REPUBLIC OF GHANA

TWENTY TWENTY-TWO

Electricity Supply Plan

for the Ghana Power System

a power supply outlook with medium term projections for Ghana

POWER PLANNING TECHNICAL COMMITTEE

2022 ELECTRICITY SUPPLY PLAN FOR GHANA

An Operations Planning Outlook for Power Supply in 2022 with 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 2022 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 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
Ing. Sheila Bortey-Kharis (Mrs.)	–	Ghana Grid Company Limited
Monica Debrah (Mrs.)	–	Ghana Grid Company Limited
Simpson Attieku	–	Energy Commission
Eric Kyem	–	Energy Commission
Joseph Banuro	–	Energy Commission
Adolf Nii Ashong	–	Energy Commission
Ing. Frederick Oblitey	–	Public Utilities Regulatory Commission
Ing. Hanson Monney	–	Ministry of Energy
Ing. Abdul N. Wahab	–	Volta River Authority
Ing. Justice Barnor Kyere	–	Bui Power Authority
Ebenezer Baiden	–	Electricity Company of Ghana
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 2022 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 2022 ESP are as follows:

- **2021 Performance Review**

Peak Load

The Ghana power system recorded a coincident peak demand of 3,246.0 MW in 2021. This occurred on December 8, 2021. The 2021 peak represents an increase of 156.0 MW over the 2020 peak of 3,089.5 MW (growth of 5.0%).

Load Type	Ghana Peak Demand (MW)		Difference (MW)
	Projected 2021	Actual 2021	(Projected - Actual)
Domestic Peak	2,873.72	2,864.00	9.72
Export (CEB+SONABEL+CIE)	300.00	289.00	11.00
VALCO	130.00	93.00	37.00
System Peak (coincident)	3,303.72	3,246.00	57.72

Energy Consumption

The total energy consumed, including losses, was 21,466.26 GWh representing a 8.87% increase over the 2020 consumption of 19,716.59 GWh.

Customer		Projection (GWh) 2021	Actual (GWh) 2021	Actual (GWh) 2020
ECG		13,583.00	14,194.91	12,653.33
NEDCo		1611.76	1,752.93	1,573.19
Mines		1845.73	1,409.86	1,499.20
VALCO		1055.13	771.76	721.56
EPC		306.03	232.47	242.15
Export	CEB	512.14	574.96	715.26187
	SONABEL	1000	962.00	990.47
	CIE	15.12	197.01	149.39
Direct Cust.		246.08	283.99	274.65
Losses		1079.96	1075.93	887.75
Network Usage		10.56	10.44	9.67
Total Energy Transmitted		21,265.52	21,466.26	19,716.62

Energy Generated

The total energy generated over the period was 21,466.26 GWh; this was made up of 7,520.82 GWh (35.04%) from hydro generation, 13,849.05 GWh (64.52%) from thermal generation, 52.76 GWh (0.25%) from Solar and 43.66 GWh (0.20%) import.

- ## 2022 Demand Outlook

The projected coincident Ghana peak demand for 2022 is 3,545.27 MW. This represents a growth of 9.2% (an increase of 299.27 MW) over the 2021 peak demand of 3,246.0 MW.

The projected 2022 energy consumption is 23,578.51 GWh, which includes transmission network losses and station service usage of 1,069.79 GWh. The estimated transmission losses and usage represents a 4.5% of total projected energy supply. The projected 2022 energy consumption represents an increase of 2,098.04 GWh (growth of 9.77 %) over the 2021 consumption of 21,466.27 GWh.

- ## 2022 Generation Outlook

Hydro Generation
Projected total annual hydro generation for 2022 is 7,394.15 GWh. This is made up of 5,513.3 GWh from Akosombo GS, 986.7 GWh and 894 GWh from Bui GS.

Thermal Generation
The total projected thermal energy generation in 2022 is 16,000.04 GWh. A total of US$ 988.0 Million is required for thermal fuel purchase in 2022. This comprises US$ 872.8M for Gas, US$ 18.0 Million for HFO and US$ 55 Million for LCO.

RE Generation
A total of 184.38 GWh of electrical energy is expected from Renewable Energy sources in 2022. 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.

- ## 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.

- ## 2022 Transmission System Outlook

Relocation of the 250 MW Ameri Power Plant from Takoradi to Kumasi reduces transmission system losses significantly. It also improves the voltage regulation in Kumasi & its environs and aids export.

Critical transmissions contingencies are as follows:

- Loss of 330 kV Takoradi Thermal – Anwomaso, 330 kV Anwomaso – Kintampo and 330 kV Pokuase – Volta Lines cause severe system disturbances.
- Upgrade of the 161 kV Achimota – Mallam and Achimota – Accra Central lines without significant load transfer from Kasoa, Mallam and Accra Central causes system collapse.
- With Maximum Generation from the west, the western corridor lines become heavily loaded especially the 170 MVA Tarkwa – New Tarkwa and Tarkwa – Prestea lines.

- **Medium Term Outlook**

Demand Outlook

The Ghana system peak demand is projected to increase from 3,987 MW in 2023 to 5,172 MW in 2027.

Total electricity requirement for Ghana including power exports to Togo, Benin, Burkina, and Mali is projected to increase from 25,983 GWh in 2023 to 34,920 GWh by 2027 at a Compound Annual Growth Rate (CAGR) of approximately 7.7%.

	2023	2024	2025	2026	2027
Peak Demand (MW)	3,987	4,256	4,491	4,793	5,172
Energy Demand (GWh)	25,983	27,764	29,325	31,350	34,920

Generation Adequacy Analysis

The table below shows projected demand over the medium term compared with the total projected dependable generating capacity situation. Dependable capacity comprises the total capacity of existing generation plants, committed generation plant projects as well as other planned generation projects expected to be completed and put in operation within the medium term.

	2023	2024	2025	2026	2027
Projected Peak Demand	3,987	4,256	4,491	4,793	5,172
18% Planning Reserve Margin	718	766	808	863	931
Minimum Capacity Required for Adequacy: *(Projected Peak Demand + 18% Reserve)*	4,705	5,022	5,300	5,656	6,103
Total Existing Generation	4,480	4,610	4,760	4,870	4,800
Total Committed Generation	190	190	190	450	450
Other Planned Generation	0	305	460	570	1070
Total Dependable Generation	4,670	5,105	5,410	5,890	6,320
Generation Capacity Surplus/Shortfall	-34[1]	84	111	234	217

The timely completion of all Committed Generation as well as the other Planned Generation projects is necessary to ensure generation capacity adequate to meet projected demand with adequate reserve margin as required for reliability within the medium term.

[1] This shortfall will reduce the 718 MW planning reserve margin for 2023. To ensure that it does not affect the security of supply to consumers, the Ameri Power Plant and the Bridge Power Plant 'Phase I' need to come into operation as scheduled while ensuring a high availability of all existing generating plants throughout the year

Creation of new Generation Enclave

Analysis conducted confirms the recommendation made in the Electricity Supply Plans of previous years for the establishment of a new generation enclave at Kumasi. The relocation of Ameri power plant to Kumasi will begin the creation of the new enclave.

Transmission Expansion requirements

a. 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

b. Additionally, construction of the following NITS additions is required:

- ✓ 330/161 kV Dunkwa substation
- ✓ 161kV Pokuase – Mallam line
- ✓ 2nd Circuit 330 kV Aboadze – Pokuase
- ✓ 330 kV Accra (Pokuase) – Kumasi (Anwomaso) 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)
- ✓ Kumasi third Bulk Supply Point
- ✓ Transformers and Compensation devices
- ✓ ±50 MVar STATCOM to be installed in Kumasi, Nayagnia and Prestea
- ✓ Upgrade of middle corridor transmission lines (Akosombo – Tafo – Nkawkaw – Konongo – Kumasi circuit)
- ✓ Prestea Substation Improvement Project (both 225kV & 161 kV)
- ✓ Akwatia – New Abirem Loop Closure
- ✓ A second 44km, 161kV transmission line to Obotan (to close the circuit)

- ✓ A double circuit 330kV second interconnection between Ghana (Dunkwa 330kV), and Cote d'Ivoire (Bingerville).

Conclusion

The following conclusions are drawn:

1. The Projected Peak Demand for 2022 is **3,545 MW** whiles the corresponding projected Dependable Generation Capacity is **4,618** MW. Generation capacity is therefore expected to be adequate to supply projected demand in 2022.
2. Relocation of the 250 MW Ameri Power Plant from Takoradi to Kumasi reduces transmission system losses significantly. It also improves voltage regulation in Kumasi and its surrounding as well as aid exports to Burkina.
3. In the medium term (2023 – 2027) the timely completion of the committed projects and other planned generation projects is necessary to have generation adequacy.
4. Some existing transmission lines require to be upgraded whiles some new lines require to be constructed to continue to have adequate capacity on the NITS to evacuate power generated to all Bulk Supply Points in the medium term.

Recommendation

Based on the above conclusions, the following are some of the key recommendations made:

Generation

1. Due to the growing electricity demand in Ghana, there is an urgent need to make arrangements to increase gas supply volumes from existing gas supply facilities to enable more Thermal generation.

   It is also very important to make necessary investments towards an improved gas supply reliability owing to the increasing dependency on natural gas for power generation.

2. Efforts need to be expedited to complete the relocation of the 250 MW Ameri Power Plant to Kumasi to create a new generation enclave in the middle parts of the NITS.

3. The results of analyses of the supply/demand outlook for the medium term indicate that for 2023, apart from the recommendation to expedite the re-operationalization of the Ameri Plant the following measures need to be pursued to ensure security of supply to consumers in Ghana:

i. the Bridge Power Plant 'Phase I' needs to be operational by 2023 as scheduled;
ii. ensure a high availability of all existing generating plants throughout the year.

4. For 2024 and beyond, there is a need to ensure timely completion of all Committed Genertion and Other Planned Generation projects in order to continue to adequately meet the Ghana power system demand with the required 18% reserve. These are:
   i. The Karpower Phase III plant to be located in Kumasi,
   ii. The AKSA Phase II Power Plant,
   iii. The Sunon Asogli Plant Phase III Project, and
   iv. The Pwalugu Hydro/Solar Hybrid Plant.

Transmission

The committee recommends for the implementation of works enlisted under "Transmission Expansion Requirements" above. Key among them are:

5. The following critical transmission reinforcement projects are required to ensure power supply reliability in the medium term:
   i. Upgrade of 161 kV Takoradi Thermal – Cape Coast – Winneba - Mallam lines
   ii. 161kV Pokuase – Mallam Project (Transmission Line and Substation)
   iii. Upgrade of 161 kV Akosombo – Tafo – Nkawkaw – Konongo - Kumasi lines

6. Construct a 330 kV line circuit from Pokuase – Anwomaso to enhance power evacuation in the middle corridor and improve overall system reliability.

7. Upgrade of the existing 161 kV lines in the Western Corridor coupled with the break-in on the 330 kV Takoradi Thermal – Anwomaso line at Dunkwa to address possible overloads during contingency on any of the lines in the Western corridor.

8. The construction of the proposed second tie-line (330 kV) between Ghana and Cote d'Ivoire from Dunkwa to Riviera (in Cote d'Ivoire) will boost the interconnection between the two countries and trading in the WAPP.

9. Replace the existing 200 MVA 225/330 kV auto transformers on the Ghana – Burkina tie-line at Nayagnia with two (2) autotransformers with Phase shifting capabilities.

10. Replace the existing 200 MVA 225/161 kV auto transformers on the Ghana – Cote d'Ivoire tie-line at Prestea with two (2) autotransformers with Phase shifting capabilities.

11. With the increasing load in the Kumasi Metropolis coupled with expected increase in export in the coming years, a third bulk supply point together with a minimum of 50 MVAr STATCOM is required at Kumasi. This will ensure that demand is met in the Metropolis as well as the improvement in quality of power.

12. With the expected high penetration of Renewable Energy in the Ghana grid in the coming years, the current SCADA system needs to be upgraded and equipped for RE dispatch.

TABLE OF CONTENTS

Table of Tables

Table of Figures

Chapter 1

INTRODUCTION

1 INTRODUCTION

The 2022 Electricity Supply Plan (ESP) is the operations planning report for the Ghana power system for the year 2022. It outlines projections for electricity demand and supply for the year, The ESP highlights the strategy for delivering electricity generation, transmission, and distribution services on the Ghana Power System in 2022.

The report begins with a review of the performance of the Ghana Power System in 2021, comparing projections made in the 2021 ESP with actuals attained, as well as other benchmarks. It goes on to present a forecast of the year's electricity demand and supply. The supply outlook highlights the key assumptions underpinning the projections, such as generating unit maintenance schedules and natural gas availability.

The report asserts existing generation capacities that would be available for dispatch to supply projected demand based on the new dispatch protocol and system stability requirements for the year.

Hydro generation plants are expected to continue to play the crucial role of providing load following and system stability for the Ghana power system. Energy allocations from the hydropower plants took into account the total inflows into the Akosombo and Bui hydro reservoirs during the inflow season in 2021 to ensure prudent management of the reservoirs to avert the need for spillage while ensuring that the reservoirs are not operated below their minimum levels.

With the ever increasing proportion of gas-fired thermal generating facilities in Ghana the adequacy of the various sources of gas supply for thermal generation is analysed to deduce fuel supply security. Gas supply sources in Ghana are from the Sankofa, Jubilee and TEN fields, the envisaged Tema LNG project as well as imported gas from N-Gas, Nigeria.

Alternative liquid fuel requirements to serve largely as strategic stocks for multi-fuel fired thermal plants in case of any gas supply interruption have also been analysed.

Furthermore, the report takes a critical look at the Transmission System Outlook for the year and makes recommendations for its reinforcement to improve its reliability and adequacy for power evacuation in Ghana. It goes on to outline projections for the medium-term, making recommendations to address identified challenges and conduct analysis into supply adequacy for the medium term.

Finally, the report presents a summary of recommendations for the improvement of power supply on the Ghana power system.

Chapter 2

2021 POWER SYSTEM PERFORMANCE REVIEW

2 2021 POWER SYSTEM PERFORMANCE REVIEW

2.1 Objective

In this chapter we conduct an analysis of the performance of the Ghana Power System in the year 2021. The peak demand, energy consumption and power plant generation data are compared against the projections made in the 2021 Electricity Supply Plan. The system performance with respect to voltages and transmission system losses are also analysed.

2.2 Peak Load

The actual Ghana peak load realised for the year 2021 was 3,246.0 MW. This peak load which was recorded on December 08, 2021, is just 57.7 MW (1.7%) lower than the projected peak load of 3,303.7 MW per the 2021 ESP.

The peak load recorded also represents a 5.0% (156.0 MW) growth over the 2020 peak load of 3,089.5 MW. The summary of projected and actual peak load as recorded over the period is shown in Table 2.1

Table 2.1: 2021 Ghana Peak Demand

Load Type	Ghana Peak Demand (MW)		Difference (MW)
	Projected 2021	Actual 2021	(Projection - Actual)
Domestic Peak	2,873.72	2,864.00	9.72
Export (CEB+SONABEL+CIE)	300.00	289.00	11.00
VALCO	130.00	93.00	37.00
System Peak (coincident)	3,303.72	3,246.00	57.72

Table 2.2 compares the actual monthly peak load for the year 2021 against the projected.

Table 2.2: Comparison of Monthly Peak Load 2021(Actual against Projected)

Month	Projected Demand (MW)	Actual Demand (MW)	Difference (Projected - Actual)
21-Jan	3,264.00	3,070.00	194.00
21-Feb	3,191.10	3,088.00	103.10
21-Mar	3,256.40	3,172.00	84.40

21-Apr	3,283.40	3,206.00	77.40
21-May	3,258.60	3,073.00	185.60
21-Jun	3,054.00	3,097.00	-43.00
21-Jul	2,946.87	2,903.00	43.87
21-Aug	2,851.07	2,867.00	-15.93
21-Sep	3,030.18	3,049.00	-18.82
21-Oct	3,170.74	3,152.00	18.74
21-Nov	3,284.28	3,135.00	149.28
21-Dec	3,303.72	3,246.00	57.72

2.3 Energy Consumption

The total energy consumed, including losses, was 21,466.26 GWh as against the projected total energy consumption of 21,265.52 GWh. The actual energy consumed was only 200.8 GWh (0.94%) higher than the projected. A total of 19,716.59 GWh was consumed during the same period in 2020. The 2021 energy consumption therefore represents a 1,749.68 GWh (8.87%) increase over that of 2020.

A summary of 2020 and 2021 energy consumption data is shown in Table 2.3 and Figure 2.1.

Table 2.3: Summary of Energy Consumption for 2021: actual vrs. projected Summary of Energy

Customer		Projection (GWh) 2021	Actual (GWh) 2021	Actual (GWh) 2020	% Growth (2021-2020)
ECG		13,583.00	14,194.91	12,653.33	12.18%
NEDCo		1611.76	1,752.93	1,573.19	11.42%
Mines		1845.73	1,409.86	1,499.20	-5.96%
VALCO		1055.13	771.76	721.56	6.96%
EPC		306.03	232.47	242.15	-4.00%
Export	CEB	512.14	574.96	715.26187	-19.62%
	SONABEL	1000	962.00	990.47	-2.87%
	CIE	15.12	197.01	149.39	31.88%
Direct Cust.		246.08	283.99	274.65	3.40%
Losses		1079.96	1075.93	887.75	21.20%
Network Usage		10.56	10.44	9.67	7.96%
Total Energy Transmitted		21,265.52	21,466.26	19,716.62	8.87%

The data shows significant growth in demand for ECG and NEDCo for the year 2021. Consumption for the mines experienced negative growth during the period. This was because some mines like the Perseus Mining Ghana Limited went off grid supply. Exports to SONABEL, CEB and CIE were lower than projected in the 2021 ESP. Export to SONABEL were low due to a forced outage on the 330 kV Takoradi Thermal – Anwomaso transmission line from November 9, 2021, to December 6, 2021, following the collapse of a communication mast unto the line damaging three (3) towers. The incidence put the Ghana power system in an alert state and necessitated a reduction in the export to SONABEL for the period.

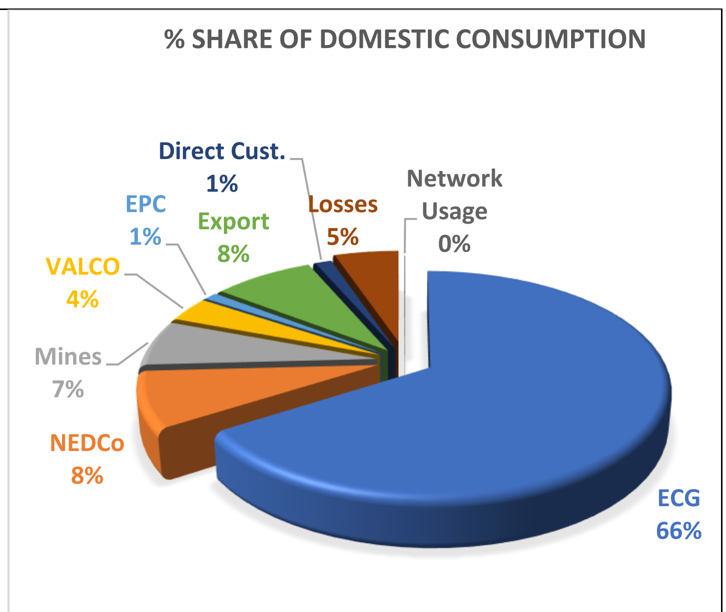
Transmission system loss recorded was slightly higher than the projected due to the same incident as well as the delay in the commissioning of the 330kV Anwomaso – Kintampo transmission line.

2.3.1 Domestic Consumption

ECG recorded a growth of 12.18% and accounted for 66% of the total domestic consumption. NEDCo recorded a growth of 11.42% and accounted for 8.0% of the total domestic consumption. VALCO consumption increased by 6.96% but could not meet the 2021 projected consumption due to their inability to fully run two potlines. The Mines and EPC on the other hand recorded reduction in growth of 5.96% and 4.00% respectively. A breakdown of the energy consumption by customer class is shown in Table 2.4.

Table 2.4: Domestic Consumption

Customer	Projection (GWh) 2021	Actual (GWh) 2021
ECG	13,583.00	14,194.91
NEDCo	1611.76	1,752.93
Mines	1845.73	1,409.86
VALCO	1055.13	771.76
EPC	306.03	232.47
Export	1527.26	1733.97
Direct Cust.	246.08	283.99
Losses	1079.96	1,075.93
Network Usage	10.56	10.44
Total Energy Transmitted	21,265.52	21,466.26



2.3.2 Exports

A total of 574.96 GWh and 962.00 GWh were exported to Togo/Benin and Burkina respectively during the period. Power exchange between Ghana and Cote d'Ivoire was made up of 197.01 GWh exports and 43.34 GWh imports (a net Exchange of 240.36 GWh). The import from Cote d'Ivoire was however inadvertent.

Table 2.5: Energy Export in 2020 and 2021

Customer/Year	2020	2021
Export to CEB (GWh)	715.23	574.96
Export to CIE (GWh)	149.37	197.01
Export to SONABEL (GWh)	990.47	962.00

2.3.3 Transmission Losses

A monthly breakdown of transmission losses recorded during the period is shown in Table 2.6.

Table 2.6: Monthly Transmission Losses for 2021

Month	Total Generation (GWh)	Losses (GWh)	% Loss
Jan	1,844.06	76.03	4.12%
Feb	1,708.68	85.06	4.98%
Mar	1,850.40	102.79	5.56%
Apr	1,847.64	115.77	6.27%
May	1,865.46	112.17	6.01%
Jun	1,729.45	99.18	5.73%
Jul	1,713.13	99.34	5.80%
Aug	1,683.48	93.36	5.55%
Sep	1,672.45	63.80	3.81%
Oct	1,806.95	69.01	3.82%
Nov	1,807.15	80.33	4.45%
Dec	1,937.40	79.11	4.08%

The total transmission losses recorded over the period was 1,075.95 GWh which is 5.01% of the total energy transmitted in 2021 (21,466.26 GWh). This is 0.37% below the projected loss in transmission of 1079.96 GWh.

Figure 2.1 compares the 2021 and 2020 transmission losses recorded.

