2021

Electricity Supply Plan

a power supply outlook with medium term projections for Ghana

POWER PLANNING TECHNICAL COMMITTEE

2021 ELECTRICITY SUPPLY PLAN FOR GHANA

An Outlook of the Power Supply Situation for 2021 and Highlights of Medium Term Power Requirements

REPUBLIC OF GHANA

POWER PLANNING TECHNICAL COMMITTEE

The Power Planning Technical Committee (PPTC) which was inaugurated in 2020 by the Hon. Minister of Energy to among others develop planning reports for the Ghana Power System worked to develop the 2021 Electricity Supply Plan (ESP) as per the requirement in Section-7 of the National Electricity Grid Code and Section 2 (2)(c) of the Energy Commission Act 1997 (ACT 541).

The Committee is made up of technical experts as follows:

Chairpersons:

Ing. Frank A. Otchere (Chairman)	–	Ghana Grid Company Limited
Salifu Addo (Co-Chairman)	–	Energy Commission

Other Members:

Ing. Frederick Okang	–	Ghana Grid Company Limited
Ing. Kassim Abubakar	–	Ghana Grid Company Limited
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Ing. Mohammed T. Tampuri	–	Northern Electricity Company Limited
Hamis Ussif	–	Ghana National Petroleum Corporation
Benjamin Buabeng-Acheampong	–	Ghana National Gas Company

ACKNOWLEDGEMENT

We hereby wish to acknowledge all Wholesale Suppliers, Bulk Customers and other key stakeholders who provided relevant information to conduct demand forecasts, determine sources of supply, firm up maintenance programmes, potential new projects and other information required for developing the 2021 ESP.

We also acknowledge Mrs. Laura Zordeh (Energy Commission) who provided administrative support to the PPTC during the development of the report.

The highlights of the 2021 ESP are as follows:

1.1 2020 Performance Review

Peak Load

The Corona Virus Disease (COVID-19) pandemic has brought about disruptions in regular routine operations in economies all over the world as a result of restrictions imposed to contain it. Despite its devastating effects on global economies, the COVID-19 pandemic did not have any significant effect on electricity supply and demand in 2020. To that effect, the System Peak demand which occurred at 20.15 h on December 4, 2020 is as follows:

Load Type		2020 SYSTEM PEAK (MW)	
		Projected	Actual
Domestic Peak		2,631	2,682
Export	CEB	150	100
	SONABEL	180	128
	CIE	0	95
	Total Export	*330*	*323*
VALCO		100	85
System Peak (coincident)		3,061	3,090

The coincident 2020 System Peak load (3090 MW) represents a 10.2% growth on the 2019 peak load (2,803.7 MW).

Energy Consumption

Consumer	Projection (GWh)	Actual (GWh)
ECG	12,562.62	12,653.33
NEDCo	1,537.02	1,573.19
Mines	1,533.99	1,499.20
VALCO	702.32	721.56
EPC	258.13	242.15
Export	1,787.06	1,855.09
Direct Cust.	300.16	274.65
Losses	897.03	887.75
Network Usage	9.63	9.67
Total Energy Transmitted	19,608.21	19,716.59

The total energy consumed, including losses, was 19,716.59 GWh representing a 10.23% increase over the 2019 consumption of 17,887 GWh.

Energy Generated

The total energy generated over the period was 19,716.59 GWh; this was made up of 7,293.23 GWh (36.99%) from hydro generation, 12,365.09 GWh (62.71%) from thermal generation and 58.24 GWh (0.3%) imports.

1.2 2021 Demand Outlook

The projected base case coincident Ghana peak demand for 2021 is 3,303.72 MW. This represents a growth of 6.9% (an increase of 213.72 MW) over the 2020 peak demand of 3,090 MW.

The projected 2021 base case energy consumption is 21,265.52 GWh, which includes transmission network losses and station service usage of 1,090.53 GWh. The estimated transmission losses and usage represents a 5.13% of total projected energy supply. The projected 2021 energy consumption represents an increase of 1,548.93 GWh (growth of 7.86 %) over the 2020 consumption of 19,716.59 GWh.

1.3 2021 Generation Outlook

Hydro Generation
Projected total annual hydro generation for 2021 is 7,001.2 GWh. This is made up of 5,650 GWh from Akosombo GS, 850 GWh from Kpong GS. The projected total annual hydro generation from Akosombo and Kpong is 6,500 GWh.

The headwater level at Bui GS is critically low. Projected energy to be generated from Bui GS is 501.2 GWh.

Thermal Generation
The total projected thermal energy generation in 2021 is 14,111.97 GWh. A total of US$ 758.8M is required for thermal fuel purchase in 2021. This comprises US$ 753.33M for Gas and US$ 5.48M for HFO.

RE Generation
A total of 152.34 GWh of electrical energy is expected from Renewable Energy sources in 2021. The renewable energy sources will include the grid connected solar RE farm at Bui, the embedded BXC and Meinergy solar plants and VRA's facilities at Navrongo and Lawra/Kaleo.

1.4 Imports

No power import is anticipated till the end of the year. However, inadvertent energy exchanges on tie-lines could result from transient flows. Emergency imports may be necessitated as a result of short-term capacity shortages caused by faults or fuel supply contingencies.

1.5 2021 Transmission System Outlook

Due to low water level in the Bui dam, generating units at Bui Hydro Plant shall not be dispatched during off-peak periods. A system condition with no Bui units in service would lead to voltage stability issues especially across the northern parts of the grid.

Transmission projects which are expected to be completed to improve system performance in 2021 are as follows:

- 330/34.5 kV Pokuase Substation;
- 161 kV Volta – Achimota – Mallam line corridor upgrade
- 330 kV Anwomaso – Kintampo line and
- 161/34.5 kV Kasoa Substation

1.6 2021 Distribution System Outlook

As a measure towards improving distribution network performance, the Distribution companies have embarked on a number of activities including the reconstruction of BSPs at Tafo, Kpong, Juapong, Daboase, Inchaban, Awaso; the expansion of Weija, Tokuse, Koforidua and Winneba, etc.

EPC has commenced with the development of a 2km double circuit sub-transmission line and a switching station for the evacuation of 60MVA of power to the business park area in the Tema Freezones Enclave.

1.7 Medium Term Outlook

Demand Outlook

The Ghana system peak demand is projected to increase from 3,539 MW in 2022 to 4,460 MW in 2026.

Total electricity requirement for Ghana including power exports to Togo, Benin, Burkina and Mali is projected to increase from 22,799 GWh in 2022 to 28,550 GWh by 2026 at a Compound Annual Growth Rate (CAGR) of approximately 5.8%.

	2022	2023	2024	2025	2026
Peak Demand (MW)	3,539	3,739	3,964	4,171	4,460
Energy Demand (GWh)	22,799	24,177	25,572	27,069	28,550

Generation Adequacy Analysis

The table below shows projected demand over the medium term compared with the total generating capacity situation.

	2022	2023	2024	2025	2026
Projected Demand + 18% Planning Reserve Margin (MW)	4,176	4,412	4,678	4,921	5,262
Total Existing Generation (MW)	4,470	4,600	4,420	4,420	4,420
Committed Generation Projects Expected to become operational in the Medium Term					
Early Power Limited [1]	190	190	390	390	390
Pwalugu Hydro				60	60
Total Committed Generation	**190**	**190**	**390**	**450**	**450**
Total Dependable Generation (MW)	**4,660**	**4,790**	**4,810**	**4,870**	**4,870**
Actual Reserve Margin (MW)	1,121	1,052	846	700	411
Actual Reserve Margin (%)	31.69%	28.13%	21.35%	16.78%	9.21%
Surplus/Deficit (MW)	**484**	**379**	**133**	**-51**	**-392**
Surplus/Deficit (%)	13.69%	10.13%	3.35%	-1.22%	-8.79%

Existing generating capacity is projected to be adequate to serve demand with 18% reserve for years 2022 and 2023. This is however, contingent on good hydrology at the hydro plants, adequate and reliable fuel supply for thermal plants and minimal faults on generating units.

However, the completion and operationalisation of all committed power generation projects currently under construction is needed to have generation adequacy in 2024.

Additional generation capacity will however be needed in 2025 and 2026 to continue to meet projected demand with adequate reserve margin as required for reliability.

Transmission Reinforcement/Expansion requirements

Upgrade of the following transmission equipment is required:

- ✓ 161kV Aboadze – Mallam line Upgrade
- ✓ 161kV Bogosu – Dunkwa – New Obuasi upgrade
- ✓ 161 kV Dunkwa – Asawinso upgrade
- ✓ 161kV Aboadze-Takoradi-Tarkwa-Prestea line circuit
- ✓ Cross-border interconnection transformers (both at Prestea and Nayagnia) to be replaced with phase shifting transformers.
- ✓ SCADA System

In addition, the construction of the following NITS equipment is required:

- ✓ 2^{nd} 330 kV Prestea – Dunkwa – Kumasi line

- ✓ 330/161 kV Dunkwa substation for break-in of the 330 kV Takoradi Thermal – Anwomaso line
- ✓ 161kV Pokuase – Mallam line
- ✓ 2nd Takoradi Thermal – Pokuase 330 kV line
- ✓ Accra (Pokuase) – Kumasi (Anwomaso) 330 kV line
- ✓ Eastern Transmission Corridor Projects:
    - o 161 kV Akosombo/Kpong GS -Asiekpe Transmission Line
    - o 161 kV Asiekpe -Kpando Transmission Line
    - o 161kV Kpando – Juale Transmission Line
    - o 161kV Juale – Yendi Transmission Line
    - o A 161kV, 2x33 MVA Substation at Nkwanta (to supply Nkwanta, Salaga and Bimbila)
- ✓ A third Bulk Supply Point in Kumasi
- ✓ A ±50 MVar STATCOM to be installed in Kumasi

Creation of new Generation Enclaves

Analysis conducted confirms the recommendation made in the Electricity Supply Plans of previous years for the establishment of two new generation enclaves at:

i. Kumasi and
ii. between Kasoa and Winneba.

1.8 Conclusion

The following conclusions are drawn from the 2021 Electricity Supply Plan and the medium-term outlook:

1. Despite the crippling effect the COVID-19 pandemic had on economies globally in the year 2020, there was no significant net impact on Electricity demand in Ghana.
2. There is the need to dispatch Bui Hydro Plant conservatively throughout 2021 to ensure that the reservoir is not drawn down below its minimum operating levels to guarantee sustainable operations in the coming years.
3. There is no projected requirement for LCO in 2021due to anticipated high volumes of gas from Sankofa, Jubilee, TEN and Nigeria as well as the envisaged completion of the LNG project. Strategic stocks will, however, be required to be kept in reserve for use as backup fuel in the event of any gas supply upsets.
4. An amount of US$ **63.23** Million is required every month *(US$**758.8** Million for the year)* to procure Natural gas and HFO for the operation of thermal power plants in 2021.
5. The completion of projects to upgrade the transmission systems by mid-2021 is expected to improve system performance with reduced transmission losses.
6. A number of upgrade projects have been commissioned into service to help augment ECG's ability to increase distribution capacity and reliability of supply to customers.

7. Some interventions such as the conversion of shield wire systems to conventional 34.5kV feeder circuits and procurement of smart meters have been initiated by NEDCo to improve supply reliability and combat electricity theft within their operational area.
8. The deployment of the committed generation capacities would be adequate to meet projected demand, including a reserve capacity of 18% up to 2024.
9. Additional generation capacity will be needed from 2025. Specifically, 51 MW and 392 MW additional generation capacity will be needed in 2025 and 2026, respectively.

1.9 Recommendation

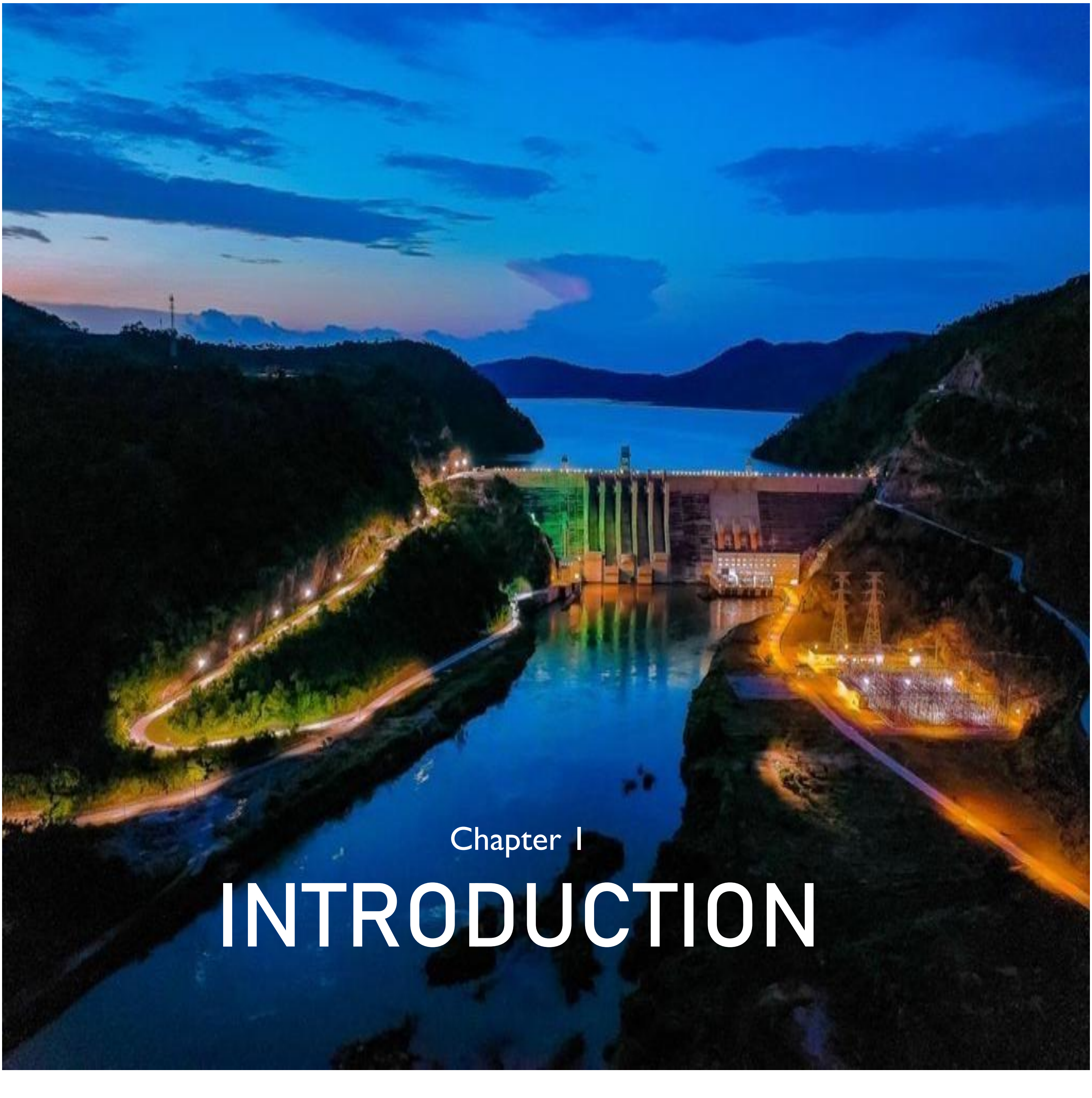
Based on the above conclusions, the following recommendations are made:

1. Adopt a conservative dispatch of the Bui GS to manage the use of its limited head water until the next inflow season.
2. Installation of a third 161/34.5kV transformer at Anwomaso Substation and the transfer of some load from the ECG substation at Ridge, Kumasi to Anwomaso in order to limit congestion on the 161 kV Anwomaso – Kumasi line, especially when Bui is not running during off-peak periods.
3. Ongoing transmission expansion projects should be expedited and completed in the first half of 2021 to ensure that the NITS continues to have adequate capacity to supply all projected customer loads with minimal losses.
4. Power Supply Outage management for the ongoing projects should be well coordinated to reduce the impact on customers.
5. Implementation of the break-in on the 330 kV Takoradi Thermal – Anwomaso line at Dunkwa with the construction of the 330/161kV Dunkwa II Substation by GRIDCo to address the low voltage situation in the Western parts of the NITS. This will help improve power system stability.
6. Create a generation enclave in Kumasi for network stability, and to address voltage limit violations in the mid-sections of the Ghana power system in situations such as where Bui units are not in service and to reduce line loadings between Kumasi and the South East.
7. Considering the time required for planning, procurement, design, construction and commissioning of power plants, there is the need to commence procure processes for additional generation capacity (51 MW in 2025 and 392 MW in 2026 - through a competitive least cost procurement process) in order to continue to meet the Ghana power system electricity demand with the required reserve margin by 2025.

TABLE OF CONTENTS

Table of Tables

Table of Figures



Chapter 1

INTRODUCTION

1 INTRODUCTION

The 2021 Electricity Supply Plan (ESP) outlines projections for electricity demand and supply for the year, based on energy sector data collected and assumptions for load forecasting and the year's expected generation. The ESP highlights various strategies for delivering electricity generation, transmission, and distribution services on the Ghana Power System in 2021.

The report commences with a review of the actual Ghana Power System performance of the preceding year (2020) with reference to projections and other benchmarks. It continues to forecast the year's electricity supply and demand, which is largely driven by economic variables, for the three main end-user categories; domestic, VALCO and exports. Additionally, it highlights the key assumptions underpinning the 2021 projections, including maintenance schedules and natural gas availability.

In 2021, it is envisaged that power supply capacity will continue to outstrip forecasted demand and would require an optimised dispatch regime to adequately and efficiently meet the forecasted demand. The report assesses all available generation resources for dispatch based on considerations such as merit order dispatch (including lower overall system losses) and system stability requirements in the analysis for the demand-supply balance for the year. Also, the optimisation of thermal power plants' dispatch due to their increasing proportion in the overall energy mix was considered in the report.

The Hydro generation plants continue to play the crucial role of system stability and the required energy mix for the PURC tariff for regulated customers. The energy allocations from the hydropower plants took cognisance of the average inflows into the Akosombo and Bui hydro reservoirs during the inflow season in 2020 and prudent management of the reservoir to prevent the need for a spill or to operate below the minimum reservoir levels.

In line with government policy which leans towards natural gas utilisation as the primary fuel source for thermal power generation, priority is given to plants with a stable supply of natural gas. The adequacy of the two main sources of gas (Indigenous gas and N-Gas) have been analysed in the report to ensure fuel supply security for the thermal power allocations needed to compliment the Hydro and renewable sources. The plants' alternative liquid fuel requirements have also been discussed albeit insignificant due to anticipated high volumes of gas from Sankofa, Jubilee and TEN fields and the envisaged Tema LNG project.

Furthermore, the report takes a critical look at the major challenges anticipated, which can adversely impact the reliability of power supply in 2021. It also proffers immediate to medium-term recommendations to address the identified challenges such as grid reinforcements and budgetary allocations for fuel procurement and supply.

For the first time since its inception, the ESP has been prepared by the Power Planning Technical Committee (PPTC) which is jointly chaired by the Ghana Grid Company Limited and the Energy Commission. This is in line with the IPSMP recommendation to ensure planning was more collaborative among the key players in the power sector; which hitherto was carried out in "silos" and with different sets of assumptions, data sets, planning horizons, and technical analyses.

Chapter 2

2020 POWER SYSTEM PERFORMANCE REVIEW

2.1 Objective

The review of the Ghana Power System performance includes an analyses of the peak demand for the year, the total energy consumption and an assessment of the generation capacities in service at the time of occurrence of the peak demand compared to what was projected in the 2020 ESP. It also takes a look at the overall performance at hydro power plants including their hydrological turn out; the performance of thermal sources, and finally, it assesses the NITS performance through analysis of some indicators.

2.2 The Impact of some Major Events on Electricity Supply

In this section, we highlight major events which occurred during the year and its impact on the power system. Further analysis is carried out on system voltages and transmission system losses.

2.2.1 The Impact of the WAGP Intelligent Pigging Operation

A mandatory intelligent pigging operation of the offshore segment of the West African Gas Pipeline (WAGP) required for the assessment of the integrity pipeline was carried out from January 20, 2020 to March 5, 2020 by the West African Gas Pipeline Company (WAPCO). It involved the launch of five (5) pigs from Itoki to Takoradi.

Natural gas supply for thermal generation in Tema was curtailed over the period, rendering the Sunon Asogli Power Plant, CENIT, VRA's TT1PP and TT2PP plants inoperable (810MW capacity unavailable in Tema). Cenpower plant and VRA's KTPP which also became inoperable on gas, however switched to liquid fuel - Cenpower switched, running one gas turbine in combined cycle on LCO whiles KTPP switched to run on Diesel Fuel.

Notwithstanding the huge capacity that became unavailable, it was projected that the remaining generation capacity would be adequate to serve all Ghana demand. Unfortunately however, the TICO gas turbine unit no. 1 and its corresponding steam unit as well as Bui unit no. 1 became faulted few days after the start of the pigging exercise and remained unavailable through the period. This resulted in periodic situations of generation inadequacy, compounded by periodic liquid fuel challenges at Cenpower Plant and AKSA. Load management was therefore carried out at certain times to address periods of generation inadequacy.

Please note that WAPCO took advantage of the gas supply outage in Tema to upgrade its metering skid in Tema as part of works under the Takoradi – Tema Interconnection Project, increasing its capacity from the then 140 mmscf to 235 mmscf. This has made it possible for Thermal plants in Tema to use more domestic natural gas produced in the West and improve gas supply reliability.

2.2.2 The Impact of the COVID-19 Pandemic

The outbreak of Corona Virus Disease (COVID-19) in the last quarter of 2019 brought disruptions in economies worldwide when measures put in place to curb the spread involved the slowing down and grounding of activities in the transport, industrial and services sectors etc.

Ghana, upon recording its first case in March 2020, closed down educational institutions and advised people to as much as possible stay at home including relaxed working conditions allowing as many as could to work from home. The President of Ghana instituted partial lockdowns in the Greater Accra Metropolitan Area, Greater Kumasi Metropolitan Area and Kasoa in the Central Region with restrictions on movement of people (with the exception of essential services such as hospitals, electricity workers and the food chain sector operatives). The lockdown lasted from March 30 to April 20 2020

2.2.2.1 Impact of Covid-19 on the Distribution System

For northern Ghana, average electricity consumption increased by 9% between March and June 2020 when the partial lockdown was imposed. Residential consumption increased by 13% from March to June 2020 though it was forecasted to have grown by only 5.3% during the same period. In the case of industry, there was no significant change in consumption.

Generally, electricity consumption between March and June 2020, increased by 5.3% in southern Ghana whilst consumption reduced by 0.95% over the same period and location in 2019. Residential consumption increased by 10% between March and June 2020 but decreased by 1.3% within the same period in 2019.

In the case of industry, Special Load Tariff Low Voltage (SLT-LV) and SLT-HV customers' consumption reduced significantly by 1.9% and 17.2% respectively over the period March to June 2020. Although there was decrease in consumption for these two customer groups over the same period in 2019, the decrease was more during the lockdown period when all non-food related industries had to shut down operations and workers stayed at home until the lockdown was over.

In the case of medium voltage (SLT-MV) customers, which includes the canneries and food processing companies, consumption during the lockdown period of 2020 on average increased by about 5.9% whilst in 2019 consumption grew by only 0.75% within the same period.

Table 2.1: Comparison of growth in electricity consumption between March and June for 2018, 2019 & 2020

Customer Class	March to June		
	2020	2019	2018
	CAGR	CAGR	CAGR
Residential	6.03%	-2.03%	8.66%
Non-Residential	1.19%	-1.20%	-7.55%
SLT-LV	-3.30%	-3.00%	1.79%
SLT-MV	4.58%	1.76%	8.68%
SLT-HV	-6.92%	-2.60%	-13.48%
Total	**3.64%**	**-1.41%**	4.44%
CAGR: Cumulative Average Growth Rate			
March to June 2020 is the full lockdown period			

In the case of EPC, actual consumption for April 2020 dropped by 42.5% compared to the forecast and this is attributed to the lockdown.

Table 2.2: Quarterly Cumulative Average Growth Rate for 2018-2020

Customer Class	As At End of Q1			As At End of Q2			As At End of Q3		
	2020	2019	2018	2020	2019	2018	2020	2019	2018
	CAGR	CAGR	CAGR	CAGR	CAGR	CAGR	CAGR	CAGR	CAGR
Residential	0.34%	-1.82%	-9.74%	6.03%	-2.03%	0.89%	-1.07%	-2.12%	-0.96%
Non-Residential	-0.46%	-0.12%	-5.31%	1.19%	-1.20%	-6.66%	-2.00%	-4.02%	-5.82%
SLT-LV	-5.38%	-5.60%	-3.27%	-3.30%	-3.00%	-0.27%	-2.98%	-3.06%	-2.34%
SLT-MV	2.70%	2.52%	-5.22%	4.58%	1.76%	2.89%	-0.70%	0.79%	-3.77%
SLT-HV	10.83%	-2.17%	4.85%	-6.92%	-2.60%	-6.57%	2.49%	-2.00%	8.56%
Total	**1.21%**	**-1.16%**	**-6.74%**	**3.64%**	**-1.41%**	**-0.18%**	**-0.92%**	**-1.97%**	-1.19%
CAGR: Cumulative Average Growth Rate									

The above table compares the growth in consumption on a quarterly basis from 2018 to 2020. In all cases, the cumulative average growth in total consumption in southern Ghana is higher in 2020 compared to the previous years. As at Q2, 2020, Residential consumption, SLT – MV and HV consumption experienced some significant growth. However, as at Q3 2020, the SLT-HV Consumption showed more sustained growth.

2.2.2.2 Overall impact of COVID-19 on Ghana demand

Analysis conducted to determine the impact of COVID-19 on electricity demand in Ghana in 2020 showed that, there was a dip in demand during the three week partial lockdown attributed to reduced activities in the industrial and service sectors. However following the easing of restrictions and the announcement of electricity relief by the government on April 11, 2020, system demand returned to normal such that peak demand in 2020 grew by 10.2% over that of 2019.

Similar analysis carried out with energy data shows that though actual energy consumption tipped below the projected over the lockdown period, total actual energy consumption for 2020 also grew by 10.2% over that of 2019.

It can therefore be concluded that overall, the COVID-19 pandemic did not have any significant impact on electricity demand in Ghana. There was however an increase in residential energy consumption possibly due to the social adjustments driven by containment measures adopted where most Ghanaians stayed at home in accordance with the Presidential directive and the increased use of home appliances as some pupils/students took to virtual learning programmes using computers, television sets, laptop or mobile phones as a result of the prolonged closure of schools.

2.3 Peak Load

The coincident peak load for the year 2020 was 3,089.5 MW which occurred at 20.15 h on December 4, 2020. This represents only a marginal deviation of 29.27 MW (0.96%) from the projected 2020 peak load of 3060.7 MW. The peak load recorded also represents a 10.2% (286.3 MW) growth over the 2019 peak load of 2,803.7 MW. The summary of projected and actual peak load as recorded over the period is shown in Table 2.3:

Table 2.3 System Peak Demand for 2020 and Projection

Load Type		System Peak(MW) Projection 2020	System Peak (MW) Actual 2020	Difference (MW) (Projection - Actual)
Domestic Peak		2,630.70	2,681.8	-51.3
Export	CEB	150	99.4	51
	SONABEL	180	128	52
	CIE	0	95	-95
VALCO		100	85.3	15
System Peak (coincident)		3060.7	3,089.50	-28.8

Table 2.4 on the other hand compares monthly actual peak loads with projections for 2020.

Table 2.4: System Projected and Actual Peak Demand for 2020[1]

Month	Projected Demand(MW)	Actual Demand (MW)		Difference
	System	System	Domestic	(Projected -Actual)
Jan-20	2,918.9	2,900.0	2,606.0	18.9
Feb-20	2,986.6	2,893.0	2,640.0	93.6
Mar-20	3,064.2	2,957.0	2,609.0	107.2
Apr-20	3,093.2	2,825.0	2,551.0	268.2
May-20	3,054.2	2,781.0	2,439.0	273.2
Jun-20	3,019.5	2,870.0	2,584.0	149.5
Jul-20	2,839.7	2,653.0	2,364.0	186.7
Aug-20	2,857.91	2,637.0	2,443.0	220.9
Sep-20	2,818.28	2,677.0	2,410.0	141.3
Oct-20	3,001.50	2,848.0	2,660.0	153.5
Nov-20	3,020.01	2999.50	2691.0	20.51
Dec-20	3,060.73	3089.50	2857.0	(28.77)

[1] Projected demand from July to December is taken from the 2020 Electricity Supply Plan Mid-Year Review Report

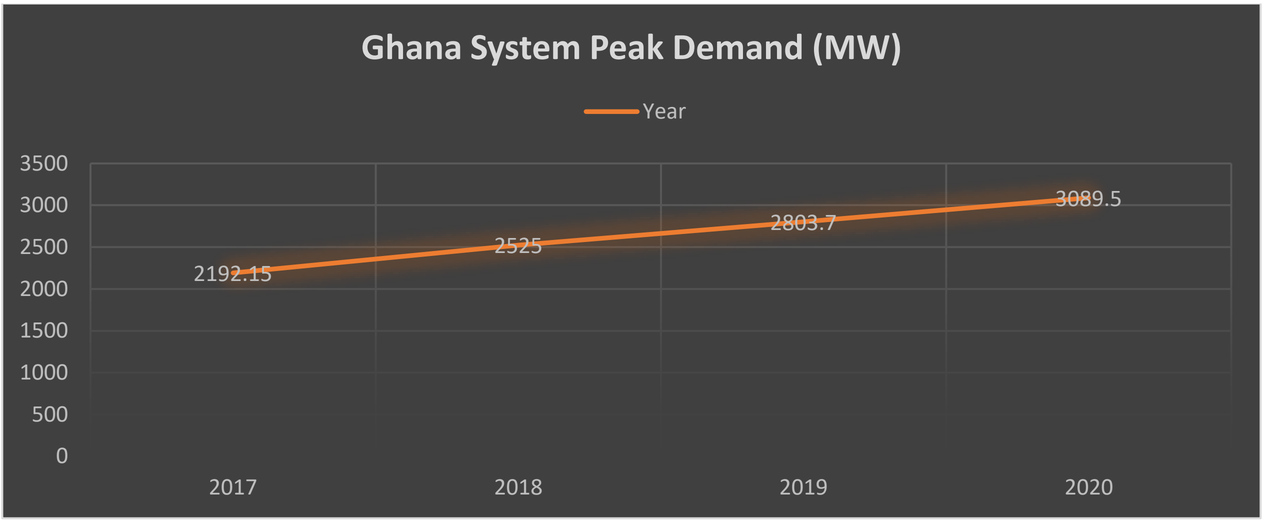


Figure 2.1: Ghana System Peak Demand (2017 - 2020)

The Ghana peak demand has grown from 2,192.5 MW in 2017 to 3,090.0 MW in 2020 at a cumulative annual average of 8.96%. This is represented in Figure 2.1.

