire. This was made up of 139.69 GWh imports and 77.48 GWh exports.

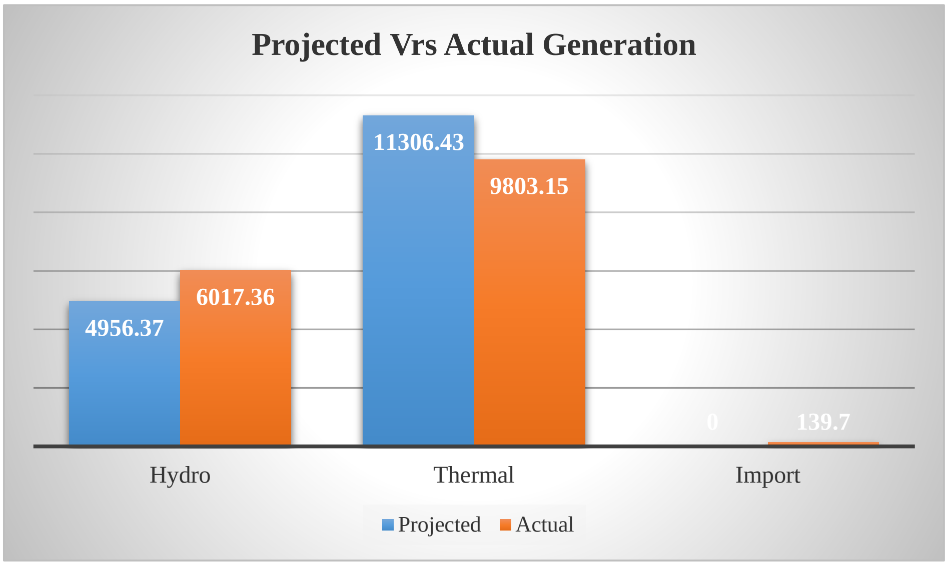
2.5 Energy Generation

Summary of actual monthly energy generation against the projected in 2018 is shown in Table and Figure below.

Table 3: Projected versus Actual Energy Generation in 2018

Month	Hydro (GWh)		Thermal (GWh)		Import (GWh)		System Total (GWh)	
	Actual	*Projected*	*Actual*	*Projected*	*Actual*	*Projected*	*Actual*	*Projected*
Jan	420.81	434.63	850.19	889.59	2.02	0.00	1273.02	1284.00
Feb	492.68	390.07	673.52	825.35	41.27	0.00	1207.47	1149.00
Mar	397.41	420.16	943.46	914.52	12.62	0.00	1353.49	1294.00
Apr	486.81	407.02	878.59	986.79	10.54	0.00	1375.94	1338.00
May	499.52	420.16	842.87	989.82	7.09	0.00	1349.48	1346.00
Jun	501.40	410.05	760.85	915.04	8.24	0.00	1270.49	1261.00
Jul	393.47	391.32	911.54	939.53	10.36	0.00	1315.37	1262.00
Aug	367.96	383.47	939.02	968.15	6.19	0.00	1313.17	1256.00
Sep	391.93	403.37	877.45	926.34	9.20	0.00	1278.58	1255.00
Oct	646.14	436.93	702.13	965.59	14.55	0.00	1362.82	1363.00
Nov	691.01	423.25	701.21	969.91	12.63	0.00	1404.85	1344.00
Dec	728.22	435.94	722.32	1015.80	4.99	0.00	1455.53	1407.00
Total	6017.36	4956.37	9803.15	11306.43	139.70	0.00	15960.36	16262.80

Figure 1: Projected versus Actual Energy Generation in 2018



The total energy generated including imports from Côte d'Ivoire over the period was 15,960.36 GWh; made up of 6,017.36 GWh from hydro generation, 9,803.15 GWh from thermal and 139.70 GWh Imports. The corresponding percentage share of each generation type for the period was 37.70%, 61.42% and 0.88% for hydro, thermal and imports respectively.

The generation mix at the end of the period was therefore 38% hydro, 61% thermal and 1% import. Figure 2 gives a graphical representation of the generation mix.

Figure 2: Generation Mix for 2018

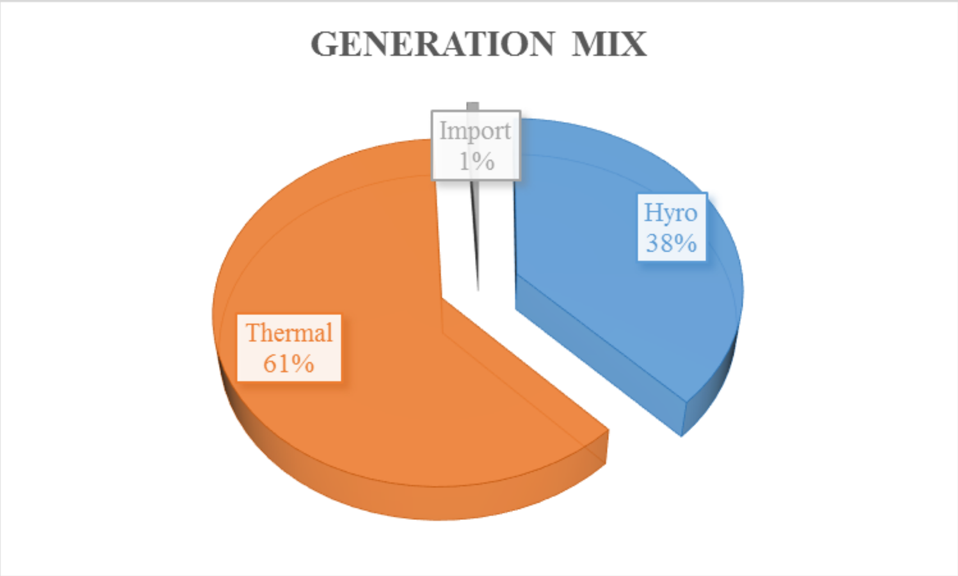
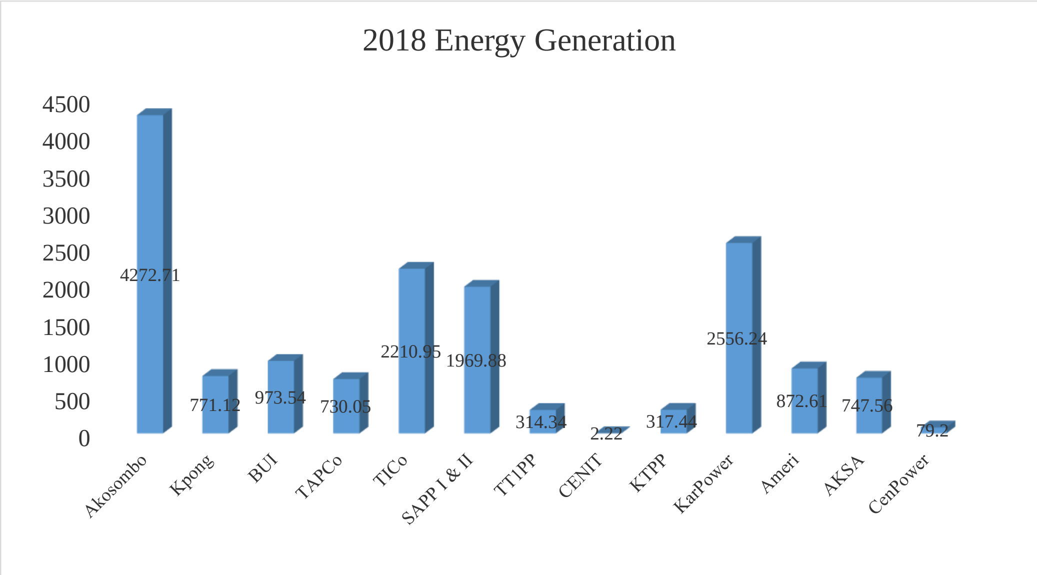


Table 4 and Figure 3 show the actual energy generated against the projected for 2018.

Table 4: Plants projected and actual energy generated

Plants	Projection 2018 (GWh)	Actuals 2018 (GWh)	variation (GWh)	% variation
Akosombo	3600	4272.71	-672.71	-19%
Kpong	600.14	771.12	-170.98	-28%
BUI	756.21	973.54	-217.33	-29%
TAPCo	1457.28	730.05	727.23	50%
TICo	2155.06	2210.95	-55.89	-3%
SAPP I & II	1466.14	1969.88	-503.74	-34%
TT2PP	-	-	-	-
TT1PP	353.28	314.34	38.94	11%
CENIT	380.93	2.22	378.71	99%
KTPP	369.24	317.44	51.8	14%
KarPower	2708.25	2556.24	152.01	6%
Ameri	796.55	872.61	-76.06	-10%
AKSA	558.49	747.56	-189.07	-34%
CenPower	1061.21	79.2	982.01	93%

Figure 3: Generating Plant projected & actual energy production for the year 2018



2.6 Hydro Reservoir Operation

1.6.1 Akosombo Reservoir

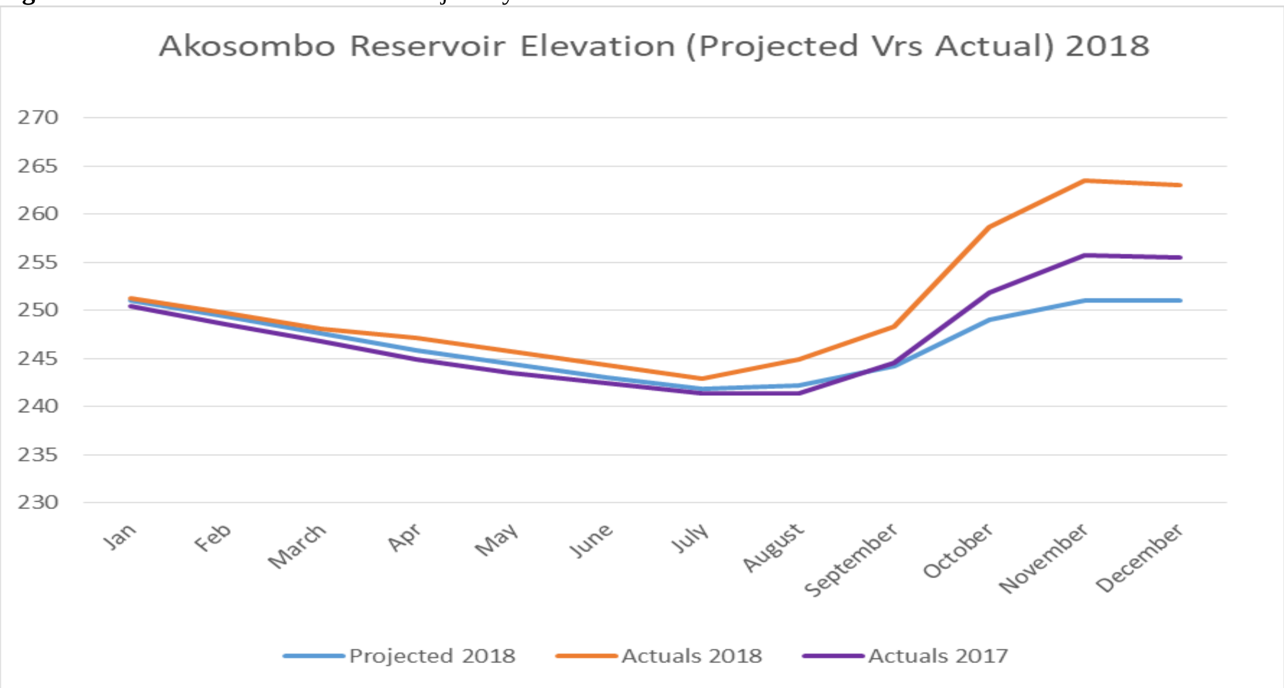
The elevation of the Volta Lake for the start of 2018 was 76.61 m (251.34 feet). Based on this low reservoir elevation, it was recommended to operate three (3) and five (5) units at off-peak and peak respectively.

Following the implementation of the above recommendation, the reservoir elevation dropped to a minimum of 74.03 m (242.96 feet) during the dry season in 2018. This elevation was 0.03 m (0.96 feet) higher than the projected for the year.

1.6.2 Inflows in 2018

The reservoir elevation at the end of 2018 was 261.85 ft, representing an increase of 10.85 ft above the projected of 251.0 ft for the year. The recorded maximum lake elevation at the end of 2018 inflow season was 263.67 feet, a rise of 23.67 feet above the minimum operating level of 240 feet. The total net inflow recorded in 2018 was 40.01 MAF (million acre feet), which implies that an above average inflow was obtained in 2018. Figure 4 shows the Akosombo reservoir trajectory recorded for 2018.

Figure 4: 2018 Akosombo Reservoir Trajectory



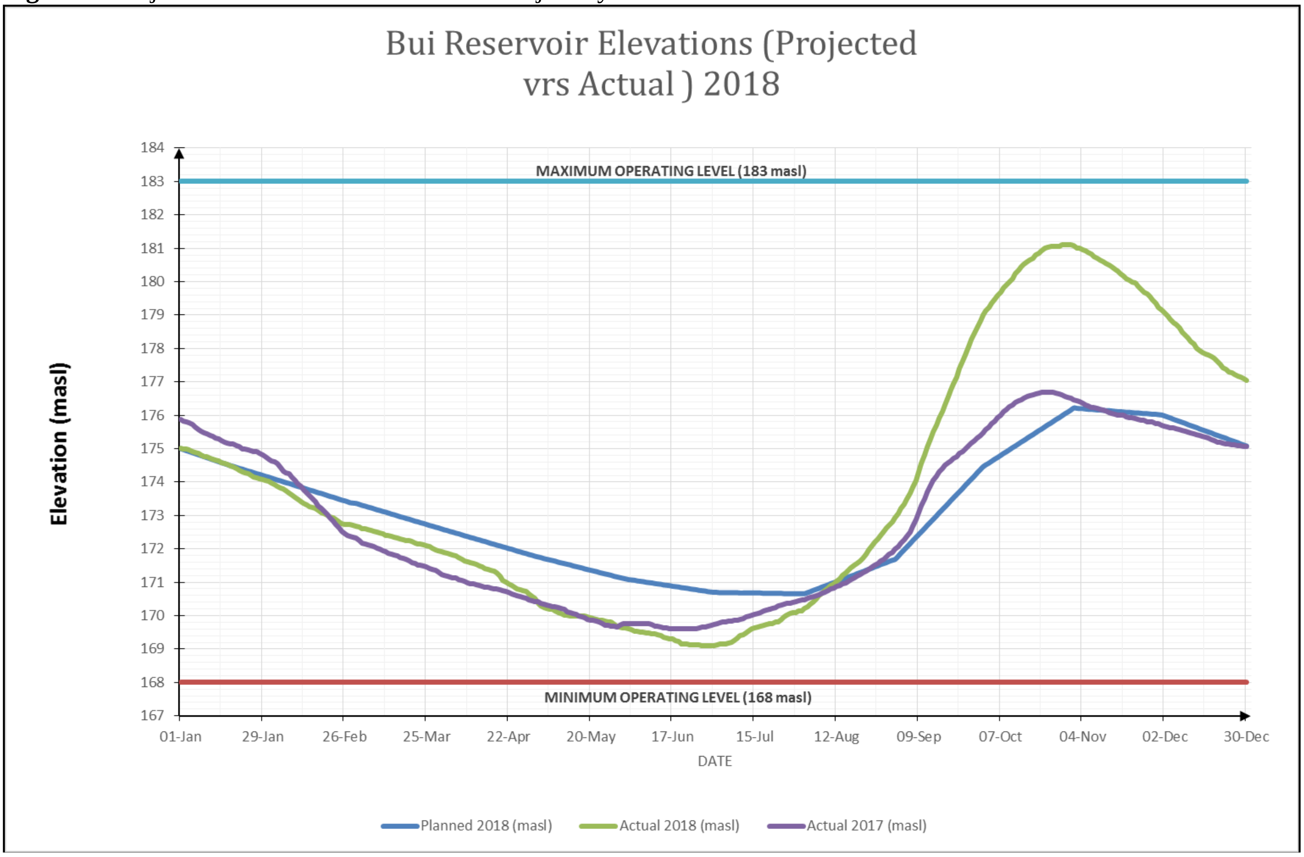
2.7 Bui Reservoir

The Bui Reservoir level at the beginning of 2018 was 175.01 MASL, dropping to a minimum of 169.10 MASL at the end of the dry season. The minimum level attained was thus 1.56 MASL lower than the projected minimum of 170.66 MASL for the year. This drop in elevation below the projected was due to over-drafting of the Lake to make up for the power deficit arising from the shortfall in gas supply from Ghana Gas in the first quarter of 2018.

The total energy generated in 2018 was 968.14 GWh compared to the projected of 754 GWh. The higher than projected generation was due to higher than average inflows into the reservoir in the flood season of 2018, forcing a revised strategy to avoid the spillage of the Bui reservoir leading to a much higher than anticipated generation.

At the end of the inflow season the reservoir level rose to a maximum of 181.10 MASL on October 28, 2018. The year-end elevation on December 31, 2018 was 177.01 MASL.The recorded reservoir trajectory in 2018 is as shown in Figure 5.

Figure 5: Projected and Actual Bui Reservoir Trajectory



2.8 Generating Plants Availabilities in 2018

Table 5 presents the actual availabilities of the generating plant recorded as against the forecast for 2018.

Table 5: Generating Plants' actual and estimated availability for the year 2018

Plant	Forecast (%) Availability	Actual (%) Availability
Akosombo Hydroelectric Plant	90	97.49
Kpong Hydroelectric Plant	72	67.65
Bui Generation Station	85	97.8
Takoradi Thermal Power Plant (TAPCo)	65	48.77
Takoradi Thermal Power Plant (TICo)	85	86.62
Tema Thermal Power Plant (TT1PP)	85	67.4
CENIT	90	25.78
Karpower	90	93.15
Tema Thermal Power Plant (TT2PP)	85	34.66
Sunon Asogli Power Plant	90	70.52
Ameri	90	81.76
Kpone Thermal Power Plant (KTPP)	85	42.11
AKSA	90	86.51

Table 5 shows that the Takoradi Thermal Plant (TAPCo), Tema Thermal Power Plant – T2, CENIT and the Kpone Thermal Power Plant (KTPP) plants recorded a lower than fifty (50) percent availability during the period. It should be noted however that the plants availability factors were calculated based on the total plant dependable capacity and fuel availability.