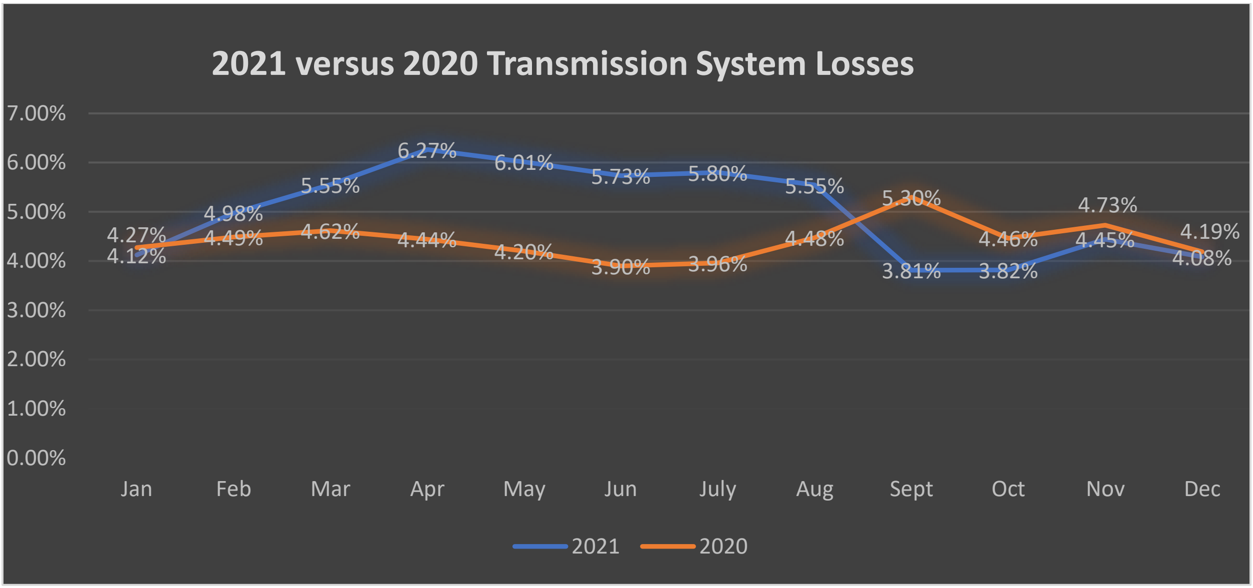


Figure 2.1: Comparison of 2021 and 2020 transmission losses

Comparing the losses for 2020 and 2021, figure 2.1 shows that losses increased between the month of February and August 2021. This was due to the conservative dispatch of the Bui hydro plant as a result of the low reservoir level in the first half of the year, causing poor voltages in Kumasi and the Northern parts of the grid. The voltage situation improved in the fourth quarter of the year when the 330 kV Anwomaso – Kintampo transmission line was completed and commissioned. In addition, dispatch of the Bui hydro plant was increased during the inflow season when there was an unusually high inflow into the reservoir.

2.3.3.1 System reinforcement in 2021 to reduce transmission losses

In 2021, GRIDCo put in the following investments to increase power transmission capacity and reduce transmission losses. These are:

- energization of the 330kV Anwomaso-Kintampo line,
- completion of the first phase of the upgrade of Volta-Achimota-Mallam line corridor and
- addition of a third 161/34.5 kV 50/66 MVA transformer at Anwomaso.

2.4 Energy Generation

The projected 2021 monthly energy generation based on the estimated availability factors of the generating plants are compared in Table 2.7 with the actuals recorded over the period.

Table 2.7: Projected versus Actual Energy generation for 2021

Months	Projected (GWh)					Actual (GWh)				
	Total Hydro (GWh)	Total Thermal (GWh)	Total Solar (GWh)	Import (GWh)	Total (GWh)	Hydro (GWh)	Thermal (GWh)	Solar (MW)	Import (GWh)	Total (GWh)
January	583.07	1,217.9	6.90	0	1,807.84	566.80	1,276.14	0.00	1.11	1,844.06
February	526.65	1,162.0	6.23	0	1,694.85	550.23	1,156.47	0.00	1.98	1,708.68
March	583.07	1,239.8	6.90	0	1,829.77	534.85	1,310.68	0.00	4.87	1,850.40
April	564.26	1,242.8	8.47	0	1,815.55	528.25	1,313.061	3.268	3.06	1,847.64
May	583.07	1,216.1	8.75	0	1,807.87	628.26	1,227.265	5.341	4.60	1,865.46
June	564.26	1,111.5	8.47	0	1,684.26	569.20	1,148.878	5.995	5.38	1,729.45
July	583.07	1,096.5	8.75	0	1,688.29	549.12	1,153.029	4.746	6.24	1,713.13
August	583.07	1,104.1	8.75	0	1,695.93	537.86	1,136.935	4.736	3.95	1,683.48
September	564.26	1,107.0	8.47	0	1,679.72	691.92	971.706	5.171	3.66	1,672.45
October	629.07	1,147.6	8.75	0	1,785.43	823.97	972.723	6.885	3.37	1,806.95
November	608.26	1,204.4	8.47	0	1,821.15	792.70	1,001.464	8.756	4.22	1,807.15
December	629.07	1,262.3	8.75	0	1,900.17	747.64	1,180.677	7.861	1.22	1,937.40

The proportions of the various types of generation are presented graphically in Figure 2.2.

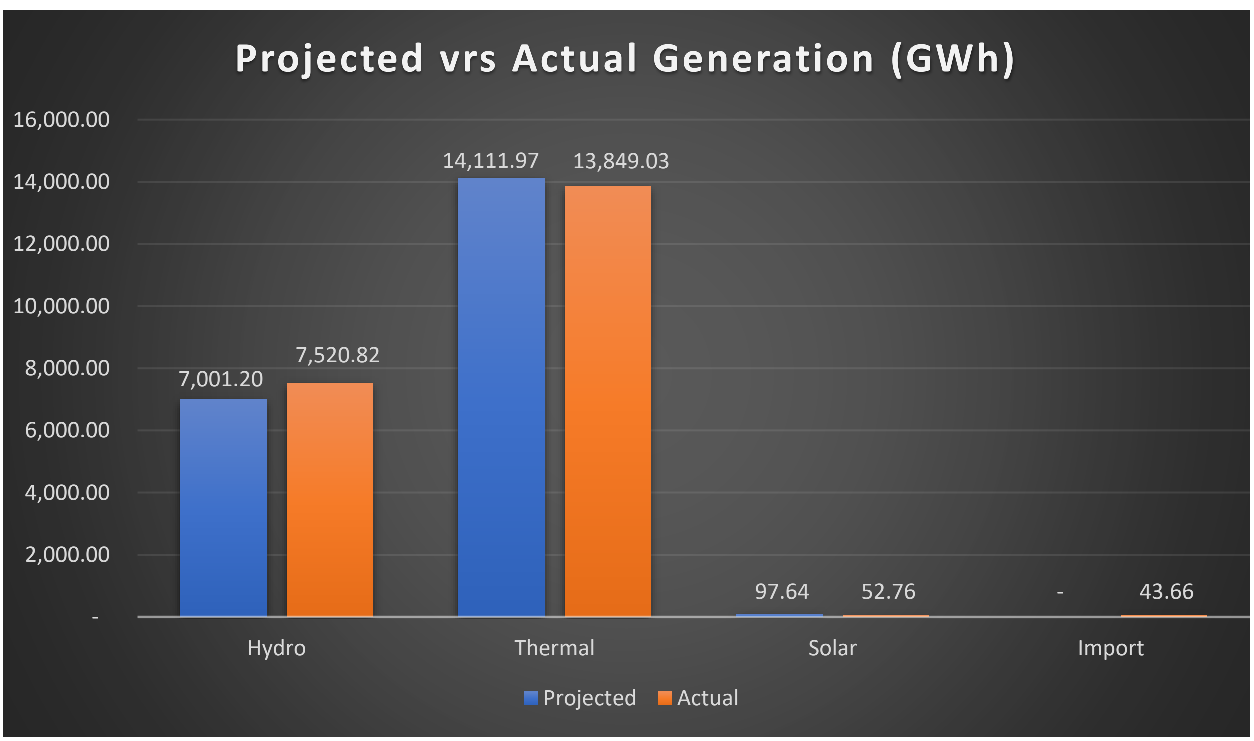
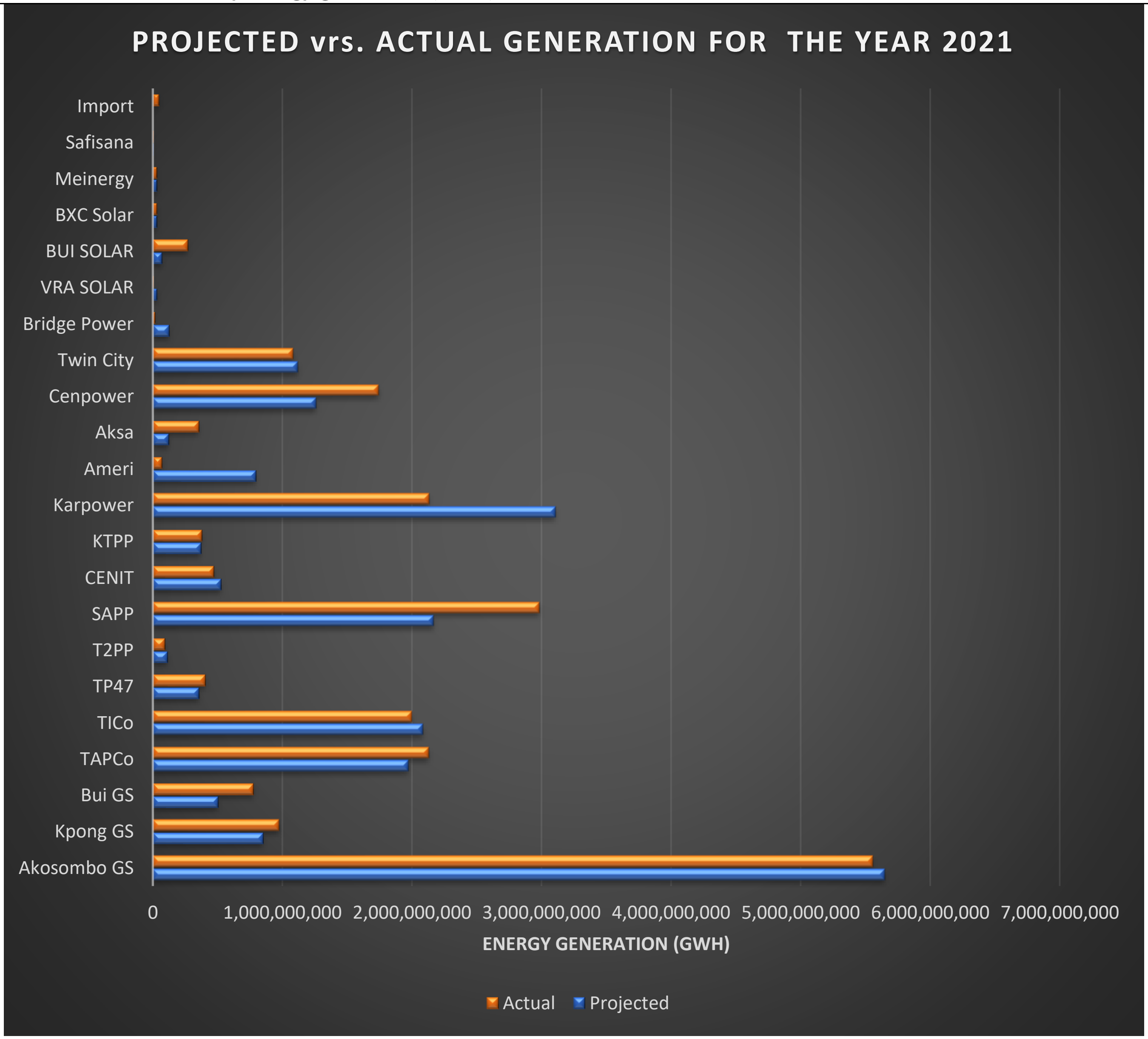


Figure 2.2 Projected versus Actual Energy Generation for 2021

Table 2.8 shows details of monthly generation by the individual plants in 2021. The table also shows the availability of the plants for Dispatch over the period. The Ameri plant recorded a low availability for the year when it was shutdown to enable processes for transfer of ownership to VRA and to relocate the plant to Kumasi.

Table 2.8: Comparison of projected and actual monthly energy generation (GWh)

Plant	(%) Availability
Akosombo	98.69
Kpong	99.22
Bui	97.86
TAPCO	87.80
TICO	86.26
TT1PP	87.17
KTPP	94.92
TT2PP	50.07
SAPP	91.50
CENIT	99.11
AMERI Power Plant	24.34
Karpower Barge	99.54
AKSA	99.65
CENPOWER	89.92
TWIN CITY	98.99
Bridge Power	-
Bui Solar	-
Kaleo Solar	-



The total energy generated over the period was 21,466.26 GWh; this was made up of 7,520.73 GWh (35.04%) from hydro generation, 13,849.03 GWh (64.52%) from thermal generation, 52.76 GWh (0.25%) from Solar (directly connected to the NITs) and 43.66 GWh (0.20%) import.

Figure 2.3 shows a graphical illustration of the actual generation mix for 2021

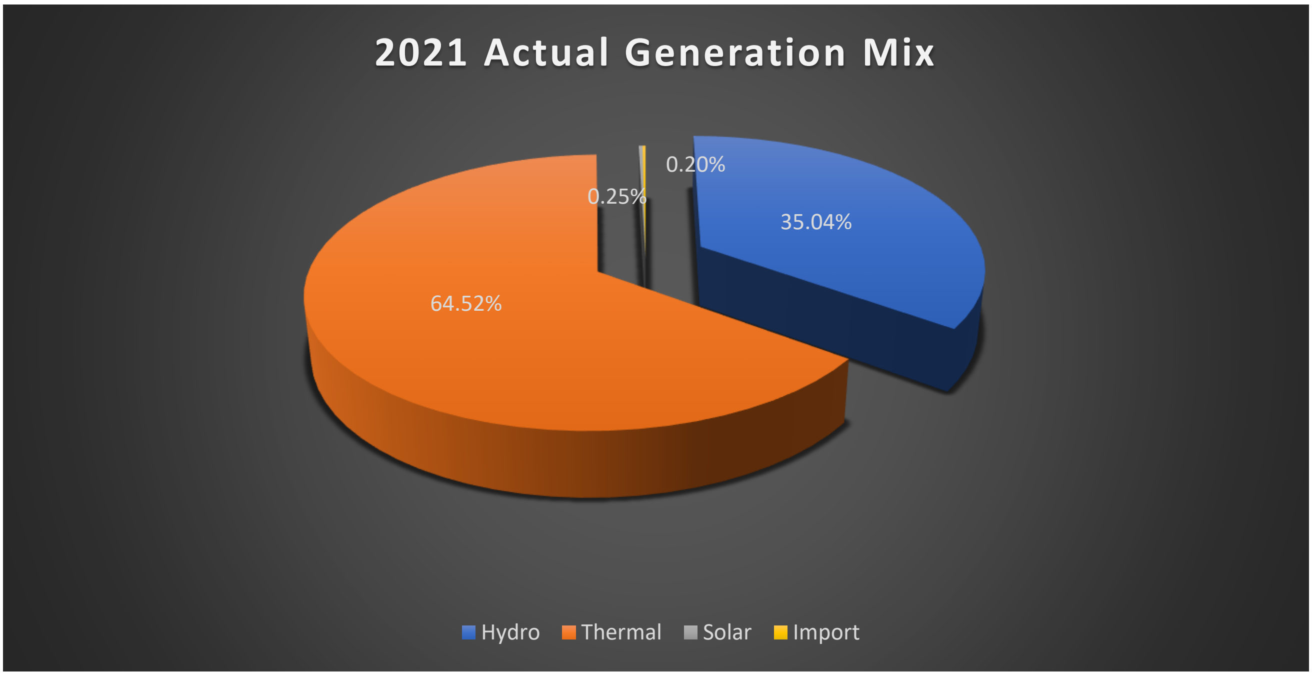


Figure 2.3: Generation Mix for 2021

2.5 Generation Facilities

2.5.1 Hydro Facilities

The projected dependable capacities and energies against the actual for the individual hydro plants are shown in Table 2.9.

Table 2.2.9: 2021 Projected and Actual Hydro Generation

Plants	Dependable Capacity (MW)	Projected Energy (GWh)	Actual Energy (GWh)	Variations	% Variations
Akosombo GS	900	5,650.00	5,557.15	92.85	1.64%
Kpong GS	140	850.00	972.47	-122.47	-14.41%
Bui GS	345	501.20	991.20	-490.00	-97.77%

From Table 2.9 the total hydro generation for 2021 was 7,520.82 GWh as against the projected of 7,001.20 GWh. This was made up of 5,557.15 GWh, 972.47 GWh and 991.20 GWh from Akosombo, Kpong and Bui generating stations, respectively.

2.5.1.1 Akosombo Reservoir

The elevation of the Volta Lake at Akosombo at the start of the year 2021 was 267.73 ft. (81.60 m) and at 269.19 ft. (82.04 m) at the end of the year. The recorded maximum Lake elevation at the end of the 2021 inflow season was 271.25 ft., which is 31.25 ft. above the minimum operating level of 240 ft. and a rise of 11.80 ft. above the minimum level recorded for 2021 (259.45 feet). The total net inflow recorded in 2021 was 31.01 MAF, which implies that an above average inflow of 30.01 MAF was obtained in 2021. The Akosombo GS reservoir trajectory for 2021 is shown in Figure 2.4.

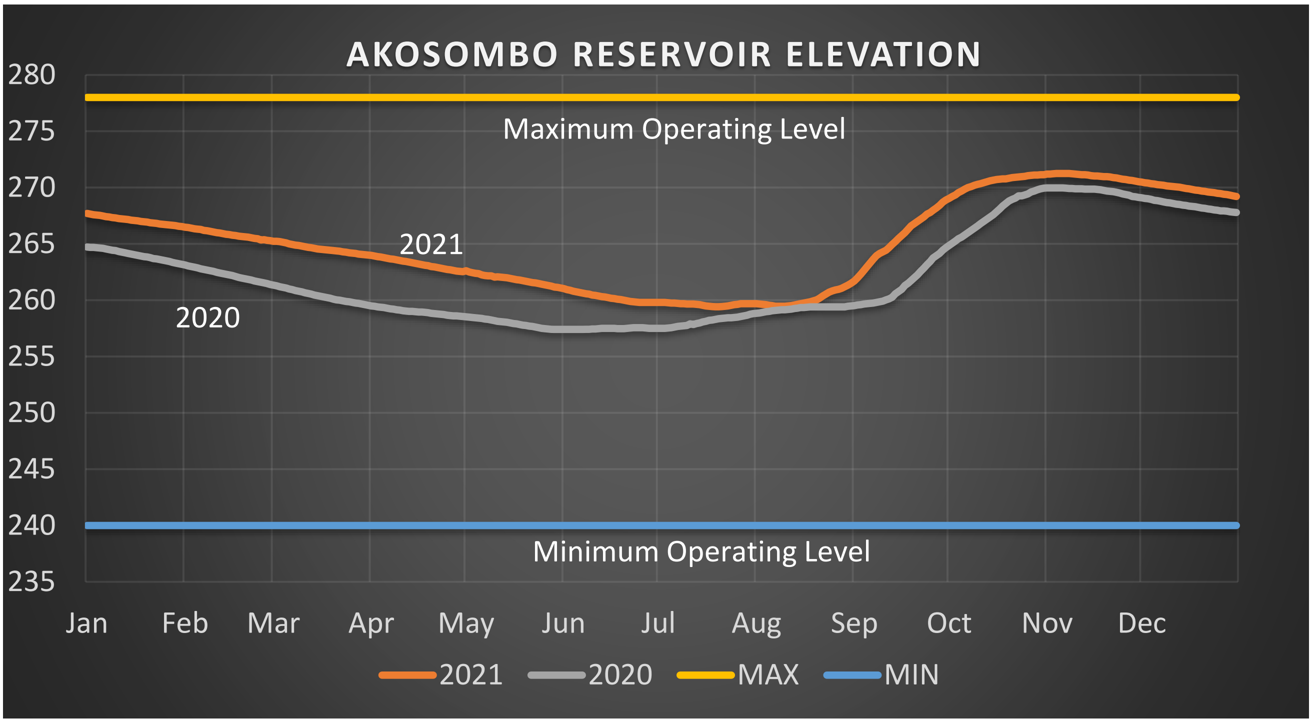


Figure 2.4: Akosombo Reservoir Trajectory for 2021

2.5.1.2 Bui Reservoir

The Bui Reservoir level at the beginning of 2021 was low at 172.16 masl. The reservoir dropped to a minimum water level of 166.70 masl on June 25, 2021, at the end of the dry season.

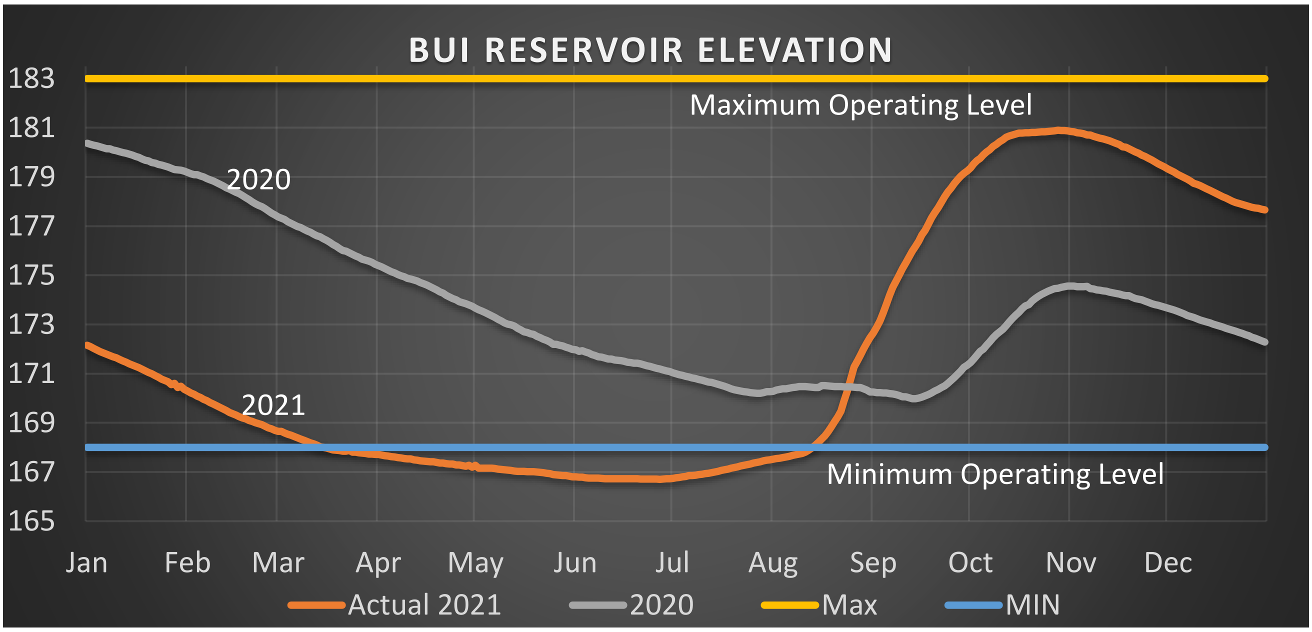


Figure 2.5: Bui Reservoir Trajectory 2021 versus 2020

This was the lowest elevation of the reservoir since the commissioning of the plant. The minimum level reached was thus 1.3 m below the Minimum Operating Level (MOL) of 168.00 masl. The reservoir elevation at the end of 2021 was 177.58 masl, which is 9.58m above the minimum operating level (168 masl). The maximum level attained during the inflow season was 180.90 masl on October 27, 2021. Figure 2.5 shows the Bui Reservoir trajectory for 2021 as against the trajectory for 2020.