2.3.1 Supply at Peak (MW)

The generation facilities in service at the time the 2020 Peak Demand of 3,089.5 MW occurred are as shown in Table 2.5.

Table 2.5: Plants dispatched to meet Peak Demand for 2020[2]

Plants		*Available Capacity MW*	*Capacity at Peak MW*
HYDRO	Akosombo GS	990	902.7
	Kpong GS	140	141
	Bui GS	315	212.7
	Total Hydro	**1,445.00**	**1,256.40**
THERMAL	KTPP	206	102
	AKSA	330	16
	CENIT	110	108
	SAPP	450	438.6
	Cenpower	120	128
	TT1PP	103	0
	TT2PP	14	0
	Total East	**1,333.00**	**792.6**
	TAPCO (T1)	155	161
	TICO (T2)	210	110
	AMERI	168	164.2
	KARPOWER	412	403.4
	Twin City	202	201.8
	Total West	**1,147.00**	**1,040.40**
	Total Thermal (East +West)	**2,480.00**	**1,833.00**
	TOTAL	**3,925.00**	**3,089.40**

[2] Twin City plant was running under test

This was made up of 1,256.40 MW (40.7%) hydro generation and 1,833.0 MW (59.3%) thermal generation; between the Western and the Eastern thermal enclaves, the generation contributions were: 1,040.4 MW (38%) from the Western enclave and 792.6 MW (20%) from the Eastern enclave. There was no import at the time.

2.4 Energy Consumption

The total energy consumed in 2020, including losses, was 19,716.59 GWh. Comparing with the projected total energy consumption of 19,608.21 GWh per the 2020 ESP, it is noteworthy that the actual energy consumed was only marginally higher than what was projected by 108.38 GWh (0.55%). A total of 17,887.0 GWh was consumed during the same period in 2019: the 2020 energy consumption thus represents a 1,829.59 GWh (10.23%) increase over that of 2019.

A breakdown of the energy consumed over the period is as shown in Table 2.6.

Table 2.6: Energy projection for 2020 and actual consumption for 2020 & 2019

Customer	Projection (GWh) 2020	Actual (GWh) 2020	Actual (GWh) 2019	% Growth (2020-2019)
ECG	12,562.62	12,653.33	11,487.24	10.15%
NEDCo	1,537.02	1,573.19	1,410.51	11.53%
Mines	1,533.99	1,499.20	1,318.94	13.67%
VALCO	702.32	721.56	892.55	-19.16%
EPC	258.13	242.15	235.51	2.82%
Export	1,787.06	1,855.09	1,430.39	29.69%
Direct Cust.	300.16	274.65	259.41	5.87%
Losses	897.03	887.75	842.85	5.33%
Network Usage	9.63	9.67	9.45	2.31%
Total Energy Transmitted	19,608.21	19,716.59	17,886.85	10.23%

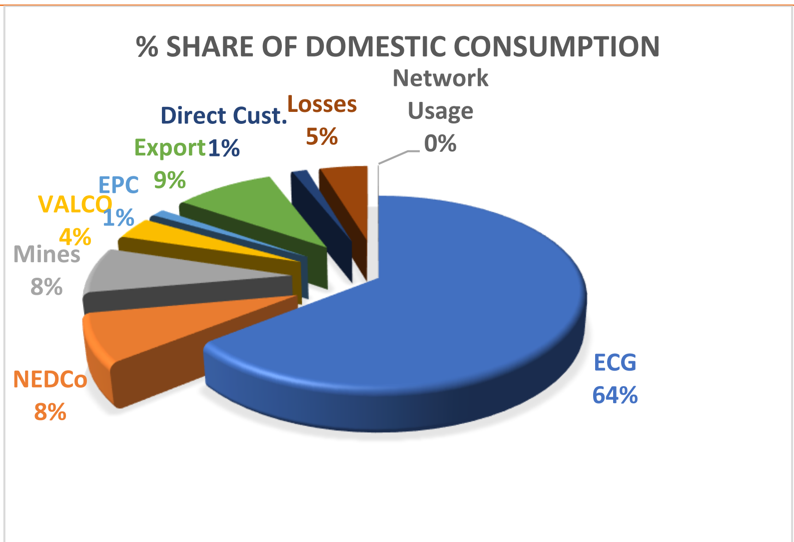
The data shows tremendous growth in exports which is primarily due to increased supply to Burkina Faso. Additionally there was also export to CIE in the last quarter of 2020 when some of their thermal plants at Azito were under maintenance. Mining load has also grown appreciably. Transmission losses on the other hand increased due to the increase in energy transmitted while VALCO consumption reduced significantly due to their inability to operate their two pot lines as planned.

2.4.1 Domestic Consumption

ECG recorded a growth rate of 10.15% and accounted for 64% of the total domestic consumption. NEDCo recorded a growth of 11.53% and accounted for 8.0% of the total domestic consumption. VALCO consumption dropped by 19.16% due to their inability to fully run two potlines but increased by 2.7% compared to the projected. Other Direct/Bulk Customers and the Mines recorded growth rates of 5.87% and 13.67% respectively. A breakdown of the energy consumption by customer class is shown in Table 2.7.

Table 2.7: Domestic Consumption

Customer	Projection (GWh) 2020	Actual (GWh) 2020
ECG	12,562.62	12,653.33
NEDCo	1,537.02	1,573.19
Mines	1,533.99	1,499.20
VALCO	702.32	721.56
EPC	258.13	242.15
Export	1,787.06	1,855.09
Direct Cust.	300.16	274.65
Losses	897.03	887.75
Network Usage	9.63	9.67
Total Energy Transmitted	19,608.21	19,716.59



2.4.2 Exports

A total of 715.23 GWh and 990.47 GWh were exported to Togo/Benin and Burkina respectively during the period. A net of 207.53 GWh was also exchanged between Ghana and Cote d'Ivoire. This was made up of 58.18 GWh imports and 149.37 GWh exports.

Table 2.8: Energy Export in 2019and 2020

Customer/Year	2019	2020
Export to CEB (GWh)	777.45	715.23
Export to CIE (GWh)	76.40	149.37
Export to SONABEL (GWh)	576.54	990.47

Total power export increased by 29.69% from 1,430.39 GWh in 2019 to 1,855.09 GWh in 2020. The growth was largely due to increased exports to SONABEL.

2.4.3 Losses

This section analyses transmission and distribution losses.

- Transmission losses

A monthly breakdown of transmission losses recorded during the period is shown in Table 2.9.

Table 2.9: Monthly Transmission Losses for 2020

Month	Total Generation (GWh)	Losses (GWh)	% Loss
Jan	1,636.43	69.92	4.27%
Feb	1,624.65	72.92	4.49%
Mar	1,738.88	80.28	4.62%

Apr	1,602.40	74.71	4.66%
May	1,722.14	84.26	4.89%
Jun	1,594.63	73.51	4.61%
July	1,574.15	69.96	4.44%
Aug	1,531.62	64.40	4.20%
Sept	1,481.63	57.81	3.90%
Oct	1,654.54	65.59	3.96%
Nov	1,702.01	76.18	4.48%
Dec	1,853.52	98.18	5.30%

The total transmission losses recorded over the period was 887.75 GWh which is 4.50% of the total energy transmitted in 2020 (19,716.59 GWh). This is only 1.02% below the projected loss in transmission of 897.03 GWh.

Figure 2.2 compares the 2020 and 2019 transmission losses recorded.

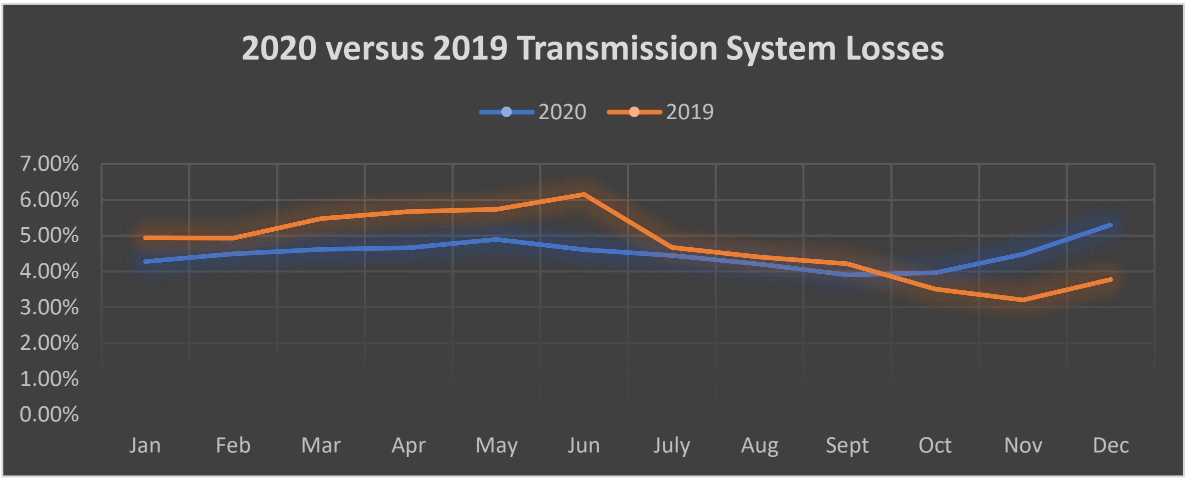


Figure 2.2: Comparison of 2020 and 2019 transmission losses

Comparing the losses for 2019 and 2020, it can be seen in figure 2.4 that there was reduction in losses in 2020 which is attributable to the energization of the 330 kV Aboadze – Anwomaso and, the 330 kV Kintampo – Adubiyili – Nayagnia line circuits in the last quarter of 2019. Further to the energization of the line, the Bui plant was dispatched one unit offpeak and two units during peak continuously due to the high reservoir elevation. This dispatch scenario curtailed the poor voltages normally experienced in the northern part of the grid which resulted in reduction in losses.

However, losses increased in the last quarter of 2020 which can be attributed to increased energy transmitted to SONABEL and poor reactive compensation across the NITS.

2.4.3.1 ECG Distribution losses

ECG distribution losses as at the end of the second quarter, 2020 is presented in Table 2.10

Table 2.10: ECG's Distribution System Losses 2020

	Purchases (Gwh)	Sales (GWh)	%Losses

1st Quarter 2nd Quarter	3,207.39 3,173.20	2,304.23 2,219.45	28.16% 30.06%

2.4.3.2 NEDCo Distribution losses

The NEDCo distribution network losses as at September, 2020 is presented in the Table 2.11

Table 2.11: NEDCo Distribution system losses 2020

Month	Energy Loss (KWh)	%Losses
Jan-20	28,894,297.59	25.3%
Feb-20	31,320,398.86	26.0%
Mar-20	43,121,159.99	27.6%
Apr-20	41,495,449.73	28.3%
May-20	38,710,057.12	28.0%
Jun-20	24,034,012.43	26.5%
Jul-20	27,393,615.21	25.9%
Aug-20	38,017,395.93	26.5%
Sep-20	35,159,194.24	26.7%

2.5 Energy Generation

The projected 2020 monthly energy generation based on the estimated availability factors of the generating plants are compared in Table 2.12 with the actuals recorded over the period.

Table 2.12: Projected versus Actual Energy generation for 2020

Months	Projected (GWh)					Actual (GWh)			
	Total Hydro (GWh)	Total Thermal (GWh)	Total Solar (GWh)	Import (GWh)	Total (GWh)	Hydro (GWh)	Thermal (GWh)	Import (GWh)	Total (GWh)
January	639.3	974.2	4.8	0.00	1,618.35	639.28	993.65	3.50	1,636.43
February	622.4	939.3	4.4	0.00	1,566.07	760.48	858.51	5.66	1,624.65
March	583.50	1,136.73	4.8	0.00	1,725.07	732.73	1,002.63	3.51	1,738.88
April	508.00	1,162.69	4.7	0.00	1,675.37	562.80	1,035.02	4.58	1,602.40
May	484.80	1,196.30	4.8	0.00	1,685.94	616.26	1,098.97	6.91	1,722.14
June	466.53	1,102.13	4.7	0.00	1,573.34	482.75	1,106.39	5.50	1,594.63
July	564.2	973.0	4.9	0.00	1,542.10	476.74	1,091.31	6.08	1,574.14
August	588.2	949.9	4.9	0.00	1,543.00	544.19	978.87	8.56	1,531.62
September	621.9	896.3	4.6	0.00	1,522.80	600.04	873.95	7.62	1,481.61
October	636.2	1,034.10	5.3	0.00	1,675.60	595.75	1,053.39	5.39	1,654.54
November	583.9	1,119.70	5.0	0.00	1,708.60	661.37	1,039.99	0.65	1,702.01
December	598.2	1,166.30	5.3	0.00	1,769.80	620.84	1,232.40	0.28	1,853.52

The hydro/thermal proportions is presented graphically in Figure 2.3.

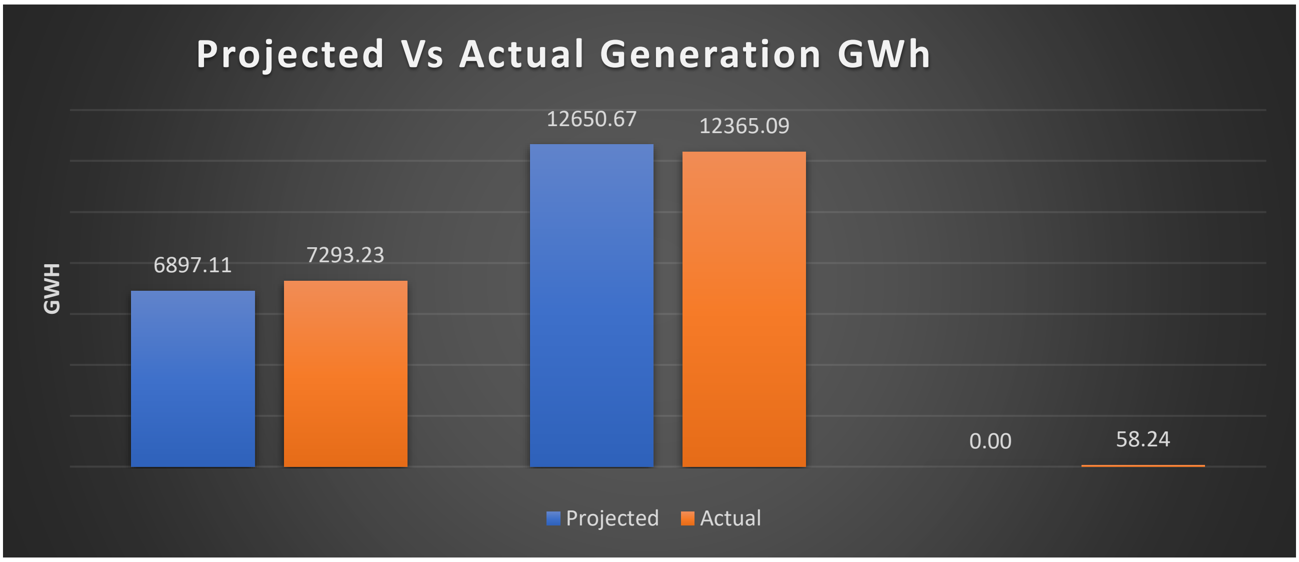
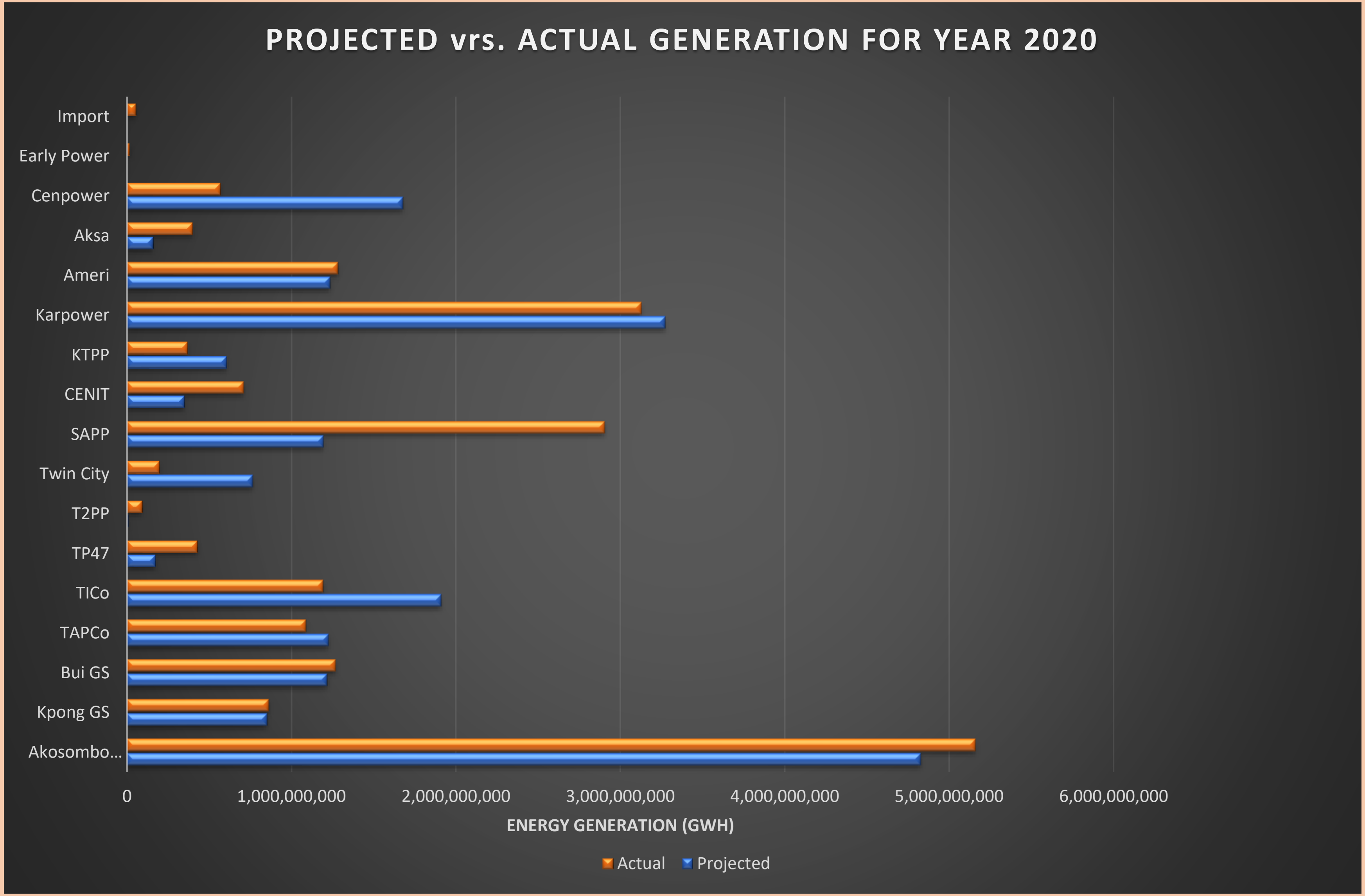


Figure 2.3: Projected versus Actual Energy Generation for 2020

Table 2.13 gives a monthly breakdown of the individual plant generation.

Table 2.13: Comparison of projected and actual monthly energy generation (GWh)

Plant	Availability (%)
Akosombo	96.88
Kpong	82.75
Bui	93.45
TAPCO	66.29
TICO	78.61
TT1PP	97.62
KTPP	99.94
TT2PP	82.02
SAPP	97.89
CENIT	95.79
AMERI Power Plant	94.26
Karpower Barge	99.87
AKSA	99.99
CENPOWER	82.12
TWIN CITY	-
Early Power	-



The total energy generated over the period was 19,716.59 GWh; this was made up of 7,293.23 GWh (36.99%) from hydro generation, 12,365.09 GWh (62.71%) from thermal generation and 58.24 GWh (0.3%) import.

Figure 2.4 shows a graphical illustration of the actual generation mix for 2020.

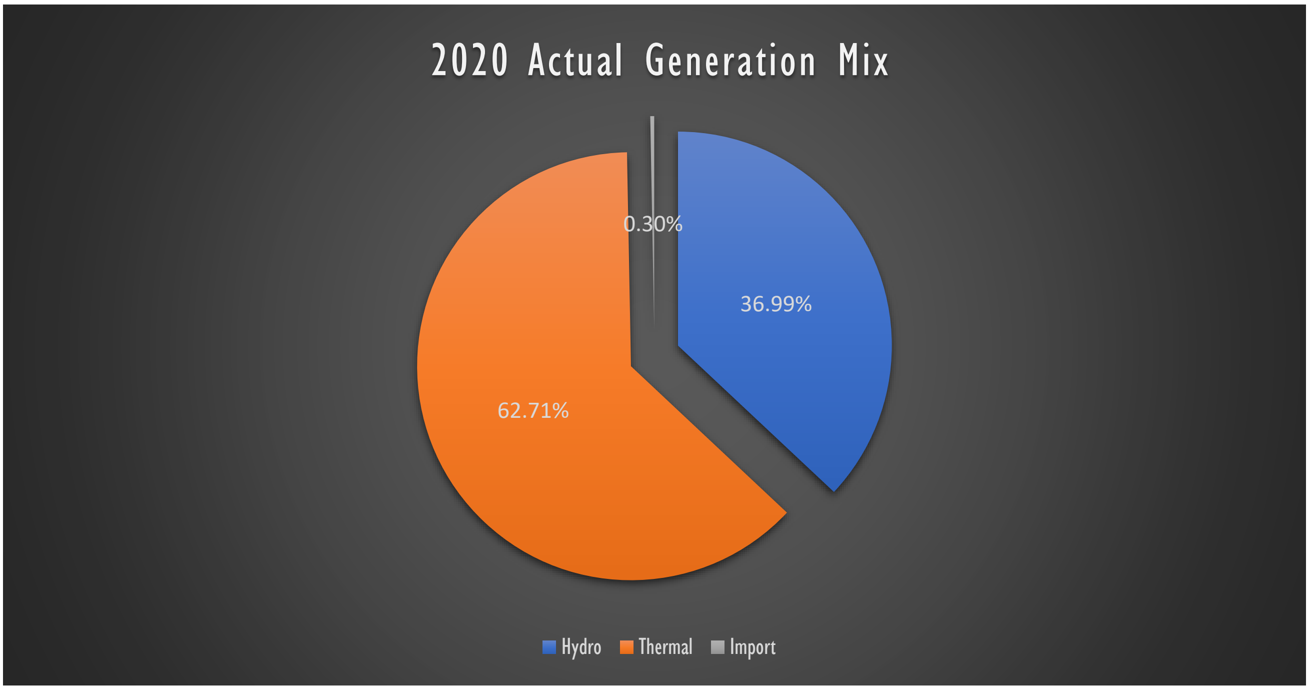


Figure 2.4: Generation Mix for 2020

2.6 Generation Facilities

2.6.1 Hydro Facilities

The dependable capacities and the projected energies for the individual hydro plants are shown in Table 2.14.

Table 2.14: 2020 Projected and Actual Hydro Generation

Plants	Dependable Capacity (MW)	Projected Energy (GWh)	Actual Energy (GWh)	Variations	% Variations
Akosombo GS	900	4,827.1	5,161.45	334.35	6.93%
Kpong GS	105	851.5	862.25	(10.75)	(1.26) %
Bui GS	360	1,218.6	1,269.52	(50.92)	(4.17)%

From Table 2.14 it can be seen that the total hydro generated for 2020 was 7,293.23 GWh as against the projected of 6,897.2 GWh. This was made up of 5,164.45 GWh, 862.25 GWh and 1,269.52 GWh from Akosombo, Kpong and Bui Generating Stations respectively.

2.6.1.1 Akosombo & Kpong

The elevation of the Volta Lake at the start of the year 2020 was 80.70 m (264.76 feet). Based on this reservoir elevation, and the intent to store water in the reservoir, it was recommended to operate up to four (4) units during the off-peak period and up to five (5) units during the peak period in the year 2020. As a result to the adherence to the above recommendation, the reservoir elevation dropped to a minimum of 78.46 m (257.41 feet) during the dry season in May 2020 and started rising on July 02, 2020.

The Kpong Generation Station (Kpong GS), was also planned to operate three (3) out of the four (4) generating units at the plant. The fourth unit which was unavailable for major retrofit was restored to service on September 19, 2020.

Inflows in 2020

The reservoir elevation at the end of 2020 was 81.60 m (267.73 ft). This figure represents an increase of 3.80 ft above the projected elevation of 260.96 ft. The recorded maximum lake elevation at the end of year 2020 inflow season was 269.97 feet, a rise of 29.97 feet above the minimum operating level of 240 feet. The total net inflow recorded in 2020 was 31.86 MAF, which implies that net inflow obtained was above the long term average of 25.21 MAF. Figure 2.5 shows the Akosombo reservoir trajectory for 2020 plotted against the trajectory for 2019 and the projected trajectory for 2020.

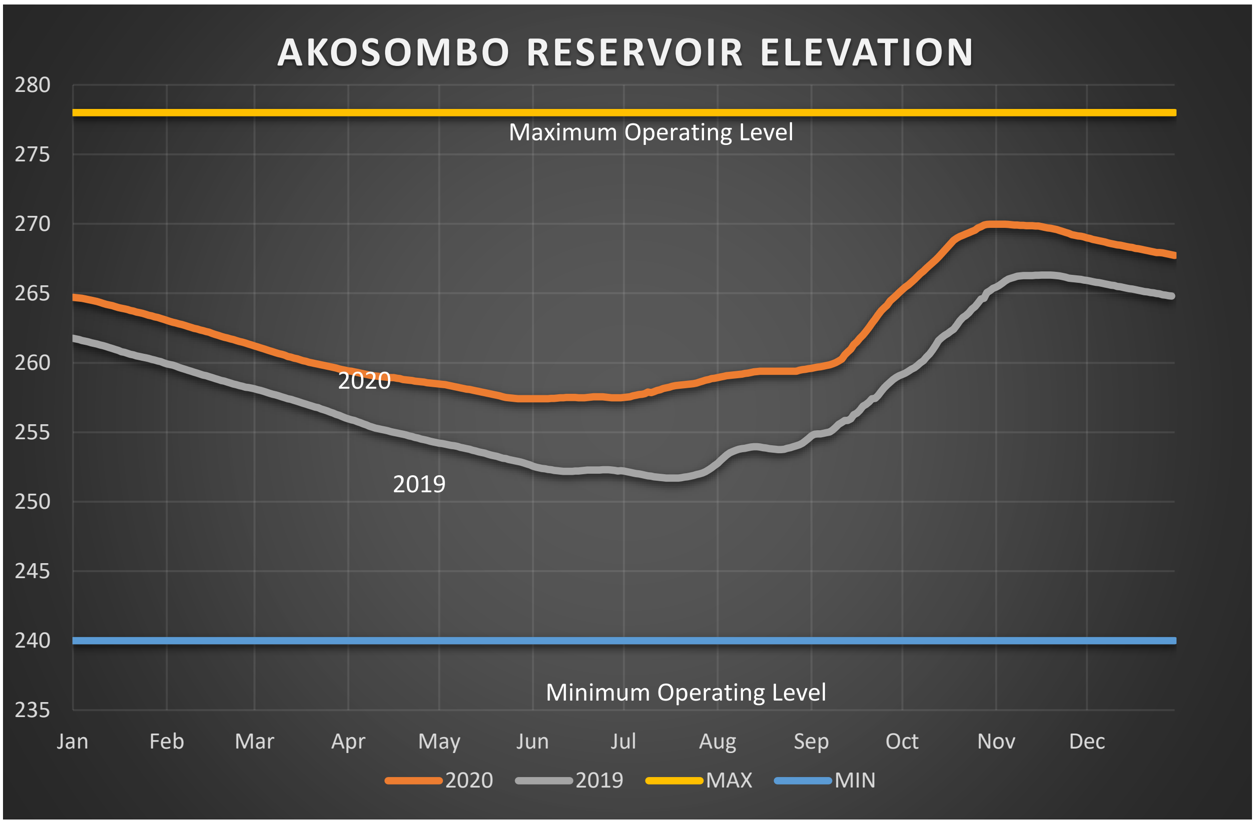


Figure 2.5: Akosombo Reservoir Elevation

2.6.1.2 Bui

The Bui Reservoir level at the beginning of 2020 was 180.37 masl, dropping to a minimum of 169.98 masl at the end of the dry season. The minimum level reached was thus 0.02 m lower than the projected minimum of 170.00 masl for the year. At the end of the inflow season, the reservoir level rose to a maximum of 174.56 masl, the lowest ever recorded since the dam was constructed. The year-end elevation is 172.22 masl.