2.9 Quality of Supply

1.9.1 System Frequency

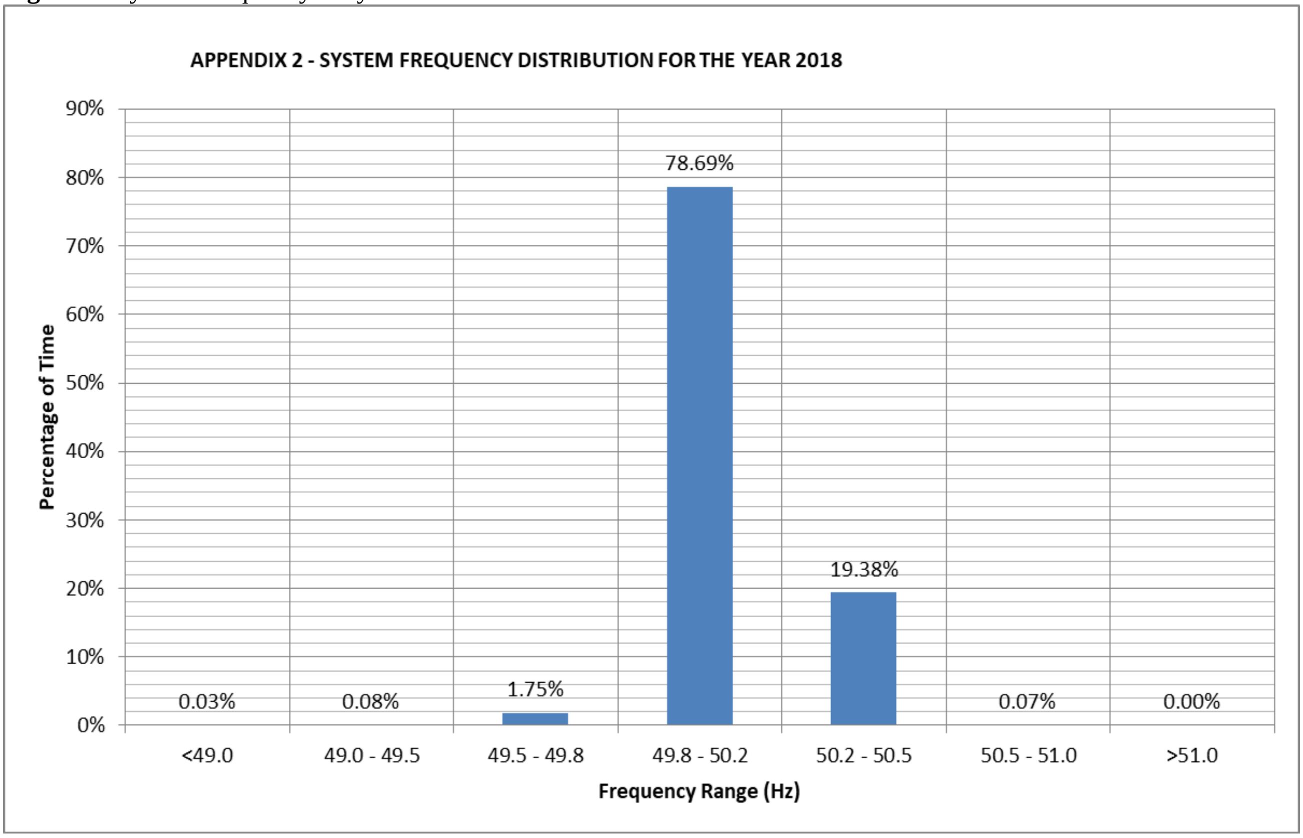
Figure 6 shows system frequency performance during 2018. It is seen from the graph that system frequency was within the normal range (49.8Hz – 50.2Hz) - 78.69% of the time which is lower than the 79.68% recorded in 2017. It was in the alert state 21.16% of the time in the entire year as follows:

- ✓ 49.5 – 49.8Hz - 1.78% of the time.
- ✓ 50.2 – 50.5 Hz - 19.38% of the time.

It was in emergency state 0.28% of the time in the entire year as follows:

- ✓ 49.0 – 49.5Hz - 0.08% of the time.
- ✓ 50.5 – 51.0Hz - 0.17% of the time.
- ✓ below 49.0Hz, 0.03% of the time.
- ✓ above 51.0Hz, 0.00% of the time.

Figure 6: System Frequency for year 2018



1.9.2 System Voltages

An analysis of voltages at selected Bulk Supply Points (BSP) at peak time indicates that voltages across the NITS were largely within normal limits, except Kumasi as shown in the Table below.

Table 6: Bus Voltages at Bulk Supply Points in 2018

Station	Number of Days of the Year			% of the Year		
	Normal	Below Normal	Above Normal	Normal	Below Normal	Above Normal
Achimota	**353**	11	1	**96.71**	3.01	0.27
Mallam	**344**	21	0	**94.25**	5.75	0
New Tema	**365**	0	0	**100**	0	0
Kumasi	**174**	191	0	**47.67**	52.33	0
Takoradi	**365**	0	0	**100**	0	0
Tamale	**363**	1	1	**99.45**	0.27	0.27

Kumasi voltages were below limits for 158 days in 2018. The low voltages were largely due to poor customer (ECG) load power factors and the relatively long circuit distance from generating plants.

2.10 Transmission Network Performance

1.10.1 Feeder Availability

The average feeder availability on the NITS in 2018 was 99.85 % as compared to 99.84% in 2017.

1.10.2 Transmission Lines

The System Average Availability (SAA) for the transmission grid was 99.48 % in 2018(see Table 7).

Table 7: The percentage transmission line availability in 2018

Voltage Class	Availability (%)
69kV	99.26%
161kV	99.57%
225kV	99.31%
330kV	99.20%
System Average Availability (%)	99.48%

2.11 Transformer Capacity

Over the period under review, transformer capacity on the NITS increased from 5,609.9 MVA to **8,064.2 MVA**, an increase of **2,454.3 MVA**.

Table 8 shows the breakdown of transformer additions.

Table 8: Transformer additions for year 2018

Substation	Transformer Code	Voltage level	Rating (MVA)
Dunkwa	11T2	161/34	33
Afienya	71T2	161/34	66
Tafo	15T2	161/34	33
Juaboso	64T2	161/34	33
Nayagnia	82T1	330/330	200
	82T2	330/330	200
	82T3	330/330	200
	82T4	330/330	200
Accra Central	83T1	161/34	125
	83T2	161/34	125
	83T3	161/35	125

Table 9 shows typical transformer peak loadings in some major substations in 2018.

Table 9: Transformer peak loadings for year 2018

Substation	Transformer Code	Rating (MVA)	Peak Loading (MVA)	% of Rating
Achimota	5T1	66	67.04	102%
	5T2	66	70.94	107%
	5T3	66	70.95	108%
	5T4	66	71.94	109%
	5T5	66	70.34	107%
	5T6	66	71.9	109%
Mallam	37T1	66	55.73	84%
	37T2	66	65.16	99%
	37T3	66	59.25	90%
	37T4	66	55.98	85%
New Tema	4T1	66	45.24	69%
	4T2	66	50.74	77%
	4T3	66	28.3	43%
	4T5	66	55.61	84%
	4T5	20	0.03	0%
	4T6	20	3.2	16%
Kumasi	13T1	66	69	105%
	13T2	66	61.3	93%
	13T3	66	53.8	82%
	13T4	66	62.4	95%
Takoradi	8T1	33	47	142%
	8T2	33	19.28	58%
	8T3	33	21.75	66%

2.12 New installations in 2018

Table 10 shows the projects that were commissioned during the year under review.

Table 10: Commissioned Projects in 2018

Equipment	Projects
Transmission Line	1. 161 kV Kpone Collector - Smelter II line 1
	2. 161 kV Kpone Collector - Smelter II line 2
	3. 161 kV Akosombo - Afienya
	4. 161 kV Bolgatanga - Nayagnia
	5. 161 kV Cenpower - Kpone Collector line 2
	6. 330 kV Sunon Asogli - Dawa
	7. 161 kV AKSA - Smelter II
	8. 330 kV Dawa - Davie
	9.161 kV Achimota - Accra Central
	10. 161 kV Accra Central - Mallam
Substation/Transformers	1. Afienya Substation
	2. Accra Central GIS Substation

3. DEMAND OUTLOOK FOR 2019

2.1 Peak Demand

It is projected that in 2019, the Ghana Power System will register a coincident peak demand of 2,665.68 MW and 2,796.92 MW for base and high case growth scenarios respectively. The projected 2019 reference peak of 2,665.68 represents an increase of 140.68 MW or in percentage terms, a growth of 5.54 % over that of 2018 peak demand of 2,525 MW which occurred on December 17, 2018.

The following spots loads are expected to contribute to the 2019 peak demand growth:

- ✓ Full operation of the Second Cell – line by VALCO, increasing the Company's peak demand to about 147 MW
- ✓ Increase in export to SONABEL (Burkina Faso)- from an average of 57.5 MW in 2018 to 100 MW
- ✓ Demand increases attributable to ongoing distribution network expansion works intended to extend coverage and improve service quality to ECG and NEDCo customers.
- ✓ Expected completion and commissioning of various ongoing rural electrification projects within the ECG and NEDCo distribution zones in 2019.

2.2 Summary of 2019 Peak and Energy Demand Forecast

Table 11 shows a summary of 2019 Projected Peak Demand for the base case.

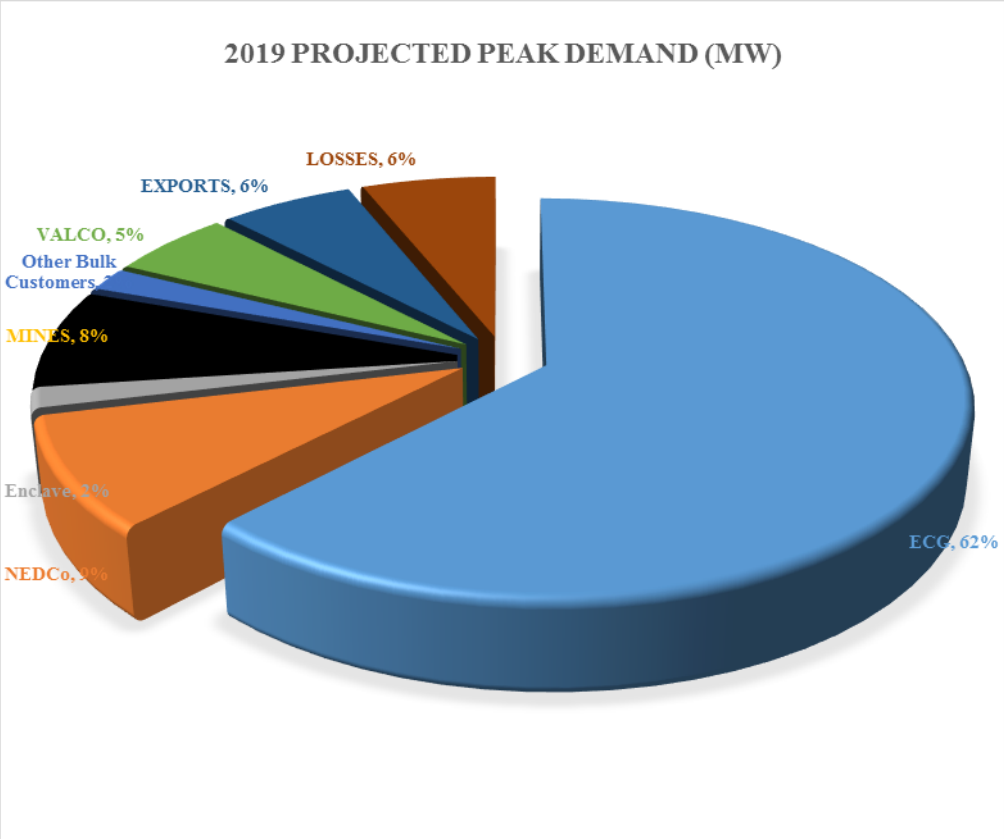
Table 11: Summary of 2019 Projected Peak Demand

Demand	Customer		2019 – Projected Coincident Peak (MW)
Domestic Peak Demand	**ECG**		**1,657.44**
	NEDCo		**241.43**
	EPC		**44.29**
	Mines	New Obuasi Obuasi New Tarkwa Prestea Ahafo/Kenyase (Newmont) New Abirim (Newmont) Akyempem (Wexford) Perseus (Ayanfuri) Bogosu Akwatia Konongo Adamus Gold Resources Asanko Gold Drill Works	**201.74**
	Other Bulk Customers	Akosombo Textiles Aluworks Ghana Water Company Ltd Diamond Cement Generation Plants Station Service Volta Hotel Savana Cement (Buipe) VRA Townships	**50.79**
	Losses +Network Usage		**162.57**
Total Domestic Peak Demand			**2,358.26**
Exports	**CEB**	**60**	
	CIE	**0**	
	SONABEL	**100**	
Total Exports			**160.00**
VALCO			**147.42**
Coincident Peak Demand MW			**2,665.68**

The Pie-Chart below describes the constituents of the 2019 Peak Demand, and it shows the percentage share of each customer class. As shown in the Chart, ECG's demand constitutes 62% of the total system peak followed by NEDCo and the Mines at 9%. VALCO at two Cell-lines constitutes 6%. Other Bulk

Consumers constitute 2 % whilst Exports to CEB and SONABEL together account for 5% of total peak demand

Figure 7: 2019 projected peak demand



2.3 Outlook of Energy Consumption

In 2019, the projected base case energy consumption is 17,237.79 GWh, this includes transmission network losses of 898.03 GWh. The estimated transmission losses, represents a 5.21 % of total projected energy supply. The projected 2019 energy consumption represents an increase of 1,277.43 GWh or in percentage terms, a growth of approximately 8.00 %, over the 2018 consumption of 15,960.36 GWh. The energy demand estimate for the high growth scenario is 18,013.96 GWh.

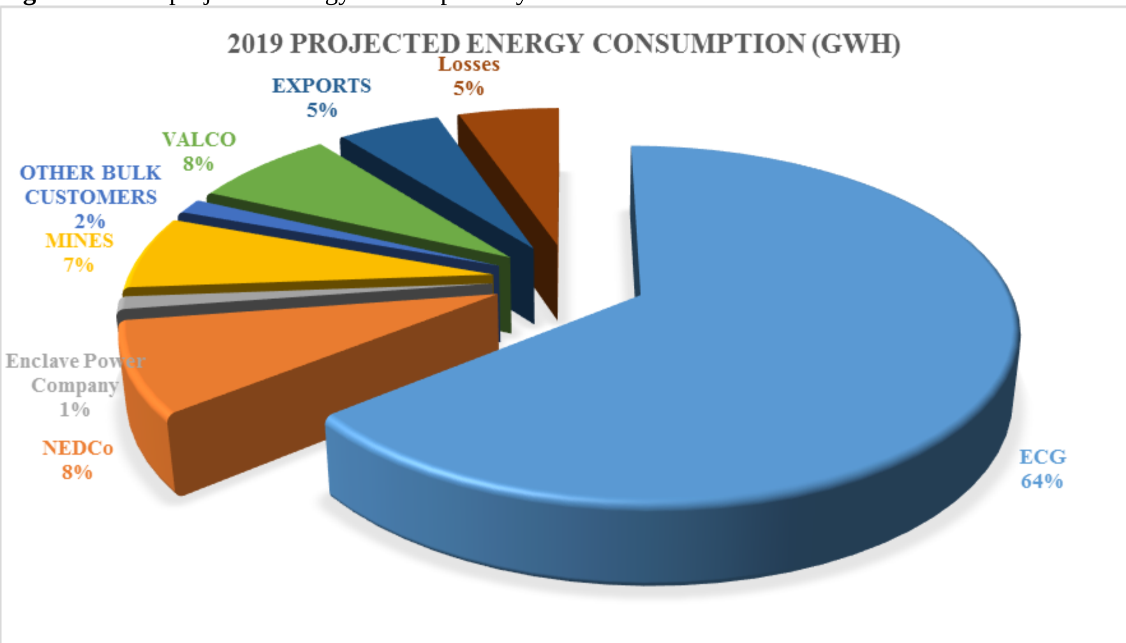
The summary of 2019 consumption by customer class is presented in Table 13.

Table 12: Summary of 2019 Energy Consumption by Customer

Energy	Customer	2019 – Projected Consumption (GWh)
Domestic Consumption	ECG	11,075.00
	NEDCo	1,443.99
	Enclave Power Company	200.00
	Mines	1,173.47
	Other Bulk Customers	238.58
	Losses + Network Usage	907.15
Total Domestic		15,038.19
Exports	CEB	349.72
	CIE	0.00
	SONABEL	566.09
VALCO		1,283.80
Total Energy (GWh)		17,237.79

Figure 8 below shows a Pie-Chart representation of the projected consumption of the various customer classes in 2019 and their percentage shares. As shown, ECG's consumption of 11,075.00 GWh represents about 64% of the total projected energy consumption for 2019. It is followed by NEDCo with a projected consumption of 1,443.99 GWh representing 8.38% of total consumption.

Figure 8: 2019 projected Energy consumption by customer



2.4 ECG Energy and Demand Forecast Methodology and Assumptions

The ECG Energy and Demand Forecast is annually reviewed to take into consideration changing trends in external factors likely to impact energy consumption. The ECG Energy and Demand Forecast review is expected as external factors affecting the demand for energy consumption by consumers have varied considerably due to the following:

- ✓ Higher GDP growth projection for Ghana[1]
- ✓ Increase in generation capacity[2]

In addition, energy losses (i.e. percentage system losses) are projected for the same period in line with the ongoing system losses reduction plan by the ECG Management.

ECG customers are categorized into Special Load Tariff (SLT) customers and Non – Special Load Tariff (NSLT) customers. The SLT customers include industrial customers who consume a demand of 100 kVA and above whilst the Non SLT customers include both residential and commercial customers who consume a demand less than 100 kVA.