2.5.2 Thermal Facilities

The Projected Dependable Thermal Capacities for 2021 was 3,301.00 MW which was made up of 1,492 MW and 1,809 MW from Eastern and Western Enclaves, respectively. The total thermal energy generated for the year was 13,849.03 GWh.

Table 2.10 details the capacities of the individual thermal plants and their energies generated.

Table 2.10: 2021 Thermal Capacities and Energy generated

	Plants	Dependable Capacity (MW)	Generated Energy (GWh)
Western Enclave	TAPCO (T1)	300	2,130.27
	TICO (T2)	320	1,997.66
	Ameri	230	66.82
	Twin City	192	1,081.80
	KAR Power	450	2,132.26
	Sub-Total	*1492*	*7,408.81*
Eastern Enclave	TT1PP	100	403.72
	TT2PP	80	89.68
	KTPP	200	378.49
	Sunon Asogli	530	2,984.23
	CENIT	100	469.69
	AKSA	330	355.92
	CEN Power	325	1,743.96
	Bridge Power	144	14.53
	Sub-Total	*1809*	*6,440.22*
TOTAL SUPPLY		**3301**	**13,849.03**

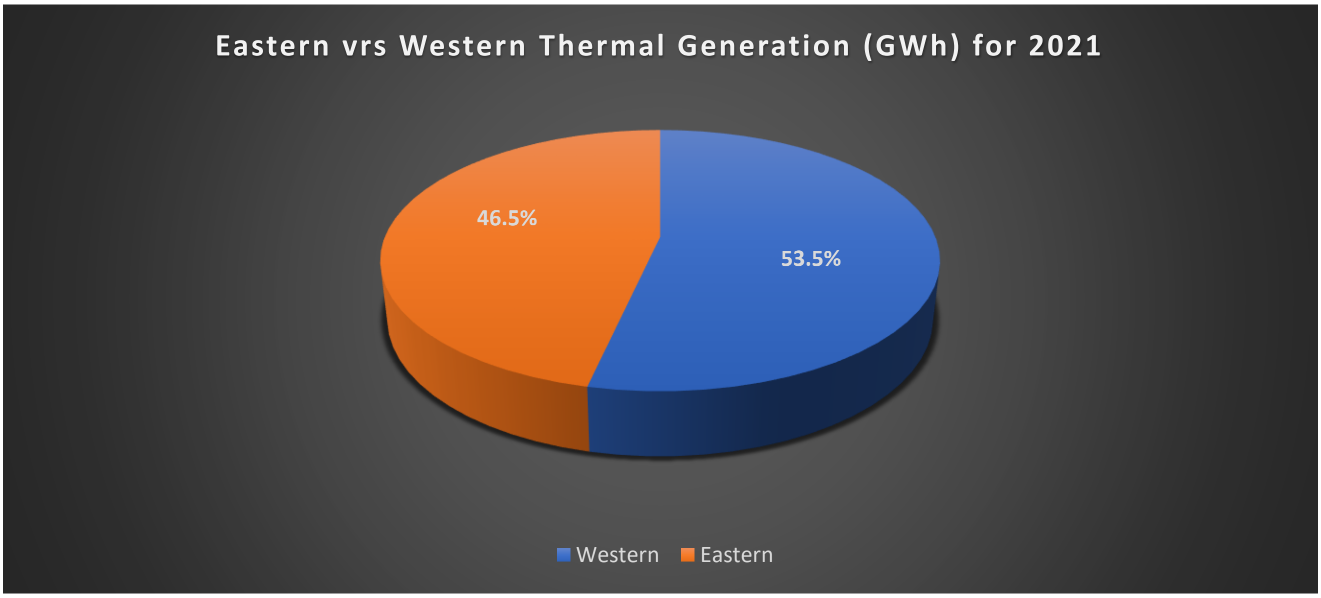


Figure 2.6: Eastern vrs Western Thermal Generation for 2021

2.5.2.1 Fuel Usage

2.5.2.1.1 Natural Gas Supply

Gas supply from the domestic gas sources – Jubilee, TEN and Sankofa for 2021 totaled 98,824 MMscf. Jubilee and TEN together constituted 34.1% of the total domestic gas offtake, with annual gas export of 33,689MMscf and a monthly average of 2,807MMscf. Sankofa gas exports made up 65.9% of the total domestic gas offtake for the year, with a total annual contribution of 65,136MMscf and a monthly average of 5,428MMscf.

2.5.2.1.2 Natural Gas Usage

The domestic gas consumption by plant for the year 2021 is shown in Table 2.12.

Table 2.11: Domestic Gas Consumption by Plants for 2021

Plant	Planned Gas (MMBtu)	Actual Gas (MMBtu)	Deviation (Planned – Actual)	%
TAPCO	17,641,463.00	17,680,401.00	-38,938.00	-0.22%
TICO	16,478,514.00	15,377,838.00	1,100,676.00	6.68%
TT1PP	4,133,376.00	4,886,248.00	-752,872.00	-18.21%
TT2PP	1,317,942.00	961,557.00	356,385.00	27.04%
KTPP	4,349,647.00	4,384,334.00	-34,687.00	-0.80%
AMERI	8,967,518.00	745,258.00	8,222,260.00	91.69%
Sunon Asogli	17,947,940.00	23,862,275.05	-5,914,335.05	-32.95%
Cenit	6,206,320.00	5,571,912.26	634,407.74	10.22%
Cenpower	10,358,917.00	13,159,957.00	-2,801,040.00	-27.04%
Karpower	25,101,546.00	18,151,419.92	6,950,126.08	27.69%
Twin City	9,216,291.00	8,414,249.89	802,041.11	8.70%
Bridge Power	1,427,013.00	0.00	1,427,013.00	100.00%
Aksa	756,759.00	0.00	756,759.00	100.00%
Total	**123,903,246.00**	**113,195,450.12**	**10,707,795.88**	**8.64%**

2.5.2.1.3 Maintenance of Natural Gas Supply Facilities

In January and February 2021, GNPC took enough gas from Sankofa to achieve the 45-day High Flow Test required to end the Run-in Period (ended on 22nd February 2021) under the Sankofa/OCTP GSA. This helped to reduce GNPC's monthly offtake obligation and liability. Jubilee, together with GNGC (Ghana National Gas Company), also successfully conducted a 12-hour high gas flow test during the first half of the year. This test was conducted to assess the maximum export capacity of the Jubilee offshore facilities and Atuabo Gas Processing Plant (GPP) and improve reliability of the facilities along that gas supply corridor.

Further to the above outage, the Atuabo Gas Processing Plant (GPP) underwent a planned maintenance in the month of October spanning a total of fourteen (14) days, starting from the 4th of October through to 18th October. There were no Jubilee/TEN gas exports for the period. In the same month of October, GNGC commissioned the Anokyi Mainline Compressor Station (AMCS).

WAPCo on the other hand, undertook an offshore lateral pipeline integrity assessment exercise which caused a shutdown for four hours on the 19th of December. This exercise curtailed gas offtake in Tema from the 20th to the 28th of December.

There were a number of challenges across the value chain, including offshore outages, shutdowns at the GPP as well as downstream challenges with the national electricity grid, which affected gas supply during the period.

2.5.2.1.4 Liquid Fuel Usage

The AKSA plant which is the only thermal plant that operates solely on liquid fuel (HFO) was dispatched as a strategic peaking plant to meet demand for the year 2021. When the plant is not in dispatch, it provides strategic reserve capacity to be called-in in case of emergency.

The Cenpower and Twin City plants which normally run on gas, also switched to operate on Light Crude Oil (LCO) during various periods of the year. This was in order to make up for generation capacity shortages caused by the reduction in gas supply whenever there were planned or forced shutdown of gas infrastructure.

The details of liquid fuel consumed per power plant in 2021 are as follows:

Table 2.12: Liquid Fuel Consumed 2021

Plant	Fuel type	Actual Volume (m^3)
TICO	LCO	30,764.52
Cenpower	LCO	24,528.00
Twin City	LCO	18,469.31
Aksa	HFO	73,766.23
KTPP	DFO	5,456.92

2.5.3 Renewables

A 50 MWp Bui Solar PV plant (including FPVs) and a 13 MWp VRA Kaleo solar PV plant were commissioned in April, 2021 and October 2021, respectively.

Table 2.13 details capacities of the existing renewables and their energies delivered for the year.

Table 2.13: Renewables Capacities and Energy generated

Plants	Source	Dependable Capacity (MW)	Projected Energy (GWh)	Actual Energy (GWh)
Connected on NITS				
BUI	SOLAR	50.00	68.00	49.92
KALEO	SOLAR	13.00	26.60	2.85
Embedded				
BXC	SOLAR	20.00	27.00	29.42
MEINERGY	SOLAR	20.00	27.00	26.95
SAFISANA	BIOGAS	0.10	0.70	2.31

2.6 System Disturbances

The Ghana Power System in the year 2021 experienced several disturbances caused mostly by transmission line faults and gas supply related trips, leading to supply interruptions to various consumers on the power system. Most significant is the total system collapse which occurred on March 7, 2021, as a result of a transmission line fault while the system was already operating in alert state. Below is a list of disturbances that occurred and their causes.

i. January 5, 2021: At 20:55 h, the 161 kV Kumasi – Konongo line tripped on fault resulting in cascaded trips to the 161 kV Anwomaso – Kumasi, Kumasi – New Obuasi, Nkawkaw – Anwomaso, Obuasi – Kenyasi transmission lines and all lines serving the northern part of the grid. By 22:06 h, all lines in addition to customer loads were restored.

ii. January 19, 2021: At 06:18 h, a system disturbance occurred when transmission trips initiated by faults on the 161 kV Techiman – Kintampo and the 161 kV Anwomaso – Kumasi lines resulted in cascaded trips to all lines serving the northern portion of the NITS. All lines and customers which were affected were restored by 07:53 h.

iii. February 3, 2021: At 00:49 h a snapped conductor on 161 kV Tarkwa – Takoradi line resulted in cascaded trips to the 161 kV Aboadze – Tarkwa, Prestea – Obuasi, Dunkwa – Bogosu and Bui – Techiman lines and all lines serving the northern portion of the NITS. The grid was fully restored by 01:40 h.

iv. March 07, 2021: At 14:04 h The Prestea – Obuasi transmission line tripped on a fault while Bui was not generating active power into the grid. This resulted in increased loading on the 330 kV Aboadze – Anwomaso transmission line causing overloading on the Anwomaso 330/161 kV transformers. The transformers tripped together with the 330 kV Aboadze-Anwomaso line and caused a severe surge on the NITS. This led to cascaded trips on other transmission lines and generating units in service, leading to a total system collapse. Restoration started immediately and by 18:30 h, supply had been restored to all bulk supply points.

v. March 19, 2021: At 14:14 h, system disturbance initiated by fault on the 161 kV Kumasi – Techiman line resulted in a trip to all lines serving the Techiman substation and subsequently resulting in an outage to the northern portion of the NITS. The system was however fully restored by 15:04 h.

vi. March 28, 2021: At 12:02 h, trip on the 161 kV Kumasi – Techiman and the 330 kV Aboadze – Anwomaso lines resulted in cascaded trips to all lines serving the northern portion of the NITS including the 225 kV Prestea – Bingerville, 161 kV Konongo – Kumasi and the 161 kV Dunkwa – Bogosu lines. Supply was fully restored by 14:32 h when the 225 kV Prestea – Bingerville line was brought back into service.

vii. April 3, 2021: At 23:06 h, the 161 kV Volta–Accra East line no. 1 tripped when a conductor on the line fell near the Accra East substation. This resulted in trips on all lines within the Volta – Achimota Corridor and subsequently customers served within the corridor. Generating plants in service at Aboadze also tripped. All lines except the faulted line and feeders which were taken out of service due to low voltages being recorded were fully restored by 14:01 h on April 4, 2021.

viii. April 12, 2021: At 13:36 h the 330 kV Takoradi Thermal-Anwomaso transmission line tripped, triggering cascaded trips on some other transmission lines and all generating units in service at Aboadze. Automatic frequency relays operated to take some customer loads during the disturbance. Restoration started promptly and by 14:05 h, all transmission lines which tripped had been restored.

ix. April 29, 2021: At 06:41 h the two (2) 330/161 kV auto transformers (2T1 and 2T2) at the Volta substation tripped due to a fire outbreak on 2T1 transformer. This resulted in cascaded trips on Aboadze – Volta – Asogli – Dawa – Davie 330 kV transmission circuit and some generating units in service at Aboadze and Tema. Automatic frequency relays operated to take some customer loads during the disturbance. By 09:21 h, all transmission lines which tripped and supply to all affected bulk supply points had been restored.

x. April 30, 2021: At 09:34 the 161 kV Prestea – New Tarkwa line tripped and led to cascaded trips on some other transmission lines and all generating units in service at Aboadze. Automatic frequency relays operated to take some customer loads during the disturbance. Restoration started promptly and by 11:37 h, all transmission lines which tripped had been restored, and supply had also been restored to all affected bulk supply points.

xi. May 23, 2021: At 11:27 h on Sunday May 23, 2021, the Volta 330/161 kV auto transformer no. 2 (2T2) tripped on overload and led to cascaded trips on some other transmission lines and generating units in service at Tema and Takoradi. Automatic frequency relays operated to take some customer loads during the disturbance. Restoration started promptly and by 15:33 h, all transmission lines which tripped had been restored, and supply had also been restored to all affected bulk supply points except Kumasi. Supply to Kumasi was eventually restored at 18:27 h.

xii. May 30, 2021: At 13:48 h the 161 kV Akosombo – Tafo transmission lines tripped due to an earlier tripping of the 161 kV Tafo – Nkawkaw line, while the 161 kV Cape Coast – Mallam, Winneba – Mallam and Akosombo-Nkawkaw lines were out of service for planned work. This led to power swings resulting in cascaded trips on some other transmission lines and generating units in service at Tema, Kpong GS and Takoradi. Automatic frequency relays operated to trip some customer loads during the disturbance. Restoration started promptly and by 18:26 h, all transmission lines which tripped had been restored, and supply had also been restored to all affected customers.

xiii. October 21, 2021: At 19:50 h, the 161 kV Takoradi Thermal – Takoradi transmission line No. 1, Takoradi Extension – Winneba, Takoradi Extension – Cape Coast lines together with the 330/161 kV auto transformer No. 2 at Takoradi Thermal generating station tripped, resulting in the interruption of power supply to Mallam, Cape Coast and Winneba. This was because of a fallen conductor on the Takoradi Extension – Winneba line. Power supply was subsequently fully restored by 22:59 h.

xiv. October 31, 2021: At 14:40 h, the 330 kV Volta – Pokuase – Takoradi Thermal transmission circuit tripped, resulting in cascaded tripping of other transmission lines and all generating units in service at Takoradi Thermal and Bui generating stations. This was as a result of a shattered lightning arrester on the 330 kV Amandi – Takoradi Thermal line. Power supply was fully restored by 20:45 h.

xv. November 8, 2021: At 19:50 h, the 330 kV Takoradi Thermal – Anwomaso transmission line tripped, resulting in cascaded tripping of other transmission lines and all generating units in service at Takoradi Thermal and Bui generating stations. Power supply was fully restored by 03:48 h November 9, 2021.

xvi. November 9, 2021: At 04:47 h, the 161 kV Anwomaso – Kumasi transmission line tripped due to a transient fault. The 330/161 kV auto transformers at Anwomaso became overloaded and tripped leading to interruption of power supply to some portions of Accra, the entire west, middle and north of the NITS. Power supply was fully restored by 21:15 h.

2.6.1 Gas/Fuel Related Disturbances

i. Compressor trip at ENI ORF on February 27, 2021

At 18:24 h on February 27, 2021, a compressor at the ENI Sankofa Onshore Receiving Facility (ORF) tripped, causing interruption of gas supply to Sunon Asogli, Amandi and Karpower. The units were shut down immediately to avoid tripping. Customer loads were taken off at Mallam, Smelter II, Anwomaso, Winneba and VALCO.

ii. ESDV closure at WAPCO Tema RMS on March 1, 2021

At 14:55 h on March 1, 2021, the emergency shutdown valve at the WAPCO Regulatory and Metering Station (RMS) in Tema closed, cutting off gas supply to Sunon Asogli. The plant was shut down immediately. Customer loads were taken off at Mallam, Winneba, Kumasi, and Cape Coast to correct the dipping frequency.

iii. ESDV closure at WAPCO Tema RMS on March 3, 2021

At 06:31 h on March 3, 2021, the emergency shutdown valve at the WAPCO regulatory and metering station in Tema closed, cutting off gas supply to Sunon Asogli. The plant was shut down immediately. Customer loads were taken off at Mallam to correct the falling frequency.

iv. Compressor trip at ENI Sankofa ORF on March 5, 2021

At 03:10 h on March 5, 2021, a compressor at the ENI Sankofa Onshore Receiving Facility (ORF) tripped, causing interruption of gas supply to Amandi and Karpower. Customer loads were taken off at Winneba to balance the frequency following the sudden generation shortfall when the generating units were shut down.

v. Sudden gas pressure dip at Takoradi RMS at Aboadze on March 5, 2021

At 10:08 h on March 5, 2021, TAPCO and TICO units suddenly de-loaded due to a sudden dip in gas pressure. KTPP was instructed to switch from gas to DFO due to falling gas pressure. The unit, however, tripped while switching over. Customer loads were taken off at Mallam and Asawinso to correct the falling frequency.

vi. ESDV closure at WAPCO Tema RMS on March 14, 2021

At 12:45 h on March 14, 2021, the emergency shutdown valve (ESDV) at the WAPCO regulatory and metering station in Tema closed, cutting off gas supply to Sunon Asogli, TT1PP, TT2PP, CENIT. The plants were shut down immediately. Customer loads were taken off at Mallam, Accra East and Kumasi to correct the falling frequency.

vii. Compressor trip at Ghana Gas on March 24, 2021

At 01:02 h on March 24, 2021, a compressor trip at Ghana Gas resulted in interruption of gas supply to KARPOWER, CENIT, and part loading of TICO and TAPCO. Customer loads were taken off at Accra East and Winneba to correct the falling frequency.

viii. Compressor trip at Ghana Gas on March 31, 2021

Reduced gas pressures from WAPCO resulted in shutdown of some generating plants resulting in outages at Accra East and Tamale to correct the falling frequency.

2.7 Quality of Supply

Technical Schedule TS-L of the Ghana Electricity Grid Code states that the NITS frequency shall be maintained between 49.8 Hz and 50.2 Hz at all times under normal state of operation. It also states that NITS voltage magnitudes shall be kept within ±5% of the nominal voltage at all times under normal state. In this section, some quality of supply parameters are considered.

2.8 System Frequency

In the year 2021, system frequency was within the normal range of 49.8Hz - 50.2Hz for 79.67% of the time as compared to the 78.51% recorded in 2020.
The others are:

- 49.5Hz - 49.8Hz – 1.74% of the time.
- 50.2 Hz - 50.5 Hz – 18.42% of the time.

Fig 2.7 shows the details of system frequency performance for the year.

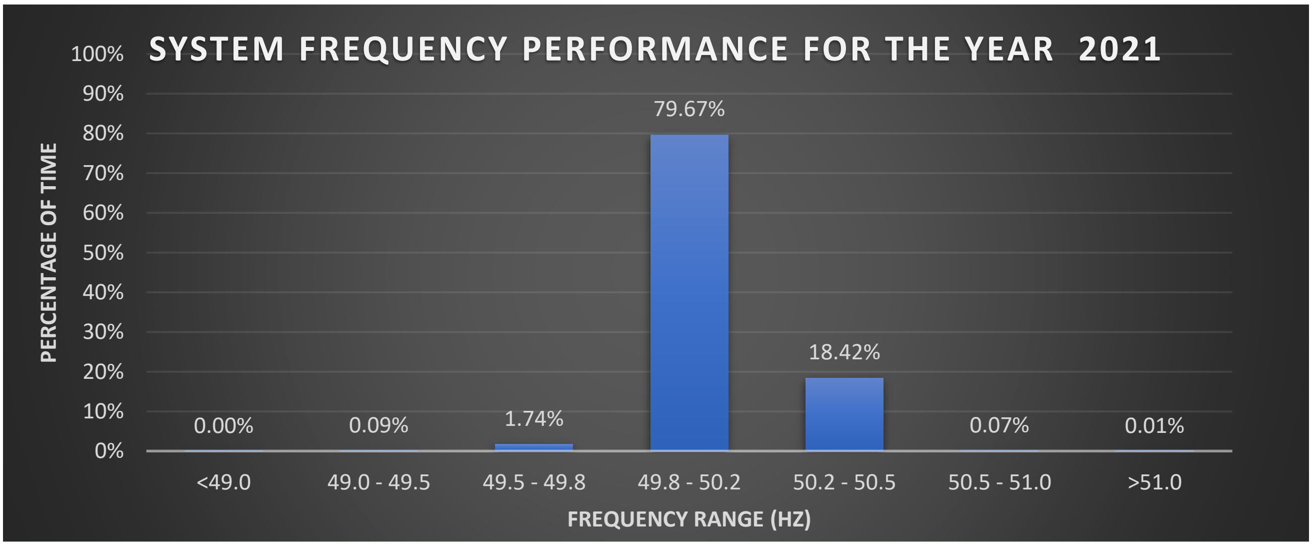


Figure 2.7: System Frequency for 2021

2.8.1 System Voltages

An analysis of voltage statistics at selected Bulk Supply Points (BSP) at peak time shows that voltages across the NITS were poor for Mallam and Kumasi substations. The Achimota, Takoradi, Tamale and

New Tema substations were however largely within the normal limits. The low voltages observed at Mallam are attributable to the period of upgrade works on the 161 kV Accra Central – Mallam and Achimota – Mallam transmission lines. During the period, the two lines were taken out of service leading to low voltages at the Mallam substation. Low voltages in Kumasi on the other hand were during the period when the Bui water level was low and thereby had to be shut down during the off-peak period with only one unit available for some peak periods. During this period, voltages recorded at Kumasi and its environs were low. Table 2.14 shows the details from the selected substations.

Table 2.14: System Voltages

Station	Number Of Days			Percentage		
	Normal	Below Normal	Above Normal	Normal	Below Normal	Above Normal
Achimota	292	73	0	80.00%	20.00%	0%
Mallam	185	180	0	50.68%	49.32%	0%
New Tema	214	0	151	58.63%	0%	41.37%
Kumasi	264	101	0	72.33%	27.67%	0%
Takoradi	354	11	0	96.99%	3.01%	0%
Tamale	363	1	1	99.45%	0.27%	0.27%

2.9 Transmission Network Performance

2.9.1 Power Supply (Feeder) Availability

The NITS registered an average feeder availability of 99.79% for the year. This performance was above the PURC approved benchmark of 95%.