The total energy supplied to the NITS in 2020 was 1,260 GWh compared to the projected 764 GWh (this was revised to 1,213 GWh during the Mid-year review of the 2020 Electricity Supply Plan). The recorded reservoir trajectory in 2020 is as shown in Figure 2.6.

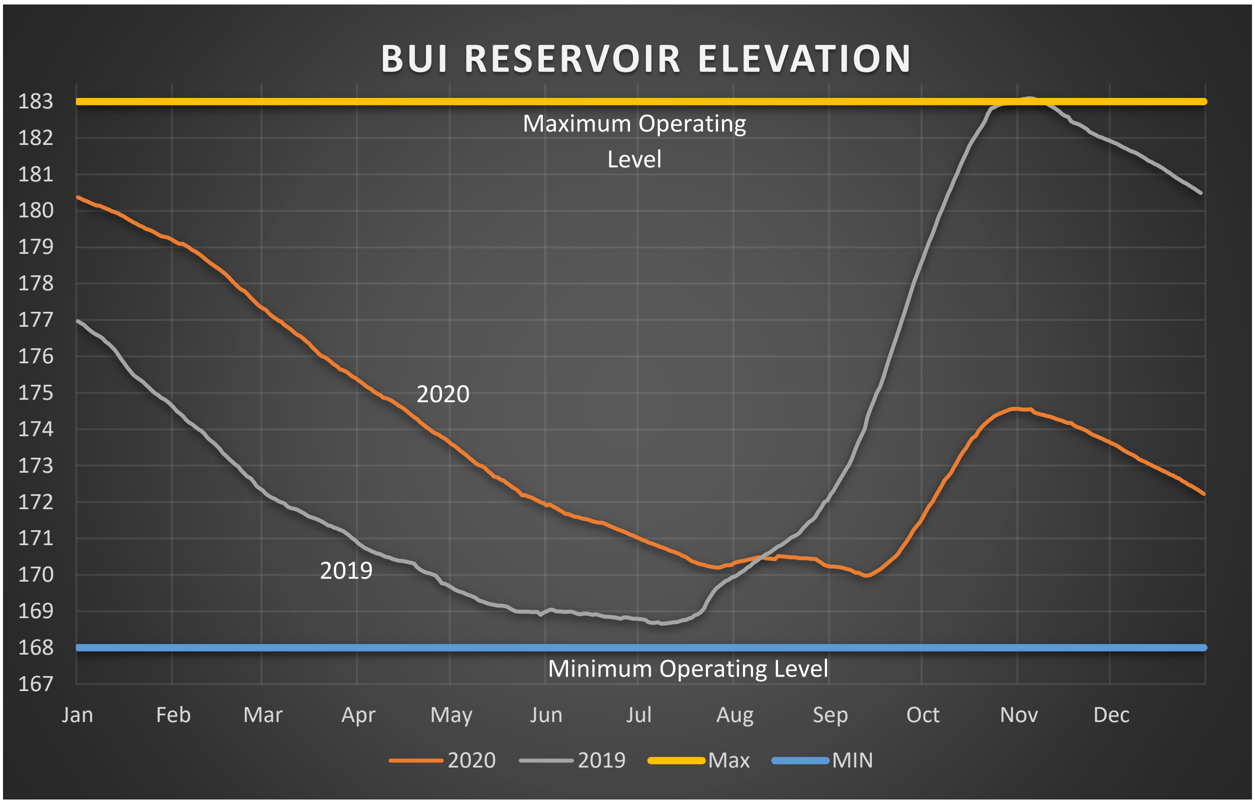


Figure 2.6: Bui Reservoir Elevation

2.7 Thermal Facilities

The Projected Dependable Thermal Capacities for 2020 was 3,314 MW which was made up of 1,492 MW and 1,678 MW from Eastern and Western Enclaves respectively. The total thermal energy generation projected for the same year was 13,307.96 GWh, made up of generation outputs from VRA and IPP Plants. Table 2.15 details the capacities of the individual thermal plants and their energies delivered.

Table 2.15: 2020 Thermal Capacities and Energy generated

	Plants	Dependable Capacity (MW)	Generated Energy (GWh)
Western Enclave	TAPCO (T1)	300	1087.48
	TICO (T2)	320	1,193.31
	Ameri	230	1,283.07
	TwinCity	192	195.99
	KAR Power	450	3,128.12
	Sub-Total	1492	6887.97
Eastern Enclave	TT1PP	100	427.26
	TT2PP	58	90.06
	KTPP	200	368.43
	Sunon Asogli	530	2,905.22
	CENIT	100	710.86
	AKSA	330	397.76
	CEN Power	360	567.71
	Sub-Total	1678	5467.31
Committed			
	Early Power	144	9.81
	TOTAL SUPPLY	**3314**	**12,365.09**

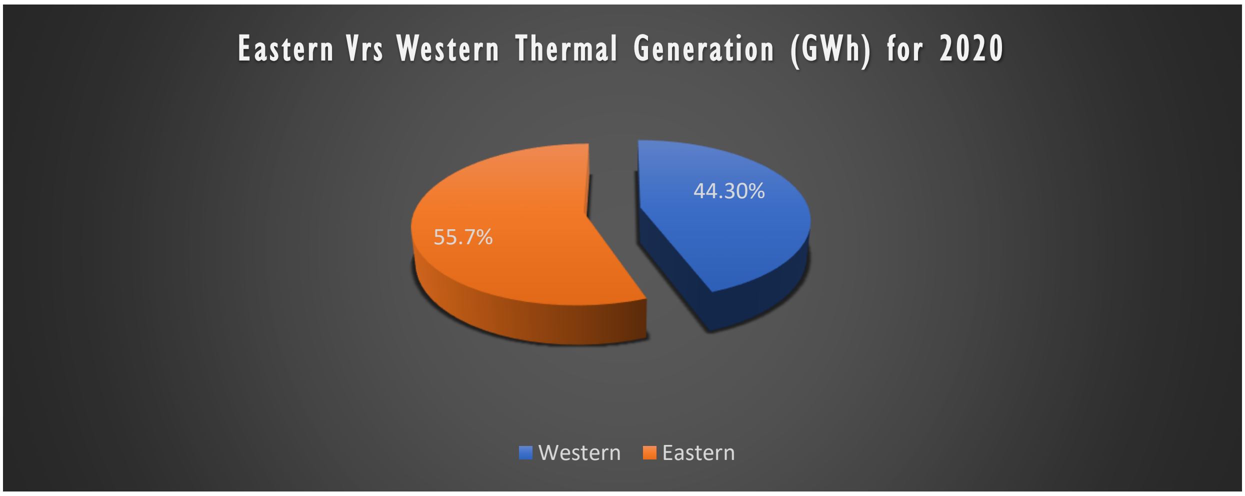


Figure 2.7: Eastern Vs Western Thermal Generation for 2020

2.8 Fuel Supply

Thermal plants on the Ghana Power System make up 68% of the total installed capacity with plants running on fuel sources such Natural gas, Light Crude Oil and Heavy Fuel Oil. The various fuel sources consumed by the thermal plants for the year 2020 is highlighted below:

2.8.1 Fuel Usage

2.8.1.1 Natural Gas Usage

Up to 89% of installed thermal plants depend on natural gas as the primary fuel source. The sources of supply include the associated gas fields (Jubilee and TEN) and the non-associated gas field (Sankofa) in the western offshore of Ghana, as well as imports from Nigeria through the West African Gas

Pipeline (WAGP). The domestic gas consumption by plant for the year 2020 is as shown in Table 2.16.

Table 2.16: Domestic Gas Consumption by Plants for 2020

GAS USER	QUANTITY (MMBTU)
TAPCO	9,074,910.00
TICO	10,564,047.00
TT1PP	5,310,005.00
SIEMENS	869,884.00
KTPP	3,915,969.00
AMERI	8,789,517.11
KARPOWERSHIP	25,826,035.78
SUNON ASOGLI	11,350,911.26
CENIT	8,099,757.59
Cenpower	2,835,095.71
TwinCity	1,676,366.29
GENSER	5,101,988.58
TOTAL	93,414,487.33

Gas utilization by power producers from the Nigeria (WAGP) amounted to a total of 10,095,857.00 MMBtu.

2.8.1.2 Liquid Fuel Usage

AKSA was the only thermal plant that operated on Liquid fuel for the year 2020. The total HFO used as at the end of November, 2020 was 3,215,114.12 MMBTU.

2.8.2 Natural Gas Supply Security

Supply of gas was beset in the first half of 2020 with few midstream and downstream challenges. Natural gas supply curtailment to the Tema power enclave due to the pigging exercise as projected in the 2020 Electricity Supply Plan commenced in January 20, 2020 and lasted for a period of 46 days on the West African Gas Pipeline (WAGP). During the period there was no supply of gas to Tema hence the thermal power plants that operate on gas were all shut down. Furthermore, Jubilee and TEN associated gas were curtailed within the period January 22, 2020 - February 6, 2020 and March 13 – 20, 2020 to resolve a restriction on the offshore gas export pipeline. Additionally there was a planned maintenance activity on the Gas Processing Plant (GPP) from February 21, 2020 to March 12, 2020. In September, the gas flow from Jubilee and TEN was limited to circa 96MMscfd due to malfunctioning inlet separator at the GPP. In light of this, Sankofa gas increased production to make up for the shortfall hence preserving the reliability of domestic gas supply in Ghana.

2.9 Renewables

VRA commenced construction of 17 MWp solar power plant in September 2019 at Kaleo and Lawra. A total of 6 MWp has been commissioned in October 2020. The remaining 11 MWp will be commissioned during the first quarter of 2021.

Bui Power Authority (BPA) commenced the construction of a 50 MWp solar plant at Bui. The Authority has commissioned 10 MWp of the 50 MWp solar plant and a 1 MW floating solar PV installation on the Black Volta, at Bui. The remaining 40 MWp is expected to be commissioned by the end of March 2021. The BPA has also completed and commissioned Ghana's first micro-hydropower plant at Tsatsadu in the Volta Region. Is a run-of-river hydro plant and has an installed capacity of 45kW with the possibility adding another 45 MW capacity turbine in the future.

Six (6) Operational Wholesale Electricity Supply Licenses have also been granted to the following Independent Power Producers:

1. BXC (Ghana) Company Limited (20 MWp solar PV plant located at Gomoa Onyadze in the Central Region.)
2. Safi Sana Ghana Limited (100kW waste-to-energy plant) located at Ashaiman, near Tema.
3. Meinergy Technology Company Limited (20 MWp solar PV plant located at Gomoa Onyaadze in the Central Region).
4. Crossboundary Energy Ghana Limited (400 kWp rooftop solar PV plant at Kasapreko Company Limited located at Spintex Road, Accra).
5. CrossBoundary Energy Ghana Limited (970kWp rooftop solar PV plant at Unilever Ghana Limited) located at Tema.
6. SolarPlast Project Company Limited (782kWp rooftop solar PV plant at Miniplast) located on the Spintex Road in Greater Accra.

The Ministry of Energy issued a policy directive on 11th August 2020, granting the Electricity Company of Ghana (ECG) the permission to conduct a competitive tendering process for the procurement of 100MW of power from solar PV, as part of the Cycle 1 targets under the Renewable Energy Master Plan (REMP). The tender is for the licensees whose PPAs have been reviewed and approved.

The Renewable Energy Act, 2011 (Act 832) was amended by Parliament on 6th November, 2020, with the Feed-in Tariff Scheme being replaced with a Competitive Procurement Scheme.

Due to the excess grid generation capacity and the over-subscription of Power Purchase Agreements (PPAs), especially for solar and wind projects, the Ministry of Energy issued a policy directive that effective 1st July 2019, all power (conventional and renewable) to be procured by any

Government agency should be done through a competitive tendering process. The Energy Commission has therefore placed a temporary suspension on the issuance of Provisional Licenses, Siting & Construction Permits, and Operational Licences for projects with distribution utilities as potential off-takers.

2.10 System Disturbances

The Ghana Power System experienced several major system disturbances in the year. The disturbances were mainly due to challenges in the transmission network. Typical of them are the disturbances which occurred in the month of September caused by fault on the 330 kV transmission circuit resulting in cascaded trips on other 161 kV transmission lines and outages to customers. The fault was as a result of flashovers on the post insulators supporting the Aboadze 330 kV P Bus due to the aggregation of salt and heavy dew on the insulators. In the course of rectifying the problem, a major fault occurred on the Tafo – Akwatia 161 kV transmission line when a truck run into the line towers, damaging the towers and snapping the line conductors. The outage to this line further weakened the grid hence the series of disturbances.

2.11 System Reliability

2.11.1 Quality of Supply

The quality of supply to consumers on the NITS is assessed based on the frequency of the system for the period and the voltage at which power was delivered. Substations with substantive amount of demand are considered.

2.11.2 System Frequency

Fig 2.8 shows system frequency performance for the year. It is seen from the graph that system frequency was within the normal range of 49.8Hz - 50.2Hz, 78.51% of the time which is largely higher than the 70.68% recorded in the same period in 2019. System frequency over the years have deviated most often above the 50.2 Hz limit, indicating inadequate primary frequency regulation on the NITS. It is therefore necessary that other units are included in primary frequency regulation to support the Akosombo generating units which have over the years solely played that role.

The others are:

- 49.5Hz - 49.8Hz – 0.79% of the time.
- 50.2 Hz - 50.5 Hz - 20.66% of the time.

It was in emergency state for 0.05% of the time in the entire year as follows:

- 49.0 – 49.5Hz - 0.30% of the time.
- 50.5 – 51.0Hz - 0.02% of the time.

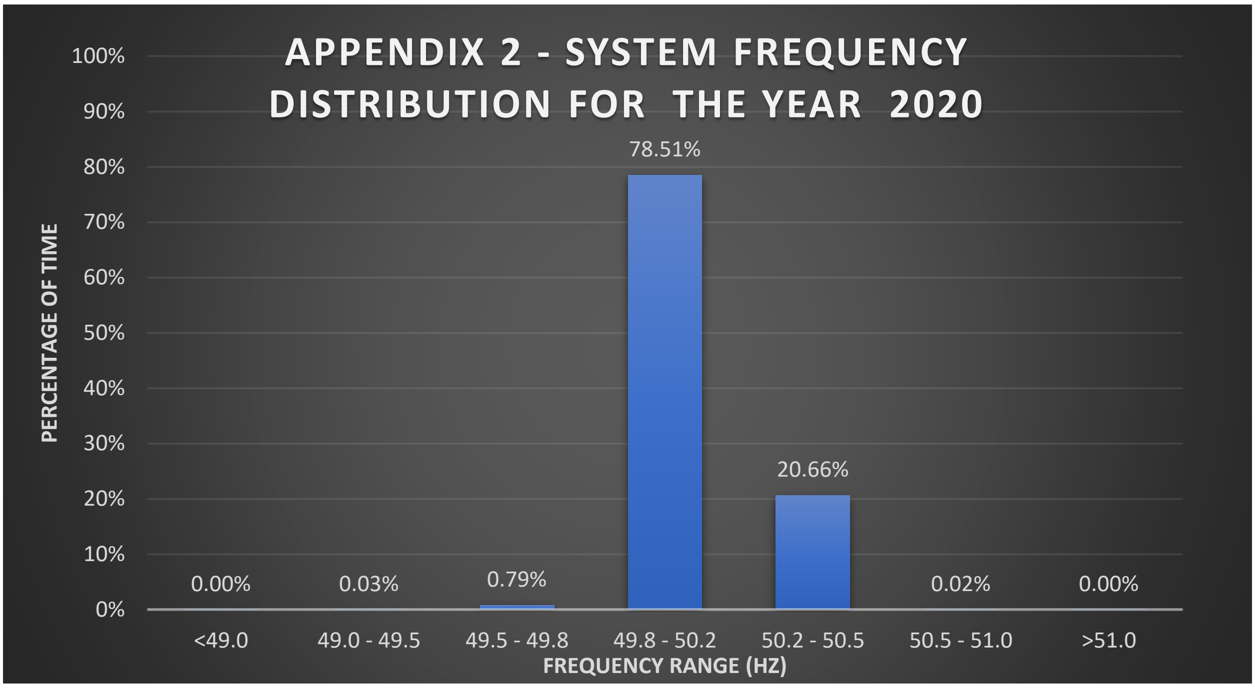


Figure 2.8: System Frequency for 2020

2.11.3 System Voltages

An analysis of voltages at selected Bulk Supply Points (BSP) at peak time indicated that voltages across the NITS were generally within normal (acceptable) limits except New Tema which recorded high voltages for 29% of the period. There was however, a significant period where voltages below the normal limits were recorded in Mallam and Kumasi as shown in Table 2.15. That notwithstanding, voltages in Kumasi have seen significant improvements. Additional improvements will be realised upon completion of the Anwomaso – Kintampo 330 kV transmission line. The cause of the low voltages in Mallam and Achimota is attributable to congestion on the Volta – Achimota line circuits and supply of customers from the western corridor and the pigging period when generation in the Tema Enclave was less than the 650 MW requirement.

Table 2.17: System Voltages

Station	Normal		Below Normal		Above Normal	
Achimota	315	86%	51	14%	0	0%
Mallam	249	68%	115	31%	2	1%
New Tema	219	60%	42	11%	105	29%
Kumasi	280	77%	81	22%	5	1%
Takoradi	353	96%	13	4%	0	0%
Tamale	327	89%	36	10%	3	1%

2.12 Transmission Network Performance

2.12.1 Power Supply (Feeder) Availability

The GRIDCo network registered an average feeder availability of 99.85% as against the approved PURC 95% benchmark. ECG, NEDCO and other bulk customers recorded average feeder availability of 99.81%, 99.84% and 99.84% respectively.

Table 2.18 shows the availability of feeders for year 2020.

Table 2.18: Feeder Availability for 2020

Customer	Availability %
ECG	99.81
NEDCO	99.84
Other Bulk Customers	99.84

2.12.2 Transmission Line Availability

The transmission lines recorded an average availability of 99.15 % for the period, as shown in Table 2.19. The Table also shows average availability for the transmission lines of the various voltage classes.

Table 2.19: Transmission line availability for 2020.

Voltage Class	Availability %
69kV	99.58%
161kV	99.21%
225kV	96.78%
330kV	98.92%
System Average Availability	99.15%

2.12.3 Transformer Capacity

The total transformer capacity as at the end of 2020 was 8,901.8 MVA. The total capacity of conventional step down transformers within the NITS is 5,301.8 MVA. The Transformer Utilisation Factor (TUF) of the transmission system is 51.28%, computed based on the peak load of 2,719.2 MVA and system average load factor of 0.88 for the period. This is indicative of a high transformer redundancy within the NITS for adequate and reliable power supply.

2.13 Distribution Network Performance

Electricity distribution in Ghana is done by the Electricity Company of Ghana Limited (ECG), Northern Electricity Distribution Company (NEDCo) and Enclave Power Limited (EPC) namely the Discos. Whereas ECG and EPC are located in the southern part of Ghana, where the population is dense and electricity consumption is about 89% of total consumption in Ghana, NEDCo is responsible for the northern part of Ghana with its geographical area starting from the Bono Region. NEDCo has a wide operational area covering 64% of the landmass of Ghana but few customers.

2.13.1 Operational Performance

The distribution network was stable and available for most of the periods. Voltages were generally stable, and customers experienced minimal interruptions in power supply. ECG experienced some intermittent outages from its suppliers due to the intelligent pigging exercise which was carried out during the first quarter. As a result of the pigging, natural gas (NG) supply to the eastern corridor of Ghana was curtailed and some of ECG's power producers could not access natural gas to generate power to the NITS. Accordingly, ECG also carried out critical maintenance works on some of its networks.

During the second quarter, the Western Region experienced, the washing of salt deposits on the insulators along the NITS and this created some outages to the distribution network.

Table 2.20 is the reliability indices as at the end of Q2, 2020 for the Discos:

Table 2.20: Distribution Reliability Indices as at Q2, 2020

Reliability Index	ECG			NEDCo			EPC	Regulatory Benchmarks		
	Metro	Urban	EPC	Metro	Urban	Rural		Metro	Urban	Rural
System Average Interruption Frequency Index (SAIFI)	9.22 times	15.41 times	19.46 times	23.2 times	14.2 times	18.3 times	1.68 times	6 times	6 times	6 times
System Average Interruption Duration Index (SAIDI)	15.44hrs	25.43hrs	30.28hrs	25.4hrs	19.7hrs	33.4hrs	4.1hrs	48hrs	72hrs	144hrs
Customer Average Interruption Duration Index (CAIDI)	1.67hrs	1.64hrs	1.54hrs	1.0hrs	1.1hrs	1.8hrs		8hrs	12hrs	24hrs

Chapter 3

2021 DEMAND FORECAST

3.1 Introduction

This chapter presents energy and peak demand projections for the Ghana Power System for 2021. The demand forecast is necessary for conducting operations planning activities including generation capacity planning, transmission and distribution network investment decision making, fuel (thermal generation) procurement planning, maintenance scheduling as well as financial projection of utilities, etc.

Electricity demand largely depends on economic variables (socio-economic activities) as well as weather. Being a developing country, electricity demand in Ghana is expected to continue to grow, on the levels of demand realised in the previous years.

Electricity demand in Ghana can be classified into:

- Domestic demand which refers to electricity demand within the control area of Ghana (excluding VALCO), including demand that is typically served through Distributing Companies such as the Electricity Company of Ghana, Northern Electricity Distributing Company and Enclave Power Company as well as the Mines, other bulk consumers who take supply directly from the NITS such as Diamond Cement, etc;
- VALCO; and
- Cross-border Exchanges (such as CEB, SONABEL and CIE).

3.1.1 Distribution network Demand Forecast Methodology

Distribution network demand typically accounts for approximately 80% of total Ghana demand. The demand forecast for the Distribution network (ie. ECG and NEDCo) was based on the 2021 projection for GDP growth in Ghana[3], as determined by the Ministry of Finance in the Budget Statement for the year.

Customers of the Distributing Companies have been classified into categories. 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.

For NEDCo, there are three categories of customers. These are Residential, Non-Residential and SLT customers. NEDCo's operational area covers approximately 64% of the geographical area of Ghana (including the northern parts of Volta, Ashanti and Western regions), however the customer density and consumption levels of the operational area are low.

Depending on the growth patterns for the different categories of customers, different forecast models were employed for forecasting demand for each customer category for the year 2021 taking into account projections for losses.

Regression analyses was used to determine relationship between historical energy consumption and macro-economic indicators such as GDP, Population growth (Customer Population). The relationship derived was used to forecast the electricity demand using projected macroeconomic indicators. This procedure was used to project residential, commercial, and small industrial loads. For large industrial consumers, their demand was treated as spot loads.

3.2 2021 Peak Demand

The projected base case coincident peak demand for 2021 (for the Ghana Power System) is 3,303.72 MW. This represents a growth of 6.9% (an increase of 213.72 MW) over the 2020 peak demand of 3,090 MW which occurred on December 4, 2020.

The 2020 demand survey exercise carried out identified the following activities which are expected to contribute to achieve the 2021 peak demand:

- 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 2021;
- VALCO's peak demand to grow from 90 MW to 130 MW; Increase in export to SONABEL (Burkina Faso)- from an average of 120 MW in 2020 to a maximum 160 MW in 2021;
- Exports to CEB (Togo/Benin) expected to increase from an average of 120 MW in 2020 to a planned maximum of 150 MW in 2021;
- Re-operationalisation of the AngloGold Ashanti mine at Obuasi.

The month-on-month peak demand will vary depending on the impact of demand drivers such as social and economic activities, seasonal changes in weather, etc.

3.2.1 Details of 2021 Peak Demand Projections

Table 3.1 shows a detailed breakdown of 2021 Projected Peak Demand showing the individual Load Entity/Distributing Company.

Table 3.1: Summary of 2021 Projected Peak Demand

Demand	Customer		2021 – Projected Coincident Peak (MW)
Domestic Peak Demand	ECG		2,106.75
	NEDCo		263.83
	Enclave Power		56.99
	Mines	New Obuasi	245.01
		Obuasi	
		New Tarkwa	
		Prestea	

		Ahafo/Kenyase (Newmont)	
		New Abirim (Newmont)	
		Akyempem (Wexford)	
		Perseus (Ayanfuri)	
		Bogosu	
		Akwatia	
		Konongo	
		Adamus Gold Resources	
		Asanko Gold	
		Drill Works	
		Earl Int	
	Other Bulk Customers	Akosombo Textiles	50.14
		Aluworks	
		Ghana Water Company Ltd	
		Diamond Cement	
		Generation Plants Station Service	
		Volta Hotel	
		Savana Cement (Buipe)	
		VRATownships	
	Losses +Network Usage		151
Total Domestic Peak Demand			2,873.72
Exports	CEB		150
	CIE		0
	SONABEL		150
Total Exports			300
VALCO			130
Coincident Peak Demand MW			3,303.72

The Pie-Chart below illustrates the composition of the projected 2021 Peak Demand, showing the percentage share of each customer class. As shown in the Chart, ECG has the highest demand, constituting 64% of the total system peak followed by Exports constituting 9%, followed by NEDCo and the Mines at 8% and 7% respectively. VALCO at two pot-lines constitutes 4%. Other Bulk Consumers constitute 2% of total peak demand.

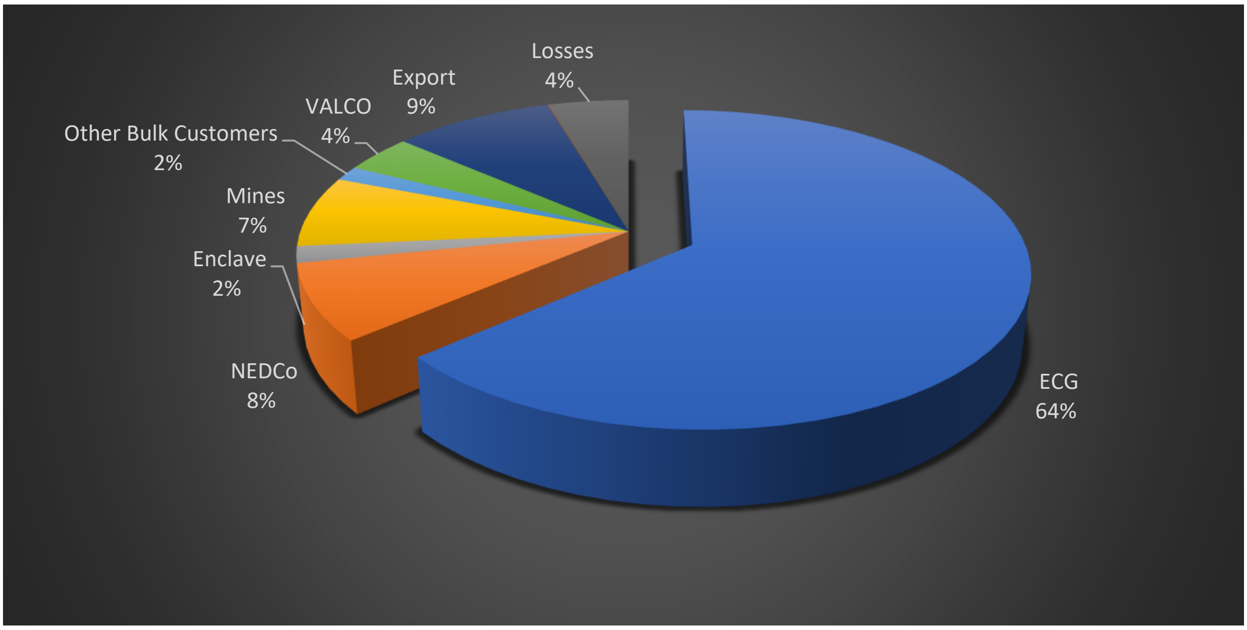


Figure 3.1: 2021 projected peak demand

3.3 2021 Energy Consumption Projections

In 2021, the projected base case energy consumption is **21,265.52** GWh, which includes transmission network losses and station service usage of 1,090.53 GWh. The estimated transmission losses and usage, represents a 5.13% of total projected energy supply. The projected 2021 energy consumption represents an increase of 1,548.93 GWh (growth of 7.86 %) over the 2020 consumption of 19,716.59GWh.

The summary of 2021 consumption by customer class is presented in Table 3.2.

Table 3.2: Summary of 2021 consumption by customer class

Energy	Customer	2021 – Projected Consumption (GWh)
Domestic Consumption	ECG	13,583.00
	NEDCo	1,611.76
	Enclave Power Company	306.03
	Mines	1,845.73
	Other Bulk Customers	246.08
	Losses + Network Usage	1,090.53
Total Domestic		18,683.13
Exports	CEB	512.14
	CIE	15.12
	SONABEL	1,000.00
VALCO		1,055.13
Total Energy (GWh)		21,265.52

Figure 3.2 below shows a pie-chart representation of the projected energy consumption of the various customer classes in 2021 and their percentages. As shown, ECG's consumption of 13,583.0 GWh represents 64% of the total projected energy consumption for 2021. It is followed by Mines and NEDCo with projected consumption of 1,845.73 and 1,611.76 GWh respectively representing 9%

and 8% of total consumption. Losses are expected to constitute 5% of the total projected energy consumption.