Two (2) energy sales forecast models were then developed for each category (SLT and Non – SLT) to forecast the **Energy Sales (MWh)** from 2018 to 2027. Non-SLT model utilized the Ordinary Least Squares (OLS) – **Multiple Linear Regression Model (Log – Log)** which examines the historical behaviour of various key variables to build a model for predicting future demand. SLT model utilized the **Auto - Regressive Model** which includes the lagged values of the dependent variable as independent variables. The forecast values were projected based on assumptions for Low, Base and High case scenarios. The scaling / disaggregation methodology[3] was employed to carry out the short-term monthly forecast for the year 2019 only.

The Tables 13 and 14 show the elasticities of price, GDP and Customer Population for both the SLT and Non - SLT energy models.

Table 13: Coefficients for Natural Log of Non SLT model

LN_NSLT		
Coefficient of Population	LNPOP_NSLT	0.227022481
Coefficient of GDP	LN_GDP	0.752405419
Coefficient of Price	LNP_NSLT	-0.109534244
Dummy Variables 1 (2000,2007,2011 and 2014)	DMN	-0.041879495
Dummy Variables 2 (1998 and 2015)	DMN-2	-0.154824082
Constant	C	-5.692035469

[1] Projected GDP for 2019 of 6.8%: Source: https://www.pwc.com/gh/en/assets/pdf/2018-budget-highlights.v2.pdf
[2] Excess generation supply: Source: 2017 Energy Supply Plan for the Ghana Power System

Table 14: Coefficients for SLT model

LN_SLT		
Coefficient of Non-Agriculture GDP	LN_GDPi	0.391503539
Dummy Variables 1 (2007 and 2015)	DMS	-0.068481664
Constant	C	0.108650921
Coefficient of lag of SLT sales	LN_S_SLT (-1)	0.350402285

ECG Energy purchases (MWh) are also projected for the ten-year period 2018 – 2029 using the relation below;

$$Energy\ Purchases\ (P) = \frac{Energy\ sales\ (S)}{1 - \%System\ Losses}$$

Where Energy sales (S) is the forecast energy sales from the sum of the SLT and NSLT energy forecast results.

% System Losses is the projected system loss in line with ECG Management loss reduction program.

The Annual **Total Non – Coincident Peak Demand (MW)** are projected for the ten year period 2018 – 2027 using the relation below;

$$Maximum\ Demand = \frac{Number\ of\ units\ (kWh)\ purchased\ in\ a\ year}{Annual\ load\ factor\ \times 8760\ hours}$$

Based on the relation above, the Maximum Demand is forecasted for the period 2018 to 2027. The Annual Load Factor for the forecast period is projected based on historical load factors and expected changes in consumption patterns. The full details of the report can be obtained directly from the Engineering Directorate of the Electricity Company of Ghana.

2.5 NEDCo Energy and Demand Forecast Methodology and Assumptions

It has been established through correlation studies that population, economic growth and the price of electricity has direct relationship with energy growth in NEDCo. The model for the energy demand in NEDCo takes into account the following variables:

- ✓ Population
- ✓ GDP per Capita
- ✓ Tariff

NEDCo uses the Ordinary Least Square (OLS) and Auto-Regression (AR) methods for performing a multivariate regression analysis. Energy Sales forecasting is undertaken for all three (3) customer categories (Residential, Non-Residential and SLT).

The forecasting model is derived using excel for each customer category and the following statistical test are used to validate the accuracy of the model at a confidence level of 95% for each hypothesis:

- ✓ Multi-collinearity
- ✓ Serial correlation
- ✓ Stationarity test
- ✓ Normality test
- ✓ Homoscedastic test

2.5.1 Residential Energy Sales Forecast

NEDCo uses the Ordinary Least Square (OLS) regression methodology to determine the energy sales forecast for the residential customer category. The regression model used is as below:

- ✓ ENERGYR = 0.0173990458735*NGDP_R_NR - 41.0098705779

Where: ENERGYR= Energy sales for residential customers

NGDP_R_NR = NEDCo Region GDP for residential/non-residential category.

2.5.2 Non-Residential Energy Sales Forecast

NEDCo performs forecast for non-residential customers using the Ordinary Least Square (OLS) regression methodology. The equation for forecasting non-residential energy sales is as below:

- ✓ ENERGYNR = 0.00997595487073*NGDP_R_NR - 50.7441667843

  Where: ENERGYNR= Energy sales for residential customers

  NGDP_R_NR = NEDCo Region GDP for residential/non-residential category.

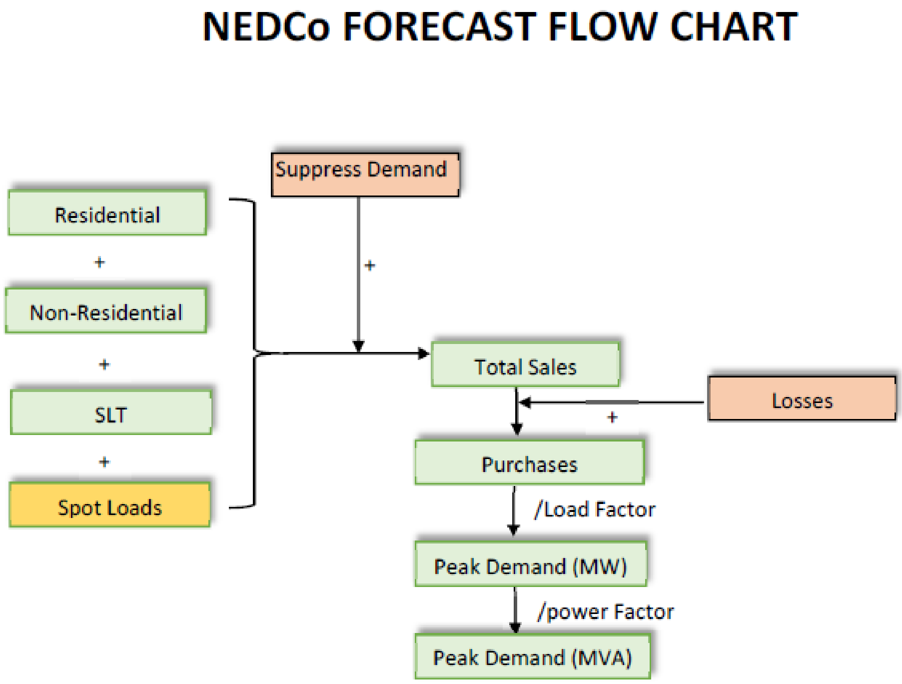
2.5.3 Special Load Tariff (SLT) Energy Sales Forecast

NEDCo used a first order Auto-Regression (log-log) to perform a forecast for its SLT (industrial) customers. The mathematical expression used for SLT energy sales forecasting is as below:

- ✓ Ln (ENERGYSLT = 0.862840699484 + 0.775968841734*Ln (ENERGYSLT (-1))

  Where: ENERGYSLT= Energy sales for residential customers

  ENERGYSLT (-1) = first order lag term of energy sales for SLT customers.



2.6 Projected Monthly Peak and Energy Demand for 2019

A summary of monthly energy consumption and the corresponding peak demand for the various customer classes is shown in Tables 15-18.

Table 15: Summary of Projected 2019 Monthly Energy (GWh) Consumption –base case scenario

Energy Forecast (GWh)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total GWh
ECG	972.83	860.09	941.61	954.30	958.08	883.96	876.98	889.32	878.83	935.61	937.67	985.73	**11075.00**
NEDCo	116.59	116.14	123.58	117.85	119.55	117.66	120.16	119.37	121.10	124.80	123.46	123.74	**1,443.99**
Enclave Power Company	14.54	13.13	14.54	16.44	16.99	16.44	16.99	16.99	16.44	19.43	18.65	19.43	**200.00**
MINES	105.45	95.07	98.42	95.68	97.31	92.50	98.55	101.71	95.42	99.20	95.75	98.42	**1,173.47**
Other Bulk Customers	21.07	20.97	21.04	20.15	19.96	18.44	19.47	18.64	18.36	19.85	19.17	21.46	**238.58**
VALCO	108.90	98.30	108.90	105.60	109.70	104.60	108.60	109.20	106.10	108.60	106.10	109.20	**1,283.80**
CEB(Togo/Benin)	29.70	26.83	29.70	28.74	29.70	28.74	29.70	29.70	28.74	29.70	28.74	29.70	**349.72**
SONABEL(Burkina)	37.91	34.44	37.88	51.34	53.00	50.83	50.35	50.49	49.43	50.49	49.43	50.49	**566.09**
CIE(Ivory Coast)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
EDM(Mali)	0	0	0	0	0	0	0	0	0	0	0	0	**0.00**
Network Usage	0.79	0.71	0.77	0.78	0.78	0.73	0.74	0.75	0.73	0.77	0.77	0.80	**9.12**
LOSSES	77.37	69.56	75.65	76.44	77.22	72.21	72.63	73.44	72.28	76.31	75.83	79.09	**898.03**
Total	**1,485.13**	**1,335.25**	**1,452.08**	**1,467.31**	**1,482.31**	**1,386.12**	**1,394.17**	**1,409.60**	**1,387.43**	**1,464.76**	**1,455.58**	**1,518.06**	**17,237.79**
Total Energy to be Transmitted less losses	**1407.76**	**1265.69**	**1376.43**	**1390.87**	**1405.09**	**1313.91**	**1321.53**	**1336.16**	**1315.15**	**1388.45**	**1379.74**	**1438.98**	**16,339.76**

Table 16: Summary of Projected 2019 Monthly Peak (MW) demand – Base Case Scenario

Coincident Peak Demand (MW)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ECG	1623.29	1630.18	1671.89	1676.83	1660.28	1582.75	1503.46	1502.26	1570.66	1632.98	1657.44	1592.97
NEDCo	228.69	233.29	242.05	229.26	233.17	233.68	233.39	236.58	238.62	238.09	241.43	240.94
Enclave Power Company	31.67	31.67	31.67	36.17	36.17	36.17	36.17	36.17	36.17	44.29	44.29	44.29
MINES	200.27	199.01	201.20	200.92	199.09	200.19	200.14	198.65	199.98	202.18	201.74	200.87
Other Bulk Customers	50.20	49.33	50.28	50.88	53.56	50.29	50.30	51.74	51.97	52.48	50.79	50.94
VALCO	146.31	146.31	146.31	146.71	147.42	145.32	146.01	146.71	147.42	146.01	147.42	146.71
CEB(Togo/Benin)	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	60.00	60.00	60.00
SONABEL(Burkina)	67.90	67.90	67.90	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
CIE(Ivory Coast)												
EDM(Mali)												
Network Usage	1.42	1.42	1.45	1.47	1.47	1.42	1.37	1.37	1.42	1.46	1.48	1.44
LOSSES	154.35	154.95	158.40	160.30	159.59	154.36	149.28	149.45	154.13	159.35	161.09	156.82
System Peak(Coincident)	**2,554.09**	**2,564.06**	**2,621.15**	**2,652.54**	**2,640.75**	**2,554.17**	**2,470.12**	**2,472.94**	**2,550.35**	**2,636.85**	**2,665.68**	**2,594.97**

Table 17: Summary of Projected 2019 Monthly Peak (MW) demand – High Case Scenario

Energy Forecast (GWh)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total GWh
ECG	1039.44	918.99	1006.10	1019.64	1023.68	944.50	937.04	950.22	939.01	999.68	1001.88	1053.23	**11833.41**
NEDCo	118.95	118.50	126.09	120.24	121.98	120.04	122.60	121.79	123.55	127.33	125.96	126.25	**1,473.29**
Enclave Power Company	14.54	13.13	14.54	16.44	16.99	16.44	16.99	16.99	16.44	19.43	18.65	19.43	**200.00**
MINES	105.45	95.07	98.42	95.68	97.31	92.50	98.55	101.71	95.42	99.20	95.75	98.42	**1,173.47**
Other Bulk Customers	21.07	20.97	21.04	20.15	19.96	18.44	19.47	18.64	18.36	19.85	19.17	21.46	**238.58**
VALCO	108.90	98.30	108.90	105.60	109.70	104.60	108.60	109.20	106.10	108.60	106.10	109.20	**1,283.80**
CEB(Togo/Benin)	34.60	51.06	56.46	54.64	37.39	23.39	24.07	24.07	23.39	32.49	37.39	51.06	**450.00**
SONABEL(Burkina)	44.00	37.30	41.30	39.97	57.29	55.44	57.29	57.29	55.44	57.29	55.44	57.29	**615.33**
CIE(Ivory Coast)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
EDM(Mali)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Network Usage	0.83	0.76	0.82	0.82	0.83	0.77	0.77	0.78	0.77	0.82	0.81	0.86	**9.65**
LOSSES	75.75	68.95	75.03	75.01	57.01	52.82	53.18	53.77	52.91	56.45	56.31	59.24	**736.44**
Total	**1,563.53**	**1,423.04**	**1,548.70**	**1,548.19**	**1,542.13**	**1,428.94**	**1,438.56**	**1,454.45**	**1,431.39**	**1,521.13**	**1,517.47**	**1,596.44**	**18,013.96**

Table 18: Summary of Projected 2019 Monthly Peak (MW) demand – High Case Scenario

Coincident Peak Demand (MW)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ECG	1673.96	1707.54	1726.99	1754.14	1732.58	1661.33	1535.06	1589.18	1638.78	1692.90	1801.13	1759.64
NEDCo	228.51	233.09	235.75	239.45	236.51	226.79	209.55	216.94	223.71	231.09	245.87	240.21
Enclave Power Company	43.00	46.00	46.00	46.00	46.00	44.00	44.00	44.00	44.00	46.00	46.00	46.00
MINES	200.27	199.01	201.20	200.92	199.09	200.19	200.14	198.65	199.98	202.18	201.74	200.87
Other Bulk Customers	50.20	49.33	50.28	50.88	53.56	50.29	50.30	51.74	51.97	52.48	50.79	50.94
VALCO	146.31	146.31	146.31	146.71	147.42	145.32	146.01	146.71	147.42	146.01	147.42	146.71
CEB(Togo/Benin)	100.00	100.00	100.00	100.00	100.00	70.00	70.00	70.00	70.00	70.00	80.00	100.00
SONABEL(Burkina)	67.90	67.90	67.90	67.90	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
CIE(Ivory Coast)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EDM(Mali)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Network Usage	1.48	1.51	1.52	1.54	1.55	1.48	1.39	1.43	1.46	1.50	1.58	1.56
LOSSES	162.62	165.15	166.78	168.83	117.51	112.24	105.82	108.61	111.25	116.34	122.40	121.09
System Peak(Coincident)	**2,674.24**	**2,715.83**	**2,742.73**	**2,776.37**	**2,734.21**	**2,611.64**	**2,462.27**	**2,527.25**	**2,588.57**	**2,658.51**	**2,796.92**	**2,767.01**

4. SUPPLY OUTLOOK

2.1 Generation Sources

The sources of generation considered for 2019 are mainly the existing Hydro, Thermal and Renewable Energy Plants, and committed power plants expected to come on line during the year.

2.2 Summary of Generation Sources

Table 19 presents a summary of the existing and committed generation sources considered for 2019.

Table 19: Existing Generation Sources for 2019

Plants	Installed Capacity (MW)	Dependable Capacity (MW)	Fuel Type
Akosombo GS	1020	900	Hydro
Kpong GS	160	105	Hydro
TAPCO (T1)	330	300	LCO/Gas
TICO (T2)	340	320	LCO/Gas
TT1PP	110	100	LCO/Gas
TT2PP	80	70	Gas
KTPP	220	200	Gas/ Diesel
VRA Solar Plant	2.5	0	Solar
TOTAL VRA	**2,263**	**1,995**	
Bui GS	404	360	Hydro
CENIT	110	100	LCO/Gas
AMERI	250	230	Gas
SAPP 161	200	180	Gas
SAPP 330	360	340	LCO/Gas
KAR Power	470	450	HFO
AKSA	370	350	HFO
BXC Solar	20	0	Solar
Meinergy Solar	20	0	Solar
Trojan	44	39.6	Diesel/Gas
Genser	22	18	Gas
CEN Power	360	340	LCO/Gas
Amandi	190	190	LCO/Gas
TOTAL IPP	**2,820**	**2,598**	
TOTAL (VRA, Bui & IPPs)	**5,083**	**4,593**	

2.3 Hydro Power Generation for 2019

The total projected hydro generation for 2019 is 5,670 GWh. This is made up of 4,258.44 GWh, 811.50 GWh and 600 GWh respectively expected from Akosombo, Kpong and Bui Generating Stations.

3.3.1 Akosombo & Kpong Hydro

It is planned to operate Three/Four (3/4) units during the off-peak period and up to five (5) units during the peak period in the year 2019. This mode of operation will result in operating capacity of up to 750 MW at Akosombo GS in 2019, which will ensure that the reservoir level is kept above the minimum operating level of 240 ft. This mode of operation will result in a projected minimum elevation of 253 feet at the end of the dry season in 2019.

Kpong Generation Station (Kpong GS), which is currently undergoing retrofit, will have three (3) out of the four (4) units available. The total average capacity that would be available at Kpong GS is 105 MW. As a result of the above mode of operation, the projected total annual hydro generation from Kpong and Akosombo generating stations is 5,070 GWh.