2.9.2 Transmission Line Availability

The transmission lines recorded an average availability of 98.89% for the period, as shown in Table 2.15. The Table also shows average availability for the transmission lines of the various voltage classes.

Table 2.15: Transmission line availability for 2021.

Voltage Class	Availability %
69kV	99.68%
161kV	98.89%
225kV	96.27%
330kV	98.79%
System Average Availability	**98.89%**

Chapter 3

2022 DEMAND FORECAST

3 2022 DEMAND FORECAST

3.1 Introduction

The electricity demand projection for 2022, consisting of peak and energy demand assessment is presented in this chapter. A good demand forecast is important in power system operations planning to ensure a balance in electricity demand and supply at all times, as well as to ensure security of supply and stable power supply. It is not only required for operations planning, but is also a key input for generation capacity planning, transmission and distribution network investment decision making, fuel (thermal generation) procurement planning, maintenance scheduling as well as associated financial projection, etc.

Electricity demand largely depends on economic variables (socio-economic activities) as well as weather. Being a developing country, electricity demand in Ghana has grown significantly over the past years and is expected to continue to grow as it has in the previous years.

Electricity demand in Ghana can be classified into:

- Domestic demand which refers to electricity consumption within the operational area of Ghana (excluding VALCO). This includes consumption that is typically served through the Distribution networks such as the Electricity Company of Ghana, Northern Electricity Distributing Company and Enclave Power Company as well as the Mines, other bulk consumers who off-take supply directly from the NITS such as Diamond Cement, etc;
- VALCO demand; and
- Demand from cross border power exports. Cross border export in Ghana is either with CEB(Togo/Benin), SONABEL(Burkina) or CIE (Côte d'Ivoire).

3.1.1 Distribution network Demand Forecast Methodology

There are three electricity distribution systems that operate in Ghana. These are the Electricity Company of Ghana (ECG), Northern Electricity Distribution company (NEDCo) and Enclave Power Company (EPC). The distribution company load adds up to about 76% of the load on the NITS. The demand forecast for the major distribution companies (i.e., ECG and NEDCo) was based on the 2022 projection for GDP growth in Ghana.

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.

The Demand forecast for the Ghana power system for the year 2022 was carried out using forecast models based on the intrinsic growth patterns for each category of customers, after accounting for losses. Regression analyses was used to determine the relationship between historical energy consumption and macro-economic indicators such as GDP, Population growth (Customer Population) and Price of electricity. The relationship derived was used to forecast the electricity demand using projected macroeconomic indicators and future electricity price. This procedure was used to project residential, commercial, and small industrial loads. Demand from spot loads, especially large industrial consumers, was also factord.

3.2 2022 Peak Demand

The projected base case coincident peak demand for 2022 (for the Ghana Power System) is 3,545.27 MW. This implies a growth of 9.2% (an increase of 299.27 MW) over the 2021 peak demand of 3,246 W which occurred on December 8, 2021.

The 2021 demand survey exercise carried out identified the following which are expected to contribute to drive the 2022 peak demand:

- Growth in ECG and NEDCo load due to network expansions.
- Expected completion and commissioning of various ongoing rural electrification projects within the ECG and NEDCo distribution zones in 2022.
- VALCO's peak demand to remain at 95 MW through the year.
- Increase in export to SONABEL (Burkina Faso)- from an average of 140 MW in 2021 to a maximum 160 MW in 2022.
- Exports to CEB (Togo/Benin) projected at an average of 60 MW and maximum 120 MW.
- Growth in demand from 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 2022 Peak Demand Projections

Table 3.1 presents a detailed breakdown of 2022 Projected Peak Demand showing the individual Load Entity/Distributing Company.

Table 3.1: Summary of 2022 Projected Peak Demand

Demand	Customer		2022 – Projected Coincident Peak (MW)
Domestic Peak Demand	ECG		2,328.00
	NEDCo		306.04
	Enclave Power		58.99
	Mines	AngloGold	216.21
		Goldfields	
		Sankofa	
		Ahafo/Kenyase (Newmont)	
		New Abirim (Newmont)	
		Golden Star (Wasa)	
		Perseus (Ayanfuri)	
		Golden Star Bogosu	
		Akwatia Diamond	
		Talos	
		Adamus	
		Asanko Gold	
		Drill Works	
		Earl Int	
	Other Bulk Customers	Akosombo Textiles	78.03
		Aluworks	
		GWCL	
		Enclave Power Company	
		Diamond Cement	
		G.P. Station Level	
		Volta Hotel	
		Savana Cement (Buipe)	
		Rider Steel	
		VRA Townships	
	Losses +Network Usage		163
Total Domestic Peak Demand			3,150.27
Exports	CEB	100	
	CIE	50	
	SONABEL	150	
Total Exports			300
VALCO			95
Coincident Peak Demand MW			3,545.27

The Pie-Chart below illustrates the composition of the projected 2022 Peak Demand, showing the percentage share of each customer class. As shown in the Chart, ECG has the highest demand, constituting 66% of the total system peak, NEDCo 9%, followed by Exports and Mines at 8% and 6% respectively. VALCO 3%. Other Bulk Consumers constitute 2% of total peak demand.

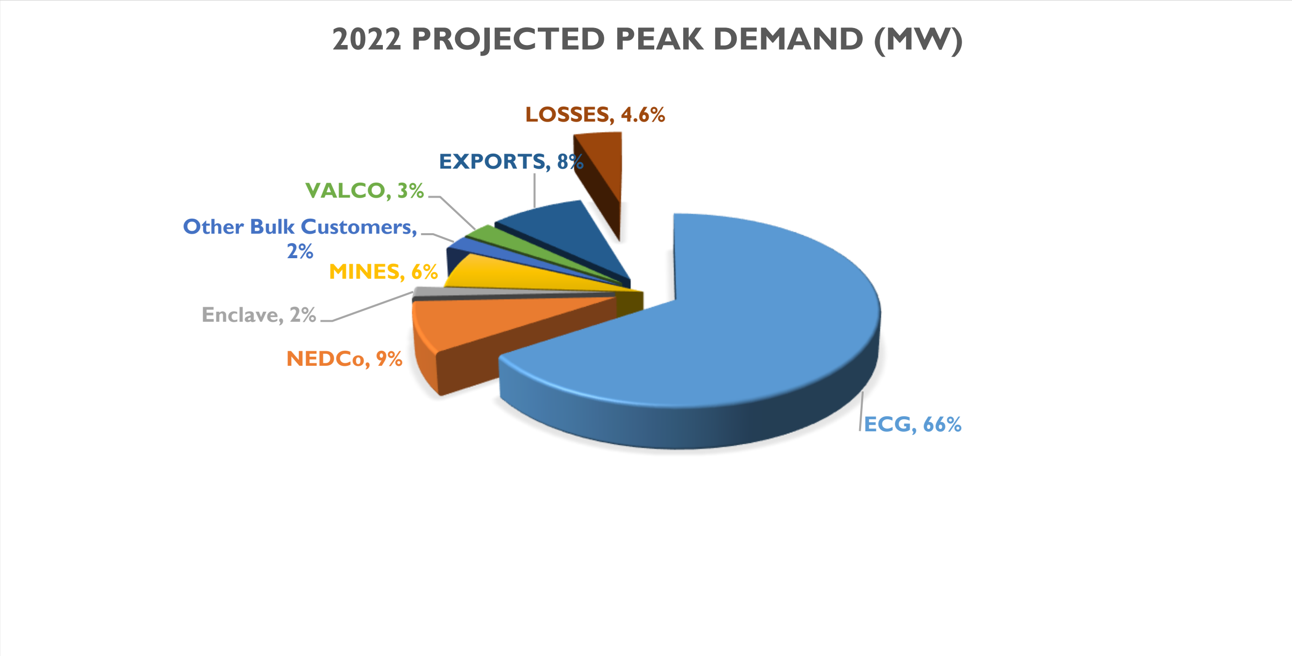


Figure 3.1: 2022 projected peak demand 2022

3.3 2022 Energy Consumption Projections

In 2022, the projected base case energy consumption is **23,578.51** GWh, which includes transmission network losses and station service usage of 1,069.04 GWh. The estimated transmission losses and usage, represents a 4.54% of total projected energy supply. The projected 2022 energy consumption represents an increase of 2,098.04 GWh (growth of 9.77 %) over the 2021 consumption of 21,466.26GWh.

The summary of 2022 consumption by customer class is presented in Table 3.2.

Table 3.2: Summary of 2022 consumption by Consumer class

Energy	Consumer	2022 – Projected Consumption (GWh)
Domestic Consumption	ECG	15,817.28
	NEDCo	1,903.73
	Enclave Power Company	283.80
	Mines	1,406.06
	Other Bulk Customers	379.25
	Losses + Network Usage	1,069.79
Total Domestic		20,859.91
Exports	CEB	650.00
	CIE	252.00
	SONABEL	1,051.20
VALCO		765.40
Total Energy (GWh)		**23,578.51**

Figure 3.2 below shows a pie-chart representation of the projected energy consumption of the various customer classes in 2022 and their percentages. As shown, ECG's consumption of 15,817.28 GWh represents 67% of the total projected energy consumption for 2022. It is followed by Exports and

NEDCo with projected consumption of 1,953.20 and 1,903.73 GWh respectively representing about 8% each of total consumption.

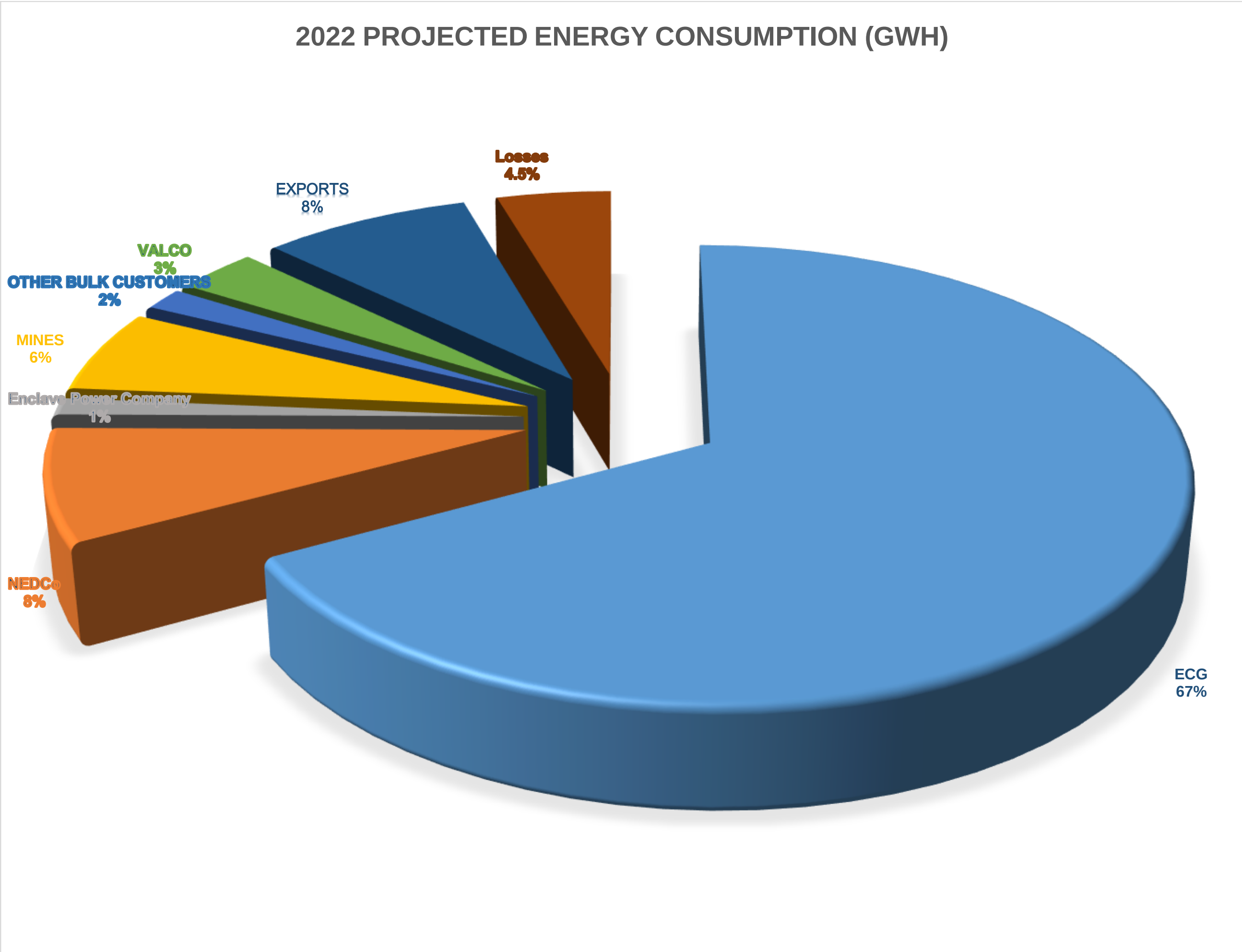


Figure 3.2: 2022 Projected Energy consumption by Customer

3.4 Projected Monthly Peak Load and Energy Demand for 2022

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

Table 3.3:Projected 2022 Monthly Energy (GWh) Consumption – Base Case

Energy Forecast (GWh)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total GWh
ECG	1358.74	1271.53	1389.88	1361.80	1357.21	1234.71	1225.92	1241.72	1232.14	1332.23	1373.76	1437.64	**15,817.28**
NEDCo	146.04	153.03	153.53	177.31	155.66	154.18	147.60	149.09	150.53	168.55	174.11	174.11	**1,903.74**
Enclave Power Company	19.20	21.08	20.64	24.20	25.54	24.48	24.89	23.78	25.36	27.00	26.33	21.31	**283.81**
MINES	122.59	107.79	119.43	115.25	119.05	109.92	119.85	116.76	117.79	120.39	117.47	119.78	**1,406.07**
Other Bulk Customers	21.85	20.73	21.70	34.07	34.18	33.55	37.15	36.27	34.03	36.38	34.16	35.19	**379.26**
VALCO	64.02	57.48	62.47	62.14	65.91	63.44	61.97	66.76	66.22	65.91	64.82	64.26	**765.40**
CEB(Togo/Benin)	94.81	86.06	73.12	54.39	51.01	44.35	38.33	29.60	30.31	46.38	45.07	56.57	**650.00**
SONABEL(Burkina)	87.20	80.80	89.60	86.40	89.60	86.40	89.60	89.60	86.40	89.60	86.40	89.60	**1,051.20**
CIE (Ivory Coast)	31.00	28.00	31.00	30.00	31.00	20.00	15.00	10.00	10.00	10.00	14.00	22.00	**252.00**
EDM(Mali)	0	0	0	0	0	0	0	0	0	0	0	0	**0.00**
Network Usage	0.95	0.89	0.96	0.96	0.95	0.87	0.87	0.87	0.87	0.94	0.96	0.99	**11.08**
LOSSES	95.27	89.44	96.05	95.27	94.47	86.73	86.20	86.36	85.83	92.87	73.52	76.72	**1,058.73**
Total	**2,041.66**	**1,916.82**	**2,058.37**	**2,041.78**	**2,024.57**	**1,858.63**	**1,847.38**	**1,850.81**	**1,839.47**	**1,990.25**	**2,010.59**	**2,098.18**	**23,578.51**

3.5 Projected Monthly Peak and Energy Demand for 2022

Table 3.4: Projected 2022 Monthly Peak (MW) demand – Base Case

Coincident Peak Demand (MW)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ECG	2,148.73	2,205.14	2,199.55	2,197.32	2,239.20	2,166.32	2,032.85	2,076.97	2,068.59	2,171.35	2,272.99	2,328.00
NEDCo	291.13	296.97	300.36	305.08	301.33	288.94	266.98	276.39	285.02	294.43	313.25	306.04
Enclave Power Company	56.05	54.64	55.67	57.62	58.32	62.25	65.52	62.07	61.47	59.22	57.53	58.99
MINES	217.17	217.2	217.23	217.24	217.22	217.26	217.21	217.27	217.04	216.75	216.47	216.21
Other Bulk Customers	58.09	56.16	60.29	79.45	79.09	78.06	77.83	76.45	75.29	78.85	78.39	78.03
VALCO	95	95	95	95	95	95	95	95	95	95	95	95
CEB(Togo/Benin)	120	120	120	120	120	110	100	100	100	100	100	100
SONABEL(Burkina)	150	150	160	160	160	160	160	160	160	155	160	150
CIE (Ivory Coast)	50	50	50	50	50	40	40	40	40	40	40	50
EDM(Mali)	0	0	0	0	0	0	0	0	0	0	0	0
Network Usage	1.88	1.92	1.93	1.94	1.96	1.9	1.81	1.83	1.83	1.9	1.97	2
LOSSES	167.54	170.64	171.32	172.56	174.59	169.21	160.66	163.23	163.14	169.09	158.68	161
System Peak (Coincident)	**3,355.59**	**3,417.67**	**3,431.35**	**3,456.21**	**3,496.71**	**3,388.94**	**3,217.86**	**3,269.21**	**3,267.38**	**3,381.59**	**3,494.28**	**3,545.27**

Chapter 4

2022 GENERATION OUTLOOK

4.1 Generation Sources

The sources of generation considered in the ESP for 2022 are primarily 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 2022. A total existing generation capacity of 5,366 MW with a dependable capacity of 4,618 MW is considered for 2022.

Table 4.1: Existing Generation Sources for 2022

Plants	Installed Capacity (MW)	Dependable Capacity (MW)	Fuel Type
Akosombo GS	1020	900	Hydro
Kpong GS	160	140	Hydro
Bui GS	404	360	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
AMERI	250	230	Gas
Takoradi Thermal Extension (T3)	132	0	Gas
CENIT	110	100	LCO/Gas
SAPP 161	200	180	Gas
SAPP 330	360	340	LCO/Gas
Karpower	470	450	Gas
AKSA	370	330	HFO
Cenpower	360	325	LCO/Gas
Twin City	215	198	LCO/Gas
Bui Solar	50	0	Solar
VRA Solar Plant (Kaleo)	13	0	Solar
Embedded Generation			
VRA Solar Plant (Navrongo)	2.5	0	Solar
VRA Solar Plant (Lawra)	6.5	0	Solar
BXC Solar	20	0	Solar
Meinergy Solar	20	0	Solar
Safisana	0.1	0	Waste-to-Energy
Genser	123	75	Gas
TOTAL	5,366.10	4,618	

4.3 Hydro Power Generation for 2022

Projected total annual hydro generation for 2022 is 7,394.15 GWh. This is made up of 5,513.3 GWh from Akosombo GS, 986.7 GWh from Kpong GS and 894 GWh from Bui GS.

4.3.1 Akosombo & Kpong Hydro

VRA is expected to continue with its SCADA installation project at the Akosombo GS. in 2022 that will make up to of 5 units available for a greater part of 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 maintenance work is ongoing. The Akosombo GS is planned to generate a total of 5,513.3 GWh in 2022.

At an Akosombo GS year start elevation of 269.11 feet (82.02 m) this mode of operation is expected to result in a total drop in elevation of approximately 9.33 feet (2.84 m) resulting in a projected minimum elevation of 259.78 feet (79.18 m). The projected Akosombo reservoir elevation chart for 2022 is shown in Figure 4.1.

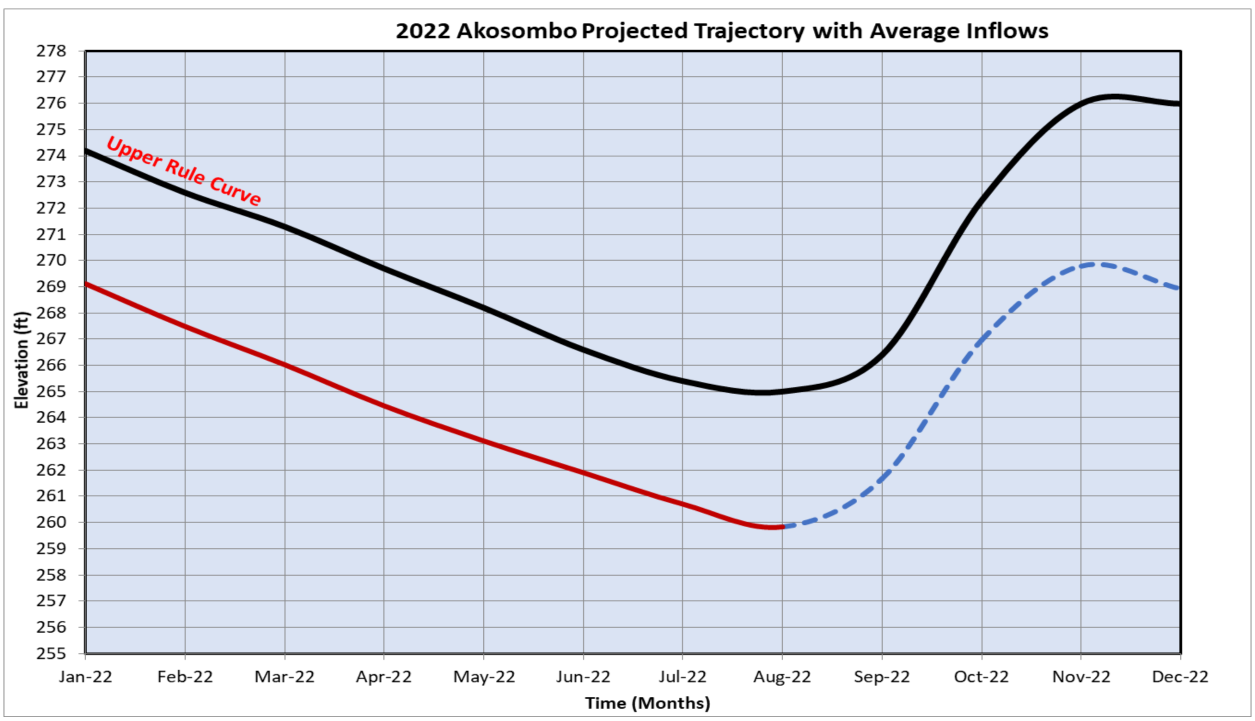


Figure 4.1: 2022 Projected Akosombo Reservoir Trajectory

The Akosombo reservoir projected year start elevation of 269.11 feet (82.02 m) is very high. The elevation is about 6 feet (1.83 m) below the Upper Rule Curve, and this poses a risk of spilling of water from the reservoir if very high inflows are recorded in 2022.

The Kpong GS is projected to have all four (4) units in service in 2022. The total average capacity that is expected to be available at Kpong GS is 140 MW. The Kpong GS is expected to generate 986.7 GWh in 2022.

On the basis of the above mode of operation, the projected total annual hydro generation from Akosombo and Kpong generating stations is 6,500 GWh.

We note that the inflow recorded in 2021 was approximately 32 MAF, hence an inflow of 40 MAF is possible in 2022. Based on our analysis, inflows above 40 MAF is likely to lead to spilling from the Akosombo GS in the year 2022. To reduce the likelihood of spilling in 2022, it would be critical to achieve the planned level of generation at the Akosombo and Kpong hydro stations.