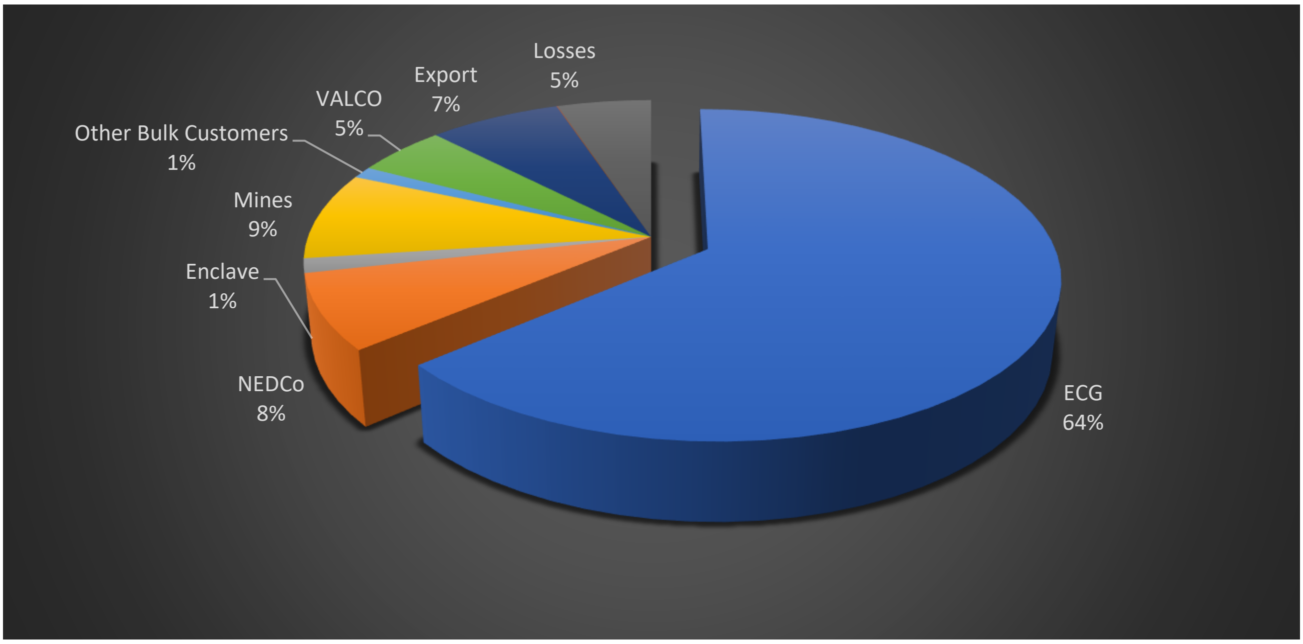


Figure 3.2: 2021 Projected Energy consumption by Customer

3.4 Projected Monthly Peak and Energy Demand for 2021

A summary of monthly energy consumption and the corresponding peak demand for the various customer classes is shown in Tables 3.3 and 3.4.

Table 3.3: Summary of Projected 2021 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	1,166.76	1,090.35	1,193.05	1,168.85	1,166.05	1,062.91	1,054.93	1,065.37	1,057.13	1,145.06	1,178.92	1,233.62	13,583.00
NEDCo	123.64	129.56	129.98	150.12	131.79	130.53	124.96	126.22	127.44	142.7	147.41	147.41	1,611.76
Enclave Power Company	21.58	22.55	23.07	23.36	24.9	24.8	27.91	28.73	28	27.96	27.51	25.65	306.02
MINES	151.44	141.05	152.54	149.96	155.01	150.26	155.18	159.65	155.27	159.78	156.26	159.33	1,845.73
Other Bulk Customers	21.76	21.43	20.6	20.05	20.8	19.74	20.13	20.38	20.06	20.53	19.89	20.7	246.07
VALCO	68.45	66.53	78.86	82.8	90.77	93.6	96.72	96.72	93.6	96.72	93.6	96.76	1,055.13
CEB(Togo/Benin)	63.89	57.99	49.27	36.65	34.37	29.89	37.86	27.84	26.95	38.93	44.21	64.3	512.15
SONABEL(Burkina)	80	76	86	88	89	84	82	82	83	86	84	80	1,000.00
CIE(Ivory Coast)	15.12	0	0	0	0	0	0	0	0	0	0	0	15.12
EDM(Mali)	0	0	0	0	0	0	0	0	0	0	0	0	0
Network Usage	0.9	0.84	0.91	0.9	0.9	0.84	0.84	0.84	0.83	0.9	0.92	0.96	10.56
LOSSES	98.94	92.74	100.13	99.35	98.94	92.18	92.41	92.83	91.93	71.5	72.92	76.08	1,079.96
Total	1,812.47	1,699.04	1,834.41	1,820.04	1,812.52	1,688.75	1,692.94	1,700.58	1,684.21	1,790.08	1,825.64	1,904.81	21,265.52

Table 3.4: Summary of Projected 2021 Monthly Peak (MW) demand – Base Case Scenario

Coincident Peak Demand (MW)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ECG	2,006.09	2,020.60	2,057.53	2,051.41	2,038.43	1,886.74	1,813.91	1,720.46	1,887.62	2,031.61	2,079.12	2,106.75
NEDCo	235.12	246.37	247.18	268.69	250.61	248.23	237.63	240.03	242.35	255.41	263.83	263.83
Enclave Power Company	54.05	52.64	53.67	55.62	56.32	60.25	63.52	60.07	59.47	57.22	55.53	56.99
MINES	235.16	237.05	238.34	238.35	238.69	239.45	239.01	244.5	245.4	245.62	245.1	245.01
Other Bulk Customers	50.26	48.41	52.8	51.91	51.56	50.29	50.08	48.89	47.74	51.18	50.6	50.14
VALCO	92	99	106	115	122	130	130	130	130	130	130	130
CEB(Togo/Benin)	150	150	150	150	150	150	150	150	150	150	150	150
SONABEL(Burkina)	150	150	160	160	160	160	140	140	140	155	150	150
CIE(Ivory Coast)	100	0	0	0	0	0	0	0	0	0	0	0
EDM(Mali)	0	0	0	0	0	0	0	0	0	0	0	0
Network Usage	1.82	1.78	1.81	1.83	1.81	1.7	1.64	1.59	1.69	1.79	1.85	1.86
LOSSES	189.5	185.27	189.06	190.63	189.19	177.31	171.09	165.53	175.92	142.91	148.26	149.14
System Peak (Coincident)	3,264.00	3,191.12	3,256.40	3,283.43	3,258.61	3,103.97	2,996.87	2,901.07	3,080.19	3,220.74	3,274.29	3,303.72

Chapter 4

2021 GENERATION OUTLOOK

4 SUPPLY OUTLOOK

4.1 Generation Sources

The sources of generation considered in the ESP for 2021 are mainly the existing Hydro, Thermal and Renewable Energy Plants, as well as committed power generation projects expected to come on-line during the year..

4.2 Summary of Generation Sources

Table 4.1 presents a summary of the existing and committed generation sources considered for 2021. A total existing generation capacity of 4,855 MW with a dependable capacity of 4,363 MW is considered for 2021.

Table 4.1: Existing Generation Sources for 2021

Plants	Installed Capacity (MW)	Dependable Capacity (MW)	Generation Type
Akosombo GS	1020	900	Hydro
Kpong GS	160	140	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	9	0	Solar
AMERI	250	230	Gas
Bui GS	404	360	Hydro
Tsatsadu Hydro	0.045	0.045	Mini Hydro
CENIT	110	100	LCO/Gas
SAPP 161	200	180	Gas
SAPP 330	360	340	LCO/Gas
KAR Power	470	450	Gas
AKSA	370	330	HFO
BXC Solar	20	0	Solar
Meinergy Solar	20	0	Solar
Safisana	0.1	0.1	Biomass
Genser	22	18	Gas
Cenpower	360	325	LCO/Gas
Twin City	203	202	LCO/Gas
BridgePower	154.30	144.77	LPG
TOTAL	5,212.45	4,709.92	

4.3 Hydro Power Generation for 2021

Projected total annual hydro generation for 2021 is 7,001.2 GWh. This is made up of 5,650 GWh from Akosombo GS, 850 GWh from Kpong GS and 501.2 GWh from Bui GS.

4.3.1 Akosombo & Kpong Hydro

The planned maintenance schedule for Akosombo GS is such that the plant will have one (1) unit out of service for SCADA works throughout the year. This will make only 5 out the 6 units available throughout the year. At an average capacity of 150 MW per unit, the Akosombo GS is expected to have up to 750 MW available when the SCADA work commences. The Akosombo GS is planned to generate a total of 5,650 GWh in 2021.

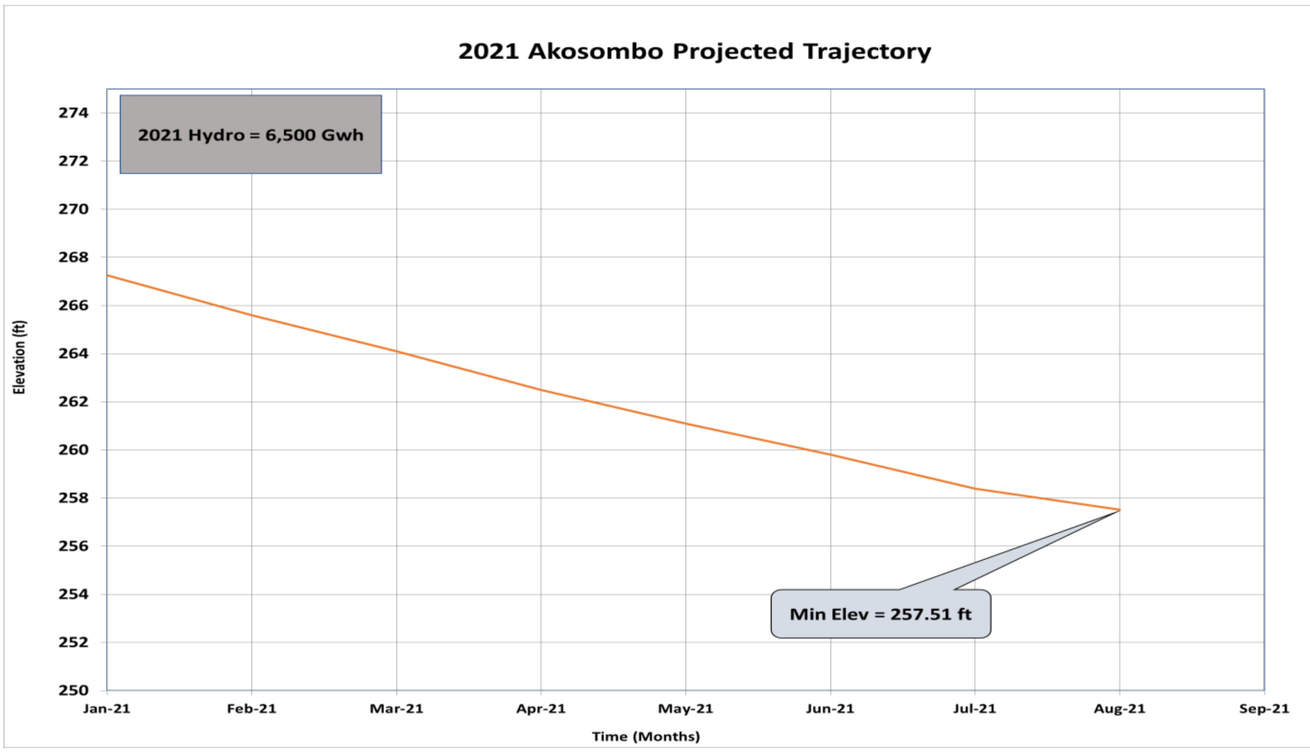


Figure 4.1: 2021 Projected Akosombo Reservoir Trajectory prior to inflow season

At an Akosombo GS year start elevation of 267.70 feet (81.595 m) this mode of operation is expected to result in a total drop in elevation of approximately 10.19 feet (3.106 m) resulting in a projected minimum elevation of 257.51 feet (78.489 m). The depletion curve of Akosombo Generation Station is shown in Figure 4.1 below.

Having completed the retrofit of all four (4) units at the Kpong GS, the plant will have all four (4) units available. The total average capacity that is expected to be available at Kpong GS is 140 MW. The Kpong GS is expected to generate 850 GWh in 2021. On the basis of the above mode of operation, the projected total annual hydro generation from Kpong and Akosombo generating stations is 6,500 GWh.

4.3.2 Bui Hydro

Due to very low inflows into the Bui reservoir during the just ended inflow season in 2020, the reservoir elevation is very low, with a year-start elevation of 172.16 masl.

Consequently, in 2021, Bui Hydro Plant is projected to generate an annual total of 501 GWh throughout the year. This implies it will generate an average of 1.37 GWh/day which corresponds to an average generation capacity of 220 MW to serve demand. With a year start elevation of 172.16 masl, the expected generation from Bui is projected to result in a year-end elevation of 178 masl.

The assumptions for the projected 2021 generation from the Bui Generating Station are as follows:

- 75% (Long Term Average Inflow (6,167 Mm^3), i.e. 4,625 Mm^3.
- The 2021 Year start elevation of Bui Reservoir – 172.16 masl
- Annual energy generation of 501 GWh.

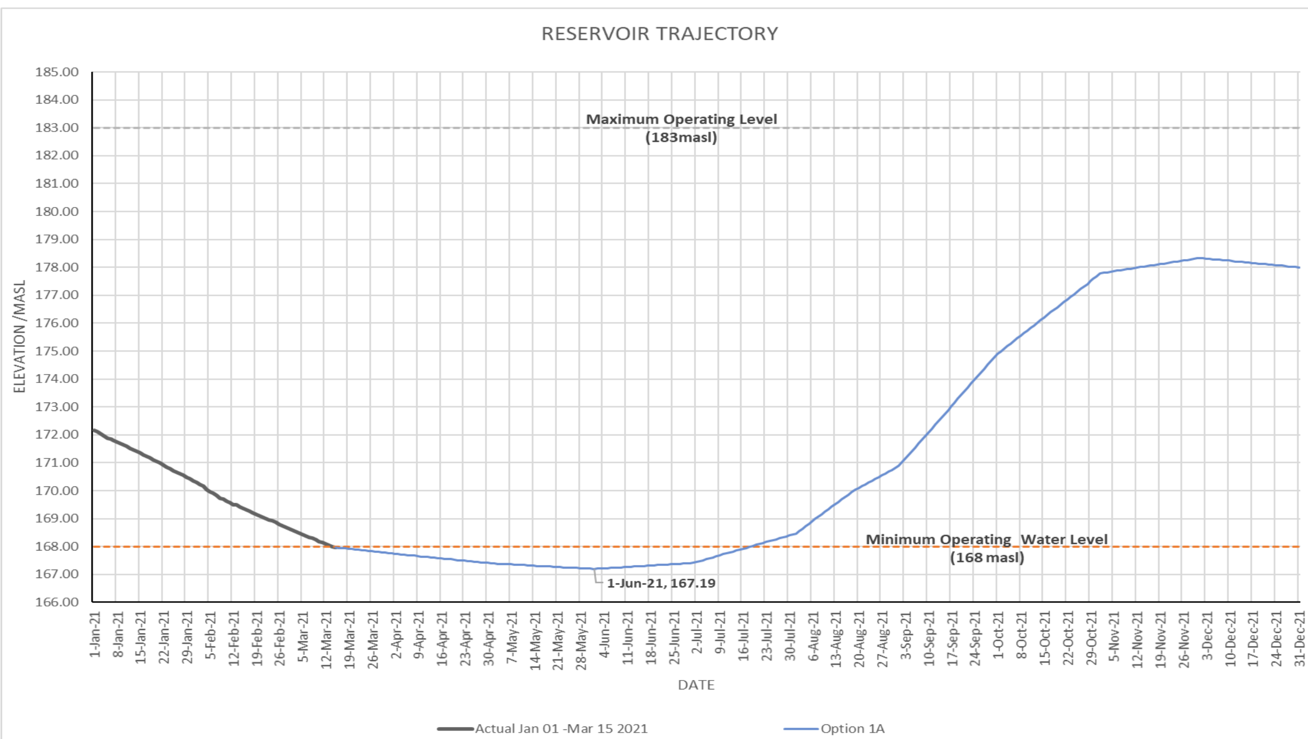


Figure 4.2: 2021 Projected Bui Reservoir Trajectory

4.4 Thermal Power Generation for 2021

The Projected Dependable Thermal Capacity from the existing generation resources is 3,222.1 MW. Additionally, a total of 347 MW of generation capacity is expected from on-going power plant projects that are expected to begin commercial operations in 2021. These are as follows:

- **203 MW Twin City Power Plant:** The plant is currently undergoing performance testing and is expected to be completed by January 2021. The plant, located within the Western enclave of the power system, is operable on both LCO and natural gas.
- **144 MW BridgePower Plant:** Construction of the power plant is completed and commissioning is expected to be completed by the end of the first quarter of 2021. The plant is operable on both LPG and natural gas. The plant is located within the Eastern enclave of the power system.

The projected cumulative thermal energy generation from VRA's portfolio of Thermal power plants and IPPs for 2021 is 14,111.97 GWh, as shown in Table 4.2.

Table 4.2: Summary of Thermal Generation

Generation Sources	2021 Projected Thermal Supply (GWh)
TAPCO	1,972.70
TICO	2,085.10
TT1PP	353.3
KTPP	369.2
TT2PP	111.7
AMERI Power Plant	795
Imports from Cote d'Ivoire	-
SAPP	2,166.60
CENIT	525.8
Karpower Barge	3,107.60
AKSA	121.2
CEN Power	1,259.60
Twin City	1,119.00
BridgePower	125.2
Total Thermal Supply (GWh)	**14,111.97**

4.5 Renewable Energy Generation Sources

In addition to the 2.5 MW Solar power plant at Navrongo, the VRA is expected to increase the installed capacity of the Kaleo/Lawra solar power plant from 6.5 MWp to 17 MWp from April 2021. The Bui Power Authority (BPA) is projected to dispatch 50MWp from the Bui Solar PV farm by the end of April 2021. Total generation from Bui Solar PV Farm is projected to be 68 GWh by end of year 2021.

Additional generation is expected from the 20 MW BXC solar power plant as well as Meinergy solar power plant and 0.1 MW Safisana Biomass plant.

A total generation of 152.34 GWh is expected from Renewable Energy sources in 2021. The summary of generation from the RE power plant facilities is as shown in Table 4.3.

Table 4.3: Summary of Renewable Energy Generation

Generation Sources	2021 Projected Renewable Energy Supply (GWh)
VRA Solar (Navrongo)	3
VRA Solar (Kaleo/Lawra)	26.6
Bui Solar Farm	68
BxC Solar	27
Safisana	0.7
Meinergy	27
Total Renewable Supply (GWh)	152.34

4.6 Key Assumptions Underpinning the Supply Plan

In developing the 2021 Supply Outlook, the following key assumptions were made:

4.6.1 Planned Maintenance

The schedule of key maintenance activities expected to be undertaken in 2021 on generating units at the various power plants is shown in Appendix B.

4.6.2 Natural Gas Quantities and Availabilities

Natural gas supply in 2021 is expected to be significantly bolstered by additional 125MMscfd from the Tema LNG Project which is expected to be operational from April 2021. Sankofa is expected to maintain its capacity to supply up to 210MMscfd, whilst Jubilee and TEN together are expected to supply 125MMscfd. Expected import from Nigeria is 50MMscfd. The maximum quantity of gas expected in 2021 is therefore projected at **480 MMscfd.**

Some maintenance activities have been scheduled for 2021 by the various facilities. However, these have been coordinated to minimize their impact on the reliability of gas supply. The Sankofa gas production facility is expected to shut down for maintenance for five (5) days in July 2021. During this period, a combination of increased supply from Jubilee, TEN, and the Tema LNG will make up for the Sankofa volumes.

The Jubilee production facility is scheduled for maintenance from 7th to 28th September 2021 (21 days). During this period, the TEN and Sankofa fields are expected to make up for the Jubilee flows. The TEN and Tema LNG facilities are not scheduled for any planned maintenance in 2021.

A planned shutdown of the Takoradi Distribution Station (TDS) and pipeline for maintenance works in mid-April 2021 is the most critical outage scheduled in 2021, because it will take out all domestic gas supply. During this period, increased imports from Nigeria and LNG are expected to make-up. Maintenance of the West African Gas Pipeline (WAGP) has been scheduled to coincide with the TDS maintenance schedule to limit the impact of gas supply disruptions in 2021. 2021 Maintenance activities on gas importing facilities in Nigeria are expected to be undertaken in the third (3rd) quarter and involve a two (2) day shutdown at Itoki Station and a five (5) day pigging operation on the Itoki to Lagos Beach stretch of the pipeline. This will lead to reduced flow of gas from Nigeria over the period of work.

Natural gas supply in 2021 from the various sources is shown in Figure 4.3.

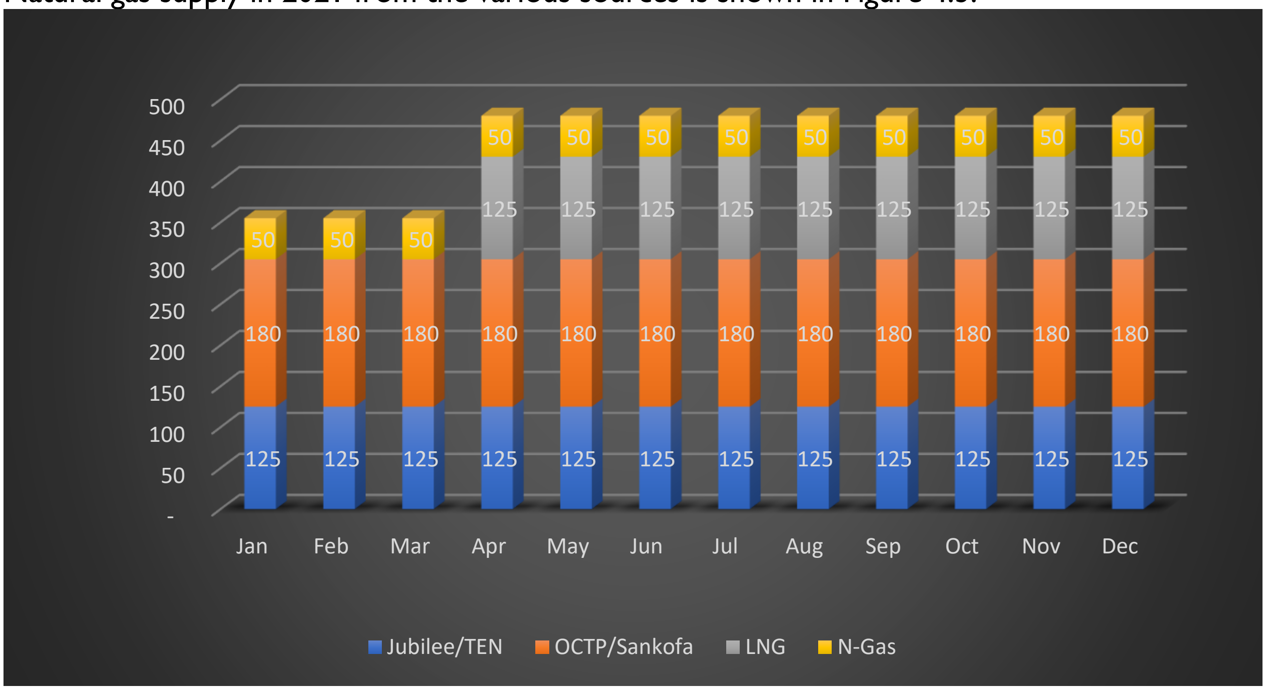


Figure 4.3: Forecasted Supply Gas Volumes (MMscfd) - 2021

Assuming each 100 MW generation capacity (simple cycle) will use a total of 30 MMscfd of natural gas, then the 480 MMscfd can be used for approximately **1,600 MW** of simple cycle generation. If all units using the gas are combined cycle units then approximately **2,400 MW** of combined cycle generation could be realized from the 480 MMscfd of natural gas.

4.6.2.1 West to East Reverse Flow

Following the completion of the West to East Reverse Flow project which has enabled the transportation of gas from domestic producing fields in the West (Takoradi) for use by thermal power plants in the East (Tema) using the WAPCo Gas Pipeline, a total of approximately 120 MMscfd of gas can be supplied from the West for use by thermal plants such as CENIT, Cenpower, TT1PP, KTPP, Sunon Asogli, etc. using the WAPCo pipeline.

The gas infrastructure at Tema has a total capacity of 235 MMscfd. Hence the quantity of natural gas that can be transported from the West to the East depends on how much gas is being supplied from Nigeria.

4.6.3 Fuel Nominations

Given the quantities of natural gas supply in 2021 as projected above, fuel usage by power plants at the Tema and Takoradi Power Enclaves is coordinated through a natural gas nomination process.

4.6.4 Fuel Price

The following assumptions on price of fuel delivered made:

- Natural Gas – US$ 6.08/MMbtu
- Delivered LCO – US$ 60/barrel
- Delivered HFO – US$ 321/MT.

4.7 Demand - Supply Analysis

This sub-section analyzes the demand – supply balance for the year 2021. The assumptions underpinning the demand - supply projections for the year are as described in Section 4.6. The analysis begins with the projected monthly energy generation from all the Generating Plants. The analysis of the monthly energy balance shows supply surplus in 2021. Therefore, the following considerations are used to determine which Plants are dispatched on monthly basis:

- Power Plant Availability
- System Stability Requirements
- Merit order dispatch

Hydro Dispatch. For system stability and also based on Electricity Market Oversight Panel (EMOP) hydro allocation and PURC tariff for 2021, is 6,500 GWh.

Furthermore, the Bui hydro power plant shall be dispatched conservatively taking into consideration the low level of inflows during the just ended inflow season. On the basis of this the Bui hydro plant is projected to generate 501.2 GWh in 2021.

Consequently a total of 7,001.2 GWh of energy generation is projected from the hydro power plants in the year.

Renewable Energy Dispatch. The solar power plants are must run plants and hence are largely dispatched based on expected energy from the plants. A total of about 152.34 GWh is expected from all the solar and other renewable sources. Especially, the Bui Solar Farm which is expected to be commissioned in the first quarter of 2021 is expected to complement generation from the hydro plant to enable the management of the headwater in its reservoir until the next inflow season.

Thermal Power Plant Dispatch. To meet projected demand, the thermal plants are dispatched after determining how much hydro and renewable generation is to be dispatched. The dispatch of the thermal power plants takes into consideration the fact that to achieve system stability there is the requirement to have at least 300 MW of generation capacity from the Western Corridor, 650 MW of generation capacity from the Eastern Corridor. Additionally, fuel supply adequacy at the thermal power plants is also taken into consideration.

Power Imports. No power import is anticipated till the end of the year. However, inadvertent energy exchanges on tie-lines could result from transient flows or emergency imports necessitated by short-term capacity shortages caused by faults or fuel supply contingencies.

On the basis of the above considerations the 2021 demand/supply balance is illustrated in Tables 4.4 and 4.5. The tables show annual energy and supply projections for 2021.