3.3.2 Bui Hydro

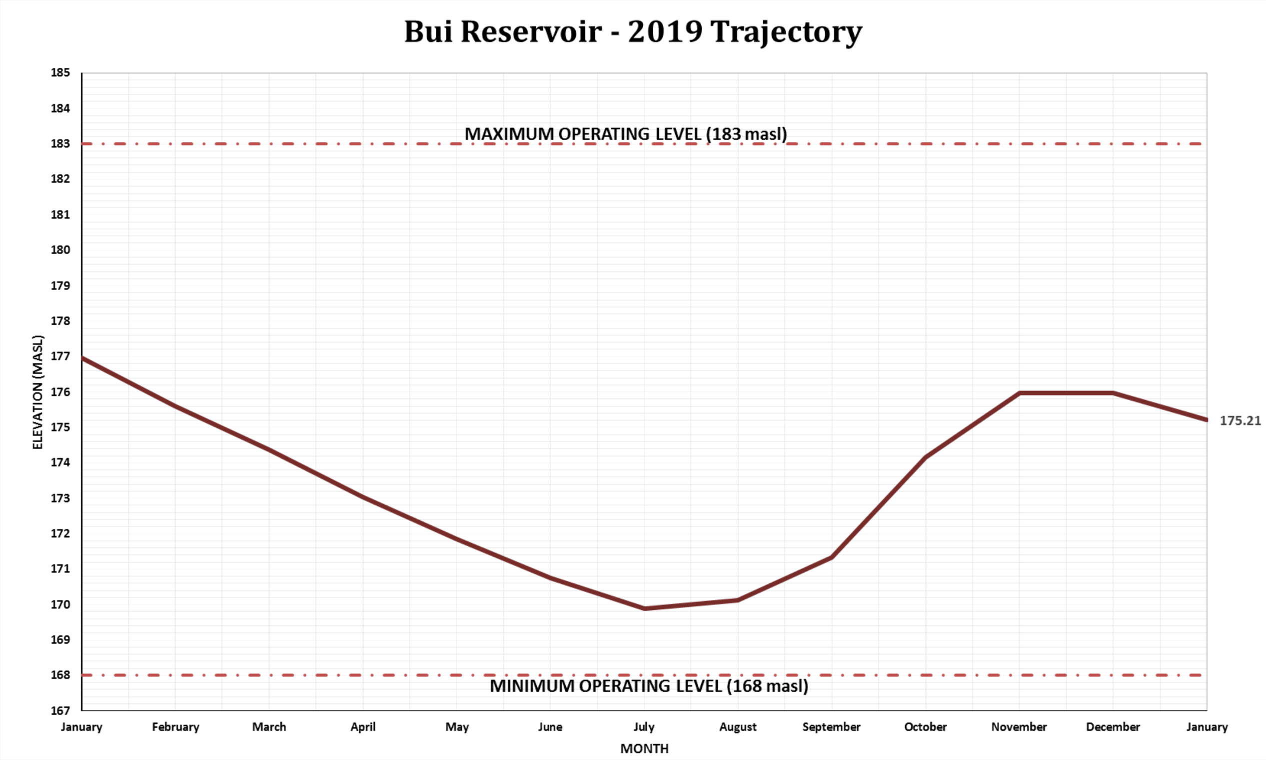
In 2019, Bui Hydro Plant is projected to operate an average of two (2) units throughout the year. This mode of operation will lead to a projected annual production of 660 GWh. The plant is assumed to provide an average generation capacity of 220 MW to support demand.

It is estimated that, for continuous and sustainable operation of the Bui GS for 2019 and for the subsequent years (in the likely event of low inflows), the reservoir level at the end of the dry season of 2019 should not drop below elevation 170 MASL. With a year-start elevation of 176.97 MASL in 2019, and the total estimated total energy production of 660 GWh for year 2019, the year-end elevation is projected at 175.21 MASL.

Assumptions for projected 2019 generation from the Bui Hydro Plant:

- ✓ 60% Long Term Average Inflow of 6,167 Mm3.
- ✓ 2019 Year start elevation of Bui Reservoir – 176.97 MASL
- ✓ Operation of two units in normal mode at 110 MW in 2019.
- ✓ Operation of third unit in Synchronous Condenser Mode (SCM) when required by NTIS from January 1 to December 31, 2019.
- ✓ Operate Turbinette at 3.75 MW from January 1 to December 31, 2019.

Figure 9**: 2018 Projected Bui Reservoir Trajectory**



2.4 Thermal Power Generation for 2019

The Projected Dependable Thermal Capacity for 2019 is 3,456 MW. This is made up of 2,906 MW from existing Units and 550 MW of committed Thermal Projects as shown in Tables 20 and 21. The projected total thermal energy generation for 2019 is 11,460.11 GWh, made up of generation outputs from VRA and IPPs Plants as shown in Tables 20 and 21.

Table 20: Existing Generation Sources

Plants	Installed Capacity (MW)	Dependable Capacity (MW)	Fuel Type
TAPCO (T1)	330	300	LCO/Gas
TICO (T2)	340	320	LCO/Gas
TT1PP	110	100	LCO/Gas
TT2PP	80	70	Gas
KTPP	220	200	Gas/ Diesel
TOTAL VRA	**1,080**	**990**	
CENIT	110	100	LCO/Gas
AMERI	250	230	Gas
SAPP 161	200	180	Gas
SAPP 330	360	340	LCO/Gas
KAR Power	470	450	HFO
AKSA	370	350	HFO
Trojan	44	39.6	Diesel/Gas
Genser	22	18	Gas
TOTAL IPP	**1,826**	**1,708**	
TOTAL (VRA, Bui & IPPs)	**2,906**	**2,698**	

Table 21: Existing Generation Sources

Generation Sources	2019 Projected Supply (GWh)
TAPCO	1491.78
TICO	1933.55
TT1PP	211.43
KTPP	158.19
TT2PP	0
Imports From Côte d'Ivoire	0
Total VRA Available Generation	**3,794.95**
SAPP 161	715.43
SAPP 330	1940.42
CENIT	0
AMERI Power Plant	1007.15
Karpower Barge	2775.15
AKSA	1227
CEN Power	0
Amandi	0
Total IPP (Thermal)	**7,665.16**
Total Supply (GWh)	**11,460.11**

2.5 New Generation Sources

In 2019, two new thermal power plants are expected to be commissioned into service as follows (Table 21):

- ✓ 340 MW Cen Power Thermal Power Plant located in Tema. The Plant would run on LCO or Gas and would be evacuated through the 161kV Collector Substation.
- ✓ 192 MW Amandi Thermal Power Plant located within the Aboadze Thermal Enclave. This plant is also dual-fired on either LCO or Natural Gas and will be evacuated through the expanded 330 kV Switchyard at Aboadze.

Table 22: Committed Generation Plants for 2019

Plants	Installed Capacity (MW)	Dependable Capacity (MW)	Fuel Type
CEN Power	360	340	LCO/Gas
Amandi	190	190	LCO/Gas
TOTAL Committed IPP	**550**	**530**	

2.6 Key Assumptions Underpinning the Supply Plan

In developing the 2019 Supply Outlook, the following key assumptions were made:

3.6.1 Planned Maintenance

The schedule of key maintenance activities expected to be undertaken in 2019 on generating units at the various power plants is shown in Table 24.

Table 23: 2019 Planned Maintenance

Plants	Planned Maintenance
Akosombo GS	Unit 1 is scheduled to undergo annual maintenance from May 20 - May 31, 2019 Unit 2 is scheduled to undergo annual maintenance from July 29 - August 09, 2019 Unit 3 is scheduled to undergo annual maintenance from June 24 - July 06, 2019 Unit 4 is scheduled to undergo annual maintenance from July 15 - 26, 2019 Unit 5 is scheduled to undergo annual maintenance from May 06 -17, 2019 Unit 6 is scheduled to undergo annual maintenance from June 10 - 21, 2019 and 1T6-Transformer Replacement from December 2 – 8, 2019 Maintenance at Akosombo GS will be scheduled in a manner that it will not affect overall power supply
Kpong GS	Unit 1: Quarterly maintenance for a period of 1 week in Jul 15 – 21 and November 04 - 10, 2019 Unit 2: Quarterly maintenance for a period of 1 week in April, August and December Unit 3: Post retrofit inspection for 30 days from March 1 – 30, 2019 Unit 3: Major Retrofit from January 1 to March, 2019 Unit 4: Major retrofit from April to December 2019
TAPCO	Unit 1: Fuel Nozzle Inspection January 01 to 30, 2019. Unit 3: Steam Turbine Generator repair works from January – March 2019. Unit 1: Offline Compressor Water Wash Repair & Maintenance July 21- 23, 2019 Unit 2: Offline Compressor Water Wash Repair & Maintenance July 28- 30, 2019
TICO	STG: Mandatory Inspection from January 7 to 11, 2019 Unit 1: Offline compressor water wash for performance test February 9 and May 9, December 10, 2019 Unit 2: Offline compressor water wash for performance test February 10 and May 10, 2019 Hot Gas Path Inspection and Casing Replacement August 1 to September 30, 2019
KTPP	Unit 1: Major Plant Inspection (Type A Maintenance) June 14 to 21, 2019
TT1PP	47G1 (TT1PS Gas Turbine) Offline Compressor Water Wash May 31 to June 01, 2019
TT2PP	Unit 1: Core Engine Swap and main gearbox overhaul July 17 to August 10, 2019 Unit 3: Generator Stator Repair Works January 07 to September 30, 2019 Unit 3: Core Engine Swap and main gearbox overhaul June 24 to July 18, 2019 Unit 5: Type A Maintenance September 03 – 08, 2019 Unit 6: Type A Maintenance September 10 – 15, 2019 Unit 1: Major Plant Inspection (Type A Maintenance) June 14 to 21, 2019

Bui GS	- Unit 4 is scheduled for January 7 to January 8, 2019.(Quarterly maintenance) - Unit 1 is scheduled for January 21 to January 25, 2019. (Quarterly maintenance) - Unit 2 is scheduled for February 11 to February 15, 2019. (Quarterly maintenance) - Unit 3 is scheduled for April 1 to June 30, 2019. (Annual maintenance) - Unit 2 is scheduled for May 27 to May 31, 2019. (Quarterly maintenance) - Unit 4 is scheduled for June 4 to June 5, 2019.(Quarterly maintenance) - Unit 1 is scheduled for June 10 to June 14, 2019.(Quarterly maintenance) - Unit 2 is scheduled for July 1 to September 30, 2019.(Annual maintenance) - Unit 3 is scheduled for August 5 to August 9, 2019.(Quarterly maintenance) - Unit 4 is scheduled for September 2 to September 8, 2019. (Annual maintenance) - Unit 1 is scheduled for October 1 to December 30, 2019. (Annual maintenance) - Unit 2 is scheduled for November 11 to November 15, 2019. (Quarterly maintenance) - Unit 4 is scheduled for November 25 to November 26, 2019. (Quarterly maintenance)
ASOGLI	- Unit 2 is scheduled for February 2 to February 23, 2019. (Type C maintenance) - Unit 1 is scheduled for March 5 to March 18, 2019. (Type C maintenance) - Unit 5 is scheduled for May 8 to May 21, 2019. (Type C maintenance) - Unit 7 is scheduled for July 10 to July 27, 2019. (Type C maintenance) - Unit 9 is scheduled for August 1 to August 18, 2019. (Type C maintenance) - Unit 1 is scheduled for December 22 to January 1, 2020. (Type B maintenance)
AKSA	- Unit 2 is scheduled for January 7 to January 28, 2019. (ABB generator L4 maintenance) - Unit 3 is scheduled for February 7 to March 1, 2019. (ABB generator L4 maintenance) - Unit 20 is scheduled for March 7 to March 29, 2019. (ABB generator L4 maintenance) - Unit 21 is scheduled for April 7 to April 29, 2019. (ABB generator L4 maintenance) - Unit 8 is scheduled for October 1 to October 31, 2019. (WARTSILA engine 36K mechanical maintenance) - Unit 9 is scheduled for November 1 to November 30, 2019. (WARTSILA engine 36K mechanical maintenance)

3.6.2 Natural Gas Quantities and Availabilities

The infrastructure bottlenecks that significantly constrained gas offtake in 2018 is expected to be resolved in 2019. The Takoradi – Tema Interconnection Project (TTIP), which will tie-in the Ghana Gas pipeline system to the West African Gas Pipeline (WAGP) system in Takoradi would allow reverse flow of surplus gas from Western offshore Ghana to Tema, through the WAGP. Commissioning of the Tema scope of the work is currently ongoing.

The tie-in would provide firm capacity to flow 20 MMscfd immediately (and additional 40 MMscfd on interruptible basis). The flow capacity will increase to 60 MMscfd firm and additional 55 MMscfd of interruptible once the Tema scope of the TTIP is completed in August 2019.

Another key piece of infrastructure that will increase gas utilization is the relocation of the 470 MW Karpowership barge from Tema to the Sekondi Naval Base. Both the gas pipeline to feed the power plant, and the power transmission line to evacuate the power generated by the plant, are currently being constructed. The Karpowership is expected to begin using circa 90 MMscfd of gas by end of August 2019.

Two additional powerplants – Cenpower and Amandi – are expected to be operational in Q2, 2019 in Tema and Q3 2019 in Takoradi respectively. These would increase gas offtake capacity by circa 90 MMscfd. The Jubilee, TEN and Sankofa fields have the capacity to supply the committed volumes of circa 90 MMscfd, 30 MMscfd and 180 MMscfd respectively. However, the lingering infrastructure bottlenecks will limit gas supply in 2019 as shown in table 24 below:

Table 24: 2019 Monthly Gas Delivery Profile (MMscfd) – due to infrastructure constraints

Gas Supply Analysis - 2019 Monthly (*in MMscfd)*

	Jan. 19	Feb. 19	Mar. 19	Apr. 19	May. 19	Jun. 19	Jul. 19	Aug. 19	Sep. 19	Oct. 19	Nov. 19	Dec. 19
Jubilee FV	48	13	34	60	73	73	73	73	73	73	73	73
TEN AG	19	-	-	-	-	-	-	24	24	24	24	24
Sankofa NAG	61	117	49	60	90	90	90	90	180	180	180	180
N-Gas	56	45	44	60	60	60	60	60	60	60	60	60
Total Gas Supply	**184**	**175**	**127**	**180**	**223**	**223**	**223**	**247**	**337**	**337**	**337**	**337**

3.6.3 West to East Reverse Flow

Ongoing works to facilitate West to East Reverse Flow of gas using the WAPCo Gas Pipeline is expected to be completed by April 2019. This will pave the way for Ghana Gas to supply natural gas to power plants in the Tema Generation Enclave.

3.6.4 Fuel Allocation

Due to the limited quantities of natural gas supply in 2018 as projected above, fuel usage at the Tema and Takoradi Power Enclaves shall be strategically managed as follows:

Tema

- ✓ 30 mmscf/day allocated to Sunon-Asogli power plants.
- ✓ 30 mmscf/day for VRA plants (TT1PP & KTPP) at Tema
- ✓ TT2PP/TT2PP-X operate on natural gas (on standby).
- ✓ Karpower to operate on HFO from January to September 2019 and then be relocated to Takoradi to run on natural gas from Sankofa Fields in the last quarter of the year.
- ✓ AKSA to operate on HFO

Takoradi

- ✓ T1 to operate mainly of Gas
- ✓ T2 to operate mainly on Gas
- ✓ AMERI to operate mainly on Gas
- ✓ Karpower to operate on Gas from Sakofa fields from September to December 2019.

3.6.5 Fuel Price

The following assumptions on price of fuel delivered made:

- ✓ Nigeria Gas – US$ 7.4/mmbtu
- ✓ Ghana Gas – US$ 7.4/mmbtu
- ✓ Delivered LCO – US$ 70/barrel
- ✓ Delivered HFO – US$ 84/bbl

2.7 Demand - Supply Analysis

This sub-section analyzes the demand – supply balance for 2019. The assumptions underpinning the demand - supply projections for the year are as described above. The analysis begins with the projected monthly energy generation from all the Generating Plants and is presented in the Table below. The analysis of the monthly energy balance shows supply surplus in 2019. Therefore, the following criteria are used to determine which Plants are dispatched on monthly basis:

a) Merit order dispatch including lower overall system losses.

b) Availability of fuel per Plant

c) Must-run Plants (e.g. Solar)

d) System stability Requirements

Table 25: Projected Monthly Generation in GWh

Customer Category	2019 Proj. Consumption (GWh)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Domestic	15,038.2	1,308.6	1,175.7	1,275.6	1,281.6	1,289.9	1,201.9	1,205.5	1,220.2	1,203.2	1,276.0	1,271.3	1,328.7
VALCO	1,283.8	108.9	98.3	108.9	105.6	109.7	104.6	108.6	109.2	106.1	108.6	106.1	109.2
Export (CEB+SONABEL+CIE)	915.8	67.6	61.3	67.6	80.1	82.7	79.6	80.1	80.2	78.2	80.2	78.2	80.2
Projected Energy Consumption	**17,237.79**	**1,485.1**	**1,335.2**	**1,452.1**	**1,467.3**	**1,482.3**	**1,386.1**	**1,394.2**	**1,409.6**	**1,387.4**	**1,464.8**	**1,455.6**	**1,518.1**
Generation Sources	**2019 Projected Supply (GWh)**												
Akosombo	4,258.5	377.1	340.6	341.4	364.9	377.1	364.9	297.3	377.1	299.2	377.1	364.9	377.1
Kpong GS	811.5	67.6	61.0	83.7	65.4	67.6	65.4	67.6	67.6	65.4	67.6	65.4	67.6
TAPCO	1,491.8	86.0	79.4	161.5	93.5	100.1	102.0	109.4	165.4	155.1	144.2	144.9	150.4
TICO	1,933.6	173.8	182.8	67.7	195.8	202.4	129.8	159.0	202.4	195.8	101.2	120.5	202.4
TT1PP	211.4	-	36.7	-	-	-	-	-	65.0	-	54.7	-	55.0
KTPP	158.2	43.6	-	-	-	-	-	-		57.3	-	57.3	-
TT2PP	-												
VRA Solar	3.0	0.3	0.2	0.3	0.2	0.3	0.2	0.3	0.3	0.2	0.3	0.2	0.3
Imports From Cote d'Ivoire													
Total VRA Generation	**8,867.94**	**748**	**701**	**655**	**720**	**747**	**662**	**634**	**878**	**773**	**745**	**753**	**853**
Bui GS	650.0	55.2	49.9	55.2	53.4	55.2	53.4	55.2	55.2	53.4	55.2	53.4	55.2
SAPP 161	715.4	62.4	50.7	56.9	60.4	57.0	60.4	62.4	62.4	60.4	62.4	60.4	59.3
SAPP 330	1,940.4	113.8	102.8	215.0	208.1	215.0	208.1	215.0	215.0	110.0	113.8	110.0	113.8
CENIT	-												
AMERI Power Plant	1,007.2	154.0	139.1	154.0	83.6	86.4	77.0	51.6	51.6	59.6	57.0	59.6	33.7
Karpower Barge	2,775.1	256.7	231.9	256.7	248.5	256.7	248.5	256.7	-	248.5	265.7	248.5	256.7
AKSA	1,227.0	90.0	56.0	55.0	89.0	60.0	72.0	115.0	143.0	78.0	161.0	166.0	142.0
CEN Power	-												
Amandi	-												0
BxC Solar	27.0	2.3	2.1	2.3	2.2	2.3	2.2	2.3	2.3	2.2	2.3	2.2	2.3
Meinergy	27.0	2.3	2.1	2.3	2.2	2.3	2.2	2.3	2.3	2.2	2.3	2.2	2.3
Safisana	0.7	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total Supply (GWh)	**17,237.79**	**1,485.1**	**1,335.2**	**1,452.1**	**1,467.3**	**1,482.3**	**1,386.1**	**1,394.2**	**1,409.6**	**1,387.4**	**1,464.8**	**1,455.6**	**1,518.1**

Table 26 on the other hand shows the annual energy and supply balance for 2019. It is seen from the Table that the total generation from the VRA Plants is **8,867.94** GWh, representing 51.44% of the projected total energy generation in 2019. Total generation from Bui Hydro and the other Independent Power Producers (IPPs) totals **8,369.86** GWh, accounting for 48.56% of the projected total generation in 2019.