4.3.2 Bui Hydro

The Bui Hydro Plant is expected to continue with planned Level 'A' maintenance in the first and second quarters which will result in a maximum availability of two units during that period.

In 2022, Bui Hydro Plant is projected to produce 894 GWh for the year, i.e.., at an average of two (2) units. The plant is therefore assumed to supply an average generation capacity of 220 MW to support demand.

It is estimated that, for continuous and sustainable operation of the Bui GS for 2022, the reservoir level at the end of the dry season in 2022 should not drop below elevation 170.00 masl. With a year-start elevation projected to be 177.58 masl in 2022, and the estimated total energy production for 2022, the year-end elevation is projected at 174.58 masl.

Assumptions for projected 2022 generation from the Bui Generating Station:

- ✓ Inflow of 4,625 Mm^3 (75% of Long-Term Average Inflow of 6,167 Mm^3)
- ✓ The 2022 Year start elevation of Bui Reservoir – 177.58 masl

- ✓ Operate averagely two units in normal mode at 100MW, 110MW or 120MW each for between 8 – 24 hours daily from January to December 2022 depending on the reservoir elevation.
- ✓ Operate the Turbinette at 3.75 MW from January 1 to December 31, 2022.
- ✓ Planned maintenance will be carried out on the units as scheduled during the year.

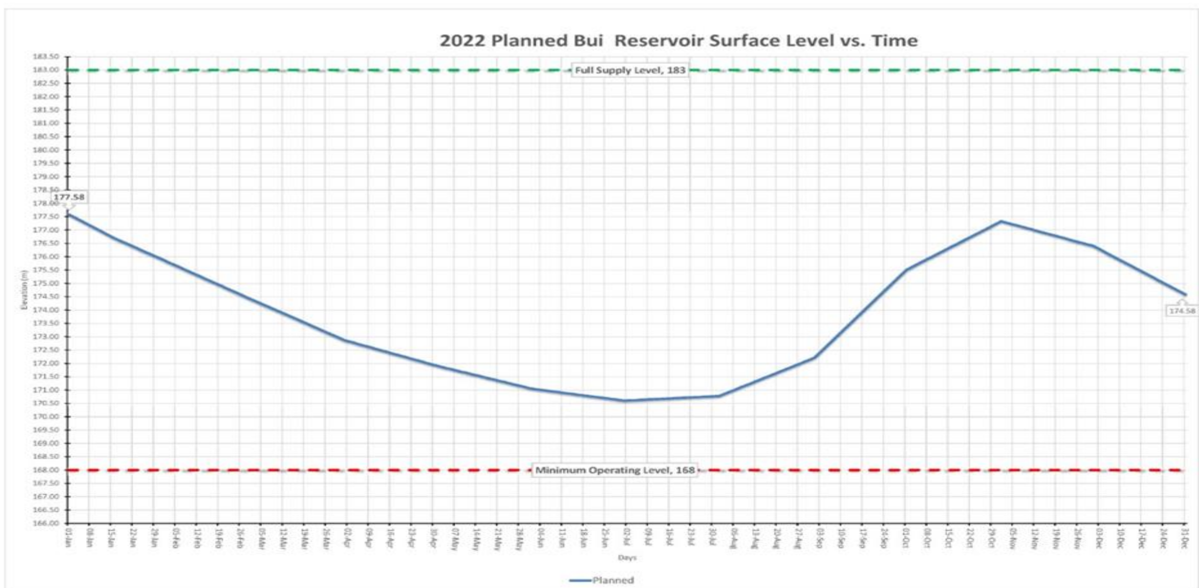


Figure 4.2: 2022 Projected Bui Reservoir Trajectory

4.4 Thermal Power Generation for 2022

The Projected Dependable Thermal Capacity from the existing generation resources is 3,306 MW. Bridge Power was expected to commission a 220 MW thermal power plant, however the developers are carrying out some works to convert the plant from running on LPG to Natural gas. As a result, the plant will not be in operation in 2022. The projected total thermal energy generation for 2022 is consequently 16,000 GWh. This is shown in Table 4.2.

Table 4.2: Summary of Thermal Generation

Generation Sources	2022 Projected Thermal Supply (GWh)
TAPCO	2,002.90
TICO	2,298.60
TT1PP	347.50
KTPP	375.40
TT2PP	111.70
AMERI Power Plant	572.40

Takoradi Thermal Extension (T3)	-
Imports From Cote d'Ivoire	-
SAPP	2,068.70
CENIT	744.60
Karpowership	3,347.30
AKSA	249.40
Cenpower	2,466.80
Twin City	1,414.70
Total Thermal Supply (GWh)	**16,000.00**

4.5 Renewable Energy Generation Sources

A total generation of 184.3 GWh is expected from Renewable Energy sources in 2022.

VRA has a total of 22 MW solar PV plants made up of the 2.5 MWp Solar power plant embedded in the NEDCo network at Navrongo, 6.5 MWp at Kaleo and a 13 MWp plant at Lawra. The Bui Power Authority (BPA) also has a 50MWp for Bui Solar PV farm at Bui. The Bui Solar PV farm is expected to add an additional 50MWp from July 2022. The BPA also has the embedded Tsatsadu Microhydro Plant which operates at 40kW from April 2022 to October 2022 (based on the hydrology) to generate about 0.2 GWh of electricity during the period.

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. These are all embedded in the ECG network. The summary of generation from the solar power plant sources is as shown in Table 4.3.

Table 4.3: Summary of Renewable Energy Generation

Generation Sources	2022 Projected Renewable Energy Supply (GWh)
Directly connected on the NITS	
Bui Solar Farm	94.8
VRA Solar (Kaleo)	21.9
Embedded	
VRA Solar (Lawra)	9.9
VRA Solar (Navrongo)	3.0
BXC Solar	27.0
Safisana	0.7
Mienergy	27.0
Total Renewable Supply (GWh)	**184.3**

4.6 Key Assumptions Underpinning the Supply Outlook

In developing the 2022 Supply Outlook, the following key assumptions were made:

4.6.1 Relocation of the Ameri Power Plant

Arrangements for the relocation of the 250 MW Ameri power plant from Takoradi Thermal to Kumasi is currently ongoing. The plant is expected to become operational by September 2022.

4.6.2 Planned Maintenance

The schedule of key maintenance activities expected to be undertaken in 2022 on generating units at the various power plants is shown in Appendix B.

4.6.3 Natural Gas Quantities and Availabilities

Gas supply from the Jubilee and TEN fields is still limited to 125 MMscfd in line with the GPP operating capacity of 135 MMscfd of raw gas. Sankofa is expected to maintain its capacity to supply 210 MMscfd. Supply from N-Gas is expected to average around 50 MMscfd in the first half of the year, then increase to 60 MMscfd in Q3 and to 80MMscfd in Q4.

4.6.4 Gas Infrastructure Maintenance for 2022

Planned maintenance activities for the year 2022 include:

1. The OCTP FPSO and ORF was shut down for maintenance for 5 days from the 21st to 26th of February 2022. This curtailed gas export from the Sankofa production facility. Jubilee and TEN gas were available to partly make up for the Sankofa gas during this period. Liquid fuel was used to supplement the thermal generation requirement during that period

2. The Jubilee FPSO is expected to shut down for maintenance for 12 days from 28th April to 11th May 2022. TEN will fully substitute Jubilee gas during this period. There are no scheduled maintenance activities for the TEN and Tema LNG facilities.

3. Maintenance on GNGC's Takoradi Distribution Station (TDS) for 17 days from 15th March to 2nd April 2022 was successful. GNGC plans to carry out a maintenance programme for the Atuabo Gas Processing Plant (GPP) to be scheduled for a period of10

days in the July to October 2022 window. This will potentially affect gas supply, but the impact is yet to be determined.

4. The West African Gas Pipeline (WAPCo) will conduct its mandatory semi-annual Emergency Shutdown (ESD) tests in Tema and Takoradi in January and will conduct the second test in July for a period of 3-4 hours. WAPCo has also provided a shutdown programme of between 7 and 10 days to be scheduled between July and October for the replacement of twelve (12) defective valves on the Takoradi process area. WAPCo is expected to conduct an external inspection and mitigation of higher risk areas on the main offshore pipeline in the year. However, there are no planned shutdown maintenance activities that will affect gas supply in the Tema area.

Figure 4.3 shows projections for gas supply in Ghana from the various sources in 2022.

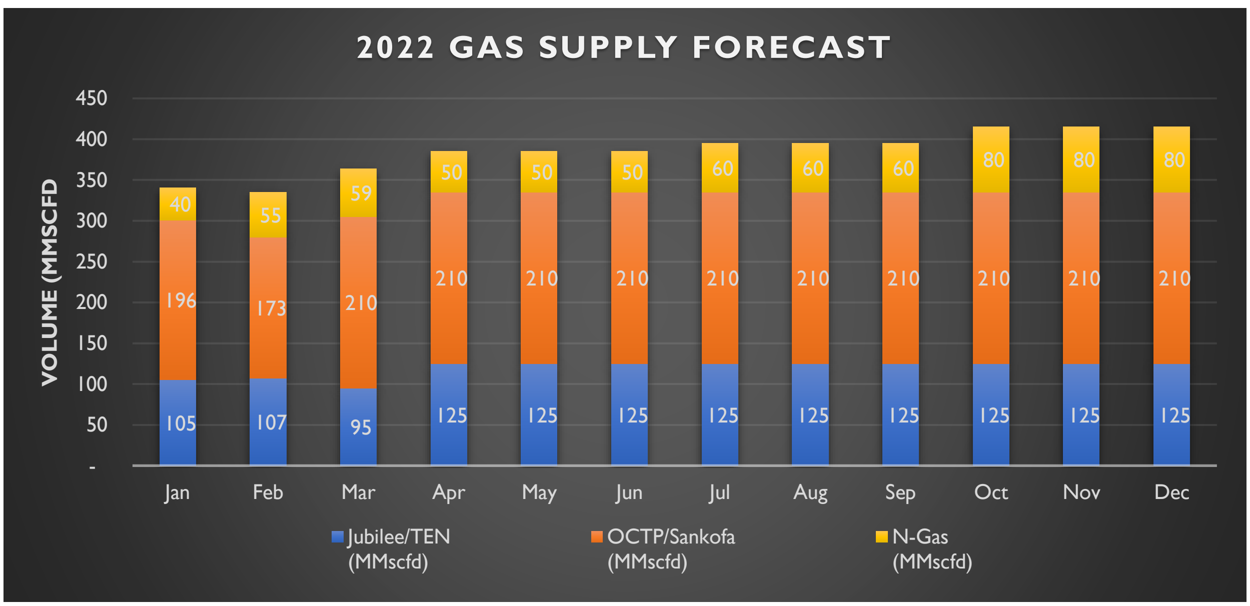


Figure 4.3: 2022 Monthly Gas Supply Volume Projection

4.6.5 Fuel Price

The following assumptions on price of fuel delivered were made:

- Natural Gas – US$ 6.08/MMBtu
- Delivered LCO – US$ 100/barrel
- Delivered HFO – US$ 490/MT.

4.7 Demand - Supply Analysis

This sub-section analyses the demand – supply balance for the year 2022. 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 following considerations are used to determine which Plants are dispatched on monthly basis:

- Power plant nomination based on new Dispatch Protocol
- Availability of fuel for Power Plants
- Must-run Plants (e.g., Solar)
- System Stability Requirements.
- PURC and EMOP (Electricity Market Oversight Panel) energy allocation for the year

Hydro Dispatch. For system stability and also based on the EMOP allocation, 6500 GWh of energy is expected to be dispatched from Akosombo and Kpong GS in 2022. Dispatchers at the System Control Centre, GRIDCo are expected to manange the dispatch of the twin hydro plants so that their cumulative energy generation by the end of 2022 is as close as possible to the EMOP allocation, as they did for the EMOP allocations in 2020 and 2021.

Also, the Bui hydro power plant is dispatched taking into consideration the level of inflows during the just ended inflow season and the level of dispatch that will ensure that the plant does not run out of water. A total of 7,394 GWh of hydro generation is projected for 2022.

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 184.3 GWh is expected from all the solar and other renewable sources.

Thermal Power Plants Dispatch. The schedule for the thermal power plants assumes there is adequate fuel supply (natural gas and HFO) for running all plants. It also takes into consideration the fact that to achieve system stability, there is the requirement to schedule in the Western Corridor (ie. the Takoradi Themal Enclave) a minimum of 300 MW and 400 MW generation capacity during off-peak and peak periods respectively. Additionally, a minimum 650 MW of generation capacity is required from the Eastern Corridor (ie. the Tema Thermal Enclave).

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 2022 energy demand/supply projections are presented in Tables 4.4 and Table 4.5:

Table 4.4: Monthly Energy Balance Projrction (GWh) for January – June 2022

Consumer Category	Jan	Feb	Mar	Apr	May	Jun
Domestic	1,764.60	1,664.50	1,802.20	1,808.90	1,787.10	1,644.40
VALCO	64	57.5	62.5	62.1	65.9	63.4
Export (CEB+SONABEL+CIE)	213	194.8	193.7	170.8	171.6	150.8
Projected Energy Consumption	**2,041.70**	**1,916.80**	**2,058.40**	**2,041.80**	**2,024.60**	**1,858.60**
Generation Sources						
Akosombo GS	486.4	444.2	486.5	467.7	482.1	422.9
Kpong GS	83.5	75.9	83.5	81	83.6	81.1
TAPCO	195.2	177.9	195.2	189.4	195.2	189.5
TICO	195.2	176.3	195.2	188.9	195.2	188.7
TT1PP	-	53.8	-	57.6	-	57.6
KTPP	63.2	-	63.2	-	63.2	-
TT2PP	9.5	8.6	9.5	9.2	9.5	9.2
AMERI Power Plant	-	-	-	-	-	-
VRA Solar (Navrongo)	0.3	0.3	0.3	0.2	0.2	0.2
VRA Solar (Kaleo)	2.3	2	2.2	1.8	1.5	1.5
VRA Solar (Lawra)	0.9	0.8	0.9	0.9	0.7	0.7
Imports From Cote d'Ivoire	-	-	-	-	-	-
Bui GS	92	83	92	56	57	51
Bui Solar Farm	5.4	5.4	5.4	5.4	5.4	5.4
SAPP	172.1	221.1	185.4	314.3	239.3	181.4
CENIT	63.2	57.1	63.2	61.2	63.2	61.2
Karpowership	281.1	257	284.6	275.4	284.6	275.4
AKSA	56.9	51.4	56.9	9.2	9.5	9.2
Cenpower	209.5	189.2	209.5	202.8	209.5	202.8
Twin City	120.2	108.5	120.2	116.3	120.2	116.3
Bridge Power	-	-	-	-	-	-
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)	**2,041.70**	**1,916.80**	**2,058.40**	**2,041.80**	**2,024.60**	**1,858.60**

Table 4.5: Monthly Energy Balance Projection (GWh) for July – December 2022

Customer Category	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Domestic	1,642.5	1,654.9	1,646.6	1,778.4	1,800.3	1,865.7	**20,860.0**

VALCO	62.0	66.8	66.2	65.9	64.8	64.3	**765.4**
Export (CEB+SONABEL+CIE)	142.9	129.2	126.7	146.0	145.5	168.2	**1,953.2**
Projected Energy Consumption	**1,847.4**	**1,850.8**	**1,839.5**	**1,990.3**	**2,010.6**	**2,098.2**	**23,578.57**
Generation Sources							
Akosombo GS	437.0	436.9	452.7	470.7	455.5	470.7	**5,513.3**
Kpong GS	83.6	83.6	81.0	84.3	81.5	84.3	**986.9**
TAPCO	183.7	74.3	81.9	195.2	189.5	135.7	**2,002.9**
TICO	195.2	195.2	188.9	195.2	188.9	195.2	**2,298.6**
TT1PP	-	59.5	-	59.5	-	59.5	**347.5**
KTPP	63.2	-	61.2	-	61.2	-	**375.4**
TT2PP	9.5	9.5	9.2	9.5	9.2	9.5	**111.7**
AMERI Power Plant	-	-	140.8	145.5	140.8	145.5	**572.4**
VRA Takoradi Extension	-	-	-	-	-	-	**0.0**
VRA Solar (Navrongo)	0.2	0.2	0.2	0.3	0.3	0.3	**3.0**
VRA Solar (Kaleo)	1.6	1.7	1.8	1.8	2.0	1.9	**21.9**
VRA Solar (Lawra)	0.7	0.8	0.8	0.9	0.9	0.9	**9.9**
Imports From Cote d'Ivoire	-	-	-	-	-	-	**-**
Bui GS	52.0	52.0	60.0	81.0	107.0	111.0	**894.0**
Bui Solar Farm	10.4	10.4	10.4	10.4	10.4	10.4	**94.8**
SAPP	118.6	235.1	81.2	44.3	94.2	181.8	**2,068.7**
CENIT	63.2	63.2	61.2	63.2	61.2	63.2	**744.6**
Karpowership	284.6	284.6	275.4	284.6	275.4	284.6	**3,347.3**
AKSA	9.5	9.5	9.2	9.5	9.2	9.5	**249.4**
Cenpower	209.5	209.5	202.8	209.5	202.8	209.5	**2,466.8**
Twin City	120.2	120.2	116.3	120.2	116.3	120.2	**1,414.7**
Early Power	-	-	-	-	-	-	**-**
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)	**1,847.4**	**1,850.8**	**1,839.5**	**1,990.3**	**2,010.6**	**2,098.2**	**23,578.57**

Figure 4.4 is a pie-charted presentation of the energy generation in 2022 showing the percentage share of each generation type. The Chart indicates that, thermal generation will constitute 68% of projected total generation whilst generation from hydro and Solar PV will constitute 31% and 1% respectively. This indicates the diminishing dominance of hydro power generation in Ghana's overall generation mix.

The high penetration and increasing dominance of thermal generation in the overall generation mix means since the thermal plants are predominantly gas-fired, any disruption in gas supply could have dire consequences on the security of power supply in the country.

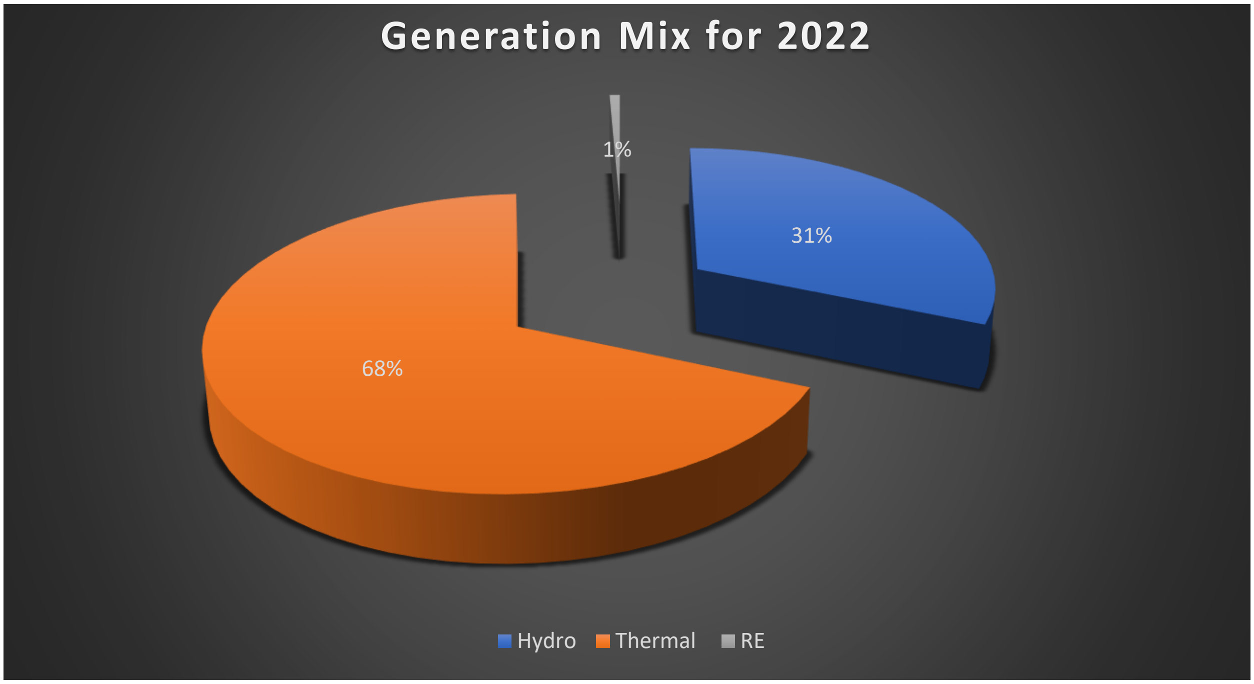


Figure 4.4: Contribution of Supply by Generation

4.8 Operating Reserve

Operating Reserves are that generation capacity above firm system demand that are required to meet the standards of an adequately responsive system for regulation, to cater for real-time mismatches between generation and demand as well as make up for generation equipment forced and scheduled outages.

Operating Reserve Requirement

Both the deterministic and probabilistic approach for the determination of operating reserve margin were employed. For the deterministic approach, a worst-case scenario of the coincidental loss of Karpowership (450 MW) and Twin City (190 MW) power plants through forced outage, fuel supply constraints or transmission constraints, e.g., the event of an outage to the 330 kV transmission circuit evacuating power from the two plants was considered. This is equivalent to the loss of 640 MW of generation. This represents 18% of the projected peak demand of 3,545.27 MW for 2022.

For the probabilistic approach, reference was made to the 2011 Ghana Generation Adequacy Assessment report as well as the 2011 Generation Master Plan reports. Both reports recommended a reserve margin of 18% of projected peak.

Thus, the reserve margin requirement for our targeted reliability of supply is set at 18% of projected peak demand.

Load serving entities and bulk consumers are consequently responsible for the arrangement of firm generation capacity that is adequate to reliably meet their firm demand witth its corresponding 18% operating reserve requirements.

4.9 Projected Capacity Situation

The projected monthly Supply Capacity levels, taking planned unit maintenance and Fuel Supply into consideration is shown in Table 4.6.