Table 4.4: Projected Monthly Generation in GWh (January – June 2021)

Customer Category	Jan	Feb	Mar	Apr	May	Jun
Domestic	1,585.0	1,498.5	1,620.3	1,612.6	1,598.4	1,481.3
VALCO	68.4	66.5	78.9	82.8	90.8	93.6
Export (CEB+SONABEL+CIE)	159.0	134.0	135.3	124.6	123.4	113.9
Projected Energy Consumption	1,812.5	1,699.0	1,834.4	1,820.0	1,812.5	1,688.8
Generation Sources						
Akosombo GS	479.9	433.4	479.9	464.4	479.9	464.4
Kpong GS	72.2	65.2	72.2	69.9	72.2	69.9
TAPCO	172.4	155.7	172.4	166.9	172.4	166.9
TICO	195.2	176.3	195.2	188.9	195.2	188.9
TT1PP	59.5	-	59.5	-	59.5	-
KTPP	-	57.1	-	61.2	-	61.2
TT2PP	9.5	8.6	9.5	9.2	9.5	9.2
AMERI Power Plant	91.4	80.9	57.1	69.3	58.1	25.1
VRA Solar (Navrongo)	0.3	0.2	0.3	0.2	0.3	0.2
VRA Solar (Kaleo/Lawra)	0.9	0.8	0.9	2.6	2.7	2.6
Imports From Cote d'Ivoire	-	-	-	-	-	-
Bui GS	31.0	28.0	31.0	30.0	31.0	30.0
Bui Solar Farm	5.8	5.2	5.8	5.6	5.8	5.6
SAPP	187.5	169.3	187.5	181.4	187.5	162.5
CENIT	47.7	47.7	47.7	47.7	47.7	47.7
Karpower Barge	267.8	241.9	267.8	259.2	267.8	239.2
AKSA	9.5	8.6	9.5	9.2	9.5	9.2
CEN Power	107.5	97.1	107.5	104.0	107.5	104.0
Twin City Energy	69.7	118.6	126.0	130.1	86.0	83.2
Bridge Power	-	-	-	15.7	15.2	14.4
BxC Solar	2.3	2.1	2.3	2.2	2.3	2.2
Meinergy	2.3	2.1	2.3	2.2	2.3	2.2
Safisana	0.1	0.1	0.1	0.1	0.1	0.1
Total Supply (GWh)	**1,812.5**	**1,699.0**	**1,834.4**	**1,820.0**	**1,812.5**	**1,688.8**

Table 4.5: Projected Monthly Generation in GWh (July – December 2021)

Customer Category	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual Total (GWh)**
Domestic	1,476.4	1,494.0	1,480.7	1,568.4	1,603.8	1,663.8	**18,683.1**
VALCO	96.7	96.7	93.6	96.7	93.6	96.8	**1,055.1**
Export (CEB+SONABEL+CIE)	119.9	109.8	110.0	124.9	128.2	144.3	**1,527.3**
Projected Energy Consumption	**1,692.9**	**1,700.6**	**1,684.2**	**1,790.1**	**1,825.6**	**1,904.8**	**21,265.52**
Generation Sources							**Total Supply (GWh)**
Akosombo GS	479.9	479.9	464.4	479.9	464.4	479.9	**5,650.0**
Kpong GS	72.2	72.2	69.9	72.2	69.9	72.2	**850.0**
TAPCO	172.4	172.4	166.9	172.4	166.9	114.9	**1,972.7**
TICO	195.2	100.7	97.4	167.8	188.9	195.2	**2,085.1**
TT1PP	59.5	-	57.6	-	57.6	-	**353.3**
KTPP	-	63.2	-	63.2	-	63.2	**369.2**
TT2PP	9.5	9.5	9.2	9.5	9.2	9.5	**111.7**
AMERI Power Plant	20.0	80.9	56.0	78.1	76.2	101.8	**795.0**
VRA Solar (Navrongo)	0.3	0.3	0.2	0.3	0.2	0.3	**3.0**
VRA Solar (Kaleo/Lawra)	2.7	2.7	2.6	2.7	2.6	2.7	**26.6**
Imports From Cote d'Ivoire	-	-	-	-	-	-	**-**
Bui GS	31.0	31.0	30.0	77.0	74.0	77.0	**501.2**
Bui Solar Farm	5.8	5.8	5.6	5.8	5.6	5.8	**68.0**
SAPP	155.5	187.5	181.4	187.5	181.4	197.5	**2,166.6**
CENIT	29.2	27.7	47.7	22.7	47.7	64.3	**525.8**
Karpower Barge	237.8	267.8	259.2	267.8	259.2	271.8	**3,107.6**
AKSA	9.5	9.5	9.2	9.5	9.2	19.0	**121.2**
CEN Power	107.5	107.5	104.0	101.3	104.0	107.5	**1,259.6**
Twin City Energy	86.0	63.0	104.0	55.8	93.0	103.5	**1,119.0**
Bridge Power	14.3	14.4	14.3	12.0	11.0	14.0	**125.2**
BxC Solar	2.3	2.3	2.2	2.3	2.2	2.3	**27.0**
Meinergy	2.3	2.3	2.2	2.3	2.2	2.3	**27.0**
Safisana	0.1	0.1	0.1	0.1	0.1	0.1	**0.7**
Total Supply (GWh)	**1,692.9**	**1,700.6**	**1,684.2**	**1,790.1**	**1,825.6**	**1,904.8**	**21,265.52**

Table 4.6: 2021 Projected energy Generation and Consumption Balance in GWh

Consumer Category	2021 Projected Consumption (GWh)
Domestic	18,683.10
VALCO	1,055.10
Export (CEB+SONABEL+CIE)	1,527.30
Projected System Energy Requirement	21,265.52
Generation Sources	2021 Projected Generation (GWh)
Akosombo	5,650.00
Kpong GS	850
TAPCO	1,972.70
TICO	2,085.10
TT1PP	353.3
KTPP	369.2
TT2PP	111.7
VRA Solar (Navrongo)	3
VRA Solar (Kaleo/Lawra)	26.6
AMERI Power Plant	795
Imports From Cote d'Ivoire	-
Bui GS	501.2
Bui Solar Farm	68
SAPP	2,166.60
CENIT	525.8
Karpower Barge	3,107.60
AKSA	121.2
CEN Power	1,259.60
Twin City	1,119.00
Bridge Power	125.2
BxC Solar	27
Meinergy	27
Safisana	0.7
Total Supply (GWh)	21,265.52

Figure 4.4 is a graphical presentation of the above energy Generation/Consumption balance showing the percentage share of each generation type. The Chart shows that thermal generation constitutes 66.4% of projected total generation whilst generation from hydro and Solar PV constitute 32.9% and 0.7% respectively.

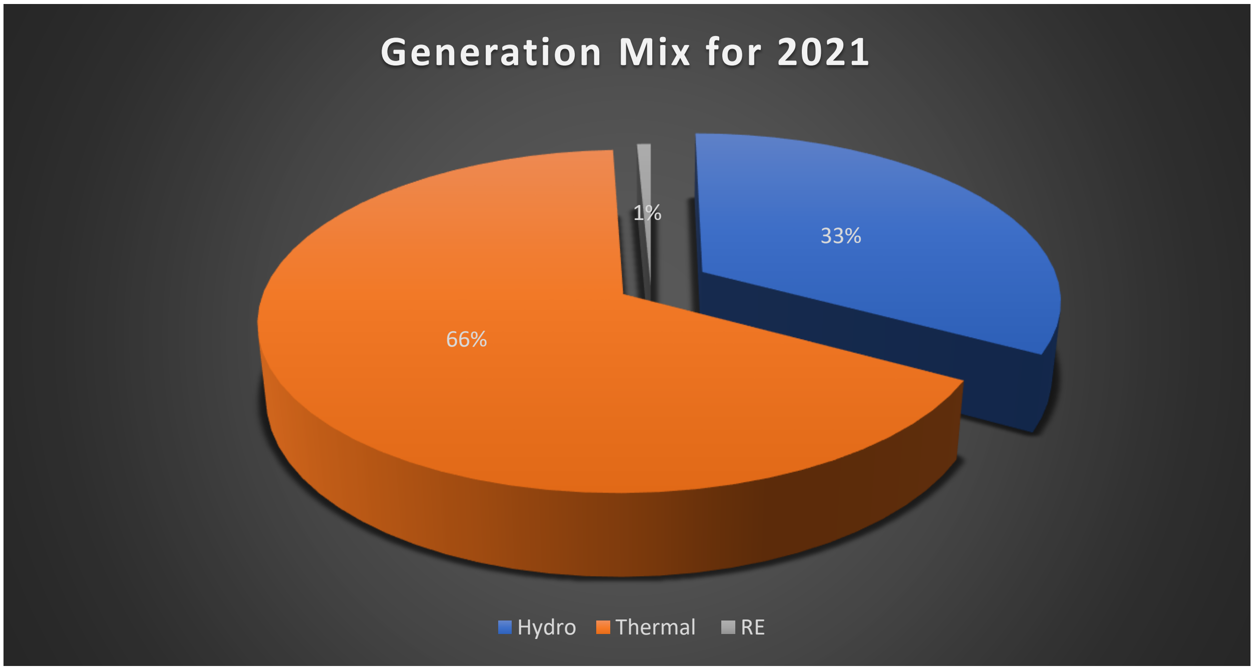


Figure 4.4: Contribution of Supply by Generation Types

The high penetration and increasing proportion of thermal generation in the overall generation mix could pose serious challenges for the following reasons;

- ✓ Since tariffs are cedi-denominated and the utilities purchase fuel and other consumables mostly in United States Dollars (USD), any major depreciation of the Ghana Cedi against the major foreign currencies, particularly the USD, could cause financial challenges,
- ✓ The thermal plants are predominantly gas-fired, consequently any disruption in gas supply could have dire consequences on the security of power supply.

4.8 Projected Capacity Situation

The projected monthly Supply Capacity levels, taking planned unit maintenance and Fuel Supply into consideration is shown in Tables 4.7 and 4.8.

Table 4.7: Projected Monthly Capacity Situation for 2021 (January – June 2021)

Customer Category	2021 Projected System Peak (MW)	Jan	Feb	Mar	Apr	May	Jun
Domestic	2798.38	2,772	2,792	2,840	2,858	2,827	2,664
VALCO	130.00	92	99	106	115	122	130
Export (CEB+SONABEL)	290.00	400	300	310	310	310	260
Projected System Demand	**3303.72**	**3,264**	**3,191**	**3,256**	**3,283**	**3,259**	**3,054**
Generation Sources	**Dependable Gen. Capacity**						
Akosombo	900	750	750	750	750	750	750
Kpong GS	140	140	140	140	140	140	140
TAPCO	300	300	300	300	300	300	300
TICO	320	320	320	320	320	320	320
TT1PP	100	100	0	100	0	100	0
KTPP	200	-	100	0	100	0	100
TT2PP	80	45	45	45	45	45	45
AMERI Power Plant	230	200	200	200	200	200	200
VRA Solar	9						
Imports From Cote d'Ivoire	0	-	-	-	-	-	-
Bui GS	345	220	220	220	220	220	220
Bui Min Unit	4	4	4	4	4	4	4
SAPP 161	180	180	180	180	180	180	180
SAPP 330	350	350	350	350	350	350	350
CENIT	100	100	100	100	100	100	100
Karpower Barge	450	400	400	400	400	400	400
AKSA	330	330	330	330	330	330	330
CEN Power	325	325	325	325	325	325	325
Amandi	192	100	190	190	190	190	190
Bridge Power	144	0	0	0	120	120	120
Trojan	0	0	0	0	0	0	0
Genser	60	60	60	60	60	60	60
Safisana	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Meinergy	20						
Solar (Central Region)	20						
Total Available Generation (MW)	**4,799**	**3,924**	**4,014**	**4,014**	**4,134**	**4,134**	**4,134**
Surplus/deficit (MW)	**1,495**	**660**	**823**	**758**	**851**	**875**	**1,080**
Required Reserve (18%)	**595**	**588**	**574**	**586**	**591**	**587**	**550**
Actual Reserve Margin	45%	20%	26%	23%	26%	27%	35%

Table 4.8: Projected Monthly Capacity Situation for 2021 (July – December 2021)

Customer Category	2021 Projected System Peak (MW)	Jul	Aug	Sep	Oct	Nov	Dec
Domestic	2798.38	2,577	2,481	2,660	2,786	2,844	2,874
VALCO	130.00	130	130	130	130	130	130
Export (CEB+SONABEL)	290.00	240	240	240	255	310	300
Projected System Demand	**3303.72**	**2,947**	**2,851**	**3,030**	**3,171**	**3,284**	**3,304**
Generation Sources	**Dependable Gen. Capacity**						
Akosombo	900	750	750	750	750	750	750
Kpong GS	140	140	140	140	140	140	140
TAPCO	300	300	300	300	300	300	220
TICO	320	320	165	165	320	320	320
TT1PP	100	100	0	100	0	100	0
KTPP	200	0	100	0	100	0	100
TT2PP	80	45	45	45	45	45	45
AMERI Power Plant	230	200	200	200	200	200	200
VRA Solar	9						
Imports From Cote d'Ivoire	0	-	-	-	-	-	-
Bui GS	345	220	220	220	220	220	220
Bui Min Unit	4	4	4	4	4	4	4
SAPP 161	180	150	180	180	180	180	180
SAPP 330	350	350	350	350	350	350	350
CENIT	100	100	100	100	100	100	100
Karpower Barge	450	400	400	400	400	400	400
AKSA	330	330	330	330	330	330	330
CEN Power	325	325	325	325	325	325	325
Amandi	192	190	190	190	190	190	190
Bridge Power	144	120	120	120	120	120	120
Trojan	0	0	0	0	0	0	0
Genser	60	60	60	60	60	60	60
Safisana	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Meinergy	20						
Solar (Central Region)	20						
Total Available Generation (MW)	**4,799**	**4,104**	**3,979**	**3,979**	**4,134**	**4,134**	**4,054**
Surplus/deficit (MW)	**1,495**	**1,157**	**1,128**	**949**	**963**	**850**	**750**
Required Reserve (18%)	**595**	**530**	**513**	**545**	**571**	**591**	**595**
Actual Reserve Margin	45%	39%	40%	31%	30%	26%	23%

The analysis of the above monthly demand and supply situation for 2021 shows monthly positive generation reserve margins of up to 40% in 2021. With such a considerably high reserve capacity, it is inevitable that some power plants would be used as non-spinning reserves to be used to provide strategic reserve capacity on the Ghana power system.

4.9 Fuel Requirement

Currently, the main fuels for power generation are Natural Gas, Heavy Fuel Oil (HFO), Light Crude Oil (LCO) and Diesel Fuel Oil (DFO). The Bridge Power Plant when fully commissioned will also use Liquified Petroleum Gas (LPG). The estimates of monthly quantity and cost of fuel requirement in 2021 is indicated in Table 4.9.

The summary of major fuel requirements for 2021 is as presented below:

- ✓ **Natural Gas:** Based on the assumed gas supply from Nigeria and Ghana, the total natural gas consumption for 2021 is projected to be about 123.903 Tbtu.
- ✓ **LCO:** There would be no significant requirement for LCO for the year 2021. This is due to anticipated high volumes of gas from Sankofa, Jubilee and TEN fields as well as from Nigeria and the envisaged LNG project. LCO stock as at January 1, 2021 at VRA power station at Tema and Takoradi was 43,605.49 barrels and 307,228 barrels.
- ✓ **HFO:** The AKSA Plant is scheduled to operate on HFO in 2021 from January to June. Therefore, an estimated 121,849 barrels would be required by AKSA.
- ✓ **Diesel.** Diesel is not projected to be used in 2021. The diesel stock as at January 1, 2021 was 13,704.57 cubic meter.

4.9.1 Monthly Fuel Requirement

A summary of Monthly fuel requirements and associated costs are as shown in Table 4.9.

Table 4.9: Monthly fuel requirements and associated costs (January – December 2021)

	Units	Jan	Feb	Mar	Apr	May	Jun
Estimated Thermal Fuel Requirement	**Units**						
TAPCO - GAS	mmbtu	1,541,970	1,392,747	1,541,970	1,492,229	1,541,970	1,492,229
TICO - GAS	mmbtu	1,542,868	1,393,558	1,542,868	1,493,098	1,542,868	1,493,098
TT1PP - GAS	mmbtu	696,384	-	696,384	-	696,384	-
KTPP - GAS	mmbtu	-	672,874	-	720,936	-	720,936
TT2PP - GAS	mmbtu	111,935	101,102	111,935	108,324	111,935	108,324
AMERI Power Plant - GAS	mmbtu	1,031,430	912,751	644,047	781,969	655,248	283,632
Karpower Barge - GAS	mmbtu	2,163,470	1,954,102	2,163,470	2,093,680	2,163,470	1,932,131
SAPP - GAS	mmbtu	1,553,137	1,402,834	1,553,137	1,503,036	1,553,137	1,345,873
CENIT - GAS	mmbtu	563,407	563,407	563,407	563,407	563,407	563,407
AMANDI - GAS	mmbtu	574,163	977,021	1,037,646	1,071,177	708,366	685,515
CENPOWER - GAS	mmbtu	884,145	798,582	884,145	855,624	884,145	855,624
Early Power - GAS	mmbtu	-	-	-	178,653	173,785	163,724
AKSA - GAS	mmbtu						
AKSA - HFO	barrels	20,869	18,850	20,869	20,196	20,869	20,196
Total Natural Gas Volume (MMBtu)		**10,662,908**	**10,168,978**	**10,739,009**	**10,862,134**	**10,594,714**	**9,644,493**
ESTIMATED FUEL COST							
Total Natural Gas Cost @ US$ 6.08/mmbtu	MMUS$	64.83	61.83	65.29	66.04	64.42	58.64
Total HFO Cost @ US$ 45/bbl	MMUS$	0.94	0.85	0.94	0.91	0.94	0.91
Total Fuel Cost (US$ Million)	**MMUS$**	**65.77**	**62.68**	**66.23**	**66.95**	**65.35**	**59.55**

	Units	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
Estimated Thermal Fuel Requirement	Units							
TAPCO - GAS	mmbtu	1,541,970	1,541,970	1,492,229	1,541,970	1,492,229	1,027,980	**17,641,463**
TICO - GAS	mmbtu	1,542,868	795,541	769,879	1,325,902	1,493,098	1,542,868	**16,478,514**
TT1PP - GAS	mmbtu	696,384	-	673,920	-	673,920	-	**4,133,376**
KTPP - GAS	mmbtu	-	744,967	-	744,967	-	744,967	**4,349,647**
TT2PP - GAS	mmbtu	111,935	111,935	108,324	111,935	108,324	111,935	**1,317,942**
AMERI Power Plant - GAS	mmbtu	225,596	912,420	632,006	880,557	859,708	1,148,153	**8,967,518**
Karpower Barge - GAS	mmbtu	1,921,145	2,163,470	2,093,680	2,163,470	2,093,680	2,195,779	**25,101,546**
SAPP - GAS	mmbtu	1,288,460	1,553,137	1,503,036	1,553,137	1,503,036	1,635,977	**17,947,940**
CENIT - GAS	mmbtu	344,139	327,356	563,407	268,343	563,407	759,226	**6,206,320**
AMANDI - GAS	mmbtu	708,366	518,817	856,894	459,517	766,296	852,513	**9,216,291**
CENPOWER - GAS	mmbtu	884,145	884,145	855,624	832,971	855,624	884,145	**10,358,917**
Early Power - GAS	mmbtu	162,754	163,652	162,644	136,800	125,400	159,600	**1,427,013**
AKSA - GAS	mmbtu	109,089	109,089	105,570	109,089	105,570	218,352	**756,759**
AKSA - HFO	barrels							**121,849**
Total Natural Gas Volume (MMBtu)		**9,536,851**	**9,826,498**	**9,817,214**	**10,128,658**	**10,640,292**	**11,281,493**	**61,231,008**
ESTIMATED FUEL COST								
Total Natural Gas Cost @ US$ 6.08/mmbtu	MMUS$	57.98	59.75	59.69	61.58	64.69	68.59	**372.28**
Total HFO Cost @ US$ 45/bbl	MMUS$	-	-	-	-	-	-	**-**
Total Fuel Cost (US$ Million)	**MMUS$**	**57.98**	**59.75**	**59.69**	**61.58**	**64.69**	**68.59**	**372.3**

4.10 Estimates of Fuel Cost

The breakdown of the estimated cost of fuel for running all the Thermal Plants in 2021 is US$ 755.9 Million. This translates into an approximate monthly average of US$ 62.99 Million. The cost is made up of US$ 737.19 Million for Natural gas at an average cost of US$ 6.08/MMbtu and US$ 18.66 Million for HFO at US$ 70/barrel.

Chapter 5

2021 TRANSMISSION SYSTEM OUTLOOK

5 2021 TRANSMISSION SYSTEM OUTLOOK

5.1 State of the Ghana National Interconnected Transmission System

The National Interconnected Transmission System (NITS) transmits electricity from the various generating stations to the various load centers across country. The NITS, predominantly a 161 kV (73.2% of total circuit length of all NITS lines) grid, also comprises transmission lines and circuits at 69 kV (3% of total circuit length of all NITS lines), 225 kV (1.3% of total circuit length of all NITS lines) and 330 kV (22.5% of total circuit length of all NITS lines) voltage levels. The Ghana power system, one of the best in sub-Saharan Africa, is interconnected with the power systems of Côte d'Ivoire and Burkina at 225 kV and with Togo at both 161 kV and 330 kV. The 330 kV interconnection with Togo was constructed as part of activities towards the implementation of the West African Power Pool (WAPP).

The state of the NITS as at end of year 2020 is as follows:

- The total circuit length is 6,185.3 km;
- The total number of Bulk Supply Points (BSPs) is 65;
- Total number of load transformers at BSPs is 138;
- Total transformation capacity is 8,901.8 MVA;
- Total capacity fixed capacitive compensation devices is 309.8 MVAr;
- Total capacity of reactors is 230 MVAr;
- One 40 MVAr Static Synchronous Compensator (STATCOM4) installed at the Tamale substation.

The fixed capacitors, reactors and the STATCOM complement the generating units in providing the reactive power requirements on the NITS in order to maintain voltages within normal levels and minimize transmission losses.

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

[4] STATCOM is a regulating device used on alternating current electricity transmission networks. It is based on a power elecrtronics voltage source converter and can act as either a source or sink of reactive AC power to an electricity network.

5.2 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 2021 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 neighbouring 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.

5.3 Scope of Network Analysis

Network analyses are carried out 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.;
- ✓ 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.

5.3.1 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 5.1: 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 5.2: 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 2021 model of the Ghana power system which was developed using the 2021 energy and capacity Demand forecast data. The study was conducted on the expected state of the power system within two periods of the year - being, the first half year (January - June) and the second half year (July – December).

e. Generation Additions

The first phase of Bridge Power Plant consisting of 147 MW located in Tema. This Plant has already been commissioned on LPG with commissioning on Natural Gas left as outstanding works.

f. Transmission Additions

The following transmission lines and substation under construction are modelled in the second half of 2021 to assess their impact on the grid:

g. Transmission Lines and substations

- ✓ 330 kV, Anwomaso – Kintampo Transmission line Project.
- ✓ 161 kV, Volta – Accra East – Achimota line reconstruction
- ✓ 161 kV Achimota – Mallam line reconstruction
- ✓ 330/161/34.5 kV Pokuase Substation project.

h. Summary of Results for the Steady State Network Analysis

The following scenarios were studied:

- ✓ 2021 Base Case (current system scenario-Peak and off-peak scenarios)
- ✓ 2021 Case Balanced Dispatch Scenario – (Voltage Analyses for first-half system off-peak and peak scenarios)
- ✓ 2021 Case Maximum East Dispatch Scenario – (Voltage Analyses for first-half system peak scenarios)
- ✓ 2021 Case Maximum West Dispatch Scenario – (Voltage Analyses for first-half system peak scenarios)
- ✓ 2021 Case Balanced Dispatch Scenario – (Voltage Analyses for second-half system peak scenarios)
    - o 2021 second-half case with the completion of the 330/161/34.5 kV Pokuase (A4BSP) substation only.
    - o 2021 second-half case with the upgrade of the 161 kV Volta-Achimota-Mallam line corridor.
    - o 2021 second-half case with the completion of the 330kV Anwomaso – Kintampo line.
- ✓ System Contingency Analyses

5.4 2021 Business as Usual Scenario (Peak and Off-Peak Analyses)

a. Off-Peak Condition – Bui water level constraints

This case simulates the current 2021 system conditions and serves as the base case for the off-peak period. In this case, a system demand of **2,670.3 MW** is simulated.

Table 5.3 shows the generation dispatch from all generation enclaves in the grid.

Table 5.3: Generation dispatch from Generation Enclaves (Off-peak conditions)

GENERATION ENCLAVE	OUTPUT (MW)
EASTERN (TEMA THERMALS)	480
WESTERN (TAKORADI THERMALS)	1,240.3
EASTERN HYDROS	949
NORTHERN HYDROS	0

TOTAL	2,670.3

During the first half year of 2021, the Bui water level is low. This situation is expected to significantly impact active power generation from the Hydro Dam. In view of this, there is the likelihood that generating units at Bui Hydro Plant will not be dispatched during off-peak periods. From system simulations, a system condition with no Bui units in service showed voltage stability issues across the northern parts of the grid. Much of the power supply to consumers in the northern parts of the grid comes from the Western generation enclave and flows along the western corridor transmission lines over long distances. Most of these transmission lines are of 170MVA small sized capacity which will tend to get overloaded leading to voltage instability and a non-convergence of the power flow analysis. To support the voltage, the Bui generator was dispatched in synchronous condenser mode to deliver 50MVAr to support low voltages in the northern portions of the grid. Substations across the middle belt of the grid mainly serving mining customers recorded poor voltages (average voltage of 0.85 P.U). These include Dunkwa, Asawinso, Ayanfuri and Obotan substations.

The analyses show that transmission losses during this period is approximately **199.52 MW** represent **7.47** % of **2,670.3 MW** generation.

b. Peak Condition

The peak demand for 2020 is **3,090 MW** . The Table 5.4 shows the generation dispatch from the various generation enclaves in Ghana at the time the peak occurred.

Table 5.4: Generation dispatch from Generation Enclaves (Peak conditions)

GENERATION ENCLAVE	OUTPUT (MW)
EASTERN (TEMA THERMALS)	889
WESTERN (TAKORADI THERMALS)	1,158.3
EASTERN HYDROS	812.7
NORTHERN HYDROS	230
TOTAL	3,090

As earlier indicated, the hydrology at Bui will allow for only two units (230 MW) of Bui GS to be dispatched during the peak periods in 2021.

From the analyses, system conditions improve compared to the off-peak scenario with an average voltage improvement of 5 kV across substations in the mining area. The 161 kV Volta - Accra East and Kumasi – Anwomaso line loadings are 100 % and 95 % respectively.

Simulations show that transmission losses during this period reduce to **195.47 MW** representing **6.33** % of peak generation **(3,090 MW)**.

2021 PEAK CASE WITH BALANCED GENERATION (1st Half).

From the 2021 capacity and energy demand forecast, the projected peak for the first half of 2021 is **3,283.4 MW**. In this scenario, power plants are dispatched optimally to realise the least acceptable transmission losses. It is worth noting that a number of the ongoing transmission projects are expected to be completed by the end of June 2021. These include the upgrade of the 161kV Volta – Achimota – Mallam corridor, the 330 kV Anwomaso -Kintampo line and 330/34.5 kV Pokuase substation. Therefore, these investments are not modelled in this case.

Again, analyses show that the overload on the 161 kV Anwomaso - Kumasi line will be reduced when a third 161/34.5 kV 66 MVA transformer is installed at Anwomaso and ECG transfers load from its Ridge BSP/Kumasi to Anwomaso. This results in a significant easing of the line overload from 111% to 88% of its line capacity.

Table 5.5 shows the generation dispatch from all generation enclaves in the grid.

Table 5.5: Balanced Generation Dispatch from Generation Enclaves (Peak conditions for 1st half year of 2021)

GENERATION ENCLAVE	OUTPUT (MW)
EASTERN (TEMA THERMALS)	959
WESTERN (TAKORADI THERMALS)	1,289.3
EASTERN HYDROS	805.1
NORTHERN HYDROS	230
TOTAL	**3, 283.4**

The results also show that there will be low voltages and transmission line overloads on key transmission corridors in the west. Comparing to the base case, system conditions for this scenario worsen due to the significant increase in system demand. The 161 kV Volta - Accra East, Tarkwa – New Tarkwa and New Tarkwa – Prestea lines record overloads of 110.3%, 94.3%, 92.9% and 99.6% of their line capacities respectively. Also the 161 kV Anwomaso-Kumasi transmission line is overloaded at 111% of its capacity. This means that without any interventions, the lines loaded above 100% will trip leading to system disturbance. The transmission losses recorded for this scenario is approximately **215.96** MW representing **6.58** % of 3,283.4 MW generation.

Again, substations across the middle parts of the grid mainly serving mining customers record poor voltages (average voltage of 0.85 P. U). This includes the 161 kV Dunkwa, Asawinso, Prestea, Ayanfuri and Obotan substations.

2021 PEAK CASE WITH MAXIMISED GENERATION IN THE EAST (1st Half).

This simulation depicts a 2021 first-half year scenario where all the Hydro units at Akosombo are engaged and complemented with Thermals in and around Tema. Such a dispatch scenario is possible during periods of gas unavailability within the western generation enclave.
Table 5.6 shows the generation dispatch from all generation enclaves in the grid.

Table 5.6: Maximum East Generation Dispatch (Peak conditions for 1st half year of 2021)

GENERATION ENCLAVE	OUTPUT (MW)
EASTERN (TEMA THERMALS)	1,349
WESTERN (TAKORADI THERMALS)	740
EASTERN HYDROS	965.7
NORTHERN HYDROS	230
TOTAL	**3,284.7**

The analyses shows that transmission losses will be **221.61 MW** (**6.75%** of **3,284.7 MW** generation). Transmission losses increase by 6 MW compared with the base case. Additionally, the 161 kV Volta – Accra East, Volta-Achimota lines are overloaded at 118.9% and 93.8% respectively. The short 161 kV line from KTPP- Volta is loaded at 93.2% with two units (220 MW) engaged at KTPP. An upgrade of the corridor will reduce the overloads and also reduce transmission losses.

Also, some severe system voltage violations are observed on the following substations serving the western mining communities. These include the 161kV Prestea, Dunkwa, Asawinso Ayanfuri, and Obotan substations recording an average voltage of 138.2kV. An average voltage of 148.3 kV is also observed across the 161 kV Kumasi, Nkawkaw and Anwomaso substations.

From the simulations, it is observed that the minimum allowable generation dispatch from the Western generation enclave considering the current grid constraints should be 700 MW. Any generation dispatch less than this total may result in voltage stability issues along the Western and Northern parts of the NITS.

2021 PEAK CASE WITH MAXIMUM GENERATION IN THE WEST (1st Half).

This case analyses the impact when majority of the Power Plants at Aboadze are put in service. It is worth noting that such a dispatch scenario is possible during periods of gas unavailability in the eastern generation enclave, such as when the WAPCO R&M Station at Tema is shut down. Table 5.7 shows the generation dispatch from all generation enclaves used in this analysis.

Table 5.7: Maximum West Generation Dispatch (Peak conditions for 1st half year of 2021)

GENERATION ENCLAVE	OUTPUT (MW)
EASTERN (TEMA THERMALS)	809
WESTERN (TAKORADI THERMALS)	1,462.9
EASTERN HYDROS	777.7
NORTHERN HYDROS	230
TOTAL	3,279.6

Transmission losses of **217.4 MW (6.63%)** were recorded from a simulated peak load of **3,279.6 MW**. This shows a marginal 1.41 MW increase in transmission losses compared with the base case of **215.96 MW**. It is observed that the 161 kV Volta - Accra East, Tarkwa – New Tarkwa, New Tarkwa – Prestea and Takoradi – Tarkwa lines are loaded at 106.9%, 97.4%, 95.9% and 86% respectively. Also, some severe system voltage violations are observed within Accra and the mining areas in the West. Specifically, an average voltage of 152 kV. is observed across the 161kV Achimota, Winneba, Mallam and Accra East. For the mining areas including the 161 kV Prestea, Dunkwa, Kumasi, Asawinso Ayanfuri and Obotan substations, an average voltage of 139 kV is recorded.