Table 26: 2019 Projected energy and Supply Balance in GWh

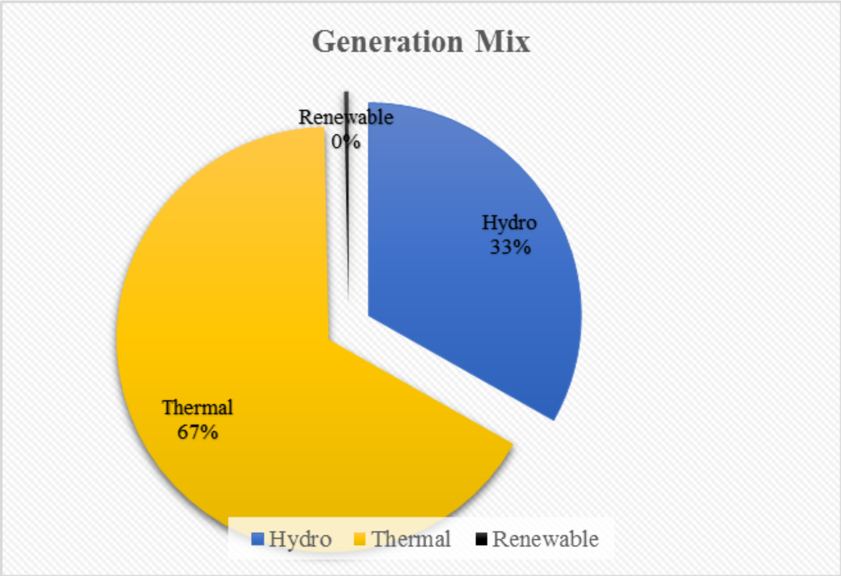
Projected Demand/Supply	Demand/Supply (GWh)
Domestic	15,038.19
VALCO	1,283.80
Export (CEB+SONABEL+CIE)	915.81
Projected System Demand	**17,237.79**
2019 Projected Supply (GWh)	
Akosombo	4,258.48
Kpong GS	811.50
TAPCO	1,491.78
TICO	1,933.55
TT1PP	211.43
KTPP	158.19
TT2PP	-
VRA Solar	3.00
Imports From Côte d'Ivoire	
Total VRA Available Generation	**8,867.94**
Bui GS	650.00
SAPP 161	715.43
SAPP 330	1,940.42
CENIT	-
AMERI Power Plant	1,007.15
Karpower Barge	2,775.15
AKSA	1,227.00
CEN Power	-
Amandi	-
BxC Solar	27.00
Meinergy	27.00
Safisana	0.70
Total IPP	**8,369.86**
Total Supply (GWh)	**17,237.79**

A graphical representation of the above energy supply showing the percentage share of each generation type is shown in Figure 10 below. The Chart indicates that, in 2019, thermal generation will constitute approximately 66.5% of projected total generation whilst generation hydro and Solar PV would constitute some 33.2% and 0.3% respectively. This shows that in 2019, generation from thermal sources would be more than twice that from hydro sources. This indicates the diminishing dominance of hydro in Ghana's overall generation mix.

The high penetration and increasing dominance of thermal generation in the overall generation mix could have serious implications for the sector for the following reasons;

- ✓ Since the tariffs are cedi-denominated and the utilities purchase fuel and other consumables in mostly United States Dollars (USD), any major depreciation of the Ghana Cedi against the major foreign currencies, particularly the USD, would throw the finances of the utilities into disarray.
- ✓ Since the thermal plants are predominantly gas-based, any disruptions in gas supply would have dire consequences on the power supply situation in the country.

Figure 10: Contribution of Supply by Generation Types



2.8 Projected Capacity Situation

The projected monthly Supply capacity levels, taking planned units maintenance and Fuel Supply Systems in to consideration is shown in Table 27.

Table 27: Projected Monthly Capacity Situation for 2019

Customer Category	**2019 Proj. System Peak (MW)**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Domestic	2358.26	2,290	2,300	2,357	2,356	2,343	2,259	2,174	2,176	2,253	2,331	2,358	2,288
VALCO	147.42	146	146	146	147	147	145	146	147	147	146	147	147
Export (CEB+SONABEL)	160.00	118	118	118	150	150	150	150	150	150	160	160	160
Projected System Demand	**2665.68**	**2,554**	**2,564**	**2,621**	**2,653**	**2,641**	**2,554**	**2,470**	**2,473**	**2,550**	**2,637**	**2,666**	**2,595**
Generation Sources	**Dependable Gen. Capacity (MW)**												
Akosombo	900	750	750	750	750	750	750	750	750	750	750	750	750
Kpong GS	105	105	105	105	105	105	105	105	105	105	105	105	105
TAPCO	300	200	200	200	300	300	300	300	300	300	300	300	300
TICO	320	320	320	320	320	320	320	320	320	320	160	160	320
TT1PP	100	-	100	0	100	0	100	0	100	0	100	0	100
MRP													
KTPP	200	100	-	100	0	100	0	100	0	100	0	100	0
TT2PP	30												
TT2PP-x	28												
T3	0												
VRA Solar	2.5												
Imports From Cote d'Ivoire	0	-	-	-	-	-	-	-	-	-	-	-	-
Total VRA Available Generation		**1,475**	**1,475**	**1,475**	**1,575**	**1,575**	**1,575**	**1,575**	**1,575**	**1,575**	**1,415**	**1,415**	**1,575**
Bui GS	345	220	220	220	220	220	220	220	220	220	220	220	220
Bui Min Unit	4	4.0	4.0	4.0	4	4	4	4	4	4	4	4	4
SAPP 161	180	180	180	180	180	180	180	180	180	180	180	180	180
SAPP 330	350	175	175	350	350	350	350	350	350	175	175	175	175
CENIT	100	100	100	100	100	0	100	100	100	100	100	100	100
AMERI Power Plant	230	230	230	230	230	230	230	230	230	230	230	230	150
Karpower Barge	450	450	450	450	450	450	450	450	0	450	450	450	450
AKSA	350	350	350	350	350	350	350	350	350	350	350	350	350
CEN Power	340	-	-	-	340	340	340	340	340	340	340	340	340
Amandi	190												190
Trojan	44	39.6	39.6	39.6	39.6	39.6	39.6	39.6	39.6	39.6	39.6	39.6	39.6
Genser	22.4	22	22	22.4	22.4	22.4	22.4	22.4	22.4	22.4	22.4	22.4	22.4
Safisana	0.1												
Meinergy	20												
Solar (Central Region)	20												
Total Available Generation (MW)		**3,246**	**3,246**	**3,421**	**3,861**	**3,761**	**3,861**	**3,861**	**3,411**	**3,686**	**3,526**	**3,526**	**3,796**
Surplus/deficit (MW)		**692**	**682**	**800**	**1,208**	**1,120**	**1,307**	**1,391**	**938**	**1,136**	**889**	**860**	**1,201**
Required Reserve (18%)		**460**	**462**	**472**	**477**	**475**	**460**	**445**	**445**	**459**	**475**	**480**	**467**
Actual Reserve Margin		27%	27%	31%	46%	42%	51%	56%	38%	45%	34%	32%	46%

The analysis of the above monthly demand and supply situation shows monthly positive generation reserve margins of up to 56% in 2019, as such, supply challenges are not anticipated barring any unforeseen fuel supply interruptions. With such a considerably high reserve capacity, it is anticipated that some of the Power Plants may not be dispatched whilst others may be forced to operate well below their full capacities.

2.9 Fuel Requirement

Currently, the main fuels for power generation include Light Crude Oil (LCO), Natural Gas and Heavy Fuel Oil (HFO). The estimates of quantity and cost of fuel requirement in 2019 is indicated in Table 28.

Table 28: **Summary of Annual Fuel Requirements**

PLANT	LCO (Barrels)	Natural Gas (MMbtu)	HFO (Barrels)
T1		15,668,149	
T2		17,731,383	
TT1PP		2,427,694	
TT2PP			
MRPP			
KTPP		1,863,437	
TOTAL VRA		**37,690,663**	
CENIT			
AMERI		11,360,507	
Cenpower			
SAPP+ SAPP Phase 2		22,270,931	
Karpower		8,919,587	2,447,363
AKSA			2,861,364
TOTAL IPP		**42,551,026**	**5,308,727**
TOTAL (VRA&IPP)		**80,241,689**	**5,308,727**

The summary of major fuel requirements for 2019 is as presented below:

- ✓ **LCO:** There would be no significant requirement for LCO in 2019 due to anticipated high volumes of gas from Sankofa, Jubilee and TEN fields.
- ✓ **Natural Gas:** Based on the assumed gas supply from Nigeria and Ghana, the total natural gas consumption is projected to be about 80.24 million mmbtu. VRA plants will use about 37.69 million mmbtu and IPPs some 42.55 million mmbtu.
- ✓ **HFO:** Karpower is expected to operate on HFO from January to September 2019. The AKSA Plant is also scheduled to operate on HFO through the year. Therefore, an estimated 5,308,727 barrels would be required by AKSA and Karpower.

3.9.1 Monthly Fuel Requirement

The breakdown of Monthly fuel requirements and their associated costs are as shown in Figure 29 below.

Table 29: Monthly fuel requirements and associated costs

	Units	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Estimated Thermal Fuel Requirement	**Units**													
TAPCO - LCO	barrels													-
TAPCO - GAS	mmbtu	1,153,362	1,064,612	2,167,043	1,253,739	1,342,714	911,837	978,433	1,479,244	1,386,702	1,289,797	1,295,535	1,345,131	**15,668,149**
TICO - LCO	barrels													-
TICO - GAS	mmbtu	2,060,407	2,166,813	802,743	2,321,585	1,599,314	1,025,712	1,256,575	1,599,314	1,547,724	799,657	952,224	1,599,314	**17,731,383**
TT1PP - GAS	mmbtu	-	421,575	-	-	-	-	-	746,330	-	627,955	-	631,834	**2,427,694**
MRP - GAS	mmbtu	-	-	-	-	-	-	-	-	-	-	-	-	-
KTPP - Gas	mmbtu	514,004	-	-	-	-	-	-	-	674,719	-	674,714	-	**1,863,437**
TT2PP - GAS	mmbtu	-	-	-	-	-	-	-	-	-	-	-	-	-
IPP Plants														-
VRA/AMERI Power Plant - GAS	mmbtu	1,737,183	1,569,068	1,737,183	942,995	974,429	868,118	582,075	582,075	672,458	642,593	672,458	379,874	**11,360,507**
Karpower Barge - HFO	barrels	357,869	323,237	357,869	346,325	357,869	346,325	357,869	-	-	-	-	-	**2,447,363**
Karpower Barge - GAS	mmbtu									2,174,003	2,325,110	2,174,003	2,246,470	**8,919,587**
SAPP - GAS	mmbtu	646,694	525,158	589,548	625,831	590,118	625,831	646,694	646,694	625,831	646,694	625,831	614,299	**7,409,223**
SAPP (Phase 2) - GAS	mmbtu	871,594	787,345	1,646,808	1,593,685	1,646,808	1,593,685	1,646,808	1,646,808	842,490	871,594	842,490	871,594	**14,861,707**
CENIT - LCO	barrels													-
Cenpower - LCO	barrels													
AKSA - HFO	barrels	209,880	130,592	128,260	207,548	139,920	167,904	268,180	333,476	181,896	375,452	387,112	331,144	**2,861,364**
ESTIMATED FUEL COST														
Total VRA LCO - Cost @ US$ 70/bbl	MMUS$	-	-	-	-	-	-	-	-	-	-	-	-	-
Total VRA Gas - Cost @ US$ 7.4/mmbtu	MMUS$	27.59	27.03	21.98	26.46	21.77	14.34	16.54	28.30	26.71	20.11	21.63	26.46	**278.91**
Total VRA Fuel Cost	**MMUS$**	**27.59**	**27.03**	**21.98**	**26.46**	**21.77**	**14.34**	**16.54**	**28.30**	**26.71**	**20.11**	**21.63**	**26.46**	**278.91**
Total VRA Imports Cost @ US$ Cents 12/kWh	**MMUS$**	-	-	-	-	-	-	-	-	-	-	-	-	-
Total VRA Cost of Fuel & Imports	**MMUS$**	**27.59**	**27.03**	**21.98**	**26.46**	**21.77**	**14.34**	**16.54**	**28.30**	**26.71**	**20.11**	**21.63**	**26.46**	**278.91**
IPP Fuel Cost														
Total IPP LCO - Cost @ US$ 70/bbl	MMUS$	-	-	-	-	-	-	-	-	-	-	-	-	-
Total IPP Gas - Cost @ US$ 7.4/mmbtu	MMUS$	24.09	21.32	29.40	23.40	23.76	22.85	21.28	21.28	31.93	33.20	31.93	30.43	**314.88**
Total IPP HFO - Cost @ US$ 84/bbl	MMUS$	47.69	38.12	40.83	46.53	41.81	43.20	52.59	28.01	15.28	31.54	32.52	27.82	**445.93**
Total IPP Fuel Cost	**MMUS$**	**71.78**	**59.45**	**70.24**	**69.93**	**65.58**	**66.04**	**73.87**	**49.29**	**47.21**	**64.73**	**64.45**	**58.25**	**760.81**
Total Cost	**MMUS$**	**99.37**	**86.48**	**92.22**	**96.39**	**87.35**	**80.38**	**90.41**	**77.60**	**73.92**	**84.84**	**86.07**	**84.71**	**1,039.72**

2.10 Estimates of Fuel Cost

The breakdown of the estimated cost of fuel for running all the Thermal Plants in 2019 is presented in the Table 30. Based on the assumed unit prices, the total estimated fuel cost for the Thermal Plants is US$ 1.04 Billion. This translates into an approximate monthly average of US$ 86.64 Million.

This total cost comprises US$ 278.91 Million or approximately US$ 23.24 Million per month for the VRA Plants and US$ 760.81 Million or monthly average of US$ 63.40 Million for the Non-VRA Plants.

Table 30: Breakdown of Estimated Fuel Cost for 2019

Type of Fuel	Cost (Million USD)
VRA - LCO	-
VRA - GAS	278.91
TOTAL VRA FUEL COST	**278.91**
IPP - LCO	
IPP - GAS	314.88
IPP - HFO	445.93
TOTAL IPP FUEL COST	**760.81**
TOTAL VRA & IPP COST	**1,039.72**

5. TRANSMISSION SYSTEM PERFORMANCE

2.1 Status of Ghana Transmission Grid

Within Ghana, electricity is transmitted at three main high voltage levels, namely; 69 kV, 161 kV and 330 kV. The 225 kV voltage lines within Ghana currently, only enables Ghana to interconnect with its western neighbour, La Côte d'Ivoire and northern neighbour, Burkina Faso. A similar interconnection with Togo is however through two 161 kV lines and a 330 kV line.

The Ghana transmission network consists approximately of 5,965.83 circuit kilometres of high voltage transmission lines which connect generating plants at Akosombo, Kpong, Tema, Bui and Aboadze to some sixty-four (64) Bulk Supply Points across the nation. The network has 134 transformers installed at various load centres across the country with a Total Transformation Capacity of **7,191.20** MVA.

The National Interconnected Transmission System (NITS) has over 600 MVArs of fixed shunts installed at various Substations including Achimota, Mallam, Smelter, Winneba, Takoradi, Kumasi etc. and a 40 MVArs of Static Synchronous Compensator (STATCOM) installed at the Tamale substation. The fixed shunts and the STATCOM complement the generating units in providing the reactive power requirements of the NITS, in order to maintain good voltages and minimize overall transmission losses.

The System Control Centre (SCC) in Tema is responsible for the real time dispatch (monitoring, coordination and control) of the Ghana Power System as well as cross-border power exchanges with neighboring countries. SCC is equipped with a Network Manager System (NMS), which is the main tool used to monitor and control dispatch operations on the Ghana Power System.

2.2 Transmission Line, Feeder and Substation Availability

The criteria used for ensuring high transmission Line, Feeder and Substation availability are as presented below:

- ✓ All existing transmission lines are expected to be in service in 2019 to ensure transmission of electricity from the generation stations to the Bulk Supply Points across the nation and to enable the execution of power exchanges with neighboring countries.
- ✓ Maintenance work on transmission lines and substations is to be organized in order not to significantly affect power supply to customers except for single transformer substations and consumers served on radial lines.

2.3 Steady State Network Analysis

Network analyses are carried out as part of the process for establishing a Supply Plan in order to determine transmission line loadings, substation bus voltages and network loss levels across the transmission network. In particular, the analyses seek to determine:

- ✓ Transmission line constraints to the evacuation of power from the generating stations to the Bulk Supply Points;
- ✓ The ability of the entire power system to withstand an N-1 contingency (i.e. forced outage of a single network element) e.g. transmission line, generator, transformer, etc;
- ✓ Reactive power demand on the NITS and the level of VAr generation from the generating units;
- ✓ Adequacy of reactive power compensation in the transmission network in achieving acceptable system voltages;
- ✓ Overall stability of the Ghana Power System;
- ✓ Overall transmission system losses during peak and off-peak periods;
- ✓ The impact of locational imbalance in generation resources.