Table 4.6: Projected Monthly Capacity Situation for 2022 (January – June 2022)

Customer Category	2022 Projected System Peak (MW)	Jan	Feb	Mar	Apr	May	Jun
Domestic	3,150.27	2,941	3,003	3,006	3,031	3,072	2,984
VALCO	95	95	95	95	95	95	95
Export (CEB+SONABEL+CIE)	300	320	320	330	330	330	310
Projected System Demand	**3,545.27**	**3,356**	**3,418**	**3,431**	**3,456**	**3,497**	**3,389**
Generation Sources	**Dependable Capacity (MW)**						
Akosombo	900	900	900	900	900	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	70	22	22	22	22	22	22
AMERI	230	0	0	0	0	0	0
VRA Takoradi Extension	120	0	0	0	0	0	0
VRA Solar Plants	22	0	0	0	0	0	0
Imports From Cote	0	0	0	0	0	0	0
Bui GS	345	220	220	220	220	220	220
Bui Mini 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
Karpowership	450	450	450	450	450	450	450
AKSA	330	330	330	330	330	330	330
Cenpower	350	350	350	350	350	350	350
Twin City	198	198	198	198	198	198	198
BridgePower	200	0	0	0	0	0	0
Trojan	0	0	0	0	0	0	0
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)	**4,949**	**3,964**	**3,964**	**3,964**	**3,964**	**3,814**	**3,814**
Surplus/deficit (MW)	**1,404**	**609**	**546**	**533**	**508**	**317**	**425**
18% Required Reserve	**638**	**604**	**615**	**618**	**622**	**629**	**610**
Actual Reserve Margin	**40%**	**18%**	**16%**	**16%**	**15%**	**9%**	**13%**

Table 4.7: Projected Monthly Capacity Situation for 2022 (July – December 2022)

Customer Category	2022 Projected System Peak (MW)	Jul	Aug	Sep	Oct	Nov	Dec
Domestic	3150.27	2,823	2,874	2,872	2,992	3,099	3,150
VALCO	95	95	95	95	95	95	95
Export (CEB+SONABEL+CIE)	300	300	300	300	295	300	300
Projected System Demand	**3545.27**	**3,218**	**3,269**	**3,267**	**3,387**	**3,494**	**3,545**
Generation Sources	**Dependable Gen. Capacity (MW)**						
Akosombo	900	750	750	750	750	750	750
Kpong GS	140	140	140	140	140	140	140
TAPCO	300	300	100	100	300	300	300
TICO	320	320	320	320	320	320	320
TT1PP	100	100	0	100	0	100	0
KTPP	200	0	100	0	100	0	100
TT2PP	70	22	22	22	22	22	22
AMERI	230	0	0	230	230	230	230
VRA Takoradi Extension	120	0	0	0	0	0	0
VRA Solar Plants	22	0	0	0	0	0	0
Imports From Cote	0	0	0	0	0	0	0
Bui GS	345	220	220	220	220	220	220
Bui Mini 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
Karpowership	450	450	450	450	450	450	450
AKSA	330	330	330	330	330	330	330
Cenpower	350	350	350	350	350	350	350
Twin City	198	198	198	198	198	198	198
BridgePower	200	0	0	0	0	0	0
Trojan	0	0	0	0	0	0	0
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)	**4,949**	**3,784**	**3,614**	**3,844**	**4,044**	**4,044**	**4,044**
Surplus/deficit (MW)	**1,404**	**566**	**345**	**577**	**663**	**550**	**499**
Required Reserve (18%)	**638**	**579**	**588**	**588**	**609**	**629**	**638**
Actual Reserve Margin	40%	18%	11%	18%	20%	16%	14%

The analysis of the above monthly demand and supply situation for 2022 shows monthly positive generation reserve margins ranging between 9% (317 MW) and 20% (663 MW) in 2022. A reserve margin of 317 MW means during that month if two units of capacity 150 MW each are lost, the system will still be in a position to meet projected demand. However, with the planned gas supply outages due to maintenance works, generation capacity outage could be up to 750 MW. This level of outage would pose supply challenges if provision for alternative fuel supply is not made. Hence there is the need to ensure the availability of fuel at all times for the power system to realize the anticipated reliability of supply that the reserve margin provides.

4.10 Thermal Fuel Requirement

Currently all thermal power plants in Ghana (except AKSA) run on Natural Gas as their primary fuel for power generation. The AKSA plant is currently in the process of converting some of its units to run on Natural Gas. There is therefore the need to invest in systems to ensure a high reliability of gas supply for power generation.

A few of thermal plants can also run on either Light Crude Oil (LCO) or Diesel Fuel Oil (DFO) as secondary fuel. These plants provide strategic options for generation in instances where gas supply interruptions occur. It is critical for strategic stocks of liquid fuel (LCO, HFO and DFO) to be kept at the respective power plants to be used in instances when there are gas supply interruption.

The summary of major fuel requirements for 2022 is as presented below:

- **Natural Gas:** Based on the assumed gas supply from the domestic suppliers in Ghana and imports from Nigeria, the total natural gas consumption for 2022 is projected to be about 137.242 Tbtu.

- **LCO:** There would be no significant requirement for LCO for the year 2022. This is because the existing gas production facilites at the Sankofa, Jubilee and TEN fields together with imports from Nigeria have adequate capacity to supply expected gas demand.

  LCO stock as of January 1, 2022, at VRA power station at Tema and Takoradi was 43,605.49 barrels and 178,658 barrels, respectively. However, because of the anticipated gas supply outages it will be necessary to make provision for about 550,000 barrels of LCO to support the operation of about 850 MW generation capacity for a period of 20 days to cover the anticipated duration of gas supply disruption in 2022.

- **HFO:** The AKSA Plant is scheduled to operate on HFO in 2022. The plant is expected to operate to support peak demand and during the gas supply outages.
- **Diesel:** The diesel stock as of January 1, 2022, was 21,012 cubic meters. It is imperative to make provision for an additional 24,000 cubic meter of diesel in 2022. This will make it possible for 2 gas turbines (220 MW) to operate for about 25 days each.

Monthly Fuel Requirement

The breakdown of Monthly fuel requirements and their associated costs are shown in Table 4.8.

Table 4.8: Monthly fuel requirements and associated costs (January – June 2022)

	Units	Jan	Feb	Mar	Apr	May	Jun
Estimated Thermal Fuel Requirement	**Units**						
TAPCO - GAS	mmbtu	1,745,912	1,591,377	1,745,912	1,694,400	1,745,912	1,694,400
TICO - GAS	mmbtu	1,542,868	1,393,558	1,542,868	1,493,098	1,542,868	1,493,098
TT1PP - GAS	mmbtu	-	628,992	-	673,920	-	673,920
KTPP - GAS	mmbtu	744,967	-	744,967	-	744,967	-
TT2PP - GAS	mmbtu	111,935	101,102	111,935	108,324	111,935	108,324
AMERI Power Plant - GAS	mmbtu	-	-	-	-	-	-
Karpowership - GAS	mmbtu	2,270,880	2,076,233	2,298,686	2,224,535	2,298,686	2,224,535
SAPP - GAS	mmbtu	1,425,468	1,831,533	1,535,572	2,603,644	1,982,623	1,502,766
CENIT - GAS	mmbtu	746,394	674,162	746,394	722,317	746,394	722,317
TWIN CITY - GAS	mmbtu	989,629	893,858	989,629	957,705	989,629	957,705
CENPOWER - GAS	mmbtu	1,723,011	1,556,268	1,723,011	1,667,430	1,723,011	1,667,430
AKSA - HFO	barrels	125,215	113,098	125,215	20,196	20,869	20,196
Total Natural Gas Volume (MMBtu)		**11,301,064**	**10,747,084**	**11,438,974**	**12,145,374**	**11,886,026**	**11,044,496**
ESTIMATED FUEL COST							
Total Natural Gas Cost @ US$ 6.08/mmbtu	MMUS$	68.71	65.34	69.55	73.84	72.27	67.15
Total HFO Cost @ US$ 70/bbl	MMUS$	8.77	7.92	8.77	1.41	1.46	1.41
Total Fuel Cost (US$ Million)	**MMUS$**	**77.48**	**73.26**	**78.31**	**75.26**	**73.73**	**68.56**

Table 4.9: Monthly fuel requirements and associated costs (July – December 2022)

	Units	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
Estimated Thermal Fuel Requirement	**Units**							
TAPCO - GAS	mmbtu	1,642,889	664,167	732,849	1,745,912	1,694,400	1,213,625	**17,911,756**
TICO - GAS	mmbtu	1,542,868	1,542,868	1,493,098	1,542,868	1,493,098	1,542,868	**18,166,025**
TT1PP - GAS	mmbtu	-	696,384	-	696,384	-	696,384	**4,065,984**
KTPP - GAS	mmbtu	744,967	-	720,936	-	720,936	-	**4,421,741**
TT2PP - GAS	mmbtu	111,935	111,935	108,324	111,935	108,324	111,935	**1,317,942**
AMERI Power Plant - GAS	mmbtu	-	-	1,587,747	1,640,672	1,587,747	1,640,672	**6,456,840**
Karpowership - GAS	mmbtu	2,298,686	2,298,686	2,224,535	2,298,686	2,224,535	2,298,686	**27,037,372**
SAPP - GAS	mmbtu	982,425	1,947,756	673,024	366,661	780,161	1,505,636	**17,137,267**
CENIT - GAS	mmbtu	746,394	746,394	722,317	746,394	722,317	746,394	**8,788,186**
TWIN CITY - GAS	mmbtu	989,629	989,629	957,705	989,629	957,705	989,629	**11,652,082**
CENPOWER - GAS	mmbtu	1,723,011	1,723,011	1,667,430	1,723,011	1,667,430	1,723,011	**20,287,070**
AKSA - HFO	barrels	20,869	20,869	20,196	20,869	20,196	20,869	**548,658**
Total Natural Gas Volume (MMBtu)		**10,782,804**	**10,720,830**	**10,887,966**	**11,862,153**	**11,956,655**	**12,468,840**	**137,242,265**
ESTIMATED FUEL COST								
Total Natural Gas Cost @ US$ 6.08/mmbtu	MMUS$	65.56	65.18	66.20	72.12	72.70	75.81	**834.43**
Total HFO Cost @ US$ 70/bbl	MMUS$	1.46	1.46	1.41	1.46	1.41	1.46	**38.41**
Total Fuel Cost (US$ Million)	**MMUS$**	**67.02**	**66.64**	**67.61**	**73.58**	**74.11**	**77.27**	**872.8**

4.11 Estimates of Fuel Cost

The breakdown of the estimated cost of fuel for running all the Thermal Plants in 2022 is US$ 872.8 Million. This translates into an approximate monthly average of US$ 72.74 Million. The cost is based on Natural gas at an average cost of US$ 6.08/MMBtu. The estimated cost of US$ 872.8 Million excludes provision to be made for LCO, Diesel and HFO for AKSA during the period of gas supply outage. Estimated cost of the required LCO US$ 55 Million, while an estimated US$ 42 Million will be required to purchase diesel and an estimated US$ 18 Million will be required to purchase HFO to operate AKSA on HFO during the gas outage period. Therefore, the total estimated fuel cost to operate the thermal plants in 2022 is US$ 988 Million.

Chapter 5

2022 TRANSMISSION SYSTEM OUTLOOK

5 2022 TRANSMISSION SYSTEM OUTLOOK

5.1 State of the Ghana National Interconnected Transmission System

The Ghana power system has expanded steadily since the 1960s when grid operations in Ghana started. The National Interconnected Transmission System (NITS) has been the backbone for transmission of electricity from the various generating stations to the various load centres across Ghana and to its neighboring countries.

The NITS comprises a 161 kV (76.5% of total circuit length of all NITS lines) network, 69 kV (3.4% of total circuit length of all NITS lines), 225 kV (1.5% of total circuit length of all NITS lines) and 330 kV (18.6% of total circuit length of all NITS lines) voltage levels. The Ghana power system, one of the most reliable 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 NITS, as at end of year 2021 was made up of:

- Total transmission circuit length of 6,472.23 km;
- Total number of Bulk Supply Points (BSPs) of 68;
- Total number of load transformers at BSPs - 144;
- Total transformation capacity – 9,642.0 MVA;
- Total capacity of fixed capacitive compensation devices – 796.2 MVAr;
- Total capacity of reactors - 230 MVAr;
- One 40 MVAr Static Synchronous Compensator (STATCOM[2]) 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.

---

[2] 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.

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.

5.2 Principle for ensuring high Transmission Network Availability

The principles used to ensure high transmission line, feeder and substation availability are:

- ✓ All existing transmission lines are expected to be in service in 2022 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 consumers except for single transformer substations and consumers served from substations on radial lines.

5.3 Network Analysis

Network analyses were carried out to determine transmission line loadings, substation bus voltages and network loss levels across the NITS. In particular, the analyses sought to determine:

- ✓ Transmission line constraints to the evacuation of power from the generating stations to Bulk Supply Points;
- ✓ Adequacy of reactive power compensation in the transmission network for maintaining normal system voltages at all NITS nodes;
- ✓ Overall transmission system losses during peak period;
- ✓ 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

5.3.2 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 across the NITS.

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

5.3.2.1 Assumptions for development of a Base Case

The study was carried out on the 2022 model of the Ghana power system which was developed using the 2022 energy and capacity demand forecast data. The study was conducted on the expected state of the power system within the period.

5.3.2.2 Generation Additions

The first phase of Bridge Power Plant located in Tema has capacity of 147 MW. This Plant has already been commissioned on LPG, however commissioning on natural gas is outstanding.

5.3.2.3 Transmission Additions

The following transmission lines under construction are modelled in the year 2022 to assess their impact on the grid:

- ✓ 161 kV Achimota – Mallam line reconstruction.
- ✓ 161 kV Achimota – Accra Central line reconstruction.

5.3.2.4 Summary of Results for the Network Analysis

The following scenarios were studied:

- ✓ 2022 Peak Case – scenario using new Dispatch Protocol
- ✓ 2022 Peak Case – scenario with Maximum Dispatch from East
- ✓ 2022 Peak Case – scenario with Maximum Dispatch from West
- ✓ 2022 Peak Case - with upgraded Achimota – Accra Central – Mallam lines
- ✓ System Contingency Analyses

5.3.2.4.1 2022 Peak Case – scenario using new Dispatch Protocol

From the 2022 capacity and energy demand forecast, the projected peak for 2022 is 3,545.3 MW. In this scenario, power plants are scheduled using nominations issued under the new dispatch protocol. The transmission loss recorded for this scenario is approximately 138.3 MW. System analyses show that all voltages and line loadings are within acceptable operation range. Table 5.3 shows the generation schedule used in this scenario.

Table 5.3: New Dispatch Protocol from Generation Enclaves

GENERATION ENCLAVE	OUTPUT (MW)
EASTERN (TEMA THERMALS)	
ASOGLI PHASE I	135.0
ASOGLI PHASE II	330.8
KTPP	100.0
CENIT	100.0
TT2PP	35.0
CENPOWER	330.2

SUB-TOTAL 1	**1,030.0**
WESTERN (TAKORADI THERMALS)	
TAPCO	300.6
TICO	330.6
AMANDI	200.3
KARPOWER	450.0
SUB-TOTAL 2	**1,281.5**
EASTERN HYDROS	
AKOSOMBO	873.5
KPONG	140.0
SUB-TOTAL 3	**1,013.5**
NORTHERN HYDRO	
BUI	220.3
SUB-TOTAL 4	**220.3**
TOTAL	**3,545.3**

5.3.2.4.2 2022 Peak Case - with maximised Generation in the West

There are incidences where dispatchers have had to operate the Ghana power system with majority of the Power Plants in the Western enclave (ie. from the Takoradi Thermal enclave). Such a scenario typically happens during incidences when gas supply to thermal plants in Tema is curtailed. For example, during the period of the intelligent pigging of the West African Gas Pipeline (WAGP) by WAPCO in the first quarter of 2020, the Tema gas lateral on the WAGP was shutoff so that power plants in Tema that were operable only on gas were shutdown throughout the period of the pigging.

Table 5.4: Maximised West Generation Dispatch

GENERATION ENCLAVE	OUTPUT (MW)
EASTERN (TEMA THERMALS)	
ASOGLI PHASE I	0.0
ASOGLI PHASE II	340.0
KTPP	0.0
CENIT	0.0
CENPOWER	325.0
AKSA	330.0
SUB-TOTAL 1	**995.0**
WESTERN (TAKORADI THERMALS)	
TAPCO	300.0

TICO	320.0
AMANDI	190.0
KARPOWER	450.0
SUB-TOTAL 2	**1,260.0**
EASTERN HYDROS	
AKOSOMBO	930.1
KPONG	140.1
SUB-TOTAL 3	**1,070.2**
NORTHERN HYDRO	
BUI	**220.1**
TOTAL	**3,545.3**

Table 5.4 shows the generation schedule that was used to model this scenario. Transmission losses of 143.2 MW were recorded from a simulated system generation of 3,545.3 MW. Loadings on the Tarkwa – New Tarkwa and New -Tarkwa – Prestea lines are 84.4% and 82.1%. All voltages and line loadings are within the limits of acceptable operation. Voltages from some nodes are shown in Table 5.5 as follows:

Table 5.5: Voltages at selected nodes with maximised Dispatch from West

Station	Asawinso	Achimota	Kumasi	Yendi
Voltage (kV)	158.28	160.48	157.06	160.13

Impact of Relocation of Ameri

Further analysis was conducted on this scenario with the 250 MW Ameri Power Plant in Kumasi. The results of the load flow simulation indicate transmission losses of 128.5 MW. Loadings on the Tarkwa – New Tarkwa and New -Tarkwa – Prestea lines are 74.1% and 73.3% respectively. All voltages and line loadings are within the acceptable levels. There are reductions in the loadings between Tarkwa – Prestea lines as compared to similar case without Ameri.

5.3.2.4.3 2022 Case - with Maximum Generation in the East

In this scenario, analyses were carried out assuming maximised generation dispatch from the eastern enclave. Such a scenario is typically what happens whenever gas supply from domestic fields in the West is curtailed so that thermal power plants in the Takoradi Thermal enclave have to shut down. Table 5.6 shows the generation schedule that was used to model this scenario.

With significant loadings at Kasoa, Accra Central and Mallam substations, there is the tendency for the Achimota - Accra Central transmission lines to be overloaded. The timely completion of the on-going upgrade is required to alleviate such overloads.

Table 5.6: Maximised East Generation Dispatch

GENERATION ENCLAVE	OUTPUT (MW)
EASTERN (TEMA THERMALS)	
ASOGLI PHASE I	180.0
ASOGLI PHASE II	340.0
KTPP	200.0
TT1PP	100.0
TT2PP	35.0
CENIT	100.0
CENPOWER	325.1
AKSA	300.0
SUB-TOTAL 1	**1,610.1**
WESTERN (TAKORADI THERMALS)	
TAPCO	320.0
TICO	150.0
AMANDI	190.0
KARPOWER	0.0
SUB-TOTAL 2	**660.0**
EASTERN HYDROS	
AKOSOMBO	915.1
KPONG	140.0
SUB-TOTAL 3	**1,055.1**
NORTHERN HYDRO	
BUI	**220.1**
TOTAL	**3,545.3**

The results of the load flow simulations show transmission losses of 153.8 MW out of a total of 3,545.3 MW generation. All voltages and line loadings are within normal operational range. Voltages from some nodes are shown in Table 5.7 as follows:

Table 5.7: Voltages at selected nodes with maximised Dispatch from East

Station	Asawinso	Achimota	Kumasi	Yendi
Voltage (kV)	158.31	162.88	156.07	160.22

Impact of Relocation of Ameri

With 250 MW Ameri power plant in Kumasi, results of the load flow simulations indicate transmission losses of 129.9 MW out of 3,545.3 MW generation.

5.3.2.4.4 2022 Case - with upgrade of Achimota – Accra Central – Mallam lines

This case considers 2022 – year scenario with ongoing works to upgrade the 170 MVA sections of the Achimota – Mallam and Achimota – Accra Central lines. The Analysis shows that load transfers from Kasoa, Mallam and Accra Central will be required to avert voltage decay at the stations and the possible overload on the Takoradi Extension – Cape Coast low capacity 170 MVA line.

Loads would have to be transferred to the eastern parts of Accra such as the Pokuase and Achimota substations.

5.3.2.4.5 Transmission Losses

Results from the analysis above indicate that lowest losses were registered on the NITS in the Balanced Generation scenario. This means that in situations where there are gas interruptions which affect thermal generation and compel high volumes of generation from a particular enclave (West or East), losses increase significantly. The relocation of Ameri to Kumasi is expected to reduce losses on the NITS.

GRIDCo is embarking on a number of projects which are expected to improve reliability, transfer capacity and to reduce losses on the NITS. These include:

- 161kV Kasoa Substation with 50MVAr SVC Plus,
- Upgrade of the 161kV Achimota-Mallam transmission corridor,
- Western Corridor Transmission system upgrades (GRIDCo is at the verge of securing funds with the assistance of the Ministries of Energy & Finance) to upgrade the old 161kV lines from the Takoradi Thermal plant through Prestea to New Obuasi along with substation upgrades and
- The Siemens projects for the development of the 330/161kV Dunkwa II substation, 3rd BSP in Kumasi and the replacement of the 161kV capacitor bank in Kumasi with a 50MVAr SVC Plus.

GRIDCo is also collaborating with the Ministry of Energy and VRA for the relocation of the 250 MW Ameri plant to Kumasi. This is expected to reduce transmission losses and improve voltages.

5.3.2.4.6 Contingency Analyses

Contingency analyses (N-1) were conducted on transmission line circuits within the NITS to determine the capability of the system to continue to provide electricity service delivery to consumers in the event of an outage to a single transmission line.

The following single line contingency (N-1) analyses were conducted on the 2022 model. The contingencies are arranged in order of severity as follows:

i. **330kV Takoradi Thermal – Anwomaso line**

The loss of the 330 kV Takoradi Thermal – Anwomaso line results in re-routing of almost all the powerflow on the 330 kV circuit unto the161kV network between Aboadze and Kumasi. This leads to overloads along segments of the 161kV network in the Western corridor. This will lead to system disturbances triggered by congestion on the 161kV lines between Takoradi Thermal and Prestea. The solution is to break into the 330kV Takoradi Thermal – Anwomaso line at Dunkwa with a connection to the 161kV network at the existing Dunkwa substation and the upgrade of the 170 MVA Western corridor lines.

ii. **330 kV Anwomaso – Kintampo line**

The loss of the 330 kV Anwomaso - Kintampo transmission line results in re-routing of powerflow on the 161 kV Anwomaso – Kumasi line. This leads to overloading on the line as well as its associated 330/161kV Autotransformers at Anwomaso. The solution to this is (i) the upgrade of the 161 kV Anwomaso - Kumasi line to increase its capacity and (ii) to construct a third bulk supply point in Kumasi at 330kV.

iii. **330 kV Pokuase – Volta Line**

Loss of the 330 kV Pokuase – Volta line overloads the low capacity Achimota – Accra Central and Achimota – Mallam lines (170 MVA). With the loss of this line, the load at Pokuase is served from Aboadze only on the 330kV Takoradi Thermal – Pokuase line. There is also a significant increase in power flow on the Achimota – Accra Central and Achimota – Mallam lines. The upgrade of the 170 MVA Achimota – Accra Central and Achimota – Mallam lines (which is already on-going) is required to address this condition.

iv. **330 kV Kintampo - Adubiyili**

A loss of the 330 kV Kintampo – Adubiyili line overloads the 161 kV low capacity between Kintampo and Tamale and cause eventual system disturbance. A second 330 kV line is required from Aboadze to Bolgatanga to avert this disturbance.

v. **161 kV Tarkwa – Prestea Line**

A loss of the 161 kV Tarkwa – Prestea line results in overload on the parallel 170 MVA Tarkwa – New Tarkwa – Prestea line circuit and causes it to trip. This situation will be mitigated by a break into the 330kV Takoradi Thermal – Anwomaso line at Dunkwa. The 161kV Aboadze-Takoradi-Tarkwa -New Tarkwa - Prestea lines will also require upgrade in the medium term.

vi. <u>161 kV Takoradi Thermal – Tarkwa line</u>

A contingency on this line overloads the smaller capacity 161kV Takoradi Thermal - Takoradi and Takoradi - Tarkwa lines. This eventually causes these lines to trip on overload. Upgrade of the Takoradi Thermal - Takoradi and Takoradi - Tarkwa lines addresses this challenge.

vii. <u>330 kV Adubiyili - Nayagnia Line</u>

Loss of the 330 kV Adubiyili - Nayagnia line leads to overloading on the low capacity 161 kV line between Tamale and Bolgatanga and causes system disturbance. Upgrade of the Tamale – Bolgatanga line will address this.