2021 PEAK CASE WITH BALANCED GENERATION (2nd Half).

The projected peak for 2021 is 3303.72 MW expected to be realised by the fourth quarter of the year. By this time it is expected the following projects would have been commissioned:

- 161 kV Volta – Achimota – Mallam corridor upgrade project,
- 330 kV Anwomaso -Kintampo line
- 330/34.5 kV Pokuase substation

If so, it is expected that the network additions will significantly improve system voltage profile and consequently reduce transmission losses (the losses will still be above the set PURC threshold, though).

Table 5.8 shows the generation dispatch from all generation enclaves in Ghana.

Table 5.8: Balanced Generation Dispatch (Peak conditions for 2nd half year of 2021)

GENERATION ENCLAVE	OUTPUT (MW)
EASTERN (TEMA THERMALS)	959
WESTERN (TAKORADI THERMALS)	1,320.4
EASTERN HYDROS	793
NORTHERN HYDROS	230
TOTAL	3,303.72

It is noteworthy that aside the effect of optimised power dispatch, the network additions from completed projects within this period contribute to the improvement observed.

The results of the load flow simulations indicate transmission losses of **149.12 MW** (**4.51**%) which is a **66.84 MW** reduction from the first half year figure of **215.96 MW** (**6.58**%). However, there are observed voltage violation at the 161kV Asawinso (143.3 kV),161 kV Dunkwa (149.7

kV), 161 kV Ayanfuri (146.5 kV) and 161 kV Obotan (139.2 kV) substations. There were no line loading violations observed system wide.

2021 CASE WITH MAXIMUM GENERATION IN THE EAST (2nd Half).

In this scenario, analyses are carried out assuming maximum generation dispatch from the western enclave (Aboadze) for the second half of 2021. Table 5.9 shows the generation dispatch from all generation enclaves in the grid.

Table 5.9: Maximum East Generation Dispatch (Peak conditions for 2nd half year of 2021)

GENERATION ENCLAVE	OUTPUT (MW)
EASTERN (TEMA THERMALS)	1597.6
WESTERN (TAKORADI THERMALS)	490
EASTERN HYDROS	1010.9
NORTHERN HYDROS	230
TOTAL	3,328.5

The results of the load flow simulations show transmission losses of 175.65 MW (5.28 %) out of a total of **3,328.5 MW** generation. Transmission loss reduction observed here is due to the assumed completion of the upgrade of the Volta – Achimota – Mallam 161 kV corridor, the completion of the 330 kV Anwomaso - Kintampo line and the 330/161/34.5 kV Pokuase substation.

The completion of these system upgrades and development during this period will relieve the NITS of most of its line overloads seen in the first half year analysis. However, the KTPP - Volta 161 kV line is highly loaded at 91.6% when two units (220 MW) are dispatched at KTPP. Voltage violations observed show an average voltage of 143.4 kV recorded within the mining areas including the 161kV Prestea, Dunkwa, Asawinso Ayanfuri, and Obotan substations.

As observed in the first half of 2021, the analysis shows that due to improved system conditions in the second half of 2021, the minimum acceptable generation dispatch from the Western generation enclave reduces to 450 MW. This dispatch flexibility is because of the removal of overloads on transmission line corridors and associated improvements in the voltage profile in the western, middle to northern parts of the NITS, that is from the Takoradi Thermal substation through the mining areas and through Kumasi to the northern parts of the grid. A generation dispatch less than the 450 MW total output from the western enclave may result in voltage stability issues along the western grid and towards the north.

2021 CASE WITH MAXIMUM GENERATION IN THE WEST (2nd Half).

A maximum western generation dispatch for the second half of 2021 is simulated. Table 5.10 shows the generation dispatch from all generation enclaves in the grid.

Table 5.10: Maximum West Generation Dispatch (Peak conditions for 2nd half year of 2021)

GENERATION ENCLAVE	OUTPUT (MW)
EASTERN (TEMA THERMALS)	690
WESTERN (TAKORADI THERMALS)	1,562.8
EASTERN HYDROS	837.9
NORTHERN HYDROS	230
TOTAL	3,320.7

The results of the simulations indicate transmission losses of **168.50 MW** (**5.07%**) out of **3,320.81 MW** generation. Again, the transmission loss figure is seen to have reduced compared with the 2021 first-half -year case due primarily to the assumed completion of all the on-going transmission system reinforcement projects .

The 161 kV Tarkwa -New Tarkwa and New Tarkwa – Prestea lines are observed to be heavily loaded at 89% and 88% of their thermal capacities respectively. Similarly, system voltage violations as observed in the earlier case improve to 145.3 kV P.U in this case.

EXPECTED IMPACT OF COMPLETION OF TRANSMISSION SYSTEM PROJECTS ON GRID PERFORMANCE IN THE 2ND HALF OF 2021

a. 330/34.5 KV POKUASE(A4BSP) SUBSTATION.

The completion and coming into service of the 330/161/34.5 kV Pokuase (A4BSP) substation is expected by the second half of 2021. Simulations show improvement in system performance. Transmission losses reduce comparing with the previous case (1st half year 2021 Balanced Generation case) from **215.96 MW** to **211.74 MW** representing **6.43%** of **3,291.62 MW** system generation. However, line overloads are recorded on the 161 kV Volta - Accra East (102

%), 161 kV Tarkwa – New Tarkwa (86.9 %), 161 kV New Tarkwa – Prestea (85.4%) lines. This is a significant improvement on results from the previous case.

Again, substation voltages at the flagged substations i.e. 161 kV Dunkwa, Asawinso Ayanfuri, and Obotan substations record an improved average of 140.1 kV P.U.

b. 161 kV VOLTA-ACHIMOTA-MALLAM LINE CORRIDOR UPGRADE

Similarly, the upgrade of the 161 kV Volta – Achimota – Mallam line corridor also will result in improvements in system performance. Line overloads reduce further with only the 161 kV Tarkwa – New Tarkwa, 161 kV New Tarkwa – Prestea recording 92.3% and 91.1 % of their line capacities respectively compared with the 2021 1st half Balanced Generation case. Also, substation voltages improve recording an average voltage of 0.86 P.U. Transmission losses also reduce from **215.96 MW**to **203.07 MW** (**6.19**% of **3,282.61 MW** system generation).

c. 330 kV ANWOMASO – KINTAMPO LINE

Comparing results of this scenario with that of the first half year balanced generation scenario above, transmission losses reduce by 62MW from **215.96 MW** to **153.30 MW** (**4.74** % of **3,231.26 MW** generation)**.** This system intervention records the most benefits compared with the other two interventions above. Thus, this project yields greatest improvements in system performance.

With this line in service, simulations show that export capability to SONABEL increases from the projected 150 MW to 200 MW on the average. However, the 161 kV Volta – Accra East and Volta –Achimota lines remain overloaded at 113.4% and 88.7% of their rated line capacities respectively. Voltage violations as seen in the 2021 1st half year Balanced Generation case are still observed, but significant improvement are observed across substations serving the western mining communities. An average voltage of 148.4 kV is recorded.

N-1 CONTINGENCY ANALYSES

N-1 contingency analyses are studies conducted on sections of a power system to determine the capability of the section to continue to provide electricity service delivery in the event of an outage to a single element/equipment, eg. transmission line, transformer, etc.

Single line contingency (N-1) analyses are conducted on the 2021 power flow model. The contingencies are ranked in order of severity and are as follows: The analyses considered the following criteria:

- Contingencies causing severe line overloads

- Contingencies causing voltage collapse issues.

Contingencies causing line overloads

a) 330 kV Takoradi Thermal – Anwomaso line

Since this high-capacity line carries an average of 450 MW at peak, a loss of the line results in re-routing of almost this amount of power on the 161 kV circuit between Aboadze Enclave and Kumasi. This leads to overloads along the 161kV line circuit in the Western corridor. This will lead to system disturbances triggered by tripping of 161 kV lines between Takoradi Thermal and Prestea on overload. The solution is to break into the 330 kV Takoradi Thermal – Anwomaso line at Dunkwa with a connection to the 161 kV network at the existing Dunkwa substation.

b) 330kV Kintampo – Anwomaso line

A 1000 MVA single circuit 330 kV strategic line connecting the 330 kV high capacity line from Anwomaso to Kintampo and forming part of the Ghana's power evacuation highway to the Northern parts of the NITS and to Burkina Faso (SONABEL). The line carries an average of 240 MW at peak. When the line is out of service, the power-flow is re-routed on the 161kV circuit between Anwomaso and Kumasi, severely overloading the line as well as the 330/161 kV Autotransformers at Anwomaso. Breaking into the 330 kV Takoradi Thermal - Anwomaso line at Dunkwa minimizes the impact of the line outage.

c) 161 kV Tarkwa – Prestea line

This higher capacity 364MVA line in parallel with the low capacity 170MVA Tarkwa- New Tarkwa – Prestea line carries an average of 160 MW at peak. A loss of this line severely overloads this parallel line. Operationally, this will also trigger overload relays to trip the lines from Tarkwa through New Tarkwa to Prestea. This once again is mitigated by a break into the 330kV Takoradi Thermal – Anwomaso line at Dunkwa. The 161kV Aboadze-Takoradi-Tarkwa -New Tarkwa - Prestea lines will however require upgrade in the medium term.

d) 161 kV Aboadze – Tarkwa line

A contingency on this line overloads the smaller capacity 161 kV Takoradi Thermal - Takoradi and Takoradi - Tarkwa lines. These lines are observed to be overloaded at **109%** and **155%** respectively. This will eventually cause these lines to trip on overload.

Contingencies causing voltage support issues

a) 330 kV Adubiyili – Nayagnia line

This is the terminal section of the 330 kV high-capacity power evacuation highway on the Ghana power ststem which espcially carries power supply to Burkina Faso. A loss of this line will cause exports to Burkina to be rerouted on the 161 kV line from Tamale to Nayagnia and towards Burkina. These lines are however small in capacity and due to their higher impedance encounter significant losses resulting in voltage dips.

a) 330 kV Takoradi Thermal – A4BSP line

This high capacity 1000 MVA 330kV line carries major portion of the power flowing from the Takoradi Thermal generation enclave towards Accra and Tema. At peak an average of 190 MW flows on this line. A loss of this line will cause power to be redirected on the smaller capacity 161 kV Takoradi Thermal T3 – Cape Coast- Winneba- Mallam line into Accra. The additional flow overloads these lines and worsens substation voltages along this corridor. Hence, the Pokuase substation is back fed from the 330 kV Volta substation in Tema.

a) 161 kV Dunkwa – Ayanfuri line

This line forms part of the long stretch of lines that serve the western mining communities from Dunkwa through Ayanfuri to Asawinso and finally to Obotan. With an average of 110 MW of power flowing on this line at peak, a loss of this line causes a severe voltage dips across the corridor. Solution is the 330/161 kV Dunkwa break-in project.

5.5 DYNAMIC SIMULATIONS

The purpose of the dynamic simulations is to analyse the transient behaviour of the Ghana power system in disturbed situations (loss of generation or loss of a critical transmission line, etc). Dynamic simulations were carried out for the power system using a 2021 demand/supply model of the Ghana power system.

The dynamic study seeks to evaluate the Ghana power system's transient response to large system disturbances such as the loss of the biggest production unit.

The scope of these simulations involves investigation of the impact of the loss of the biggest Power Plant (i.e., Twin City -190 MW) on the grid.

Loss of 190 MW Twin City Power Plant

Loss of the 190 MW Twin City Power Plant which is the biggest capacity combined cycle generator on the power system was analysed.

The loss of the Twin City Power Plant results in frequency decay to 49.53 Hz. It is observed from the plot (Figure 5.1) that only primary frequency control is engaged to arrest the frequency to avoid further decay which could lead to load shedding via AFLS relay operation.

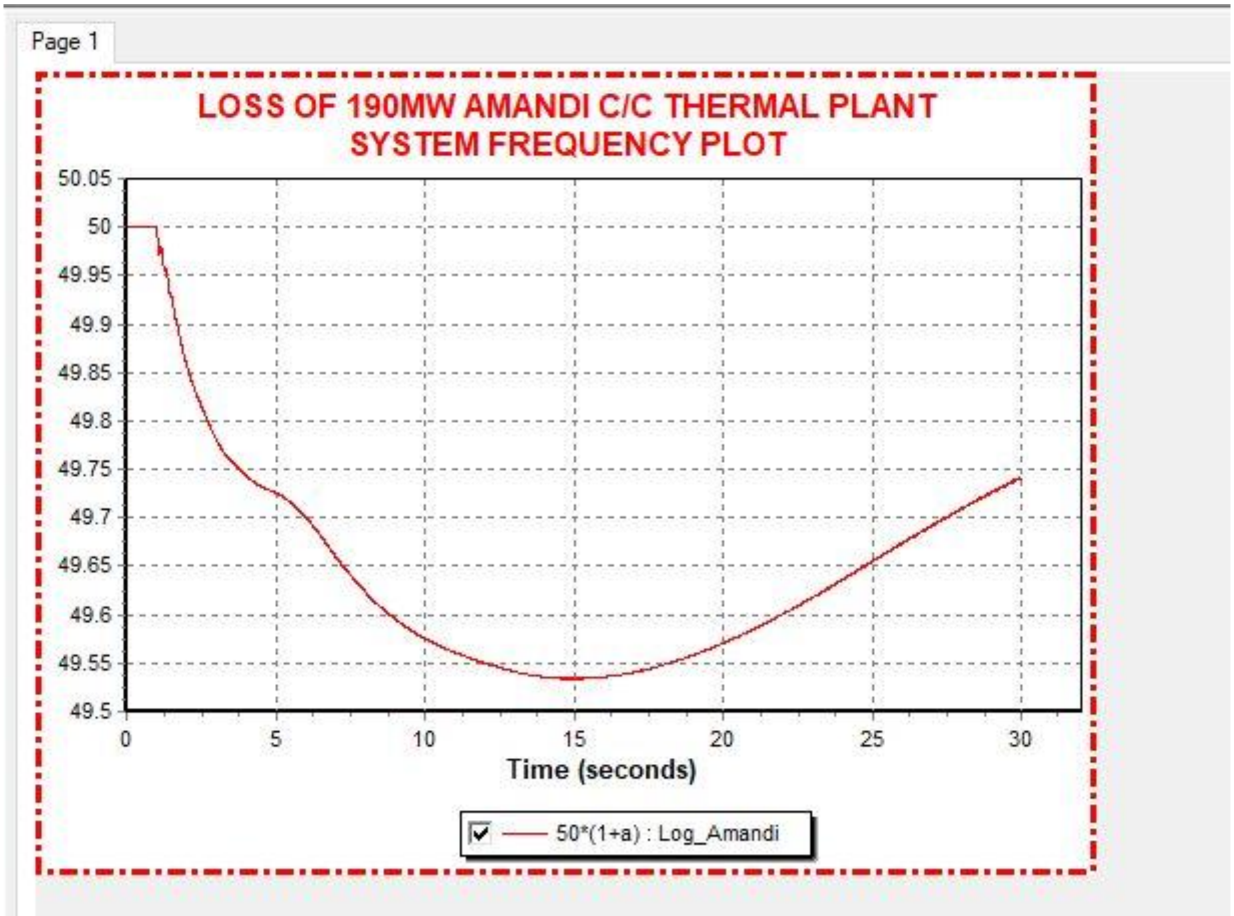


Figure 5.1: Loss of 190 MW C/C Twin City Power Plant-System Frequency plot

In Figure 5.1 we observe that the primary frequency response of all connected power plants ramped up their active power outputs sufficiently to make-up for the loss and avoid AFLS relay operation to trip loads.

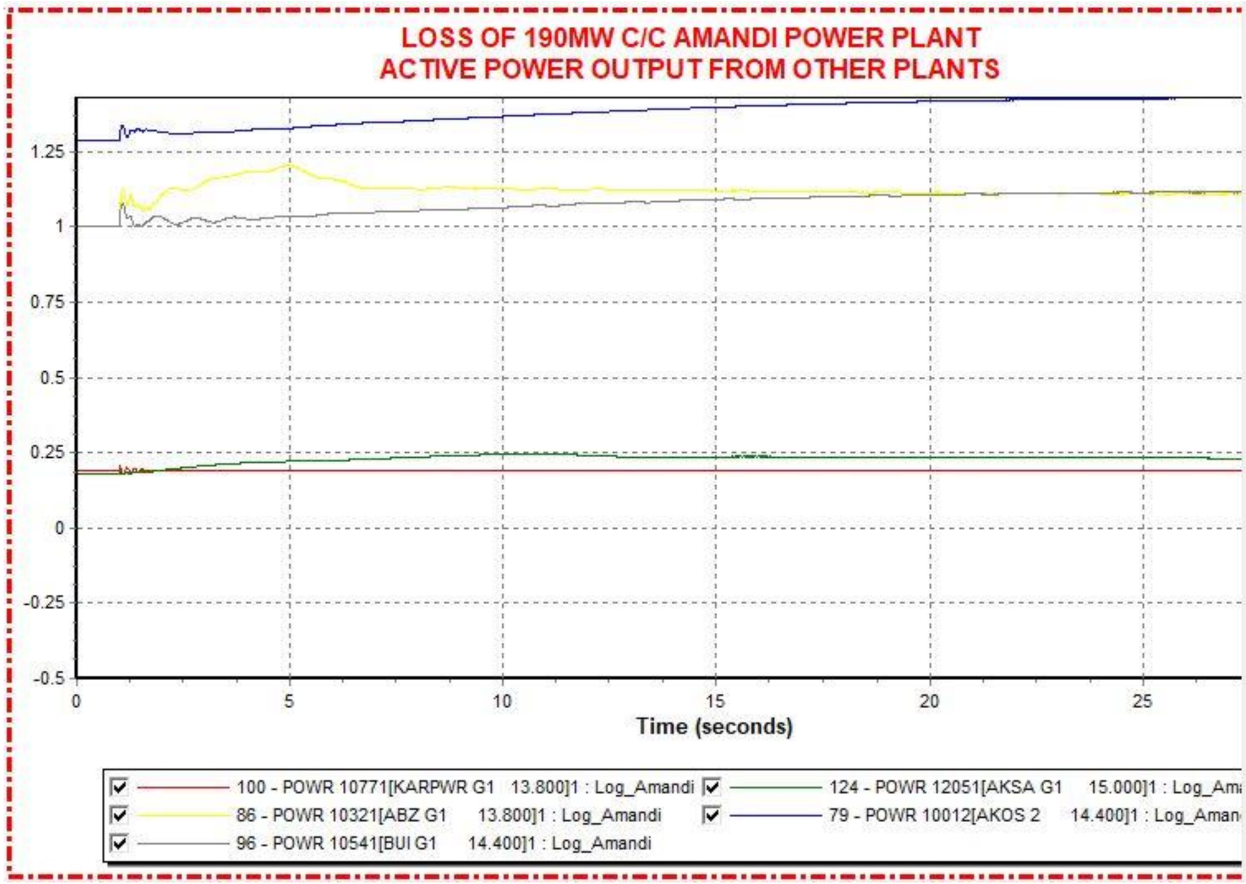


Figure 5.2: Loss of 190 MW C/C Twin City Power Plant-Active power output of other Power Plants

Chapter 6

2021 DISTRIBUTION SYSTEM OUTLOOK

6 2021 DISTRIBUTION SYSTEM OUTLOOK

6.1 Introduction

Electricity distribution in Ghana is done by the Electricity Company of Ghana Limited (ECG), Northern Electricity Distribution Company (NEDCo) and Enclave Power Limited (EPC) namely the Discos. Whereas ECG and EPC are located in the southern part of Ghana, where the population is dense and electricity consumption is about 89% of total consumption in Ghana, NEDCo is responsible for the northern part of Ghana with its geographical area starting from the Bono Region. NEDCo has a wide operational area covering 64% of the landmass of Ghana but few customers.

6.2 Interventions for Network Improvement

6.2.1 Projects Executed in Southern Ghana

The following projects and works valued at USD40million were successfully commissioned within the Southern Electricity Distribution Zone (SEDZ) to help augment ECG's ability to deliver quality electricity services to its customers:

- Reconstruction of the Tafo and Kpong BSPs, Juapong, Daboase, Inchaban and Awaso substations to permit the evacuation of power to the mentioned communities and its environs.
- Expansion of the Weija, Tokuse, Koforidua and Winneba substations to increase supply capacity to the western part of Accra, Kasoa and Winneba.
- The interconnecting 33kV and 11kV lines for the above BSPs and substations have all been completed

In the second quarter of 2020, EPC carried out critical maintenance works on some sections of the 11kV network in the Tema Free Zones Enclave. Porcelain insulators on some sections of the 11kV network were replaced with polymeric insulators. This was done to remedy the nuisance tripping on the network due to compromised insulation levels of the insulators from the pollution of nearby cement factories. Overhead conductors on some sections of the 11kV network were upgraded to increase network capacity and reduces system distribution losses.

EPC has commenced with the development of a 2km double circuit sub-transmission line and a switching station for the evacuation of 60MVA of power to the business park area in the Tema

Freezones Enclave. This is mainly to facilitate the operations of Ferro Fabric who have requested for 20MVA power at the end of 2021 third quarter (Q3).

The company also developing a Mini-SCADA system for the Tema Freezones Enclave and the Dawa Industrial Enclave. This will provide alarms and measurands for analog data monitoring only from both BSP's to a centralized location at the Enclave Power Company head office.

At the end of Q2 2020, EPC completed the construction of a laboratory in the Tema Free Zones Enclave equipped with specialized test instruments to enable EPC conduct test such as meter calibration and dissolved gas analysis on transformer oils.

6.2.2 Projects Executed in Northern Ghana

In the northern zone, NEDCo's initiated and continued the implementation of the following projects as part of efforts to improve the performance of its distribution infrastructure:

- 30kV shield wire conversion to 34.5kV network to Techiman Aboufour;
- 20kV shield wire conversion to 34.5kV network at Walewale;
- Installation of auto reclosers and sectionalizer on NEDCo feeders; and
- Procurement of 287,000 split-smart meters to help combat energy theft within the NEDCo operational Area. The first batch of the meters has arrived, and installations works are in progress.
- Construction of eight (8no.) primary substations, a Distribution Network Management System (DNMS/SCADA), and the installation of smart metering systems to revolutionize the distribution infrastructure of NEDCo and achieve operational efficiency.

NEDCo has also commenced designs works for the construction of eight (8no.) primary substations across its operational area over a period of 5 years. These substations are expected to improve the quality of supply to customers as well as reduce technical losses.

6.3 Expected Impact of Ongoing & Executed Projects

The above projects in addition to other planned and ongoing works will help the Discos to achieve the following regulatory benchmarks for its operations by end of 2021:

- A system losses target of 23%;
- Revenue collection rate of 98%;
- The outage and reliability benchmarks provided in LI 1935; and

- Generally bring electricity services closer to the doorsteps of customers

6.4 New Developments

6.4.1 Implementation of the Cash Waterfall Mechanism

The Energy Sector commenced the implementation of the Cash Waterfall Mechanism (CWM) in April 2020. The CWM is a mechanism to ensure the equitable distribution of tariff revenues accruing to agencies of the Energy Sector on a prorate basis using the amount of generation and associated invoices from suppliers and the PURC approved allocation of tariffs. The CWM commenced with ECG and its suppliers including fuel providers and is supported by a natural gas clearing house.

It is planned that tariff revenues from all discos (including NEDCo and EPC) as well as VRA will later be included in the CWM. Additionally, a framework to top up and provide for shortages in payments will be developed and implemented under the CWM to ensure that all utilities and suppliers receive full payment for invoices.

6.4.2 Additional Renewable Generation in Northern Ghana

In another development, NEDCo will offtake power from a newly commissioned 6.8MWp solar PV plant commissioned by VRA at Larwa in the Upper West Region. The project which is the first phase of 17MW and is connected to NEDCo's 34.5kV distribution infrastructure at Lawra, will improve the voltage profile on the 110km long 34.5kV feeder of NEDCo.

6.4.3 Utilities MoU with Energy Commission of Ghana

The Energy Commission of Ghana has signed a performance-based memorandum of understanding with the Discos to help improve the operational performance of the Discos in Ghana. Under the MoU, KPIs have been set and will be monitored by the EC from time to time.

6.4.4 Network Expansion Initiatives by EPC

The first phase of the distribution network development for the Dawa Industrial Enclave is currently underway. This comprises the construction of approximately 11km of overhead lines and a switching station to cater for the expected power demand of current and potential customers in the Dawa Enclave.

6.4.5 Influx of Small-Scale Renewable Energy (RE) Technologies in Ghana

It is observed that all classes of customers are gradually exploring the use of REs as a way of introducing reliability to their premises. The Discos have noted and are working towards driving such initiatives in a win-win manner. The aim is to ensure that customers have value for money and the electricity distribution assets are not stranded. Additionally, the utilities await on the regulators to redefine the modalities for electricity exchange under the net metering scheme and approve the draft procedures and guidelines for enrolment of customers as well as the contract framework. This will help to properly truck and manage the small scale RE installations to ease out the threat to grid supply.

6.4.6 Support for Electric Vehicles in Ghana

The Energy Commission and ECG are actively working to promote the use of Electric Vehicles (EVs) in Ghana. The Commission, is currently developing regulations for EV charging infrastructure detailing technical guidelines and setting out the statutory requirements for installations. This is to ensure conformity with international standards, establish the requisite legal and regulatory framework, ensure compatibility and guard against factors that could affect the health and safety of consumers,.

Meanwhile, ECG has partnered some firms to support the rollout of the electric vehicle technology and to provide charging points at selected locations within ECG operational area. This is to ensure that the company is ahead of innovation and embraces evolving technologies that boost the consumption of electricity.

Chapter 7

OVERVIEW OF MEDIUM TERM SUPPLY

7 OVERVIEW OF MEDIUM-TERM SUPPLY: 2022 - 2026

A power system must have sufficient generating capacity at all times to reliably supply its electrical energy demand. Typically, it takes averagely five years for a conventional power plant project to evolve from conception through arrangements for funding, detailed design, construction and commissioning to the commencement of commercial operation.

In a developing country such as Ghana, demand for electricity is expected to continue to grow. It is therefore expedient for managers of power systems to continually carry out relevant planning activities to assess the adequacy of generation resources and identify other challenges which would require addressing in a way to ensure the reliability, security and quality of supply to consumers.

Medium-term power system planning accordingly assesses electricity demand projections for the ensuing five (5) year period, the generating resources available to supply demand over the period and determines the need, if any, for additional generating capacity. It also assesses the need for reinforcements or changes to the transmission and distribution networks, etc., where it is found meritorious.

In line with this, we present in this chapter peak demand and consumption projections for the Medium-Term (2022 - 2026) together with an analysis of the adequacy of generation capacity over the period to serve as a guide for power system investment planning in order to ensure security of supply in the Ghana Power System in the medium term.

7.1 Demand Outlook

The Projected electricity demand for the period 2022 – 2026 is based on data collated from a load survey exercise conducted by the Technical Committee. It takes into consideration projections for natural growth in domestic demand over the period. It also incorporates some Spot Loads expected to add to demand in the medium term.

The spot loads expected in the medium term are as follows:

- ✓ Development of an Integrated Aluminum Industry in Ghana:

  Volta Aluminium Company Limited (VALCO) projects to operate 2 potlines (150 MW) through 2021 to 2022. Per their projection, demand is expected to increase to 300 MW in 2023 and is expected to further increase to 500 MW by 2024. Upon the completion of the expansion works of VALCO by 2027, the maximum demand is projected to be about 1,000 MW.

However, the ability to purchase power depends on generation cost vis-à-vis the price of aluminium. In recent times, the price of aluminium has been lower than the grid electricity generation cost. In view of this and considering VALCO as a strategic industry, the government by a policy decision, gave legacy hydro with a generation cost of about $3.5 cent to VALCO. This agreement is for a 150 MW and valid to 2023. Beyond 2023 remains unknown at the time of writing this report.

In view of this the PPTC, for the purpose of this report which influences investment for generation capacity and grid transmission plan, downgraded VALCO's demand for the base case to a **maximum of 150 MW (translating to 2potlines) throughout the planning period**. The 500 MW for VALCO is therefore considered under the High case scenario. These are subject to review in the development of 2022 Annual Supply Plan.

✓ Mines:

Total demand for mines is expected to increase from 271 MW in 2022 to 331 MW MW in 2026. Some of the specifics are as follows

- Newmont Mines, Ahafo - demand is expected to increase from 46 MW in 2021 to 89 MW in 2026 at Ahafo-North;
- Azuma Mines - 18 MW by 2025 at Yagha (50km North West of Wa);
- Anglogold Ashanti – demand is expected to increase to 49 MW by 2026.

✓ Potential Exports:

Total export is expected to increase from 322 MW in 2022 to 430 MW in 2026

- No planned export to CIB but inadvertently export can occur owing to interconnected system conditions;
- 150 MW export to CEB through to 2026
- 170 MW in 2022, 184 MW in 2023 and further increasing to 200 MW from 2024 onwards as export to SONABEL
- 80 MW export to Mali is expected to begin by 2026.

Total electricity requirement for Ghana including power exports to Togo, Benin, Burkina Faso and Mali is projected to increase from **22,799** GWh in 2022 to **28,550** GWh by 2026 at a Compound Annual Growth Rate (CAGR) of approximately 5.8%. The Ghana system peak demand is projected to increase from 3,539 MW in 2022 to 4,460 MW in 2026.

The summary of 2022-2026 projected demand is illustrated in Tables 7.1 and 7.2.