4.3.1 Technical Adequacy Criteria

The following criteria were used to assess the performance of the system under both normal and contingency conditions.

a. Normal Condition

Table 31: Criteria, normal condition

Parameter	Range
Bus Voltages	0.95 pu to 1.05 pu
Transmission Line Power flows	not exceeding 85% of Line Capacity
Transformers	Not exceeding 100% *(nameplate rating)*
Generators	Not exceeding their Capability Curves

b. Contingency Conditions

Table 32: Criteria, contingency condition

Parameter	Range
Bus Voltages	0.90 pu to 1.10 pu
Transmission Line Power flows	not exceeding 100% of Line Capacity
Transformers	Not exceeding 120% of Nameplate Rating
Generators	Not exceeding their Capability Curve

c. Technical Analysis

Load Flow analyses were carried out to determine the transfer capability and assess the level of reliability of the transmission network to evacuate power from the generation centres to the various Bulk Supply Points.

Loadings on transmission lines and other power equipment are monitored to determine whether there are any limit violations. Also overall transmission system losses are compared to determine the impact of generation and transmission investments on grid performance.

d. Assumptions and Development of a Base Case

The study was carried out on the 2019 network model as highlighted in Section 3 of this report.

e. Generation Additions

The 350 MW Cenpower Plant located in Tema and the 192 MW Amandi plant located in Aboadze are expected to be commissioned into service in the second half of 2019.

f. Transmission Additions

The following transmission lines under construction modeled to assess their impact on the grid:

Transmission Lines

- ✓ 330 kV, Aboadze – Prestea - Kumasi Transmission line Project.
- ✓ 330 kV, Kintampo – Tamale - Bolgatanga Transmission line Project.
- ✓ 161 kV, Asawinso – Juabeso Transmission line Project.
- ✓ 161 kV, Volta – Accra East - Achimota Transmission line reconstruction
- ✓ 330 kV, Sekondi – Aboadze Transmission line Project for Karpower evacuation.

Substations

- ✓ Partial completion of 330kV Aboadze Switchyard Expansion,
- ✓ Kintampo 330kV
- ✓ 330kV Adobiyile

4.3.2 Summary of Results for the Steady State Network Analysis

The following scenarios were studied:

- ✓ **2019 Base Case with current system conditions.**
- ✓ **2019 Base Case with commissioning of the 330kV Aboadze – Prestea – Kumasi line.**
- ✓ **2019 Base Case with:**

  330 kV Aboadze – Prestea – Kumasi

  330 kV Kintampo – Tamale – Bolgatanga
- ✓ **2019 Cases above with:**

  Relocation of 450MW KarPower barge to Sekondi and the construction of the 330kV Sekondi - Aboadze line. This Case determines the impact of the KarPower in the West (Sekondi) as compared to the East (Tema).

- ✓ **2019 Cases above with:**

  Maximum generation from the West

  Maximum generation from the East

  Balanced generation case

- ✓ **2019 Cases above with:**

  161kV Volta – Accra East- Achimota – Mallam transmission line upgraded.

4.3.2.1 Results of load Flow simulations

Q1: 2019 Base Case with current 2018 System conditions

This Case has a Peak demand of 2,539 MW, the results of the load flow simulations indicate average transmission losses of 149.6 MW (~6%). This loss increment is attributable to increased Ghana system demand and export to SONABEL on the 161kV Network. The Volta – Accra East – Achimota corridor records 92% loading whilst the Achimota – Mallam line is overloaded to 107% due to the introduction of Accra Central GIS. With the upgrade of the 161kV Volta – Achimota – Mallam corridor, the overloads are expected to reduce. In the West, overloads will be recorded on the 161kV Tarkwa – New Tarkwa line recording 106% of its line capacity. With the commissioning of the 330kV Aboadze – Kumasi line, the line overloads will reduce.

Q2: 2019 Base Case with commissioning of the 330kV Aboadze – Prestea – Kumasi line

The load flow results indicate that system losses reduce to 110MW (4.81%). The new line carries 232MW from Aboadze towards Kumasi. This reduces the loading on the 161kV lines connecting Aboadze to Prestea and clears the 161kV Tarkwa – New Tarkwa overloads. However, the Volta – Achimota – Mallam lines remains overloaded.

Q3: 2019 Base Case with commissioning of the 330kV Aboadze – Kumasi and Kintampo – Tamale-Nayagnia (Bolgatanga) lines.

System losses further reduces to 97.7MW (4.24%) due to the introduction of the 330kV line from Kintampo to Nayagnia. The export to SONABEL increases from 53MW in the Base Case to 78MW on the average. The 161kV Volta – Achimota – Mallam lines still remain highly loaded.

Q3: 2019 with previous case with introduction of 450MW KarPower Barge at the West.

This simulation is similar to the previous case except that 450MW KarPower Barge has been relocated to the West. This relocation is to enable GNPC utilize all indigenous gas from the Sankofa, Jubilee and Ten Fields in fulfilment of the Take or Pay Gas Contracts.

The simulation indicate that system losses increase from 97.7MW in the previous case to 104.86MW (~7MW). The 330kV lines from Aboadze to Kumasi and Volta are loaded at 310MW and 183MW respectively. The Autotransformers at Volta are loaded at 77% whilst Achimota – Mallam line remains overloaded at 103%.

Q3: 2019 with previous case with Maximum generation in the West.

This case simulates the severest impact on the grid with majority of the Power Plant at Aboadze in service. It is similar to the previous case except for increased generation from the Aboadze Enclave. Due to gas contractual arrangements, this scenario is likely to occur and may be the must run scenario for 2019. System losses increases by 18MW to 122.9MW (4.86%). There will be low voltages in Achimota, Mallam, Accra Central and Winneba. The 161kV Volta – Achimota – Mallam and Aboadze – Mallam corridors will be overloaded. In this case the most critical issue will be the overload of the 330/161kV Autotransformers at Volta (105%). As indicated in the 2018 Supply Plan, the relocation of KarPower should be accompanied with A4BSP to utilize power on the 330kV to directly serve the loads in Accra. In the absence of A4BSP the excess power overloads the autotransformers at Volta along with huge losses in the transformers.

Q3: 2019 with previous case with Maximum generation in the East.

This simulation depicts a scenario where all the Hydro units at Akosombo are engaged and complemented with Thermals in Tema. The load flow indicates that system losses will be 97.3MW (3.91%) of generation. This is due to the close proximity of generation to the loads in Accra and Tama. However, the 161kV Volta – Accra East lines will be overloaded at 96% as well as the short line from KTPP- Volta overloaded at 109% with two units (220MW) engaged at KTPP. The 161kV Achimota – Mallam line remains overloaded at 116%. An upgrade of the corridor will reduce the overloads and further reduce losses.

Q3: 2019 with previous case with balanced generation in the West.

With a more balanced generation from both Eastern and Western generation enclaves, some line overloads and bus voltage violations are recorded in the Accra to Tema areas. The 161kV Volta – Accra East lines are loaded at 94% of its line capacity. There are observed low voltages at the Winneba, Mallam and Accra Central substations. System losses recorded for this case is 105MW (4.18%).

Q3: 2019 with 161kV Volta – Achimota – Mallam lines upgraded.

The upgrade of the 161kV Volta – Achimota – Mallam lines from the simulations proves to be a better case with improved system conditions. Line overloads from previous case above are cleared as well as improved substation voltages at the flagged substations (i.e. Winneba, Mallam and Accra central). Voltages at Mallam improves from 143kV to 152.5kV System losses improve as this case records approximately 96.6 MW representing 3.86% of total system generation. This case hence represents the ultimate scheme of developments expected in the Network to ensure improved system performance.

Contingency Analyses

In 2019, Aboadze will be the biggest Generation hub in Ghana with the inclusion of Amandi and the relocation of the KarPower Barge. With a total generation capacity of approximately 1,540 MW power flow studies indicate that contingencies out of the Aboadze Enclave towards load centres will have the greatest impact on the grid. The contingencies are ranked in order of severity and are as follows:

a) 330kV Aboadze – Prestea – Kumasi line

Since it carries over 300MW at peak, a loss of the line means that 330 MW needs to be re-routed on 161kV lines from Aboadze – Kumasi. This may lead to system disturbances triggered by overload tripping of 161kV lines from Aboadze to Prestea.

b) 161kV Kumasi – Anwomaso line

A strategic line connecting the 330kV from Aboadze to Kumasi, serving as an extension of the 330kV to link the Network in Kumasi. An outage on the line collapses the load flow case. A solution is to upgrade the line to a double circuit.

c) 161kV Aboadze – Mallam (Coastal lines)

A low capacity double circuit line that connects the load centres in Accra through Cape Coast and Winneba. Due to the overload on the Volta autotransformers, the corridor carries excess power and gets overloaded. In a contingency, the power it carries is transferred to the 330kV line but for the same Autotransformer overloads the load flow case diverges.

d) 161kV Aboadze – Tarkwa line

A contingency on this line due to its higher capacity overloads the small capacity 161kV lines from Aboadze – Takoradi – Tarkwa – New Tarkwa.

e) 330kV Kintampo – Tamale lines

An outage on the 330 kV Volta –Aboadze line results in overloads on the 330/161 kV auto transformers at Volta, however with the Pokuase (A4BSP) station in service the overload situation clears.

4.3.3 Radial Lines and Single Transformer Stations

The following lines in the NITS are presently radial and therefore the customers served by these lines suffer complete blackout anytime the lines are out-of-service. For the single transformer stations, customers served by these transformers also suffer complete blackout anytime they go out-of-service.

Radial Lines

- ✓ 161 kV Takoradi – Esiama Line
- ✓ 161 kV Bogoso – Akyempim Line
- ✓ 161 kV Bolgatanga – Zebilla – Bawku Line
- ✓ 161 kV Tamale –Yendi Line
- ✓ 69 kV Asiekpe – Sogakope Line
- ✓ 69 kV Asiekpe – Ho – Kpeve – Kpandu -Kadjebi Line

Single Transformer Stations

- ✓ Sogakope
- ✓ Yendi
- ✓ Esiama
- ✓ Dunkwa
- ✓ Konongo
- ✓ Ayanfuri
- ✓ Obotan
- ✓ Mim
- ✓ Buipe

6. POTENTIAL SUPPLY CHALLENGES IN 2019

This chapter presents the challenges that may occur during 2019 and its mitigation measures.

2.1 Managing the Hydro Risk

Due to the above-average inflow into the Akosombo and Bui hydro dams in 2018, optimum amount of generation from hydro is expected. This however, requires proper coordination of maintenance activities. The availability and reliability of the thermal units are also very key to maintain the planned hydro draft rate.

2.2 Thermal Fuel Supply Risk

Reliability of Gas supply from WAGP and Ghana Gas Company remains a major risk to electricity supply reliability in Ghana. Although, there is high installed generating capacity, any disruptions in fuel supply, mostly gas, could adversely impact supply reliability.

5.2.1 Gas Supply Disruptions

There is a planned total shutdown of the Atuabo gas processing plant for two (2) week in April 2019. This is to enable Ghana Gas to interconnect its systems with the West African Gas Pipeline Company (WAPCO) for reverse gas flow to Tema through the WAGP pipeline. This would result in the curtailment of gas supply from Ghana Gas to Aboadze generation enclave.

2.3 Supply Reliability of Customers served by Radial Lines and Single Transformer Stations

5.3.1 Radial lines

Currently, supply reliability to customers served via single circuit radial lines is quite low. This is because an outage on such single circuit radial lines interrupts supply to such customers. The following are some of the single circuit radial lines on the NITS:

- ✓ Tamale – Yendi line;
- ✓ Takoradi – Esiama line;
- ✓ Bogoso – Akyempim line;
- ✓ Bolga - Zebilla line;
- ✓ Zebila – Bawku line
- ✓ Kpando – Kadebi
- ✓ Asiekpe - Sogakope

Supply reliability to customers served on these lines would improve in future when such lines are upgraded through construction of additional line(s) or by looping them into other adjoining substations.

5.3.2 Single Transformer Stations

Similar to single circuit radial lines, consumers supplied by single transformer substations also suffer low level of supply reliability. Consumers facing such challenges are those in Akosombo Township, Yendi, Sogakope and Esiama. Since these townships are supplied via single transformer stations, Maintenance and/or upgrade works at these stations are often a challenge due to difficulties in securing outages.

5.3.3 Power Evacuation

There are also transmission capacity constraints in some portions of the network which could lead to transmission line overloads:

- ✓ Insufficient reactive power compensation could lead to poor customer supply voltage in areas such as Kumasi, Accra, and some parts of the Western region
- ✓ Some sections of the NITS do not satisfy the N-1 criteria and will be unable to withstand some single line/transformer contingencies

7. DISTRIBUTION OUTLOOK

2.1 ECG Network

Based on sub-transmission reliability studies undertaken by ECG, a number interventions and projects were commissioned in 2018 or currently underway and expected to be completed in 2019 to resolve various constraints of *low voltages, feeder and transformer overloads during firm and non – firm conditions*. Some of the key projects under construction are the following:

- ✓ Installation Voltage regulators at Nsawam, Mampong and Aburi to improve voltages
- ✓ Construction of the Pokuase BSP, this project is under construction- Upon completion it will boost voltage support to Dodowa, Mampong, Aburi and Ofankor. it will also improve reliability by serving as an alternative to Achimota BSP and Afienya BSP
- ✓ Construction of Afienya BSP- this will boost voltage at Dodowa, Mampong and Aburi
- ✓ Ongoing construction of the Asekyem primary substation - To support load on the Ridge ("A") and Amanfrom substations

The details of the expansion projects are attached in Appendix B

2.2 NEDCo Distribution Network

Power supply reliability in NEDCo Areas is generally good. However, reliability in some areas of the network has been lower than expected due to over extension of these lines and over-ageing resulting in high technical losses. Some of these lines have been extended, as part of Self Help Electrification Project (SHEP) implementation, beyond technically allowable distances. Some interventions, however, have been made on some of these lines resulting in improved supply reliability on them.

The following are the lines and substations/equipment in NEDCo with challenges affecting supply reliability to customers. Short-Medium term as well as long-term solutions being pursued are also indicated.

6.2.1 Sunyani-Berekum-Dorma/Sampa 34.5 kV Line

This line takes its source from GRIDCo's BSP in Sunyani. The increased load on this line has resulted in low voltages to customers; especially, in some sections of Berekum, Dorma Ahenkro, Sampa and its environs. There was also inadequate protective/control equipment at various branches of the lines. This results in outage to the entire line when there is a fault on any section of the line.

6.2.2 Network Reinforcement and Technical Loss Reduction Strategy to Resolve Challenges

Autoreclosers have been installed at selected portions of the line to ensure that faulty portions of the line are isolated automatically without interrupting supply to the entire line. Some distribution transformers have also been installed in some communities within the distribution network to improve supply voltages to customers.

As part of the implementation of the JICA funded Distribution Master Plan for Ghana, which was completed in 2008. A 161/34.5kV BSP was proposed in Berekum to improve the supply voltages in the Berekum and Dorma Ahenkro areas. GRIDCo is now constructing the proposed 161/34.5kV BSP at Berekum. This new substation when completed, will improve the low voltage situation in the area.

6.2.3 Yendi-Bimbilla-Kete Krachi 34.5kV Line

This 34.5kV line takes its source from GRIDCo's BSP in Yendi. This line is very long with high voltage drops resulting in low voltages on some sections of the line. There is also inadequate protection/control equipment on the line for segregation of faults.

6.2.4 Network reinforcement and technical loss reduction strategy to resolve challenges

A contract has been awarded for the installation of Autoreclosers and Sectionalizers on the line to minimize outages on the line in the medium term. Some distribution transformers have been installed in the distribution network to improve supply voltages to customers in the affected communities.

As part of the implementation of the JICA funded Distribution Master Plan for Ghana, a booster station was proposed in Bimbilla to improve the voltage on the Yendi-Bimbilla- Kete-Krachi line. The Korea EXIM Bank is proposing to fund the construction of this 20MVA booster/switching station. As part of this construction, separate feeders with independent protection/control devices will be provided to improve supply reliability in the Bimbilla and Kete-Krachi area.

The long-term measure to improve supply reliability in the Area is to construct a 161/34.5 kV BSP in Kpandai to improve power supply to Bimbilla, Salaga, Kpandai and Kete-Krachi areas. NEDCo has also communicated this request to GRIDCo for consideration.

6.2.5 Yendi-Gushegu-Gambaga-Bunkprugu 34.5kV Line

This 34.5kV line also takes its source from GRIDCo's BSP in Yendi. This line is one of the longest lines with numerous branches due to SHEP. There are no protective/control equipment on the branches for segregation of faults. The effect is that a fault on a branch results in outage to the entire line, resulting in increased and prolong outages.

6.2.6 Network Reinforcement and Technical Loss Reduction Strategy to Resolve Challenges

A contract has been awarded for the installation of Autoreclosers and Sectionalizers on the line to minimize outages on the line in the medium term. Another measure being taken is to construct a 14km line from Garu to transfer part of the load to the Bawku primary substation, which is fed from the Bawku BSP.

The long-term measure to improve supply to the Gambaga, Gushiegu and Bunkprugu areas is to construct a 161/34.5 kV BSP at Walewale to serve, not only Gambaga, Gushiegu and Bunkprugu areas, but also serve the Walewale and Yagaba areas. Yagaba is currently served from the Bolgatanga BSP, a distance of about 140km away. Gambaga and Gushiegu are located about 140km from the Yendi BSP. Walawale is therefore seen as an ideal place for the construction of a 161kV substation. NEDCo has communicated this request to GRIDCo.

6.2.7 Tamale-Dalun-Nasia 34.5kv Line

This 34.5kV line takes its source from GRIDCo's BSP in Tamale. This line is one of the longest lines with numerous branches due to SHEP. There are inadequate protective/control equipment on the branches of the line for segregation of faults. The effect is that a fault on a branch results in outage to the entire line, resulting in increase and prolong outages.

6.2.8 Network Reinforcement and Technical Loss Reduction Strategy to Resolve Challenges

A contract has been awarded for the installation of Autoreclosers and Sectionalizers on selected portions to minimize outages on the line in the medium term. A switching station is to be constructed in the line at Gumo in order to create separate feeders with independent protection/control equipment.