5.3.2.5 Tie-Line Transformers

At present, one of the two 200 MVA 225/161 kV auto-transformers in service on the Ghana – Cote d'Ivoire tie-line is faulted. Also, one of the two 200 MVA 225/330 kV auto-transformers in service on the Ghana – Burkina tie-line is faulted and being shipped to the supplier for examination. This has limited the capacity of the Ghana power system to export power to Cote d'Ivoire and also to Burkina.

In order to improve the capacity and the reliability of the Ghana power system to export supply to our neighbours in the sub-region, there is a need to replace the two each 200MVA 161/225kV Prestea and 200MVA 330/225kV Nayagnia auto transformers with ones having phase shifting capabilities. The replacement of the transformers with Phase Shifting ones will help dispatchers to have greater control of power flow on our interconnections with our neighbours and reduce inadvertent power flows especially on the Ghana – Cote d'Ivoire interconnection.

5.4 Summary of Network Analyses

The network analyses shows that in incidences where there is a lot of generation either in the East or in the West (for example in situations such as where gas supply for thermal generation is lost) transmission losses go high.

Contingency analysis also show that as demand continues to grow, the transmission network is beginning to show congestion in some critical corridors.

Reinforcement works will be required to expand the transmission network to increase transfer capacity and ensure adequate transfer capacities across the NITS and reliability of supply.

Due to the time it takes to initiate and complete these transmission network expansion projects, they are considered further in the next chapter on the "Overview of Medium-Term Supply".

Chapter 6

OVERVIEW OF MEDIUM TERM SUPPLY

6 OVERVIEW OF MEDIUM-TERM SUPPLY: 2023 - 2027

A power system must have sufficient generation 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 generation capacity. It also assesses the need for reinforcements or changes to the transmission network, etc., where it is found meritorious.

In line with this, we present in this chapter peak demand and consumption projections for the Medium-Term (2023 - 2027) 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.

6.1 Demand Outlook

The Projected electricity demand for the period 2023 – 2027 is based on data collated from a load forecast 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 Aluminium Industry in Ghana:

  As part of efforts by the Government of Ghana's policy to develop an Integrated Aluminium Industry in Ghana, the Volta Aluminium Company Limited (VALCO), projects to operate 2 potlines (150 MW) in 2022 but 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 operations of VALCO are dependent on the availability of low-cost electricity vis-à-vis the prevailing price of aluminium. In recent times, the price of aluminium has been low. In view of this and considering VALCO as a strategic industry, the government by a policy decision, gave legacy hydro at a cost of $3.5 cent for VALCO's operations for demand up to 150 MW and valid until 2023. The decision was not specific on the price beyond 2023 and for VALCO demand beyond 150 MW.

In view of this, for the purpose of this report VALCO's demand for the 'Base case scenario' was set to a **maximum of 165 MW (translating to 2 potlines) throughout the planning period**. The 500 MW for VALCO is therefore considered under the High case scenario.

Highlights on the demand projections are as follows:

✓ Mines:

Total demand for mines is expected to increase from 255 MW in 2023 to 369 MW MW in 2027. Some of the specifics are as follows

- Newmont Mines, Ahafo – demand is expected to increase from 60 MW in 2022 to 87 MW by 2024 at Ahafo – North;
- Azuma Mines – 18 MW by 2026 at Yagha (50km North-West of Wa);
- Anglogold Ashanti – demand is expected to increase from 42 MW in 2022 to 55 MW by 2027.
- Namdini Mines – is expected at 40 MW by 2024

✓ Potential Exports:

Total export is expected to increase from 345 MW in 2023 to 429 MW in 2027

- Export of up to 100 MW to CIE, especially in 2023
- 120 MW export to CEB through to 2027
- 225 MW in 2023 through to 2025, increasing to 237 MW in 2026 and further increasing to 249 MW by 2027 as export to SONABEL

- Export to Mali is expected to begin by 2027 at 60 MW.

Total electricity requirement for Ghana, including power exports to Togo, Benin, Cote d'Ivoire, Burkina, and Mali is projected to grow from **25,983** GWh in 2023 to **34,920** GWh by 2027 at a Compound Annual Growth Rate (CAGR) of approximately 7.7%. The Ghana system peak demand is projected to increase from 3,987 MW in 2023 to 5,172 MW in 2027.

The summary of 2023-2027 projected demand is illustrated in Tables 6.1 and 6.2.

Table 6.1: Projected Base Demand Versus Supply balance (2023 - 2027)

	2023	2024	2025	2026	2027
Domestic	22,648	24,334	25,896	27,850	29,933
VALCO	1,371	1,371	1,371	1,371	2,438
Exports	1,964	2,058	2,058	2,128	2,550
TOTAL	25,983	27,764	29,325	31,350	34,920

Table 6.2: Projected Annual Peak Demand (MW) in the Medium Term

	2023	2024	2025	2026	2027
Domestic	3,477	3,746	3,982	4,271	4,579
VALCO	165	165	165	165	165
Exports	345	345	345	357	429
TOTAL	3,987	4,256	4,491	4,793	5,172

6.2 Generation Adequacy Analysis

Having established the demand outlook for the medium term, we go on to conduct analyses to determine the adequacy of Generating facilities in Ghana to serve the projected demand over the period.

The analysis first asserts the capacity evolution of existing generation facilities over the period, as well as Committed Generation projects currently at various stages of implementation together with Other Planned Generation projects currently under consideration.

The assessment of generation adequacy is based on ensuring that sufficient generation resources are available to serve the firm demand at all times in the medium term, while having the extra 18% capacity required to serve as operating reserve (refer to Section 4.8).

It should be noted that the analysis is conducted on generation capacity at peak time. On the Ghana power system, peak demand typically occurs between 6pm and midnight (ie., in the evening) each day when the output from Solar plants is usually at nil (0.0 MW). Consequently, dependable capacities of all Solar plants are assumed to be **0.0 MW** in the analysis.

a. Existing Generation

The existing generating facilities in Ghana are made up of hydro, thermal and renewable energy sources. In the medium term, some existing power plants project to carry out some expansion works while others will undergo retrofit as follows:

Expansion/Retrofit of some Existing Power Plants

- ✓ **TAPCO:** The 300 MW TAPCO plant is scheduled to undergo a major rehabilitation in the period 2023 - 2024. VRA plans to take the units at the plant out, one at a time for rehabilitation in order to minimise the impact of the rehabilitation. Thus, the dependable capacity for the plant will reduce from the current 300 MW to 150 MW in 2023 and 2024.

- ✓ **KTPP Conversion to Combined Cycle:** The existing 220 MW simple cycle plant is to be expanded with the addition of a 110 MW steam turbine unit to convert the plant into a 330 MW combined cycle plant by end of 2025. The plant is expected to be in operation from Q1 2026. Currently procurement process to engage an EPC contractor for the project has commenced. The process is to be completed by Q3 2023 for construction to commence by Q4 2023.

- ✓ **TT1PP/CENIT Conversion to Combined Cycle:** Arrangements are in progress for a 110 MW steam turbine unit is to be constructed to convert the existing 110 MW each TT1PP and Cenit simple cycle thermal units into a combined cycle in Tema by end of 2026. The steam turbine unit is expected to become operational by Q1 2027. Currently a Joint Implementation Agreement (JIA) has been finalized for signing by the parties.

- ✓ **Takoradi Thermal Extension (T3) Power Plant:** Under the "T3 Thermal Power Plant Repowering Project", the Ministry of Energy and VRA are working to bring the Takoradi Thermal Extension Power Plant (T3) back into service. The repowering strategy involves the replacement of the four (4) engines and associated testing and re-commissioning of the plant. VRA currently has been undertaking activities on the steam turbine and Balance of Plant (BoP) to preserve the assets in readiness for the project. The plant is expected to resume operations by 2024.

- ✓ **Sunon Asogli (Phase I) units:** Management of Sunon Asogli Power Plant are making arrangements for a project to expand the plant with the construction of the Phase III of the plant (see Section 6.2c). If arrangements go through as planned, the new 'Phase III' will replace the existing 'Phase I'. It is expected that the Asogli Phase I units will be de-commissioned by the year 2027 to make way for the new Phase III.

The breakdown of projected demand versus expected supply from Existing Generation resources in the medium term is shown in Table 6.3.

Table 6.3: Medium Term Projected Peak Demand vs Existing Generation Capacity

Projected Capacity Requirement (MW)	2023	2024	2025	2026	2027
Projected Peak Demand	3,987	4,256	4,491	4,793	5,172
Projected Peak Demand + 18% Reserve	**4,705**	**5,022**	**5,300**	**5,656**	**6,103**
Dependable Capacities of Existing Generation (MW)					
Akosombo	**900**	**900**	**900**	**900**	**900**
Kpong GS	**140**	**140**	**140**	**140**	**140**
Bui GS	**360**	**360**	**360**	**360**	**360**
TAPCO	**150**	**150**	**300**	**300**	**300**
TICO	**320**	**320**	**320**	**320**	**320**
TT1PP	**100**	**100**	**100**	**100**	**155**
KTPP	**200**	**200**	**200**	**310**	**310**
TT2PP	**70**	**70**	**70**	**70**	**70**
AMERI Power Plant	**230**	**230**	**230**	**230**	**230**
Karpower Barge	**450**	**450**	**450**	**450**	**450**
Asogli (SAPP (Phase 1))	**180**	**180**	**180**	**180**	**0**
Asogli (SAPP (Phase 2))	**350**	**350**	**350**	**350**	**350**
CENIT	**100**	**100**	**100**	**100**	**155**
AKSA	**330**	**330**	**330**	**330**	**330**
CENPOWER	**325**	**325**	**325**	**325**	**325**
Twin City	**200**	**200**	**200**	**200**	**200**
VRA Takoradi Extension	**0**	**130**	**130**	**130**	**130**
New Tarkwa (Genser)	**40**	**40**	**40**	**40**	**40**
Chirano (Genser)	**15.4**	**15.4**	**15.4**	**15.4**	**15.4**
Damang (Genser)	**20**	**20**	**20**	**20**	**20**
Bui Solar					
VRA Solar					
BXC					
Meinergy					
Bui Solar					
VRA Kaleo					
Total Existing Generation	**4,480.40**	**4,610.40**	**4,760.40**	**4,870.40**	**4,800.40**
Surplus/Shortfall (MW)	**-224.60**	**-411.60**	**-539.60**	**-785.60**	**-1,302.60**

The table shows that existing generation alone will not be adequate to supply projected demand with the minimum required 18% operating reserve within the medium term. The shortfall on generation increases from 224.60 MW in 2023 to 1,302.60 MW in 2027 if no generation capacity is added within the period.

There are a number of on-going Committed Generation projects as well as some Other Planned Generation Projects whose capacity additions will be required within the medium term.

b. Committed Generation Projects

The following are committed generation facility projects already at various stages of implementation and are expected to be completed and commissioned in the medium-term:

Projects Under Construction

- ✓ **Bridge Power:** This is a 400 MW power plant located at Tema and would be constructed in two phases made up of 200 MW each. The initial part of the first phase, Phase 1A (147 MW) commenced commissioning in 2021 and is expected to begin commercial operations in 2022. The second part, phase 1B (53 MW), is also expected to come online in 2022. The second phase (200MW) which will bring the plant up to 400 MW is expected to be commissioned by 2024.
- ✓ **Pwalugu Hydro/Solar Hybrid Plant:** This is a 60 MW hydroelectric plant designed to operate in hybrid with a 50 MWp Solar PV plant which is expected to be completed and commissioned by 2025. The plant is to be located in the Upper East Region.

Consequently, the capacity of generation addition over the medium term expected from Committed Generation projects is shown in Table 6.4 as follows:

Table 6.4: Committed Generation Projects in the Medium Term

Committed Project	2023	2024	2025	2026	2027
Bridge Power	190	190	390	390	390
Pwalugu Hydro				60	60
Total Committed Generation Capacity	190	190	390	450	450

c. Other Planned Generation Projects

The Ministry of Energy has also informed about some other Planned Generation Projects for which arrangements are on course for implementation and operationalisation within the medium term. These planned projects are as follows:

- ✓ **Karpower Phase III:** This is a 235 MW thermal Power Plant proposed to be constructed in Kumasi. It will comprise of 12 gas-fired units together with one (1) steam turbine unit. The construction period for the plant is 28 (twenty-eight) months. Proposed Commencement is the fourth quarter of 2022.
- ✓ **AKSA Phase II:** This is a 350 MW thermal plant planned for construction in Kumasi. It will be configured as a 2x125 MW gas turbine units to run on natural gas as primary fuel in combined cycle with one steam turbine unit (100 MW). Construction time for Phase 1 of 125MW is 9 months. Construction time for Phase 2 of 125MW is 5 months. Construction time for Phase 3 (steam unit) of 100MW is 6 months from the Phase 2 Commercial Operation Date. Proposed Commencement: Q1 2023.
- ✓ **508 MW Sunon Asogli Power Plant Phase III:** A 508 MW thermal power plant to be constructed to replace the existing Sunon Asogli Phase 1 units in Tema. It will be configured as a 2x254 MW Siemens SGTS-2000E combined cycle. Construction is expected to commence in the second quarter of 2024 and to be completed within 36 months. The plant is expected to be commissioned into service by 2027.

Consequently, the capacity of generation addition over the medium term expected from Other Planned Generation Projects is shown in Table 6.5:

Table 6.5: Committed Generation Projects in the Medium Term

Plant	Installed Capacity	Dependable Capacity				
		2023	2024	2025	2026	2027
KarpowerShip Phase III	235		180	230	230	230
AKSA Phase II	350		125	230	340	340
Sunon Asogli Phase III	508					500
Total Planned Generation	**1093**	**0**	**305**	**460**	**570**	**1070**

d. Adequacy Analysis

The results of the Generation Capacity Adequacy Analysis carried out for the medium term is summarised in Table 6.6.

Table 6.6: Generation Capacity Adequacy Analysis for the Medium Term

	2023	2024	2025	2026	2027
Projected Peak Demand	3,987	4,256	4,491	4,793	5,172
18% Planning Reserve Margin	718	766	808	863	931
Minimum Capacity Required for Adequacy: *(Projected Peak Demand + 18% Reserve)*	**4,705**	**5,022**	**5,300**	**5,656**	**6,103**
Total Existing Generation	4,480	4,610	4,760	4,870	4,800
Total Committed Generation	190	190	190	450	450
Other Planned Generation	0	305	460	570	1070
Total Dependable Generation	**4,670**	**5,105**	**5,410**	**5,890**	**6,320**
Generation Capacity Surplus/Shortfall	**-34**	**84**	**111**	**234**	**217**

The analysis shows that the timely completion of all Committed Generation projects as well as the Other Planned Generation projects, is necessary to ensure generation capacity adequacy for 2024 to 2027. There is generation capacity surplus from 2024 to 2027.

However, in 2023 there is a minor shortfall of 34 MW. This implies a shortfall on the 718 MW planning reserve margin requirement for the year. To mitigate the impact of this shortfall and ensure that it does not affect the security of supply to consumers, we recommend the following:

i. Ensure the Ameri Power Plant is operational in Kumasi as scheduled;

ii. Ensure the Bridge Power Plant 'Phase I' is operational as scheduled; and

iii. Ensure a high availability of all existing generating plants throughout the year.

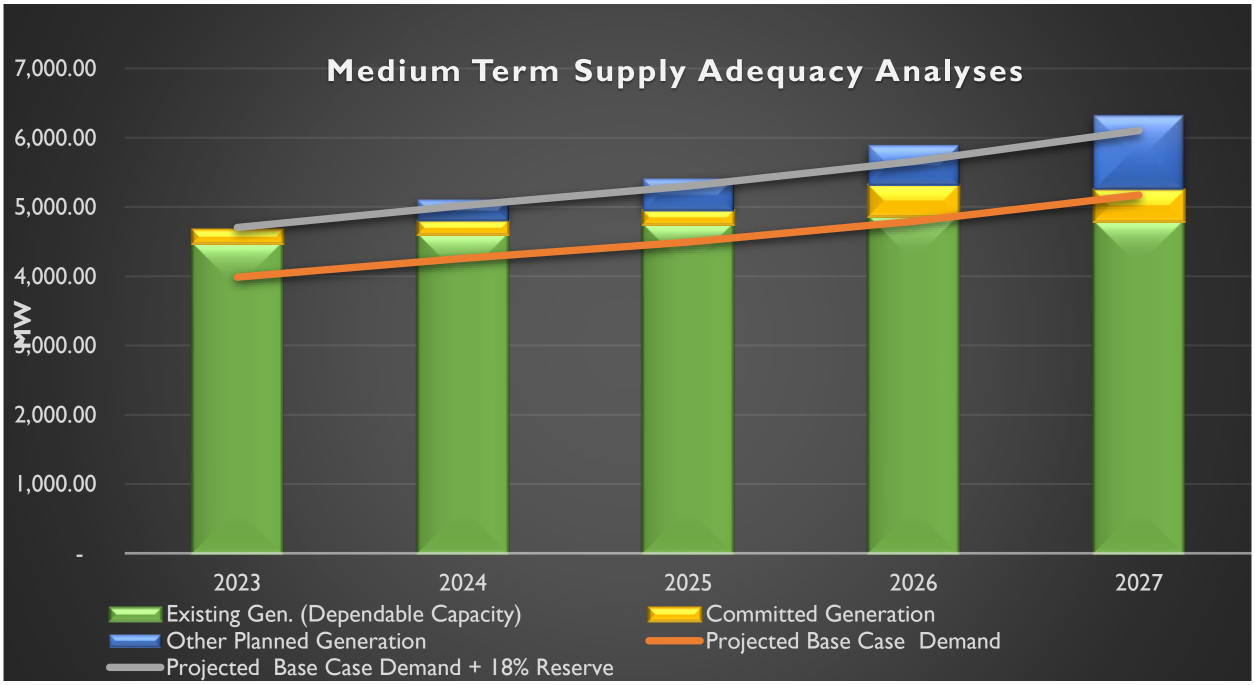


Figure 6.1: Projected Base Demand Versus Supply balance (2023 - 2027)

Base Case Demand with Sensitivity on Supply

For the few years that Bui GS has operated since its commissioning in 2013, there have been a number of occasions where, for various reasons (such as low reservoir levels, unit unavailability etc.) only two units (220 MW) at the plant have been operable during periods of high system demand. Accordingly, in this section we assess the generation adequacy requirements with Bui GS capacity credit at 220 MW.

From analysis, reducing the capacity credit for Bui Hydro Plant during peak periods from 360 MW to 220 MW increases the capacity shortfall for 2023 to 174 MW. The deficit would reduce to 56 and 29 MW in 2024 and 2025 respectively when the planned generation capacity additions are implemented. However, there is adequate generation capacity for 2026 and 2027 as indicated in Figure 6.2.

Table 6.7: Additional Capacity Needed with Bui GS at 220 MW

Year	2023	2024	2025	2026	2027
Surplus/Shortfall (MW)	174	0	0	0	0

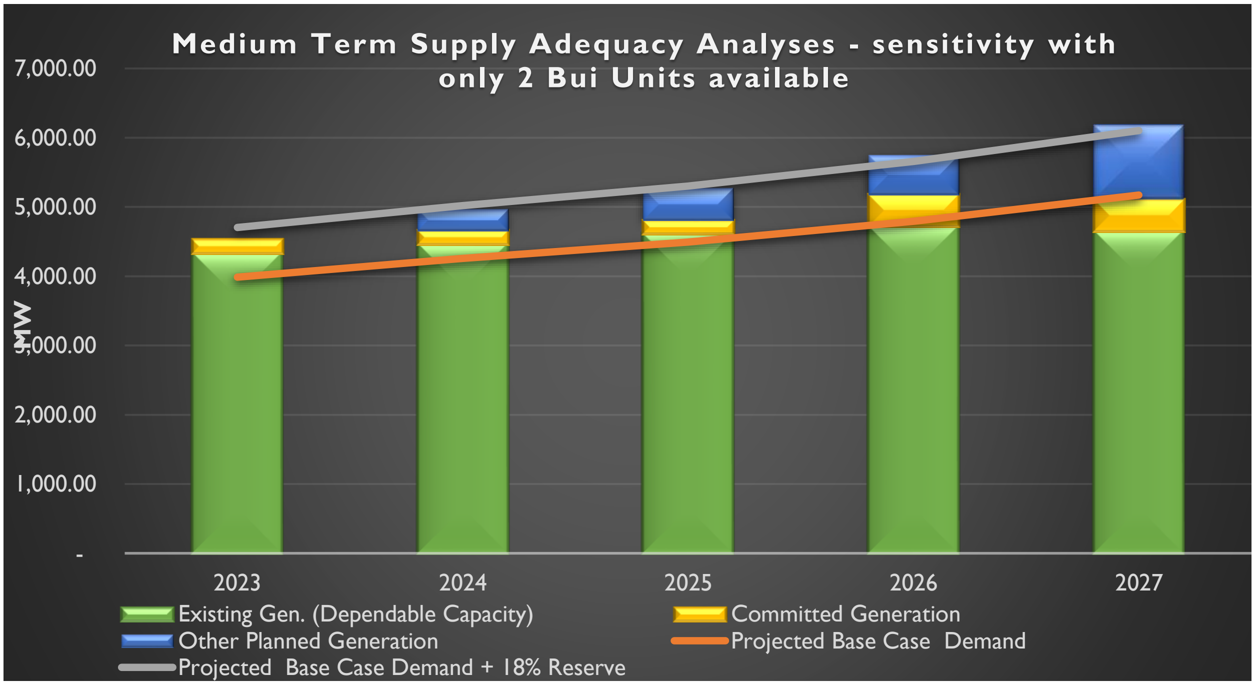


Figure 6.2: Projected Base Case with Derated Bui

6.3 High Demand Scenario: Impact on Supply Adequacy

In this section, we analyse the impact of a possible high electricity demand scenario on supply adequacy. This is likely to happen due to the potential surge in electricity demand especially as a result of the government of Ghana's flagship programmes such as the development of an "Integrated Aluminium Industry", the "Integrated Iron and Steel Industry", etc.