Table 7.1: Projected Energy Demand (GWh) (2022- 2026)

	2022	2023	2024	2025	2026
Domestic	19,590	20,859	22,199	23,639	25,031
VALCO	1,315	1,371	1,371	1,371	1,371
Exports	1,894	1,946	2,001	2,059	2,148
TOTAL	22,799	24,177	25,572	27,069	28,550

Table 7.2: Projected Peak Demand (MW) (2022- 2026)

	2022	2023	2024	2025	2026
Domestic	3052	3240	3449	3656	3865
VALCO	165	165	165	165	165
Exports	322	334	350	350	430
TOTAL	3,539	3,739	3,964	4,171	4,460

7.2 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 including the required 18% capacity operating reserve margin.

7.2.1 Existing Generation

The existing generating facilities in Ghana are made up of hydro, thermal and renewable energy sources. The breakdown of projected demand versus expected supply from the existing generation resources is as shown in Table 7.3.

Table 7.3: Projected Demand and Supply balance (2022- 2026)

Projected Capacity Demand (MW)		2022	2023	2024	2025	2026
Domestic		3052	3240	3449	3656	3865
VALCO		165	165	165	165	165
Exports		322	334	350	350	430
TOTAL		**3,539**	**3,739**	**3,964**	**4,171**	**4,460**
Projected Demand + 18% Planning Reserve Margin		**4,176**	**4,412**	**4,678**	**4,921**	**5,262**
Existing Generation Capacity MW						
Akosombo	1020	900	900	900	900	900
Kpong GS	160	140	140	140	140	140
Bui GS	400	360	360	360	360	360
TAPCO	330	150	150	300	300	300
TICO	340	320	320	320	320	320
TT1PP	110	100	100	100	100	100
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	0	0	0
CENPOWER	360	325	325	325	325	325
Twin City Energy Ltd	204	190	190	190	190	190
VRA T3	132	0	130	130	130	130
New Tarkwa (Genser)	63	40	40	40	40	40
Chirano (Genser)	30	15.4	15.4	15.4	15.4	15.4
Damang (Genser)	30	20	20	20	20	20
VRA Solar	2.5					
BXC	20					
Meinergy	20					
Total Existing Generation	**5,241.50**	**4,470.40**	**4,600.40**	**4,420.40**	**4,420.40**	**4,420.40**
Committed						
Early Power Limited[1]	400	190	190	390	390	390
Pwalugu Hydro	60				60	60
VRA Lawra						
Bui Solar	100					
VRA Kaleo ==>total is 17	17					
Total Committed Generation	**577**	**190**	**190**	**390**	**450**	**450**
Total Dependable Generation (MW)	**5,819**	**4,660**	**4,790**	**4,810**	**4,870**	**4,870**
Actual Reserve Margin (MW)		1,121	1,052	846	700	411
Actual Reserve Margin (%)		31.69%	28.13%	21.35%	16.78%	9.21%
Surplus/Deficit (MW)		**484**	**379**	**133**	**-51**	**-392**
Surplus/Deficit (%)		13.69%	10.13%	3.35%	-1.22%	-8.79%

7.2.2 Committed Generation Projects

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

Projects Under Construction

- ✓ **Early Power:** This is a 400 MW power plant located at Tema and would be constructed in two phases made up of 200 MW each. Phase 1A of the first phase (147 MW) is expected to be commissioned in the first quarter of 2021, while the second part, phase 1B of 53 MW, would come online in 2022. The final phase making up the 400 MW is planned to be commissioned by 2024.

- ✓ **Pwalugu Hybrid Hydro and Solar Plant:** This is a 60 MW hydro electric plant in hybrid operation with a 50 MWp Solar PV plant which is expected to be completed and commissioned by 2025. The plant is planned to be located in the Upper East Region.

- ✓ **Kaleo Solar PV Plant**: This is a 17 MW PV plant being constructed by VRA at Kaleo and Lawra in the Northern Region. It is planned to be commissioned in 2020.

- ✓ **Edikan Power Plant**: This is a 42 MW thermal power plant. It's an embedded generation at Ayamfuri in the Central Region. It is expected to commence operation third quarter of 2022.

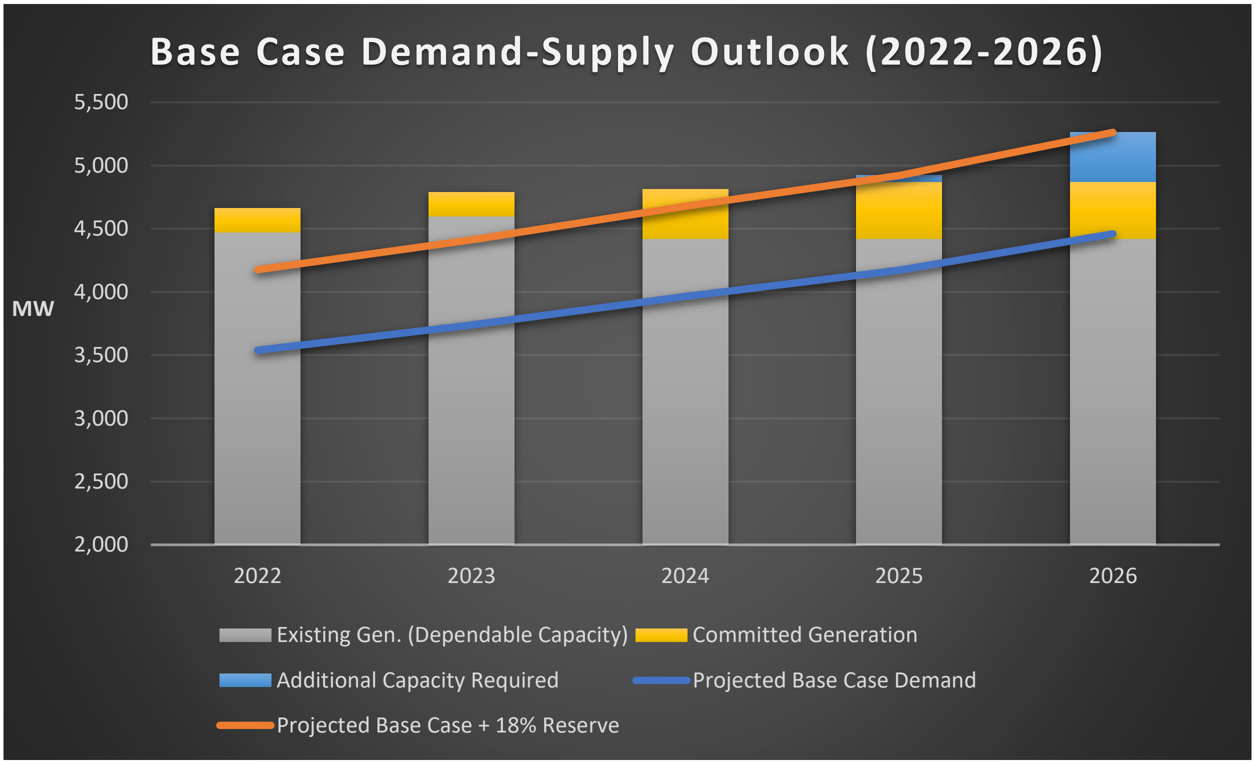


Figure 7.1: Projected Base Demand Versus Supply balance (2022 - 2026)

7.2.3 Demand and Supply Balance

A comparative analyses of the projected medium term demand and the corresponding projected supply generating capacity was carried out, as presented in Table 7.3 and Figure 7.1. The total dependable capacity, including existing and committed/ongoing generation projects was compared with projected reference case peak demand with 18% operating reserve margin.

The results of the analyses indicate that existing generating capacity will be adequate to serve projected demand and 18% reserve margin for 2022 and 2023 with corresponding surplus being 484 MW (13.69%) and 133 MW (3.35%) respectively. However, the completion of the committed projects are needed from 2024 onwards. The committed projects would suffice upto 2024, additional generation capacity is needed in 2025 and 2026 to meet the reserve margin required for reliability.

7.2.4 Additional Generation Requirement

Requirements for additional electricity generation resource acquisition are determined in accordance with the policy to balance supply and demand taking into account the need for the provision of adequate reserve capacity to cater for contingencies.

Deducing from the demand and supply balance analysis, total (existing and committed) dependable capacity for the years up to 2026 would **NOT** be adequate to serve projected demand and the 18% operating reserve margin required for reliability. Specifically, **51 MW and**

392 MW additional generation capacity (aside the committed power plants) is needed in 2025 and 2026 respectively to meet the reserve margin required for reliability.

7.2.5 High Demand Sensitivity on Supply

The aim is to analyse the sensitivity of power demand on supply. This is particulary important due to government's flagship programmes such as the integrated aluminium and steel programme. The successful completion of this singular programme can increase the consumption of aluminium smelting in the country by multiple folds.

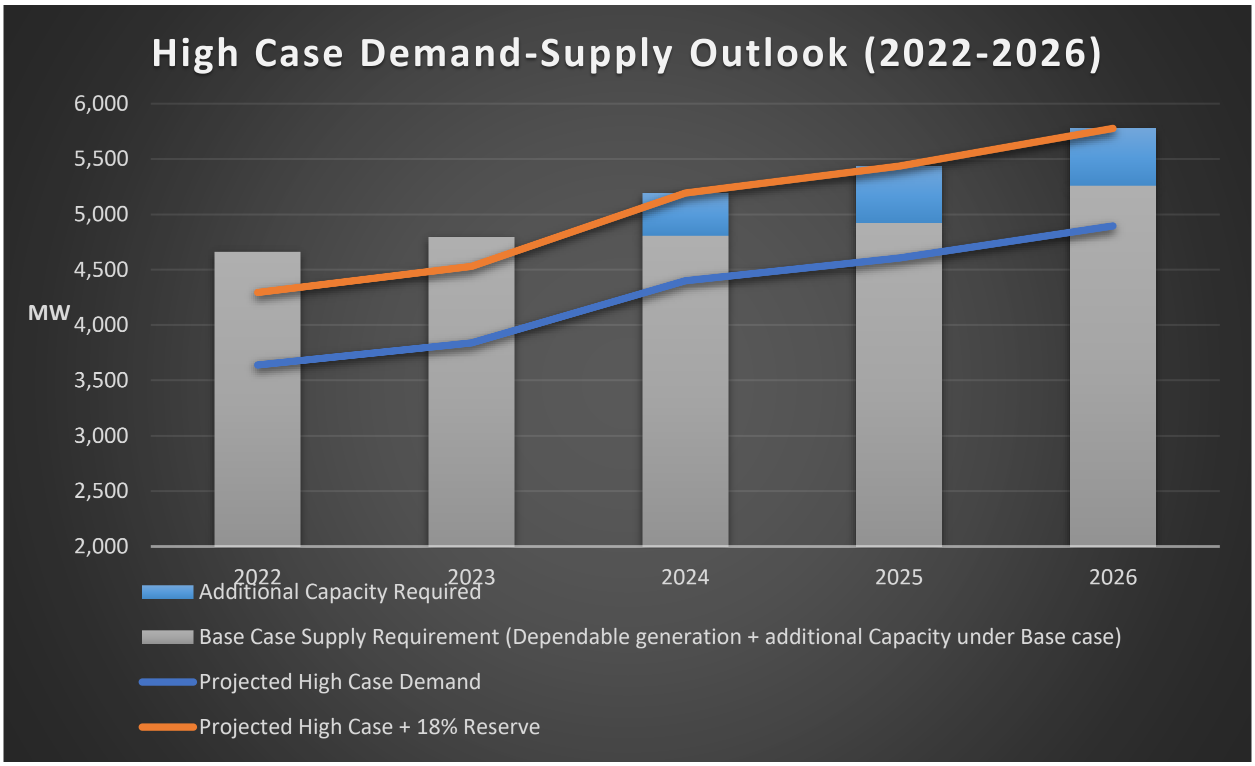


Figure 7.2: Projected High Demand Versus Supply balance (2022 - 2026)

If VALCO's demand should increase to 500 MW from 2024 onwards, and Domestic demand should also increase by 100 MW on top of base case for each ensuing year, then as evident in figure 8.2, in addition to the additional capacity needed under Base Case, a further 381 MW, 514 MW and 514 MW of generation would be required in 2024, 2025 and 2026 respectively.

7.3 Medium Term Transmission Network Expansion/Upgrade Requirements

Extensive system network analyses were carried out using the projected demand and supply scenario in the Tables above, and the results indicate that there would be the need for some transmission network reinforcement works in the medium term in order to continue to meet the required supply reliability indices.

Upgrade of the following transmission equipment is required:

- ✓ 161kV Aboadze – Mallam line Upgrade
- ✓ 161kV Bogosu – Dunkwa – New Obuasi upgrade
- ✓ 161 kV Dunkwa – Asawinso upgrade
- ✓ 161kV Aboadze-Takoradi-Tarkwa-Prestea line circuit
- ✓ Cross-border interconnection transformers (both at Prestea and Nayagnia) to be replaced with phase shifting transformers
- ✓ SCADA System

Additionally, construction of the following NITS equipment additions is required:

- ✓ 2nd Circuit 330 kV Prestea – Dunkwa – Kumasi line
- ✓ 330/161 kV Dunkwa substation
- ✓ 161kV Pokuase – Mallam line
- ✓ 2nd Circuit 330 kV Aboadze – Pokuase
- ✓ Accra (Pokuase) – Kumasi (Anwomaso) 330 kV line
- ✓ Eastern Transmission Corridor Projects:
  - 161 kV Akosombo/Kpong GS -Asiekpe Transmission Line
  - 161 kV Asiekpe -Kpando Transmission Line
  - 161kV Kpando – Juale Transmission Line
  - 161kV Juale – Yendi Transmission Line
  - A 161kV, 2x33 MVA Substation at Nkwanta (to supply Nkwanta, Salaga and Bimbila)
- ✓ Kumasi third Bulk Supply Point
- ✓ Transformers and Compensation devices
- ✓ A ±50 MVar STATCOM to be installed in Kumasi

7.4 Creation of new Generation Enclaves

Currently apart from Akosombo GS and Bui GS, there are two other generation enclaves in Ghana, namely the Tema and the Takoradi thermal generation enclaves.

Power system network analyses carried out show that establishing new generation enclave near Kumasi and Winneba result in considerable improvement in the stability of the NITS and significantly reduces transmission system losses. It also improves the quality of supply to end users through improved network voltage control via generators.

7.4.1 360 MW Plant sited at Kumasi

Results for an analysis carried out on a 2022 network model which assumes a total system generation of 3,543.2 MW. For the base case scenario, total system losses were 132.5 MW representing 3.74 % of total generation.

Power flow and analyses indicate that siting a 360 MW combine cycle thermal plant at Kumasi results in a the significant reduction in transmission losses to 107.6 MW representing 3.1% of total generation. A reduction in total system losses of 24.9 MW is thus achieved.

Table 7.4 shows the load flow results.

Table 7.4: Comparison of system losses (MW) - Siting Generation at Kumasi

	No generation at Kumasi	360 MW generation at Kumasi
Losses (MW)	132.5 MW	107.6 MW

The results again show significant reduction in some transmission line loadings (congestion) within the South West to Ashanti corridor as shown in Table 7.5:

Table 7.5: Comparison of line loadings (% line thermal capacity) - Siting Generation at Kumasi

	Percentage Line Loading	
	No Generation	360 MW Generation at Kumasi
New Tarkwa – Tarkwa	76%	56%
Takoradi - Tarkwa	56%	41%
Dunkwa -Ayanfuri	93%	87%
Dunkwa - New Obuasi	86%	107%

It also shows bus voltage improvements as shown in Table 7.6.

Table 7.6: Comparison of bus Voltages (kV) - Siting Generation at Kumasi

Bus Voltage (kV)	No generation at Kumasi	360 MW generation at Kumasi
Dunkwa	150.7	162.9
Ayanfuri	148.7	159.8
New Obuasi	153.7	160.9
Kumasi	156.4	159.1

7.4.2 360 MW Plant sited between Winneba and Kasoa

Power flow analyses indicate that siting a 360 MW generation facility in the immediate western part of Accra (ie., between Winneba and Kasoa) also results in significant improvements in the transmission network voltage profile. It also reduces congestion on the 161 kV Aboadze – Mallam and Volta – Mallam transmission corridors. Additionally, total transmission system losses of 135.2 MW (3.8 %) is reduced to 115.1 MW (3.2%).

Tables 7.7 to 7.8 show the load flow results.

Table 7.7: Comparison of system losses (MW) - Siting Generation at Kumasi

	No generation at Winneba	360 MW generation at Winneba
Losses (MW)	135.2 MW	115.1 MW

It also shows bus voltage improvements in Accra, Winneba and Kasoa as shown in Table 8.8.

Table 7.8: Comparison of bus Voltages (MW) - Siting generation at Winneba

Bus Voltage (kV)	No generation at Winneba	360 MW generation at Winneba
Mallam	152.5	156.4
Achimota	155.3	157.9
Winneba	149.7	161.3
Accra Central	152.7	156.1
Kasoa	150.5	158

Furthermore, in the event of an outage to the 330kV Aboadze – Volta line, the remaining Coastal lines get highly loaded (about 86% of line thermal capacity). With generation in Winneba the flow on the line reduces to 29% of the line's thermal capacity under same contingency (with the 330kV Aboadze - Volta line still out of service).

Chapter 8

CONCLUSIONS

8 CONCLUSIONS

The following conclusions are drawn in respect of the Electricity Supply Plan for 2021 and for the medium term (2022 – 2026):

a) Despite the crippling effect the COVID-19 pandemic had on economies globally in the year 2020, there was no significant net impact on Electricity demand in Ghana. Actual demand and supply statistics for the year were as follows:

2020 Demand Statistics	2020 Projection	2020 Actual	% Deviation
System Peak Demand	3,060.7 MW	3,089.5 MW	0.9
Total System Energy Consumption(less Losses)	18,711.2 GWh	18,828.8 GWh	0.6
Domestic Energy Consumption	17,118.8 GWh	17,561.5 GWh	2.5
Total Exports	1,787.1 GWh	1,855.1 GWh	3.8
Total Energy Generated	19,608.2 GWh	19,716.6 GWh	0.5
Total Imports	0 GWh	58.2 GWh	

b) It is noteworthy from the above table that the actuals attained were very close to the projections made in 2020.

8.1 Demand and Supply Outlook

a) The 2021 total system demand is projected to be 3,303.72 MW (base case), representing a 6.9 % growth over the 2020 peak demand of 3,090 MW. The corresponding projected energy consumption for 2021 is 21,265.52 GWh of which:

- ✓ Hydro supply will be 7,001.2 GWh representing 32.92% of the total energy supply;
- ✓ Thermal supply will be 14,111.8 GWh representing 66.36% of total energy supply; and
- ✓ Renewables supply will be 152.3 GWh representing 0.72% of total energy supply

b) Total projected energy exports are 1,527.26 GWh for 2021.

c) VALCO is expected to operate on two pot lines with projected total consumption of 1,055.13 GWh.

d) There is the need to dispatch Bui Hydro Plant conservatively throughout 2021 to ensure that the reservoir is not drawn down below its minimum operating levels to guarantee sustainable operations in the coming years.

Natural Gas		123,903,040 MMBtu
HFO	-	121,849 barrels

e) There is no projected requirement for LCO in 2021due to anticipated high volumes of gas from Sankofa, Jubilee, TEN fields as well as from Nigeria and the envisaged LNG project. Strategic stocks will however be required to be kept in reserve for use as back-up fuel in the event of any gas supply upsets.

f) In terms of fuel cost for gas and HFO, an annual total of approximately **758.8** Million USD is required, averaging a monthly total of US$ **63.23** Million.

8.2 Requirements for NITS Reinforcement

a) By the end of the first half of 2021, the following projects are expected to be completed and commissioned. The expected corresponding savings in losses are also indicated:

- ✓ 161kV Volta – Achimota – Mallam line corridor upgrade project, saving 12MW at peak
- ✓ 330/34.5 kV Pokuase substation which saves 4MW at peak
- ✓ Energization of the 330kV Anwomaso – Kintampo line offers the system conditions with losses reduced by 62MW to **153.3 MW** (4.86 %). Loading on the 161kV Anwomaso-Kumasi line will reduce significantly thus improving voltages in Kumasi

b) A first half-year analysis of the network considering a maximum West, maximum East and Balanced generation dispatch scenarios show that

- ✓ A maximum East dispatch will result in the highest recorded transmission losses of 221. 61 MW representing 6.75 % of peak demand of 3,284.7 MW
- ✓ Transmission losses recorded in the maximum west dispatch scenario follows with an average of 217.4 MW representing 6.63 % of peak demand.
- ✓ A balanced generation dispatch records the lowest transmission losses of 215.96 MW representing 6.58 % of 3,283.4 MW peak demand

c) In all the simulated dispatch scenarios for the first half of 2021, there are overloads on the 161kV Volta-Accra East- Achimota corridor, the 161kV Kumasi – Anwomaso and the

161kVTarkwa - New Tarkwa - Prestea lines. There will be low voltages recorded predominantly across substations serving the mining communities in the West. These overloads and low voltages will be the main drivers of high transmission losses for this period.

d) With the expected low water level of the Bui Hydro Plant in the first half of 2021, a current system simulation considering a Bui Hydro Plant maximum output of 200 MW (two units) show that transmission losses increase to a high of **199.52 MW** represent **7.**47 % of **2,670.4 MW** off-peak demand.

e) For the second half of 2021, the system peak demand is 3,303.72 MW. During this period, it is expected that all the above-mentioned projects under construction will be commissioned.

f) Simulations show that during the second half of 2021, the balanced generation dispatch scenario significantly improves system performance with reduced transmission losses to about 149.12 MW representing 4.51 % of peak demand, with few observed line loading violations.

g) In contrast, a maximum east dispatch scenario proves to be the least preferred option with transmission losses recording a high of 175.65 MW representing 5.28 % of peak demand.

h) During the second half of the year, the following transmission lines may record overloads with maximum generation from their adjoining enclaves;

    - ✓ 161 kV KTPP –Volta
    - ✓ 161 kV Tarkwa – New Tarkwa – Prestea lines

i) Single line contingency (N-1) analyses for 2021 show that the 330 kV and 161kV transmission line corridors from Aboadze Enclave to Kumasi are the most critical. A contingency on any of the transmission lines leads to system disturbance since the evacuate heavy amounts of power from Aboadze

j) There are low voltages recorded in the Dunkwa, Ayanfuri, Asawinso substations.

8.3 Distribution Systems

a) ECG has initiated the use of drones to monitor the distribution networks and collect data for preventive maintenance on their distribution network.

b) A number of upgrade projects have been commissioned into service to help augment ECG's ability to increase distribution capacity and reliability of supply to customers. These are;

- ✓ Reconstruction of Tafo, and Kpong BSPs, Juapong, Daboase, Inchaban and Awaso substations to increase power evacuation to their communities and its environs.
- ✓ Expansion of Weija, Tokuse, Koforidua and Winneba substations to increase supply capacity to the western part of Accra, Kasoa and Winneba.

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 distribution lines resulting in high technical losses. Some interventions, however, have been made on some of these lines resulting in improved supply reliability on them. These include

- ✓ Conversion of shield wire systems to conventional 34.5kV feeder circuits at Abofuor and Walewale.
- ✓ Procurement of smart meters to help combat theft within the NEDCo operational area.
- ✓ Construction of eight (8no.) primary substations and a Distribution Network Management System (DNMS/SCADA)

8.4 Medium Term Supply

a) Total electricity requirement for Ghana including power exports to Togo, Benin, Burkina Faso and Mali is projected to increase from 22,799 GWh in 2022 to 28,550 GWh by 2026 at a Compound Annual Growth Rate (CAGR) of approximately 5.7%. The Ghana system peak demand is projected to increase from 3,539 MW in 2022 to 4,460 MW in 2026.

b) The deployment of the committed generation capacities, would be adequate to meet projected demand including a reserve capacity of 18% only up to 2024. Highest surplus of 13.7% (484 MW) in 2022 decreasing to 3.3% (133 MW) in 2024.

c) Additional generation capacity is needed from 2025. Specifically, 51 MW and 392 MW additional generation capacity is needed in 2025 and 2026 respectively.

d) Under High Demand Scenario, in addition to the additional capacity needed under Base Case, a further 381 MW, 514 MW and 514 MW are needed in 2024, 2025 and 2026 respectively.

Chapter 9

RECOMMENDATIONS

9 RECOMMENDATIONS

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

a) Adopt a conservative dispatch of the Bui GS to manage the use of its limited head water until the next inflow season.
b) Installation of a third 161/34.5 kV transformer at Anwomaso Substation and the transfer of some load from the ECG substation at Ridge, Kumasi to Anwomaso in order to limit congestion on the 161 kV Anwomaso – Kumasi line especially when Bui is not running during off-peak periods.
c) Ongoing transmission expansion projects should be expedited and completed in the first half of 2021 to ensure that the NITS continues to have adequate capacity to supply all projected customer loads with minimal losses. These projects include:
   - ✓ 161 kV Volta – Achimota – Mallam Transmission Line Upgrade Project
   - ✓ 330 kV Anwomaso – Kintampo transmission line Project
   - ✓ 330/34.5 kV Pokuase Substation
d) GRIDCo urgently needs the implementation of the break-in on the 330 kV Takoradi Thermal – Anwomaso line at Dunkwa with the construction of the 330/161kV Dunkwa II Substation to address the low voltage situation in the Western parts of the NITS. It will also help improve power system stability.
e) In order to continue to adequately meet growing demand as well as transmission reliability index requirements, the following critical transmissions additions and upgrades are required in the medium term:
   - ✓ Upgrade of 161 kV Takoradi Thermal – Takoradi – Tarkwa – Prestea circuit.
   - ✓ Construction of a second 330 kV Prestea - Dunkwa – Kumasi line,
   - ✓ 161 kV Mallam – A4BSP transmission line link.
   - ✓ Construction of a second 330 kV Aboadze – Pokuase (A4 BSP) circuit.
   - ✓ Construction of a double circuit 330 kV line from Accra (A4BSP) to Kumasi (K2BSP).
   - ✓ Upgrade of 161 kV Aboadze-Mallam transmission lines
f) Prepare the grid and System Control Centre for grid connected RE sources of generation.
g) Repair and restore all defective capacitor banks and reactive compensation devices on the NITS especially in the southern parts of the NITS.

h) Power Supply Outage management for the ongoing projects should be well coordinated to reduce the impact on customers.

i) There is a need to procure additional generation capacity (51 MW in 2025 and 392 MW in 2026) (through a competitive least cost procurement process) in order to continue to meet the Ghana power system electricity demand with the required reserve margin by 2025.

j) Considering the lead time for planning, procurement, design, construction and commissioning of power plants, the procurement process should commence on time.

k) However, if proposed plans to retrofit and scale-up operations at VALCO up to 500 MW by 2024 (IAI & VALCO) materialise and domestic demand is higher than base case by 100 MW, then the requirement for additional generation will come earlier, in 2024, and much higher. In addition to the additional capacities under Base case, a further 381 MW in 2024, 514 MW in 2025 and another 514 MW in 2026 is needed. the procurement process for additional generation would have to start much earlier.

l) Continue to engage stakeholders and grid participants on loss reduction strategies which will ensure that system losses are minimised.

m) Install a dynamic voltage support device (50 MVAr Statcom) in Kumasi to address voltage excursions.

n) Create a generation hub/enclave in Kumasi for network stability, and to address voltage limit violations in the mid-sections of the Ghana power system in situations such as where Bui units are not in service and to reduce line loadings between Kumasi and the South East as well as the South West generation enclaves. It will give Ghana a competitive advantage for power export to Burkina, Mali and other potential customers north of Ghana.