6.2.9 Wa-Jirapa-Nandom-Hamile 34.5kV Line

This 34.5kV line takes its source from NEDCo's primary substation in Wa which also takes its source from the GRIDCo's BSP in Wa. This line serves various districts including Nadowli, Jirapa/Lambusie, Lawra and Nandom. The Wa - Hamile line is about 110km long and has numerous branches with inadequate protective/control equipment at the branches of the line for segregation of faults. The effect is that a fault on a branch results in outage to the entire line. Also, there is low voltage at the receiving end of the line due to the length of the line, and increasing load.

6.2.10 Network Reinforcement and Technical Loss Reduction Strategy to Resolve Challenges

A contract has been awarded for the installation of Autoreclosers and Sectionalizers on selected portions to minimize outages on the line in the medium term. Work is yet to start, but it is expected that outages on the line will be minimized after the completion of work. NEDCo has proposed to construct a switching/booster station at Domwine to improve the voltage on the line and create separate lines with independent protective/control equipment. The long-term measure being considered is the construction of 161/34.5kV BSP at Nandom to improve power supply quality in the north-western part of the Upper West region. NEDCo has communicated this request to GRIDCo.

6.2.11 Obsolete Switchgears at Navrongo and Bawku Substations

Switchgears and associated facilities at NEDCo's primary substations at Bawku and Navrongo are obsolete and unreliable.

6.2.12 Network Reinforcement and Technical Loss Reduction Strategy to Resolve Challenges

Some obsolete parts of the switchgears have been replaced to improve the reliability of the switchgears. A contract has been awarded for the replacement of the switchgears and associated facilities.

6.2.13 Rampant Power Theft Militating Against Reliable Supply

NEDCo is challenged with widespread power theft, especially in its Northern Area that needs immediate intervention. The situation is delicate as culprits steal with impunity with their expectation of getting political and chieftaincy support.

This situation is increasing NEDCo's commercial losses day by day to a level that is gradually becoming unbearable and affecting reliable power supply.

6.2.14 Commercial Loss Reduction Strategy

NEDCo is investing in capital intensive projects such as relocating existing meters unto pole-tops, replacing existing meters with smart prepaid meters and replacing bare conductors with bundled conductors.

8. OVERVIEW OF MEDIUM-TERM SUPPLY: 2020 - 2024

In this chapter, the medium-term (2020 - 2024) peak demand and consumption forecast to serve as a guide for power system investment and planning is presented. Typically, it takes at least five years for conventional power plant projects to transition from conception through funding arrangements, detail design, construction to commissioning and commencement of commercial operation. This section therefore provides an outlook for generation and transmission system requirements for the next five years (2020 – 2024) to enable adequate and timely measures to be put in place to ensure security of supply in the Ghana Power System over the medium term. The high case demand scenario was used for the analyses.

2.1 Demand Outlook

The Projected electricity demand over the period 2020 – 2024 is based on the ESP committee load forecast. It covers natural growth in domestic demand over the period and some Spot Loads. The expected spot loads for the period are as follows:

- ✓ VALCO is expected to run 2 pot-lines (147 MW) in 2019 till 2022 when the demand increases to 300 MW. The demand is expected to further increase to 500 MW by 2024
- ✓ Mines:

  Newmont Mines, Ahafo - demand is expected to increase by 10 MW in 2019 and a further increase of 12.5 MW in 2021 at Ahafo-North.

  Azuma Mines - 18 MW by 2022 at Yagha (50km North West of Wa)
- ✓ Potential Exports:

  Export to Burkina Faso is expected to increase to 150 MW from 2020;

  Export to CEB is projected to be 120 MW from 2020

  Export to Mali is expected to increase from 50 MW in 2023, to 100 MW by 2024

For the high case growth scenario, total electricity consumption of Ghana including power exports to Togo, Benin, Burkina Faso and Mali is projected to increase from **20,071** GWh in 2020 to **28,999** GWh in 2024 at a Compound Annual Growth Rate (CAGR) of approximately 9.6 %. The system peak demand is projected to increase from 3,073 MW in 2020 to 4,394 MW in 2024.

The summary of 2020-2024 projected demand is illustrated in Tables 33 and 34.

Table 33: Projected High Case Energy Demand (GWh) (2020- 2024)

Energy Consumption (GWh)	2020	2021	2022	2023	2024
Domestic	17,065	18,393	19,841	21,222	22,241
VALCO	1,284	1,284	2,628	2,628	4,380
Exports	1,721	1,721	1,721	2,050	2,378
TOTAL	20,071	21,399	24,190	25,900	28,999

Table 34: Projected High Case Peak Demand (MW) (2020- 2024)

Peak Demand (MW)	2020	2021	2022	2023	2024
Domestic	2,655	2,853	3,076	3,291	3,524
VALCO	147	147	300	300	500
Exports	270	270	270	320	370
TOTAL	3,073	3,270	3,646	3,911	4,394

2.2 Projected Supply Outlook

The power supply outlook was prepared considering the existing and committed capacity additions. The assessment of generation adequacy is based on ensuring that sufficient generation resources are available to meet the forecast demand plus the required 18% capacity reserve margin.

7.2.1 Existing Generation

The existing power supply facilities are made up of hydro, thermal and renewable energy sources. The breakdown of projected high case demand versus expected supply from the existing generation resources is as shown in Table 35.

Supply Assumptions

The following assumptions were made for Hydro Power Generation:

- ✓ **Akosombo & Kpong GS.** Provision was made for the sustenance of the Akosombo reservoir. A maximum of five (5) units were assumed over the period 2020 - 2021. From 2022 onwards, all the six (6) units are expected to be available to support peak demand. Akosombo & Kpong are assumed to generate a total of 4,800 GWh per annum over the period 2020-2021 and a total of 5,000 GWh in the period 2022 -2023. It is assumed that from 2024 onwards, the firm output of 5,300 GWh per annum would be generated by Akosombo and Kpong Plants.
- ✓ **Bui Generating Station.** Bui hydro is assumed to produce about 756 GWh of electricity/year from 2019. Bui GS is assumed to generate an average of 230 MW during peak period to support peak demand.

7.2.2 Committed Generation Projects

The following are the committed generation additions expected to come on line in the medium-term:

Projects Under Construction

- ✓ **Amandi Energy Limited:** This is a 192 MW combined-cycle power plant expected to be commissioned by 2019. The plant is located within the Aboadze Enclave.
- ✓ **Early Power:** This is a 400 MW power plant to be located at Tema and is expected to be commissioned in last quarter of 2019.

Projects not Under Construction

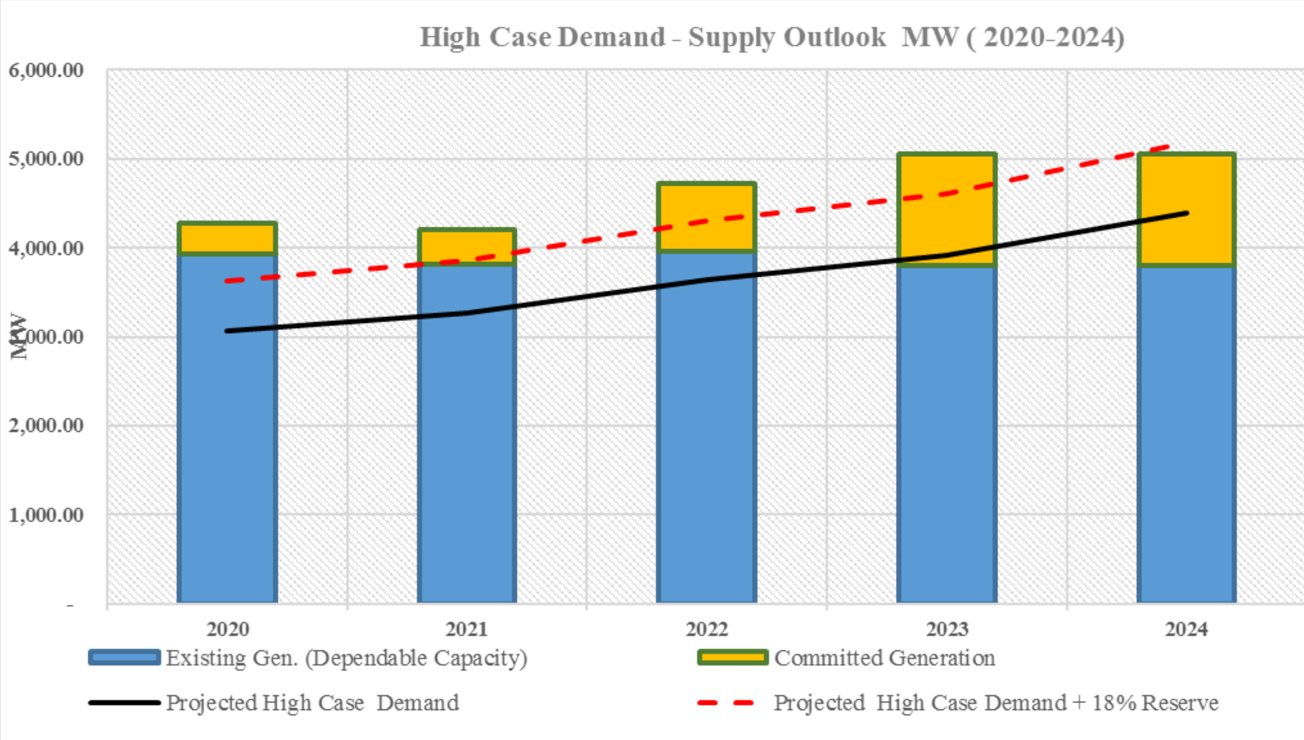
- ✓ **Marinus Energy:** This is a 26.5 MW thermal plant to be located at Atuabo in the Western Region. The plant is expected to come on line by 2021.

- ✓ **Jacobson Jelco:** This is a 360 MW combined-cycle power plant to be located at Aboadze and expected to be commissioned in 2021.
- ✓ **Rotan Power Limited:** This is a 634 MW combined-cycle power plant. 300 MW is expected to be commissioned in 2023 and the remaining 334 MW in 2025.

Table 35: Projected High Case Demand and Supply balance (2020- 2024)

Projected Demand		**Projected**				
Capacity Demand (MW)		**2020**	**2021**	**2022**	**2023**	**2024**
Domestic		2,655	2,853	3,076	3,291	3,524
VALCO		147	147	300	300	500
Exports		270	270	270	320	370
TOTAL		**3,073**	**3,270**	**3,646**	**3,911**	**4,394**
Projected Demand + 18% Reserve Margin		**3,626**	**3,859**	**4,303**	**4,615**	**5,184**
Existing Generation Capacity MW						
Akosombo	1020	750	750	900	900	900
Kpong GS	160	105	140	140	140	140
Bui GS	400	100	100	100	100	100
TAPCO	330	300	150	150	320	320
TICO	340	320	320	320	320	320
TT1PP	110	100	100	100	100	100
MRP	0	0	0	0	0	0
KTPP	220	200	200	200	200	200
TT2PP	70	70	70	70	70	70
AMERI Power Plant	240	230	230	230	230	230
Karpower Barge	450	450	450	450	450	450
Asogli (SAPP(Phase 1))	200	180	180	180	180	180
Asogli (SAPP (Phase 2))	360	350	350	350	350	350
CENIT	110	100	100	100	100	100
AKSA	370	330	330	330	0	0
CENPOWER	360	340	340	340	340	340
VRA Solar	2.5					
Solar (Central Region)	40					
Total Existing Generation	**4,782.50**	**3,925.00**	**3,810.00**	**3,960.00**	**3,800.00**	**3,800.00**
Committed						
Amandi Energy Ltd. (under construction)	192	190	190	190	190	190
VRA T3	132					
Early Power Limited (under construction)	400	145	190	190	390	390
Marinus Energy Ltd.	26.5	18	18	18	18	18
Jacobsen Elektro AS	360			360	360	360
Rotan Power	634				300	300
Total Committed Generation	**1,744.50**	**353**	**398**	**758**	**1258**	**1258**
Total Dependable Generation (MW)	**6,527**	**4,278**	**4,208**	**4,718**	**5,058**	**5,058**
Surplus/Deficit		1,205.26	937.99	1,071.75	1,147.35	664.42
Reserve Margin%		39.22%	28.68%	29.39%	29.34%	15.12%

Figure 11: Projected Demand Versus Supply balance (2020 - 2024)



7.2.4 Additional Generation Requirement

As seen in Table 32 and Figure 11, with the deployment of the committed generation capacity, there is adequate generation capacity to meet projected demand until 2023. The highest reserve margin recorded over the period is 39.22% and the lowest expected over the period is 15.12%. Since the 2024 reserve margin falls short of the required reserve margin of 18% for reliability of supply, additional generation capacity of about 130 MW would need to be procured and commissioned by January, 2024.

It is important to note that these additions are only required to meet the mandatory reserve margin of 18%. Most of the additional thermal generation capacity expected over the period will operate on natural gas. It is therefore important to ensure that efforts are made to achieve adequacy in gas supply.

2.3 Medium Term Gas Supply Outlook

By the end of 2019, the infrastructure bottlenecks in the gas supply are expected to be resolved. Gas supply is therefore expected to revert to committed levels as shown in Table 36. In addition to the existing supply sources, two LNG projects are expected to add additional 430 MMscfd by 2022.

Table 36: Medium Term (2020 - 2024) Gas Delivery Profile (MMscfd)

	2020	2021	2022	2023	2024
Jubilee FV	83	80	83	83	-
Greater Jubilee	-	-	-	-	80
TEN AG	26	26	26	26	26
Sankofa NAG	180	180	180	180	180
Takoradi LNG	-	-	180	180	180
Tema LNG	100	250	250	250	250
N-Gas	70	70	70	70	70
Total Gas Supply	**459**	**606**	**789**	**789**	**789**

2.4 Medium Term Transmission Network Expansion/Upgrade Requirements

The results of the extensive system network analyses carried out using the projected demand and supply scenario in the Tables above, indicate that there would be the need for the following transmission line and equipment additions in the medium term to meet the required supply reliability indices, and this is in addition to the investment identified under Section 5. The following are the critical transmissions additions required:

- ✓ 161kV Aboadze-Takoradi-Tarkwa-Prestea
- ✓ Construction of a second 330 kV Prestea - Dunkwa – Kumasi line
- ✓ 161kV Aboadze-Mallam Upgrade
- ✓ Construction of a second 330 kV Aboadze – A4 BSP circuit
- ✓ Construction of a double circuit 330 kV line from A4BSP to Kumasi
- ✓ Eastern Transmission Corridor Projects:
- ✓ 161kV Kpando – Juale Line
- ✓ 161kV Juale – Yendi Line
- ✓ Construction of a 330 kV substation at Dunkwa with a link to the existing 161 kV substation
- ✓ Construction of a third Bulk Supply Point in Kumasi

9. CONCLUSION

The following conclusions are drawn in respect of the electricity supply and demand plan for 2019:

2.1 Demand and Supply Outlook

a) The 2019 total system demand is projected to be 2,665.68 MW (base case), representing a 5 % growth over the 2018 peak demand of 2,525 MW. The corresponding projected energy consumption for 2019 is 17,237.79 GWh of which:

b) Hydro supply will be 5,669.95 GWh representing 33% of the total energy supply;

- ✓ Thermal supply will be 11,460.11 GWh representing 66.9% of total energy supply; and
- ✓ Renewables supply will be 57.7 GWh representing 0.1% of total energy supply

c) Total projected energy exports are 915.81GWh for 2019.

d) VALCO is expected to operate on two pot lines with projected total consumption of 1,283.8 GWh.

e) There is the need to dispatch Akosombo and Bui Hydro Plants conservatively throughout 2019 to ensure that the two reservoirs are not drawn down below their minimum operating levels to guarantee sustainable operations in the coming years

f) In terms of fuel, the following quantities of the various fuel types are required;

- ✓ Natural Gas - 80,241,689 MMbtu
- ✓ HFO - 5,308,727 barrels

g) In terms of fuel cost, an annual total of approximately 1.04 billion USD is required, averaging a monthly total of some US$ 86.64 Million.

h) In 2019, Aboadze will be the largest generation enclave in Ghana with an installed capacity of 1,540MW

i) Under maximum west generation scenario with KarPower in the West, the autotransformers at Volta will become overloaded leading with low voltages in the East (Accra/Tema Area).

2.2 Requirements for Grid Reinforcement

a) The transmission system has inadequate available transfer capacity to meet the demand requirements of the major load centres (of Accra, Kumasi, Tarkwa, etc.) particularly at peak. This situation would result in low voltages, overloading of lines and increased overall transmission system losses.

b) For radial lines and single transformer stations, significant percentage of network loads could be islanded in the event of outage of such lines and transformers.

c) In normal operation, there would be congestion on the Volta –Accra East – Achimota - Mallam transmission corridor especially when there is high generation in the east.

d) Low voltages would be experienced at Kumasi, Accra and surrounding areas due to poor customer-end power factors.

e) A fair East-West balance in generation provide better system stability and minimal overall transmission system losses.

2.3 Distribution Systems

a) The commissioning of the Accra Central BSP has increased the level of reliability and distribution capacity to meet the growing demand within the ECG network in Accra. This has resolved the loading constraints on selected 33 kV feeders and reduce technical losses within the ECG Accra network.

b) In a bid to improve voltages in Nsawan and Aburi, ECG has installed a number of Voltage Regulators to improve on reliability and quality of supply. Furthermore, a number upgrade projects have either been commissioned into service or under construction. This is to increase distribution capacity and reliability of supply customers.

c) Power supply reliability in NEDCo Areas is generally good. However, reliability in some areas of the network has been lower than expected due to over extension and over-ageing resulting in high technical losses. Some interventions, however, have been made on some of these lines resulting in improved supply reliability on them.

2.4 Medium Term Supply

a) For the high case growth scenario, it is expected that with the deployment of the committed generation capacity, there would be adequate dependable generation capacity to meet projected demand for the period 2020 - 2023 with a maximum reserve margin of 39%.

b) The system peak demand for high case growth scenario is projected to be 4,394 MW by 2024 and a corresponding dependable generation capacity of 5,058 MW. Hence, to meet the reliability requirement of the Ghana power system, an additional reserve margin of 18% representing 791 MW is required. This adds up to a total required supply capacity of 5,185 MW. This compared to the projected supply capacity implies a deficit of about 130 MW. Thus, there is the need to procure an additional generation capacity of 127 MW in time for commissioning by January, 2024.

10. RECOMMENDATIONS

Based on the above conclusions, the following recommendations are made:

a) The ongoing transmission expansion projects should be expedited and completed in 2019 to ensure that the peak demand can be supplied. These are
   - ✓ Volta – Achimota – Mallam Transmission Line Upgrade Project
   - ✓ Aboadze – Prestea - Kumasi 330 kV Transmission Line Project
   - ✓ Kumasi – Bolgatanga 330 kV transmission line Project

b) GRIDCo should explore the possibility of installing the 3rd autotransformer at Volta Substation

c) A well-coordinated maintenance programme should be pursued by both GRIDCo and the Generating Companies (GENCOs).

d) Fuel supply security and adequacy remains the single most important risk to power supply reliability in Ghana. In this vein, it is strongly recommended that all the relevant sector agencies stakeholders work conscientiously together to ensure that fuel supply is adequate and secure at all times.

e) For the medium term, the reserve margin for the 2024 falls short of the required reserve margin of 18% (for reliability of supply). Therefore, additional generation capacity would need to be procured in time for commissioning by the beginning of 2024.

f) In order to meet the transmission reliability indices, the following are the critical transmissions additions and upgrades are required:
   - ✓ Upgrade of 161kV Aboadze-Takoradi-Tarkwa-Prestea
   - ✓ Construction of a second 330 kV Prestea - Dunkwa – Kumasi line
   - ✓ Upgrade of 161kV Aboadze-Mallam transmission lines
   - ✓ Construction of a second 330 kV Aboadze – A4 BSP circuit
   - ✓ Construction of a double circuit 330 kV line from A4BSP to Kumasi
   - ✓ Construction of a 330 kV substation at Dunkwa with a link to the existing 161 kV substation

11. APPENDICES

Appendix A –Forecast: Peak and Energy Demand

A1: Base Case - Peak Demand Forecast (MW): 2019 - 2028

A2: Base Case - Energy Demand Forecast (GWh) -2019 – 2028

A3: High Case - Energy Demand Forecast (MW): 2019 – 2028

A4: High Case - Peak Demand Forecast (MW): 2019 - 2028

Appendix B – List of ECG Ugrade Projects aimed at reducing network Constraints

Appendix C – Glossary

Appendix D – Grid Map

APPENDIX A - FORECAST PEAK DEMAND AND ENERGY CONSUMPTION

A1: Base Case - Peak Demand Forecast (MW): 2019 - 2028

Base Case - Peak demand (MW)	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**
ECG	1657.44	1,799	1,882	1,972	2,078	2,191	2,309	2,434	2,565	2,704
NEDCo	241.43	249	260	265	280	284	299	306	322	330
ENCLAVE POWER COMPANY	44.29	39	41	45	48	49	50	51	53	56
MINES	201.74	223	250	294	300	304	306	311	311	311
Other Bulk Customers	50.79	58	57	58	59	60	58	58	57	58
VALCO	147.42	147	147	300	300	500	500	500	500	500
CEB(Togo/Benin)	60.00	100	100	100	100	100	100	100	100	100
SONABEL(Burkina)	100.00	100	100	100	100	100	100	100	100	100
CIE(Ivory Coast)	0.00	0	0	0	0	0	0	0	0	0
EDM(Mali)	0.0	0	0	0	50	100	100	100	100	100
Network Usage	1.48	2	2	2	2	2	2	2	2	3
LOSSES	161.09	132	104	125	141	148	164	178	189	205
Total	2,665.68	**2,848**	**2,944**	**3,261**	**3,458**	**3,837**	**3,989**	**4,140**	**4,299**	**4,466**

A2: Base Case -Projected Energy Demand (GWh) -2019-2027

Base Case- Energy (GWh)	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**
ECG	11,075.00	11,720.35	12,106.60	12,379.92	12,783.89	13,239.77	13,675.08	14,110.84	14,550.05	14,901.37
NEDCo	1,443.99	1,498.38	1,594.19	1,698.91	1,825.76	1,962.08	2,108.58	2,266.02	2,435.21	2,617.04
ENCLAVE POWER COMPANY	200.00	179.09	184.36	197.53	205.43	208.06	210.69	213.33	213.33	213.33
MINES	1,173.47	1,476.88	1,725.07	2,049.05	2,126.39	2,157.10	2,183.58	2,220.66	2,220.22	2,229.04
DIRECT	238.58	339.02	339.42	341.02	340.52	341.52	342.02	342.02	342.62	343.32
VALCO	1,283.80	1,284.00	1,284.00	2,628.00	2,628.00	4,380.00	4,380.00	4,380.00	4,380.00	4,380.00
CEB(Togo/Benin)	349.72	384.69	423.16	465.48	512.03	563.23	619.55	681.51	749.66	824.62
SONABEL(Burkina)	566.09	657.00	657.00	657.00	657.00	657.00	657.00	657.00	657.00	657.00
CIE(Ivory Coast)	-	-	-	-	-	-	-	-	-	-
EDM(Mali)	-	-	-	-	328.50	657.00	657.00	657.00	657.00	657.00
Network Usage	9.12	9.91	10.35	11.54	12.10	13.66	14.03	14.43	14.81	15.16
LOSSES	898.03	700.16	593.82	679.82	767.24	751.93	842.92	933.34	994.67	1,083.37
Total	**17,237.79**	**18,249.48**	**18,917.96**	**21,108.27**	**22,186.85**	**24,931.35**	**25,690.45**	**26,476.14**	**27,214.56**	**27,921.25**

A3: High Case - Energy Demand Forecast (MW): 2019 - 2028

High Case: Energy Forecast (GWh)	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**
Domestic	15,664.84	17,065.17	18,393.39	19,840.56	21,221.90	22,240.73	23,632.64	25,098.62	26,574.22	28,184.59
VALCO	1,283.80	1,284.00	1,284.00	2,628.00	2,628.00	4,380.00	4,380.00	4,380.00	4,380.00	4,380.00
CEB(Togo/Benin)	450	735.84	735.84	735.84	735.84	735.84	735.84	735.84	735.84	735.84
SONABEL (Burkina)	615.33	985.50	985.50	985.50	985.50	985.50	985.50	985.50	985.50	985.50
CIE(Ivory Coast)	-	-	-	-	-	-	-	-	-	-
EDM (Mali)	-	-	-	-	328.50	657.00	657.00	657.00	657.00	657.00
Total	**18,013.97**	**20,070.51**	**21,398.73**	**24,189.90**	**25,899.74**	**28,999.07**	**30,390.98**	**31,856.96**	**33,332.56**	**34,942.93**

A4: High Case - Peak Demand Forecast (MW): 2019 - 2028

High Case: Energy Forecast (GWh)	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**
Domestic	2,470	2,655	2,853	3,076	3,291	3,524	3,746	3,978	4,213	4,473
VALCO	147	147	147	300	300	500	500	500	500	500
CEB(Togo/Benin)	80	120	120	120	120	120	120	120	120	120
SONABEL (Burkina)	100	150	150	150	150	150	150	150	150	150
CIE(Ivory Coast)	0	0	0	0	0	0	0	0	0	0
EDM (Mali)	0	0	0	0	50	100	100	100	100	100
Total	**2,797**	**3,073**	**3,270**	**3,646**	**3,911**	**4,394**	**4,616**	**4,848**	**5,083**	**5,343**

B: List of ECG Upgrade Projects aimed at reducing network Contraints

No.	Project	Reason	Benefits	Consequences for not implementing the Project	Timeline
1	Construction of the Accra Central BSP	High demand growth in Accra. Distribution reliability threat on feeders supplying Accra central loads.	1. Increased level of reliability especially during contingent conditions. 2. Improved voltages within Accra central load. 3. Reduction in loading of existing feeders supplying Accra Central Demand leading to TTC margins improvement. 4. Capacity availability to serve suppressed and additional demands. 5. Assist in existing BSP contingency.	1. Severe loading constraints on feeders supplying Accra central load. 2. Improved level of reliability of supply during contingent situations	**Commissioned in November 2018**
2	Voltage Regulators (In the absence of Distributed Generation (DG) support along the Mampong – Aburi lines to improve voltage at Nsawam.	As an alternative solution to the DG option to improve voltages at Ofankor, Nsawam, Aburi and Mampong	1. Improve voltages at Ofankor, Nsawam, Aburi and Mampong.	1. Severe low voltage leading to poor power supply. 2. Limited power transfer capability from Ofankor towards Aburi as a result of the severe low voltages. 3. Increase in technical losses in the network	**First one was Installed 2018. The second one is expected to be installed March – April 2109**
3	Ongoing construction of the Asekyem primary substation	To support load on the Ridge ("A") and Amanfrom substations	To avoid potential overloading of the existing surrounding substations and improve voltage levels	1. Poor voltages 2. Poor reliability of supply	**Commissioned in 2018**
4	Construction of the Pokuase BSP with its associated circuits	This will boost voltage support to Dodowa, Mampong, Aburi and Ofankor. It will also improve reliability by serving as an alternative to Achimota BSP and Afienya BSP.	1. Improve power supply reliability to Dodowa, Mampong and possibly Aburi 2. Improve voltages at Dodowa, Aburi, Mampong. 3. Reduce technical losses	1. Severe low voltages 2. Potential power outages to customers supplied from the Dodowa switching station 3. High suppressed demand	**Last quarter of 2020**
5	Construction of Afienya BSP and its associated circuits	This will boost voltage at Dodowa, Mampong and Aburi	1. Improve voltages at Dodowa, Mampong and Aburi. 2. Improve reliability by serving as an alternative source of supply to Dodowa and beyond. 3. Capacity availability to serve suppressed and additional demands	Severe low voltages High unserved energy in the event of a contingency on the supply to Dodowa from Adenta.	**Commissioned in February, 2019**

APPENDIX B: GLOSSARY OF ELECTRICAL UTILITY TERMS

1000 Watt-hours = 1 Kilo Watt-hour (kWh)

1000 Kilo Watt-hour = 1 Mega Watt-hour (MWh)

1000 Mega Watt-hour = 1 Giga Watt-hour (GWh)

1000 Giga Watt-hour = 1 Tera Watt-hour (TWh)

Average Day Load

The average system demand is indicative of the system's load during most part of the day that is from 7: am – 5: pm apart from the peak load.

Capability

The maximum load a generator, piece of equipment, substation, or system can carry under specified (standardized) conditions for a given time interval without exceeding approved limits.

Capacitor

1) In a power system, installed to supply reactive power.

2) A device to store an electrical charge (usually made of two or more conductors separated by a non-conductor such as glass, paper, air, oil, or mica) that will not pass direct current and whose impedance for alternating current frequencies is inversely proportional to frequency. 3) In a power system, capacitors consist of metal-foil plates separated by paper or plastic insulation in oil or other suitable insulating fluid and sealed in metal tanks.

Capacitor bank

A grouping of capacitors used to maintain or increase voltages in power lines and to improve system efficiency by reducing inductive losses.

Capacity

The rated continuous load-carrying ability, expressed in megawatts (MW) or megavolt-amperes (MVA) of generation, transmission, or other electrical equipment.

Installed Capacity

The total of the capacities shown by the name plate ratings of similar kinds of apparatus, such as generators, transformers, or other equipment in a station or system.

Combined Cycle

An electric generating technology in which electricity is produced from otherwise lost waste heat exiting from one or more gas (combustion) turbines. The exiting heat is routed to a conventional boiler or to a heat recovery steam generator for utilization by a steam turbine in the production of electricity. Such designs increase the efficiency of the electric generating unit.

Conductor

A substance or body that allows an electric current to pas continuously along it.

Contingency

In a power system, the possibility of a fault or equipment failure. First contingency disturbances (outages) involve only one system element, such as a transmission line fault or a transformer failure. A second contingency disturbance would have one system element out of service and subject the system to a fault and loss of a second element.

Demand

The rate at which electric energy is delivered to or by the System or part of the System and is the sum of both Active and Reactive Power, unless otherwise stated.

Demand, Peak:

The highest electric requirement occurring in a given period (e.g., an hour, a day, month, season, or year). For an electric system, it is equal to the sum of the metered net outputs of all generators within a system and the metered line flows into the system, less the metered line flows out of the system.

Dispatch

The operating control of an integrated electric system to: (1) assign specific generating units and other sources of supply to meet the relevant area Demand taken as load rises or falls; (2) control operations and maintenance of high voltage lines, substations and equipment, including administration of safety procedures; (3) operate interconnections; (4) manage energy transactions with other interconnected Control Areas; and (5) curtail Demand.

Disturbance

An unplanned event that produces an abnormal system condition. Any occurrence that adversely affects normal power flow in a system

Fault

An event occurring on an electric system such as a short circuit, a broken wire, or an intermittent connection.

Generation (Electricity)

The process of producing electric energy from other forms of energy; also, the amount of electric energy produced, expressed in watthours (Wh).

Giga (G)

A prefix indicating a billion (1,000,000,000); 109 in scientific notation. Hence Gigawatt (GW) and Gigawatt-hour (GWh).

Grid

The transmission network (or “highway”) over which electricity moves from suppliers to customers.

Grid Operator

An entity that oversees the delivery of electricity over the grid to the customer, ensuring reliability and safety.

High voltage:

Descriptive of transmission lines and electrical equipment with voltage levels from 100 kV through 287 kV.

Independent Power Producer (IPP):

A private entity that operates a generation facility and sells power to electric utilities for resale to retail customers.

Insulator:

The porcelain support used to insulate electric service wires from the pole. All electric lines require an insulator to attach the wires to the pole or to a residence.

Interconnected System

A system consisting of two or more individual electric systems that normally operate in synchronism (matching frequency, voltage, phase angles, etc) and have connecting tie lines.

Kilowatt (kW)

One thousand watts of electricity (See Watt).

Kilo watthour (kWh):

One thousand watthours.

Load

The amount of power carried by a utility system or subsystem, or amount of power consumed by an electric device at a specified time. May also be referred to as demand. A connection point or defined set of connection points at which electrical power is delivered to a person or to another network or the amount of electrical power delivered at a defined instant at a connection point, or aggregated over a defined set of connection points.

Load Centers

A geographical area where large amounts of power are drawn by end-users.

Losses

Electric energy losses in the electric system which occur principally as energy transformation from kilowatt-hours (kWh) to waste heat in electrical conductors and apparatus.

Maximum Demand:

The highest amount of electrical power delivered, or forecast to be delivered, over a defined period (day, week, month, season or year) at a defined.

Megawatt (MW)

One million watts of electricity (See Watt).

masl

Metres above sea level

Overload

Operation of equipment in excess of its normal, full load rating or operation of a conductor in excess of ampacity, and if continued for a sufficient length of time, would cause damage or overheating.

System Planning

The process by which the performance of the electric system is evaluated and future changes and additions to the bulk electric systems are determined.

Power System

The electricity power system of the national grid including associated generation and transmission and distribution networks for the supply of electricity, operated as an integrated arrangement.

Reactive Power

Means the product of voltage and current and the sine of the phase angle between them measured in units of volt-amperes reactive and standard multiples thereof. Reactive power is a necessary component of alternating current electricity which is separate from active power and is predominantly consumed in the creation of magnetic fields in motors and transformers and produced by plant such as: (a) alternating current generators (b) capacitors, including the capacitive effect of parallel transmission wires;(c) synchronous condensers.

Reliability

The degree of performance of the elements of the bulk electric system that results in electricity being delivered to customers within accepted standards and in the amount desired. It is a measure of the ability of a power system to provide uninterrupted service, even while that system is under stress. Reliability may be measured by the frequency, duration, and magnitude of adverse effects on the electric supply. Electric system reliability has two components -- adequacy and security.

Adequacy is the ability of the electric system to supply the aggregate electrical demand and energy requirements of the customers at all times, taking into account scheduled and reasonably expected unscheduled outages of system elements.

Security is the ability of the electric system to withstand sudden disturbances such as electric short circuits or unanticipated loss of system facilities.

Single Contingency

The sudden, unexpected failure or outage of a system facility(s) or element(s) (generating unit, transmission line, transformer, etc.). Elements removed from service as part of the operation of a remedial action scheme are considered part of a single contingency.

Stability

The ability of an electric system to maintain a state of equilibrium during normal and abnormal system conditions or disturbances.

Supervisory Control and Data Acquisition (SCADA)

A computer system that allows an electric system operator to remotely monitor and control elements of an electric system.

Switching Station

An installation of equipment where several transmission lines are interconnected. Does not include equipment for transforming voltage levels.

Power System

An interconnected combination of generation, transmission, and distribution components comprising an electric utility, an electric utility and independent power producer(s) (IPP), or group of utilities and IPP(s).

Right of Way (ROW)

A corridor of land on which electric lines may be located. The Transmission Owner may own the land in fee, own an easement, or have certain franchise, prescription, or license rights to construct and maintain lines.

Thermal Limit

The maximum amount of electrical current that a transmission line or electrical facility can conduct over a specified time period before it sustains permanent damage by overheating or before it violates public safety requirements.

Transfer Capability

The amount of power, usually the maximum amount, that can be transmitted between one system and another; power flow and stability studies determine transfer capability under various outage, system loading, and system operating conditions.

Transformer

A device for transferring electrical energy from one circuit to another by magnetic induction, usually between circuits of different voltages. Consists of a magnetic core on which there are two or more windings. In power systems, most frequently used for changing voltage levels.

Transmission System (Electric)

An interconnected group of electric transmission lines and associated equipment for moving or transferring electric energy in bulk between points of supply and points at which it is transformed for delivery over the distribution system lines to consumers, or is delivered to other electric systems.

Utility

A public or private organization created for the purpose of selling or supplying for general public use water, electric energy, telephone service, or other items or services.

Voltage

The electronic force or electric potential between two points that gives rise to the flow of electricity.

Voltage Stability

The condition of an electric system in which the sustained voltage level is controllable and within predetermined limits.

Wheeling

The use of the facilities of one transmission system to transmit power and energy from one power system to another.

APPENDIX C – GRID MAP