10 APPENDICES

Appendix A –Forecast: Peak and Energy Demand

A1: Base Case - Peak Demand Forecast (MW): 2021 - 2030

A2: Base Case - Energy Demand Forecast (GWh) -2021 – 2030

Appendix B – Planned Generating Equipment Maintenance Schedule

Appendix C – Glossary

Appendix D– Grid Map

APPENDIX A - FORECAST PEAK DEMAND AND ENERGY CONSUMPTION

A1: Base Case - Peak Demand Forecast (MW): 2021 – 2030

Load forecast: Peak demand (MW)	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
ECG	2,106.8	2,210.4	2,343.9	2,485.5	2,635.6	2,794.8	2,963.6	3,142.6	3,332.5	3,533.7
NEDCo	263.8	286.6	309.4	334.0	360.5	389.1	420.1	453.4	489.5	528.4
ENCLAVE POWER COMPANY	57.0	70.8	73.6	77.3	81.9	84.6	91.0	93.8	99.4	103.0
MINES	243.0	269.1	286.9	302.8	326.6	328.5	331.7	331.3	329.7	328.1
Other Bulk Customers	59.8	59.5	59.9	70.8	71.2	71.2	71.2	71.6	71.6	71.7
VALCO	130.0	164.8	164.8	164.8	164.8	164.8	292.9	292.9	371.0	371.0
CEB(Togo/Benin)	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0
SONABEL(Burkina)	150.0	171.7	183.8	200.0	200.0	200.0	200.0	200.0	200.0	200.0
CIE(Ivory Coast)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EDM(Mali)	0.0	0.0	0.0	0.0	0.0	80.0	90.0	100.0	100.0	100.0
Network Usage	1.9	2.0	2.1	2.2	2.4	2.5	2.7	2.9	3.0	3.2
LOSSES	149.1	154.0	164.4	176.8	177.6	194.0	225.5	246.6	262.3	274.7
Total	**3,311.4**	**3,539.0**	**3,738.8**	**3,964.1**	**4,170.6**	**4,459.7**	**4,838.8**	**5,085.2**	**5,409.0**	**5,663.9**

A2: Base Case -Projected Energy Demand (GWh) -2021-2030

Load forecast: Energy (GWh)	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
ECG	13583.00	14403.41	15273.38	16195.89	17174.12	18211.44	19311.41	20477.82	21714.68	23026.25
NEDCo	1611.76	1761.20	1901.16	2052.23	2215.32	2391.36	2581.39	2786.52	3007.96	3246.99
ENCLAVE POWER COMPANY	306.03	352.44	366.17	384.48	407.36	421.09	448.56	466.86	494.33	512.64
MINES	1822.28	1928.25	2113.42	2223.72	2456.33	2503.75	2528.22	2542.11	2530.18	2520.43
DIRECT	260.37	260.43	260.50	326.42	326.49	326.57	326.64	326.71	326.79	326.86
VALCO	1055.13	1315.10	1371.47	1371.47	1371.47	1371.47	2624.85	2624.85	2546.42	2546.42
CEB(Togo/Benin)	512.14	843.59	843.59	843.59	843.59	843.59	843.59	843.59	843.59	843.59
SONABEL(Burkina)	1000.00	1050.00	1102.50	1157.63	1215.51	1215.51	1215.51	1215.51	1215.51	1215.51
CIE(Ivory Coast)	15.12	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	88.76	328.50	469.54	469.54	657.00
Network Usage	10.56	11.34	12.03	12.69	13.45	14.16	15.65	16.45	17.19	18.10
LOSSES	1079.96	873.10	932.72	1003.40	1045.44	1162.42	1337.39	1432.35	1487.37	1536.59
Total	**21,256.36**	**22,798.87**	**24,176.93**	**25,571.51**	**27,069.06**	**28,550.12**	**31,561.69**	**33,202.30**	**34,653.54**	**36,450.36**

APPENDIX B: GENERATOR PLANNED MAINTENANCE SCHEDULE

i. 1st Quarter 2021 Schedule:

GENERATING PLANT	UNIT	Jan-21	Feb-21	Mar-21	FROM	TO	DESCRIPTION OF WORK
AKOSOMBO	1G1				22-Feb	29-Apr	SCADA UPGRADE/ANNUAL MAINTENANCE
	1G2						
	1G3						
	1G4						
	1G5						
	1G6						
KPONG	19G1						
	19G2						
	19G3						
	19G4						
BUI	54G1				11-Jan	15-Jan	QUARTERLY MAINTENANCE
	54G2				15-Mar	19-Mar	QUARTERLY MAINTENANCE
	54G3				1-Feb	26-Feb	ANNUAL MAINTENANCE
	54G4				22-Mar	23-Mar	QUARTERLY MAINTENANCE
	Tsatsadu				27-Jan	29-Jan	MAINTENANCE
	Bui Solar						
TAPCO	32G1				9-Jan	10-Jan	OFFLINE WATER WASH
	32G2				30-Jan	31-Jan	OFFLINE WATER WASH
	32G3						
TICO	32G4				2-Feb	4-Feb	ENHANCED BOROSCOPE INSPECTION/OFFLINE WATER WASH
	32G5				5-Feb	7-Feb	ENHANCED BOROSCOPE INSPECTION/OFFLINE WATER WASH
	32G6						
TT1PP	47G1						
KTPP	67G1				15-Jan	22-Jan	TYPE B INSPECTION
	67G2						
TT2PP	50G1						
	50G2						
	50G3						
	50G4						
	50G5						
	50G6						
	50G7						
	50G8						
CENIT	47G2						
SUNON ASOGLI	51G1				24-Dec	6-Jan	CLASS C MAINTENANCE
	51G2						
	51G3						
	51G4						
	51G5						
	51G6						
	51G7						
	51G8						
	51G9						
	51G10						
AKSA	79G1				4-Jan	22-Jan	WARTSILA ENGINE VIBRATION DAMPER MAINTENANCE
	79G2				25-Jan	12-Feb	WARTSILA ENGINE VIBRATION DAMPER MAINTENANCE
	79G3				15-Feb	5-Mar	WARTSILA ENGINE VIBRATION DAMPER MAINTENANCE
	79G4						
	79G5						
	79G6						
	79G7						
	79G8						
	79G9						
	79G10						
	79G11						
	79G12						
	79G13						
	79G14						
	79G15						
	79G16						
	79G17						
	79G18						
	79G19				8-Mar	26-Mar	WARTSILA ENGINE VIBRATION DAMPER MAINTENANCE
	79G20						
	79G21						
	79G22						
AMERI	74G1						
	74G2						
	74G3						
	74G4						
	74G5						
	74G6						
	74G7						
	74G8						
	74G9						
	74G10						
KARPOWER	77G1				7-Jan	7-Jan	8000 hrs PLANNED MAINTENANCE
					19-Feb	20-Feb	9000+18000 hrs PLANNED MAINTENANCE
	77G2				8-Jan	8-Jan	8000 hrs PLANNED MAINTENANCE
					1-Feb	2-Feb	9000+18000 hrs PLANNED MAINTENANCE
					15-Mar	15-Mar	2000 hrs PLANNED MAINTENANCE
	77G3				1-Jan	1-Jan	8000 hrs PLANNED MAINTENANCE
					12-Feb	12-Feb	9000 hrs PLANNED MAINTENANCE
	77G4				4-Jan	4-Jan	8000 hrs PLANNED MAINTENANCE
					9-Feb	10-Feb	9000+18000 hrs PLANNED MAINTENANCE
					23-Mar	23-Mar	2000 hrs PLANNED MAINTENANCE
	77G5				26-Jan	27-Jan	18000 hrs PLANNED MAINTENANCE
					10-Feb	10-Feb	9000 hrs PLANNED MAINTENANCE
					25-Mar	25-Mar	2000 hrs PLANNED MAINTENANCE
	77G6				5-Feb	5-Feb	9000 hrs PLANNED MAINTENANCE
					19-Mar	19-Mar	2000 hrs PLANNED MAINTENANCE
	77G7				3-Jan	3-Jan	8000 hrs PLANNED MAINTENANCE
					13-Feb	14-Feb	9000+18000 hrs PLANNED MAINTENANCE
					27-Mar	27-Mar	2000 hrs PLANNED MAINTENANCE
	77G8				11-Feb	12-Feb	9000+18000 hrs PLANNED MAINTENANCE
					26-Mar	26-Mar	2000 hrs PLANNED MAINTENANCE
	77G9				12-Jan	12-Jan	9000 hrs PLANNED MAINTENANCE
					23-Feb	23-Feb	2000 hrs PLANNED MAINTENANCE
	77G10				16-Jan	16-Jan	9000 hrs PLANNED MAINTENANCE
					27-Feb	27-Feb	2000 hrs PLANNED MAINTENANCE
	77G11				18-Jan	18-Jan	9000 hrs PLANNED MAINTENANCE
					1-Mar	1-Mar	2000 hrs PLANNED MAINTENANCE
	77G12				2-Jan	3-Jan	18000 hrs PLANNED MAINTENANCE
					25-Jan	25-Jan	9000 hrs PLANNED MAINTENANCE
					9-Mar	9-Mar	2000 hrs PLANNED MAINTENANCE
	77G13				11-Jan	11-Jan	9000 hrs PLANNED MAINTENANCE
					22-Feb	22-Feb	2000 hrs PLANNED MAINTENANCE
	77G14				27-Jan	28-Jan	9000+18000 hrs PLANNED MAINTENANCE
					10-Mar	10-Mar	2000 hrs PLANNED MAINTENANCE
	77G15				15-Jan	16-Jan	9000+18000 hrs PLANNED MAINTENANCE
					26-Feb	26-Feb	2000 hrs PLANNED MAINTENANCE
	77G16				21-Jan	21-Jan	9000 hrs PLANNED MAINTENANCE
					4-Mar	4-Mar	2000 hrs PLANNED MAINTENANCE
	77G17				13-Jan	14-Jan	18000 hrs PLANNED MAINTENANCE
					4-Feb	4-Feb	9000 hrs PLANNED MAINTENANCE
					18-Mar	18-Mar	2000 hrs PLANNED MAINTENANCE
	77G18				14-Jan	15-Jan	9000+18000 hrs PLANNED MAINTENANCE
					25-Feb	25-Feb	2000 hrs PLANNED MAINTENANCE
	77G19				28-Jan	29-Jan	9000+18000 hrs PLANNED MAINTENANCE
					11-Mar	11-Mar	2000 hrs PLANNED MAINTENANCE
	77G20				17-Jan	17-Jan	9000 hrs PLANNED MAINTENANCE
					28-Feb	28-Feb	2000 hrs PLANNED MAINTENANCE
	77G21				20-Jan	20-Jan	9000 hrs PLANNED MAINTENANCE
					3-Mar	3-Mar	2000 hrs PLANNED MAINTENANCE
	77G22				10-Jan	10-Jan	9000 hrs PLANNED MAINTENANCE
					21-Feb	21-Feb	2000 hrs PLANNED MAINTENANCE
	77G23				20-Feb	21-Feb	9000+18000 hrs PLANNED MAINTENANCE
	77G24				30-Jan	31-Jan	9000+18000 hrs PLANNED MAINTENANCE
					13-Mar	13-Mar	2000 hrs PLANNED MAINTENANCE
	77G25				19-Jan	20-Jan	1000 hrs PLANNED MAINTENANCE
					2-Mar	3-Mar	1000 hrs PLANNED MAINTENANCE
	77G26				6-Feb	7-Feb	1000 hrs PLANNED MAINTENANCE
					20-Mar	21-Mar	1000 hrs PLANNED MAINTENANCE
CENPOWER	76G1						
	76G2						
	76G3						

ii. 2nd Quarter 2021 Schedule:

GENERATING PLANT	UNIT	Apr-21	May-21	JUN	from	to	Description of Work
AKOSOMBO	1G1				22-Feb	29-Apr	SCADA UPGRADE/ANNUAL MAINTENANCE (FEB 22 - APR 29)
	1G1				3-May	8-Jul	SCADA UPGRADE/ ANNUAL MAINTENANCE (MAY 3 - JUL 8)
	1G1						
	1G1						
	1G1						
	1G1						
KPONG	19G1						
	19G2						
	19G3						
	19G4						
BUI	54G1				10-May	14-May	Quarterly Maintenance
	54G2				1-Apr	30-Jun	Level-A Maintenance
	54G3				14-Jun	18-Jun	Quarterly Maintenance
	54G4				7-Jun	8-Jun	Quarterly Maintenance
TSATSADU					19-May	21-May	Quarterly Maintenance
BUI SOLAR					12-Apr	16-Apr	Solar Maintenance
TAPCO	32G1				3-Apr	4-Apr	OFFLINE WATER WASH
	32G2				24-Apr	25-Apr	OFFLINE WATER WASH
	32G3				22-Apr	6-May	Gen. CB Midlife INSP./CEMS Ugrade
TICO	32G4				22-May	22-May	OFFLINE WATER WASH
	32G5				23-May	23-May	OFFLINE WATER WASH
	32G6						
TT1PP	47G1						
KTPP	67G1						
	67G2						
TT2PP	50G1						
	50G2						
	50G3						
	50G4				14-Jun	18-Jun	TYPE A Maintenance
	50G5				21-Jun	25-Jun	TYPE A Maintenance
	50G6						
	50G7				1-Apr	17-Apr	TYPE A Maintenance
	50G8						
CENIT	47G2						
SUNON ASOGLI	51G1				18-Jun	7-Jul	CLASS C MAINTENANCE
	51G2				18-Jun	22-Jul	CLASS B+ MAINTENANCE
	51G3				25-Jun	8-Jul	CLASS C MAINTENANCE
	51G4						
	51G5						
	51G6						
	51G7				25-May	11-Jun	CLASS C MAINTENANCE
	51G8				25-May	12-Jun	CLASS C MAINTENANCE
	51G9						
	51G10						
AKSA	79G1						
	79G2						
	79G3						
	79G4						
	79G5						
	79G6						
	79G7						
	79G8				5-Apr	23-Apr	WARTSILA ENGINE 36K MECHANICAL MAINTENANCE & GAS CONVERSION
	79G9				26-Apr	14-May	WARTSILA ENGINE 36K MECHANICAL MAINTENANCE & GAS CONVERSION
	79G10				17-May	4-Jun	WARTSILA ENGINE 36K MECHANICAL MAINTENANCE & GAS CONVERSION
	79G11				7-Jun	25-Jun	WARTSILA ENGINE 36K MECHANICAL MAINTENANCE & GAS CONVERSION
	79G12				28-Jun	16-Jul	WARTSILA ENGINE 36K MECHANICAL MAINTENANCE & GAS CONVERSION
	79G13						
	79G14						
	79G15						
	79G16						
	79G17						
	79G18						
	79G19						
	79G20						
	79G21						
	79G22						
AMERI	74G1						
	74G2						
	74G3						
	74G4						
	74G5						
	74G6						
	74G7						
	74G8						
	74G9						
	74G10						
KARPOWER	77G1				2-Apr	2-Apr	2000 hrs PLANNED MAINTENANCE
					14-May	14-May	4000 hrs PLANNED MAINTENANCE
	77G2				6-Jun	6-Jun	4000 hrs PLANNED MAINTENANCE
	77G3				6-May	6-May	2000 hrs PLANNED MAINTENANCE
					30-Jun	30-Jun	6000 hrs PLANNED MAINTENANCE
	77G4				14-Jun	14-Jun	4000 hrs PLANNED MAINTENANCE
	77G5				15-Jun	15-Jun	4000 hrs PLANNED MAINTENANCE
	77G6				9-Jun	9-Jun	4000 hrs PLANNED MAINTENANCE
	77G7				18-Jun	18-Jun	4000 hrs PLANNED MAINTENANCE
	77G8				16-Jun	16-Jun	4000 hrs PLANNED MAINTENANCE
	77G9				17-May	17-May	4000 hrs PLANNED MAINTENANCE
					28-Jun	28-Jun	6000 hrs PLANNED MAINTENANCE
	77G10				20-May	21-May	4000 hrs PLANNED MAINTENANCE
					24-Jun	24-Jun	6000 hrs PLANNED MAINTENANCE
	77G11				22-May	23-May	4000 hrs PLANNED MAINTENANCE
	77G12				30-May	30-May	4000 hrs PLANNED MAINTENANCE
	77G13				16-May	16-May	4000 hrs PLANNED MAINTENANCE
	77G14				1-Jun	2-Jun	4000 hrs PLANNED MAINTENANCE
	77G15				19-May	19-May	4000 hrs PLANNED MAINTENANCE
					29-Jun	29-Jun	6000 hrs PLANNED MAINTENANCE
	77G16				25-May	26-May	4000 hrs PLANNED MAINTENANCE
	77G17				8-Jun	8-Jun	4000 hrs PLANNED MAINTENANCE
	77G18				18-May	18-May	4000 hrs PLANNED MAINTENANCE
	77G19				2-Jun	2-Jun	4000 hrs PLANNED MAINTENANCE
	77G20				21-May	21-May	4000 hrs PLANNED MAINTENANCE
					27-Jun	27-Jun	6000 hrs PLANNED MAINTENANCE
	77G21				25-Jun	25-Jun	6000 hrs PLANNED MAINTENANCE
					24-May	24-May	4000 hrs PLANNED MAINTENANCE
	77G22				15-May	16-May	4000 hrs PLANNED MAINTENANCE
	77G23				4-Apr	4-Apr	2000 hrs PLANNED MAINTENANCE
					26-Jun	26-Jun	4000 hrs PLANNED MAINTENANCE
	77G24				4-Jun	4-Jun	4000 hrs PLANNED MAINTENANCE
	77G25				13-Apr	15-Apr	3000 hrs PLANNED MAINTENANCE
					23-May	24-May	1000 hrs PLANNED MAINTENANCE
	77G26				1-May	3-May	3000 hrs PLANNED MAINTENANCE
					12-Jun	12-Jun	1000 hrs PLANNED MAINTENANCE
CENPOWER	76G1				1-Jun	8-Jun	COMBUSTION INSPECTION
	76G2						
	76G3						

iii. 3rd Quarter 2021 Schedule:

GENERATING PLANT	UNIT	FROM	TO	DESCRIPTION OF WORKS
AKOSOMBO	1G1			
	1G2	3-May	8-Jul	SCADA UPGRADE / ANNUAL MAINTENANCE
	1G3	12-Jul	10-Sep	SCADA UPGRADE / ANNUAL MAINTENANCE
	1G4	14-Sep	15-Nov	SCADA UPGRADE / ANNUAL MAINTENANCE
	1G5			
	1G6			
KPONG	19G1			
	19G2			
	19G3			
	19G4			
BUI	54G1	1-Jul	29-Sep	LEVEL A MAINTENANCE
	54G2	20-Sep	24-Sep	QUARTERLY MAINTENANCE
	54G3	23-Aug	27-Aug	QUARTERLY MAINTENANCE
	54G4	13-Sep	14-Sep	QUARTERLY MAINTENANCE
	Tsatsadu			
	Bui Solar			
TAPCO	32G1	3-Jul	4-Jul	OFFLINE WATER WASH
	32G2	24-Jul	25-Jul	OFFLINE WATER WASH
	32G3			
TICO	32G4	28-Aug	28-Aug	OFFLINE WATER WASH
	32G5	1-Aug	9-Oct	HOTGAS PATH INSPECTION/ FILTER REPLACEMENT & EXHAUST PLENUM REPLACEMENT
	32G6			
TT1PP	47G1			
KTPP	67G1			
	67G2			
TT2PP	50G1	2-Aug	16-Aug	ENGINE SWAP
	50G2	9-Aug	13-Aug	TYPE A MAINTENANCE
	50G3	16-Aug	20-Aug	TYPE A MAINTENANCE
	50G4			
	50G5	5-Jul	9-Jul	TYPE A MAINTENANCE
	50G6	19-Jul	23-Jul	TYPE A MAINTENANCE
	50G7			
	50G8	23-Aug	27-Aug	TYPE A MAINTENANCE
CENIT	47G2			
SUNON ASOGLI	51G1	18-Jun	7-Jul	CLASS C MAINTENANCE
	51G2	18-Jun	22-Jul	CLASS B+ MAINTENANCE
	51G3	25-Jun	8-Jul	CLASS C MAINTENANCE
	51G4	1-Jul	20-Jul	CLASS C MAINTENANCE
	51G5	21-Jul	9-Aug	CLASS C MAINTENANCE
	51G6			
	51G7			
	51G8			
	51G9			
	51G10			
AKSA	79G1			
	79G2			
	79G3			
	79G4			
	79G5			
	79G6			
	79G7			
	79G8			
	79G9			
	79G10			
	79G11			
	79G12	28-Jun	16-Jul	WARTSILA ENGINE 36K MECHANICAL MAINTENANCE & GAS CONVERSION
	79G13	19-Jul	6-Aug	WARTSILA ENGINE 36K MECHANICAL MAINTENANCE & GAS CONVERSION
	79G14	9-Aug	27-Aug	WARTSILA ENGINE 36K MECHANICAL MAINTENANCE & GAS CONVERSION
	79G15			
	79G16			
	79G17			
	79G18			
	79G19			
	79G20			
	79G21			
	79G22			
AMERI	74G1			
	74G2			
	74G3			
	74G4			
	74G5			
	74G6			
	74G7			
	74G8			
	74G9			
	74G10			
KARPOWER	77G1	11-Jul	11-Jul	6000HRS PLANNED MAINTENANCE
		9-Aug	10-Aug	8000HRS PLANNED MAINTENANCE
	77G2	27-Jul	27-Jul	6000HRS PLANNED MAINTENANCE
		2-Sep	3-Sep	8000HRS PLANNED MAINTENANCE
	77G3	8-Aug	8-Aug	4000HRS PLANNED MAINTENANCE
		26-Aug	31-Aug	24000HRS PLANNED MAINTENANCE
	77G4	31-Jul	31-Jul	6000HRS PLANNED MAINTENANCE
	77G5	10-Jul	10-Jul	6000HRS PLANNED MAINTENANCE
	77G6	13-Jul	18-Jul	24000HRS PLANNED MAINTENANCE
		21-Jul	21-Jul	6000HRS PLANNED MAINTENANCE
	77G7	18-Jul	18-Jul	6000HRS PLANNED MAINTENANCE
		15-Sep	15-Sep	2000HRS PLANNED MAINTENANCE
	77G8	19-Jul	19-Jul	6000HRS PLANNED MAINTENANCE
		10-Sep	10-Sep	2000HRS PLANNED MAINTENANCE
	77G9	16-Sep	16-Sep	8000HRS PLANNED MAINTENANCE
	77G10	19-Aug	19-Aug	2000HRS PLANNED MAINTENANCE
		26-Sep	1-Oct	24000HRS PLANNED MAINTENANCE
	77G11	28-Jul	28-Jul	6000HRS PLANNED MAINTENANCE
		10-Aug	15-Aug	24000HRS PLANNED MAINTENANCE
	77G12	7-Aug	7-Aug	6000HRS PLANNED MAINTENANCE
		1-Sep	1-Sep	2000HRS PLANNED MAINTENANCE
		10-Sep	15-Sep	24000HRS PLANNED MAINTENANCE
	77G13	1-Aug	1-Aug	6000HRS PLANNED MAINTENANCE
		1-Aug	6-Aug	24000HRS PLANNED MAINTENANCE
	77G14	16-Aug	16-Aug	6000HRS PLANNED MAINTENANCE
		1-Sep	2-Sep	2000HRS PLANNED MAINTENANCE
	77G15	18-Aug	19-Aug	2000HRS PLANNED MAINTENANCE
	77G16	22-Jul	27-Jul	24000HRS PLANNED MAINTENANCE
		9-Aug	9-Aug	6000HRS PLANNED MAINTENANCE
	77G17	4-Jul	4-Jul	6000HRS PLANNED MAINTENANCE
		3-Sep	3-Sep	2000HRS PLANNED MAINTENANCE
		16-Sep	21-Sep	24000HRS PLANNED MAINTENANCE
	77G18	3-Jul	3-Jul	6000HRS PLANNED MAINTENANCE
		18-Aug	18-Aug	2000HRS PLANNED MAINTENANCE
		21-Sep	26-Sep	24000HRS PLANNED MAINTENANCE
	77G19	12-Jul	12-Jul	6000HRS PLANNED MAINTENANCE
	77G20	19-Aug	20-Aug	2000HRS PLANNED MAINTENANCE
		3-Sep	8-Sep	24000HRS PLANNED MAINTENANCE
	77G21	5-Jul	10-Jul	24000HRS PLANNED MAINTENANCE
	77G22	20-Jul	20-Jul	6000HRS PLANNED MAINTENANCE
		21-Aug	26-Aug	24000HRS PLANNED MAINTENANCE
	77G23	29-Jul	29-Jul	6000HRS PLANNED MAINTENANCE
		15-Sep	16-Sep	2000HRS PLANNED MAINTENANCE
	77G24	17-Aug	17-Aug	6000HRS PLANNED MAINTENANCE
		2-Sep	2-Sep	2000HRS PLANNED MAINTENANCE
	77G25	1-Jul	2-Jul	1000HRS PLANNED MAINTENANCE
		20-Aug	22-Aug	24000HRS PLANNED MAINTENANCE
	77G26	30-Jul	31-Jul	1000HRS PLANNED MAINTENANCE
		8-Sep	10-Sep	3000HRS PLANNED MAINTENANCE
CENPOWER	76G1			
	76G2			
	76G3			

iv. 4th Quarter 2021 Schedule:

GENERATING PLANT	UNIT	OCT	NOV	DEC	FROM	TO	DESCRIPTION OF WORK
AKOSOMBO	1G1						
	1G2						
	1G3						
	1G4				14-Sep	15-Nov	SCADA UPGRADE / ANNUAL MAINTENANCE
	1G5				17-Nov	18-Jan	SCADA UPGRADE / ANNUAL MAINTENANCE
	1G6						
KPONG	19G1						
	19G2						
	19G3						
	19G4						
BUI	54G1				13-Dec	17-Dec	QUARTERLY MAINTENANCE
	54G2				22-Nov	NOV 26	QUARTERLY MAINTENANCE
	54G3				18-Oct	22-Oct	QUARTERLY MAINTENANCE
	54G4				1-Nov	30-Nov	LEVEL A MAINTENANCE
	Tsatsadu				8-Dec	10-Dec	QUARTERLY MAINTENANCE
	Bui Solar				4-Oct	8-Oct	QUARTERLY MAINTENANCE
TAPCO	32G1				4-Dec	5-Dec	OFFLINE WATER WASH
	32G2				18-Dec	19-Dec	OFFLINE WATER WASH
	32G3				1-Dec	21-Jan	STEAM TURBINE GENERATOR MAJOR INSPECTION
TICO	32G4						
	32G5				27-Nov	27-Nov	OFFLINE WATER WASH
	32G6						
TT1PP	47G1						
KTPP	67G1				4-Oct	9-Oct	TYPE A MAINTENANCE
					11-Oct	16-Oct	EGATROL EVOLUTION
	67G2				18-Oct	23-Oct	EGATROL EVOLUTION
TT2PP	50G1				5-Oct	11-Oct	GEAR BOX OVERHAUL
	50G2				12-Oct	17-Oct	GEAR BOX OVERHAUL
	50G3				2-OCT	8-OCT	GEAR BOX OVERHAUL
					2-NOV	8-NOV	GEAR BOX OVERHAUL
	50G4						
	50G5				9-Nov	15-Nov	GEAR BOX OVERHAUL
	50G6				23-Nov	29-Nov	GEAR BOX OVERHAUL
	50G7						
	50G8						
CENIT	47G2						
SUNON ASOGLI	51G1						
	51G2						
	51G3						
	51G4						
	51G5						
	51G6						
	51G7						
	51G8						
	51G9				25-Oct	18-Nov	CLASS B MAINTENANCE
	51G10				2-Nov	18-Nov	CLASS C MAINTENANCE
AKSA	79G1						
	79G2						
	79G3						
	79G4						
	79G5						
	79G6						
	79G7						
	79G8						
	79G9						
	79G10						
	79G11						
	79G12						
	79G13						
	79G14						
	79G15						
	79G16						
	79G17						
	79G18						
	79G19						
	79G20						
	79G21						
	79G22						
AMERI	74G1						
	74G2						
	74G3						
	74G4						
	74G5						
	74G6						
	74G7						
	74G8						
	74G9						
	74G10						
KARPOWER	77G1				4-Dec	9-Dec	24000HRS PLANNED MAINTENANCE
	77G2				29-Oct	4-Nov	24000HRS PLANNED MAINTENANCE
					31-Dec	31-Dec	2000HRS PLANNED MAINTENANCE
	77G3				16-Dec	16-Dec	8000HRS PLANNED MAINTENANCE
	77G4				14-Nov	19-Nov	24000HRS PLANNED MAINTENANCE
	77G5				3-Oct	4-Oct	8000HRS PLANNED MAINTENANCE
					9-Oct	14-Oct	24000HRS PLANNED MAINTENANCE
					28-Dec	28-Dec	24000HRS PLANNED MAINTENANCE
	77G6				9-Oct	9-Oct	2000HRS PLANNED MAINTENANCE
					27-Dec	27-Dec	4000HRS PLANNED MAINTENANCE
	77G7				19-Nov	24-Nov	24000HRS PLANNED MAINTENANCE
	77G8				24-Nov	29-Nov	24000HRS PLANNED MAINTENANCE
					19-Dec	19-Dec	8000HRS PLANNED MAINTENANCE
	77G9				9-Dec	14-Dec	24000HRS PLANNED MAINTENANCE
	77G10				23-Dec	23-Dec	8000HRS PLANNED MAINTENANCE
	77G11				29-Nov	29-Nov	2000HRS PLANNED MAINTENANCE
	77G12				20-Dec	21-Dec	2000HRS PLANNED MAINTENANCE
	77G13				13-Nov	14-Nov	2000HRS PLANNED MAINTENANCE
	77G14				4-Nov	9-Nov	24000HRS PLANNED MAINTENANCE
	77G15				14-Oct	19-Oct	24000HRS PLANNED MAINTENANCE
					29-Dec	29-Dec	2000HRS PLANNED MAINTENANCE
	77G16						
	77G17				21-Dec	21-Dec	2000HRS PLANNED MAINTENANCE
	77G18				22-Dec	22-Dec	2000HRS PLANNED MAINTENANCE
	77G19				4-Oct	9-Oct	24000HRS PLANNED MAINTENANCE
					26-Dec	26-Dec	2000HRS PLANNED MAINTENANCE
	77G20				17-Dec	17-Dec	2000HRS PLANNED MAINTENANCE
	77G21				3-Oct	3-Oct	2000HRS PLANNED MAINTENANCE
					25-Dec	25-Dec	4000HRS PLANNED MAINTENANCE
	77G22				14-Dec	14-Dec	2000HRS PLANNED MAINTENANCE
	77G23				29-Nov	4-Dec	24000HRS PLANNED MAINTENANCE
	77G24				24-Oct	29-Oct	24000HRS PLANNED MAINTENANCE
					30-Dec	30-Dec	2000HRS PLANNED MAINTENANCE
	77G25				1-Oct	2-Oct	1000HRS PLANNED MAINTENANCE
					15-Dec	16-Dec	1000HRS PLANNED MAINTENANCE
	77G26				10-Nov	11-Nov	1000HRS PLANNED MAINTENANCE
					18-Dec	19-Dec	1000HRS PLANNED MAINTENANCE
CENPOWER	76G1						
	76G2				1-Dec	8-Dec	COMBUSTION INSPECTION
	76G3				1-Oct	30-Nov	CIRCULATING WATER PIPE REPLACEMENT FOR STEAM TURBINE GENERATOR

APPENDIX C: 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 D – GRID MAP