Table 6.8: High Demand Scenario

Projected Capacity Demand (MW)	2023	2024	2025	2026	2027
Domestic	3,477	3,746	3,982	4,371	4,679
VALCO	165	165	165	500	500
Exports	345	345	345	357	429
TOTAL	**3,987**	**4,256**	**4,491**	**5,229**	**5,608**
Projected Demand + 18% Planning Reserve Margin	4,705	5,022	5,300	6,170	6,617

Consequently, if VALCO's demand as in the base case scenario should increase to 500 MW from 2026 onwards, and Domestic demand as in the base case scenario should also increase by 100 MW for each ensuing year, then more additional capacity is required.

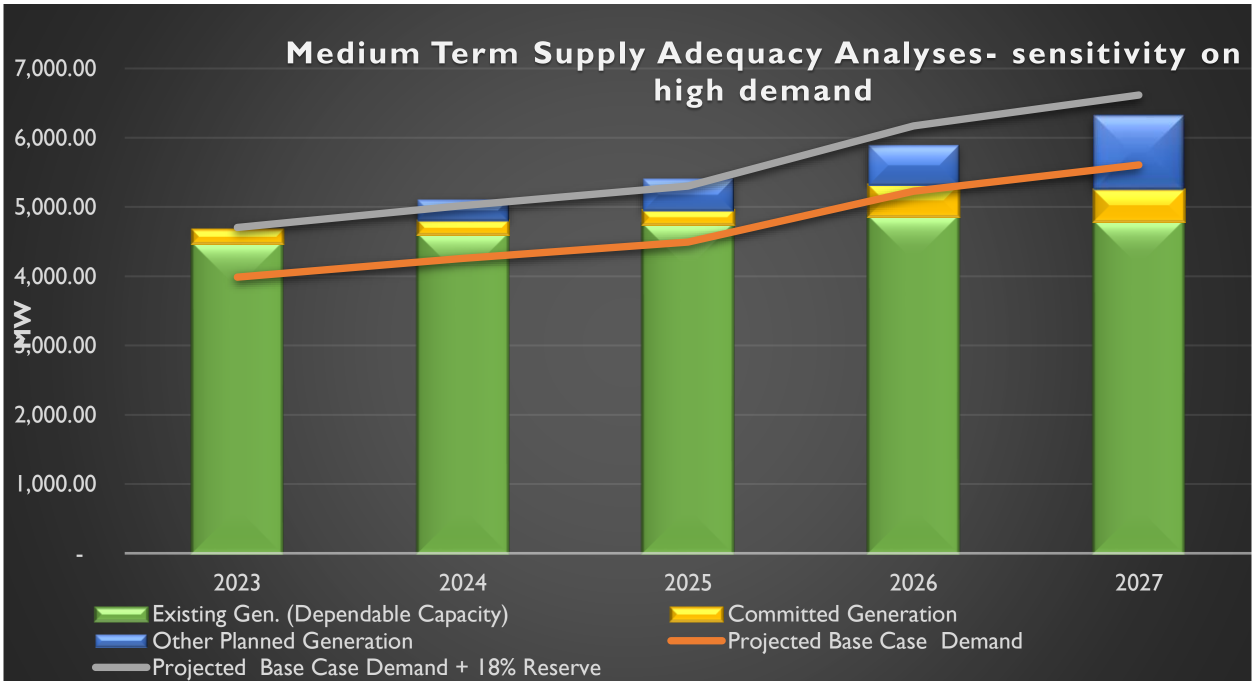


Figure 6.3: Projected High Demand Versus Supply balance (2023 - 2027)

As evident in Figure 6.3 and Table 6.9, about 245 MW additional generation capacity of 245 MW would be required in 2026 and 17 MW in 2027. In all, up to 296 MW of additional capacity would be required in the medium term for the high demand scenario.

Table 6.9: Additional Capacity Needed per High Demand Scenario

Year	2023	2024	2025	2026	2027
Extra Additional Capacity required (MW)	34	0	0	245	17

6.4 Creation of new Generation Enclave

To date, apart from Akosombo GS and Bui GS, there are two main generation enclaves in Ghana, namely the Tema (East) and the Takoradi (West) thermal generation enclaves.

Power system network analyses carried out show that establishing new generation enclave near Kumasi results in considerable improvements in:

- the stability of the Ghana power system,
- the quality of supply to end users through improved network voltage control via generators,

- transmission system losses, and
- evacuation capacity for power exports to Burkina and Mali (future).

Key to establishing this new generation enclave is the provision of an adequate source of fuel at the location. The following are some highlights from the analyses carried out into the siting of a new generation enclave in Kumasi .

360 MW Plant sited at Kumasi

The analysis was carried out on a 2022 network model which assumes a total system generation of 3,571.9 MW. For the base case simulation, total system losses were 133.4 MW representing 3.73 % of total generation.

Analyses were carried out on the impact of installing a 360 MW power plant in Kumasi (as recommended in the previous versions of Electricity Supply Plan since 2017) on quality of supply, transmission line loadings and system losses.

Results of the power flow analyses indicate that siting a 360 MW power plant (preferably a combined cycle) at Kumasi results in significant reduction in transmission losses of **27.8** MW.

Table 6.10 shows the load flow results.

Table 6.10: Comparison of system losses (MW) - Siting Generation at Kumasi

	Base Case (No generation at Kumasi)	360 MW generation at Kumasi
Losses (MW)	133.4 MW	105.6

The results again show significant reduction in some transmission line loadings (congestion) within the South-West to Ashanti corridor as shown in Table 6.11.

Table 6.11: Comparison of line loadings (% line thermal capacity) - Siting Generation at Kumasi

	Percentage Line Loading	
	No Generation at Kumasi	360 MW Generation at Kumasi
Aboadze- Tarkwa	61%	52%
New Tarkwa – Tarkwa	84%	69%
Takoradi - Tarkwa	74%	62%
Dunkwa -Ayanfuri	61%	54%

It also shows bus voltage improvements as shown in Table 6.12.

Table 6.12: Comparison of bus Voltages (kV) - Siting Generation at Kumasi

Bus Voltage (kV)	No generation at Kumasi	360 MW generation at Kumasi
Dunkwa	157.5	161.6
Ayanfuri	156.7	161.1
New Obuasi	157.5	161.5
Kumasi	156.6	160.6

6.5 Medium Term Transmission Network Upgrade Requirements

The transmission network has evolved steadily over the years. That notwithstanding, there are currently a number of challenges that need to be addressed to improve its reliability and evacuation capacity. Some of the issues are as follows:

- ✓ Congestion on some critical corridors due to high demand growth and low capacity,
- ✓ Inadequate reactive power support,
- ✓ Overloaded Transformers,
- ✓ Loads served on radial lines and
- ✓ Loads served via single transformer substations.

Some of the congested corridors on the NITS include:

- Takoradi Thermal – Cape Coast – Winneba - Mallam coastal lines
- Takoradi Thermal – Takoradi – Tarkwa – New Tarkwa – Prestea line circuit
- Bogosu – Dunkwa – New Obuasi line circuit
- Tafo – Nkawkaw – Konogo – Kumasi line circuit
- Akosombo – Tafo line no. 1
- Anwomaso – Kumasi line, etc.

Radial lines on the NITS are:

- 161kV Tamale - Yendi
- 69kV Asiekpe - Kadjebi
- 161kV Asiekpe – Sogakope
- 161kV Sunyani - Berekum
- 161kV Nkawkaw - New Abirem
- 161kV Ayanfuri - Obotan
- 161 kV Takoradi - Esiama

Single transformer stations:

- Yendi
- Esiama
- Ayanfuri
- Akosombo

In order to improve transmission service delivery all efforts must be employed to upgrade all substations served on radial lines into a loop and to double the transformers at all single transformer stations within the system.

Extensive system network analyses were carried out using the projected demand and supply scenarios in sections 6.1 and 6.2 above. 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.

Specifically, upgrade of the following NITS infrastructure/equipment will be required to increase their capacities and to improve network reliability:

- ✓ 161kV Takoradi Thermal – Cape Coast – Winneba - Mallam line circuit
- ✓ Akosombo – Tafo – Nkawkaw – Konongo – Kumasi Middle Corridor line circuit
- ✓ 161kV Bogosu – Dunkwa – New Obuasi line circuit
- ✓ 161 kV Dunkwa – Asawinso line
- ✓ 161kV Takoradi Thermal – Takoradi – Tarkwa – Prestea line circuit
- ✓ Cross-border interconnection transformers both at Prestea and Nayagnia to be replaced with phase shifting transformers (2x250 MVA each)
- ✓ SCADA Network Manager System at the System Control Center including the establishment of a Backup Control Center.

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

- ✓ 161kV Pokuase – Mallam line
- ✓ 330 kV Accra (Pokuase) – Kumasi (Anwomaso) line
- ✓ 2nd Circuit 330 kV circuit from Takoradi Thermal through Kumasi to the north
- ✓ 330/161 kV Dunkwa substation
- ✓ 2nd Circuit 330 kV Takoradi Thermal – Pokuase
- ✓ Eastern Transmission Corridor Projects:
    - o 161 kV Akosombo/Kpong GS – Asiekpe Transmission Line
    - o 161 kV Asiekpe – Kpando Transmission Line
    - o 161 kV Kpando – Juale Transmission Line
    - o 161 kV Juale – Yendi Transmission Line
    - o A 161 kV, 2x33 MVA Substation at Kpandai (to supply Nkwanta, Salaga and Bimbila)
- ✓ Kumasi third Bulk Supply Point

- ✓ Transformers and Compensation devices
- ✓ A ±50 MVar STATCOM to be installed in Kumasi, Nayagnia and Prestea
- ✓ 225/161KV Prestea Substation Improvement Project
- ✓ Akwatia – New Abirem Loop Closure
- ✓ A second circuit to Obotan by breaking into the existing 161kV Kumasi – New Obuasi transmission line
- ✓ A 330kV double circuit, second interconnection line between Ghana (Dunkwa 330kV) and Cote d'Ivoire (Bingerville).
- ✓ Supply of 6 No. 161/34.5, 125/145 MVA transformers

Chapter 7

CONCLUSIONS

7 CONCLUSIONS

The following conclusions are drawn in respect of the Electricity Supply Plan for 2022:

a. 2022 Demand and Supply Outlook

i. The projected 2022 Peak system demand in Ghana is 3,545 MW, while the projected dependable generation capacity is 4,618MW.
Consequently, we conclude that there is adequate generation capacity to supply projected demand.

ii. There were a number of gas supply interruptions in 2021 which posed a challenge to the security of supply. Due to increasing demand coupled with an increasing proportion of themal generation in the generation mix in Ghana, there is a need to arrange for increased natural gas supply for thermal generation.

iii. Relocation of the 250 MW Ameri Power Plant from Takoradi to Kumasi reduces transmission system losses significantly. It also improves the voltage regulation in Kumasi & its environs and aids export.

iv. An estimated amount of MMUSD 872.8 will be required to purchase Natural Gas to run the thermal plants (i.e., a monthly average of MUSD 72.74).

v. The projected energy consumption for 2022 is 23,579 GWh of which:

- ✓ Hydro supply will be 7,394.15 GWh representing 31.36% of the total energy supply;
- ✓ Thermal supply will be 16,000.04 GWh representing 67.86% of total energy supply; and
- ✓ Renewables supply (directly connected to NITS) will be 184.38 GWh representing 0.78% of total energy supply.
- ✓ VALCO is expected to operate on one and half pot lines with projected total consumption of 765.39 GWh.
- ✓ Total projected energy export is 1,953 GWh for 2022.

b. Requirements for NITS Reinforcement

vi. Loss of 330 kV Takoradi Thermal – Anwomaso, 330 kV Anwomaso – Kintampo and 330 kV Pokuase – Volta Lines cause severe system disturbances.

vii. Transmission network analysis shows that in instances where there is a lot of generation in the west, the transmission lines in the western corridor (especially the Tarkwa – New Tarkwa and the Tarkwa – Prestea lines) become heavily loaded.

c. Medium Term Supply

a) Total electricity requirement for Ghana including power exports to Togo, Benin, Burkina Faso, and Mali is projected to increase from 25,983 GWh in 2023 to 34,920 GWh by 2027 at a Compound Annual Growth Rate (CAGR) of approximately 7.7%. The Ghana system peak demand is projected to increase from 3,987 MW in 2023 to 5,172 MW in 2027.

b) Analyses carried out indicate that existing generation alone will not be adequate to supply projected demand with the minimum required 18% operating reserve within the medium term. There are a number of on-going Committed Generation projects as well as some Other Planned Generation Projects whose capacity additions will be required within the medium term to have supply adequacy.

Chapter 8
RECOMMENDATIONS

8 RECOMMENDATIONS

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

a. Generation

a) Due to the growing electricity demand in Ghana, there is the need to make arrangements to increase gas supply volumes to enable more Thermal generation in order to avoid excessive draw down on Akosombo and Bui hydro facilities. It is also very important to make necessary investments towards an improved gas supply reliability owing to the increasing dependency on natural gas for power generation.

b) Quantities of liquid fuel (LCO, HFO and DFO) need to be procured and stored to serve as strategic stocks for Thermal Generation for use at the respective dual-fired thermal power plants such as Cenpower, Amandi, AKSA etc. in case of instances of gas supply interruption.

c) All efforts should be expedited to relocate the 250 MW Ameri Power Plant by September 2022 and to create a new generation hub/enclave in Kumasi to improve network stability. It will address voltage limit violations in the mid-sections of the Ghana power system in situations such as when Bui units are not in service as well as reduce line loadings between Kumasi and the South-Eastern and South-Western generation enclaves.

   It will boost supply reliability to the mines in the Western parts of the NITS and also give Ghana a competitive advantage for power exports to Burkina, Mali, and other potential customers north of Ghana.

d) The results of analyses of the supply/demand outlook for the medium term indicate that for 2023, apart from the recommendation to expedite the re-operationalization of the Ameri Plant the following measures need to be pursued to ensure security of supply to consumers in Ghana:
   - ✓ the Bridge Power Plant 'Phase I' must become operational by 2023 as scheduled;
   - ✓ ensure a high availability of all existing generating plants throughout the year.

e) For 2024 and beyond, there is a need to ensure timely completion of all Committed Genertion and Other Planned Generation projects in order to continue to adequately meet the Ghana power system demand with the required 18% reserve. These are:

- ✓ The Karpower Phase III plant to be located in Kumasi,
- ✓ The AKSA Phase II Power Plant,
- ✓ The Sunon Asogli Plant Phase III Project, and
- ✓ The Pwalugu Hydro/Solar Hybrid Plant.

b. Transmission System

f) The following critical transmission reinforcement projects are required to ensure power supply reliability in the medium term:

- ✓ Upgrade of 161 kV Takoradi Thermal – Cape Coast – Winneba - Mallam lines
- ✓ 161kV Pokuase – Mallam Project (Transmission Line and Substation)
- ✓ Upgrade of 161 kV Akosombo – Tafo – Nkawkaw – Konongo - Kumasi lines

g) A 330 kV line circuit from Pokuase – Anwomaso is required to enhance power evacuation in the middle corridor and improve overall system reliability.

h) Upgrade of the Western Corridor lines coupled with Dunkwa break-in on the 330 kV Takoradi Thermal – Anwomaso line relieves overloads during normal operations and contingency on any of the Western corridor lines.

i) The construction of the proposed second tie-line (330 kV) between Ghana and Cote d'Ivoire from Dunkwa to Riviera (in Cote d'Ivoire) will boost the interconnection between the two countries and trading in the WAPP.

j) Replace the existing 200 MVA 225/330 kV auto transformers on the Ghana – Burkina tie-line at Nayagnia with two (2) autotransformers with Phase shifting capabilities.

k) Replace the existing 200 MVA 225/161 kV auto transformers on the Ghana – Cote d'Ivoire tie-line at Prestea with two (2) autotransformers with Phase shifting capabilities.

l) Repair and restore defective capacitor banks and reactive compensation devices on the NITS especially in the southern parts of the NITS to provide voltage support on the NITS and reduce system losses.

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

n) With increasing load in the Kumasi Metropolis coupled with expected increase in export in the coming years, a third bulk supply point is required at Kumasi.

o) An upgrade of the existing SCADA Network Manager System at the System Control Centre equipped with RE dispatch tools and the implementation of a backup Control Center is required in the short to medium term.

p) In addition to the projects listed above, the following transmission expansion projects are required to be implemented in the medium term to increase transmission transfer capacity and improve upon reliability of supply:

    - 2nd Circuit 330 kV circuit from Takoradi Thermal through Kumasi to the north
    - Eastern Transmission Corridor Projects:
        - 161 kV Akosombo/Kpong GS – Asiekpe Transmission Line
        - 161 kV Asiekpe – Kpando Transmission Line
        - 161 kV Kpando – Juale Transmission Line
        - 161 kV Juale – Yendi Transmission Line
        - A 161 kV, 2x33 MVA Substation at Kpandai (to supply Nkwanta, Salaga and Bimbila)
    - 225/161 kV Prestea Substation Improvement Project
    - Akwatia – New Abirem Loop Closure
    - 2nd circuit to Obotan by breaking into the existing 161kV Kumasi – New Obuasi transmission line
    - A 330kV double circuit, second interconnection line between Ghana (Dunkwa 330kV) and Cote d'Ivoire (Bingerville).

✓ Supply of 6 No. 161/34.5, 125/145 MVA transformers

9 APPENDICES

Appendix A – Forecast: Peak and Energy Demand

A1: Base Case - Peak Demand Forecast (MW): 2022 - 2031

A2: Base Case - Energy Demand Forecast (GWh) -2022 – 2031

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): 2022 – 2031

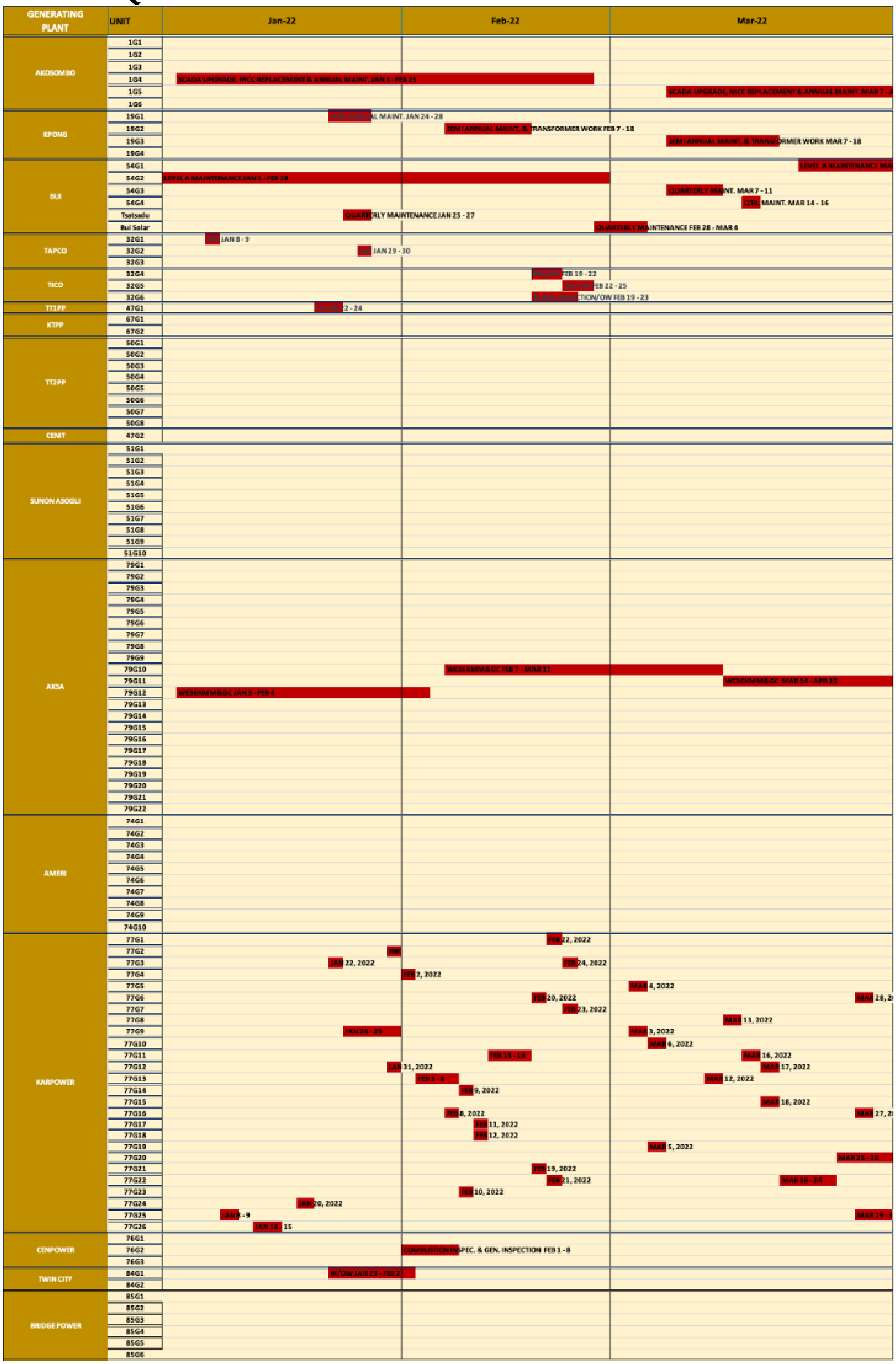
Load Forecast: Peak Demand (MW)	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
ECG	2,328.00	2,537.46	2,659.28	2,823.58	3,009.93	3,244.97	3,524.02	3,818.89	4,143.58	4,496.01
NEDCo	306.04	346.23	388.69	417.77	447.35	474.28	500.46	525.98	568.67	614.81
ENCLAVE POWER COMPANY	58.99	77.28	81.88	84.64	90.16	93.84	99.36	103.04	108.56	112.24
MINES	216.21	218.37	281.20	295.02	330.91	331.80	335.01	336.54	334.93	333.41
Other Bulk Customers	78.04	107.75	131.05	141.94	147.34	159.34	159.34	177.74	187.74	187.74
VALCO	95.00	164.80	164.80	164.80	164.80	164.80	292.93	292.93	371.05	371.05
CEB(Togo/Benin)	100.00	120.00	120.00	120.00	120.00	120.00	120.00	120.00	120.00	120.00
SONABEL(Burkina)	150.00	225.00	225.00	225.00	237.12	248.98	261.43	274.50	288.22	288.22
CIE (Cote d'Ivoire)	50.00	-	-	-	-	-	-	-	-	-
EDM(Mali)	-	-	-	-	-	60.00	80.00	100.00	110.00	120.00
Network Usage	2.00	1.84	1.97	2.07	2.21	2.38	2.61	2.79	3.03	3.23
LOSSES	161.00	188.22	201.88	216.59	243.53	271.92	298.27	319.20	346.02	368.83
Total	**3,545.27**	**3,986.96**	**4,255.74**	**4,491.42**	**4,793.36**	**5,172.30**	**5,673.43**	**6,071.62**	**6,581.79**	**7,015.53**

A2: Base Case -Projected Energy Demand (GWh) -2022-2031

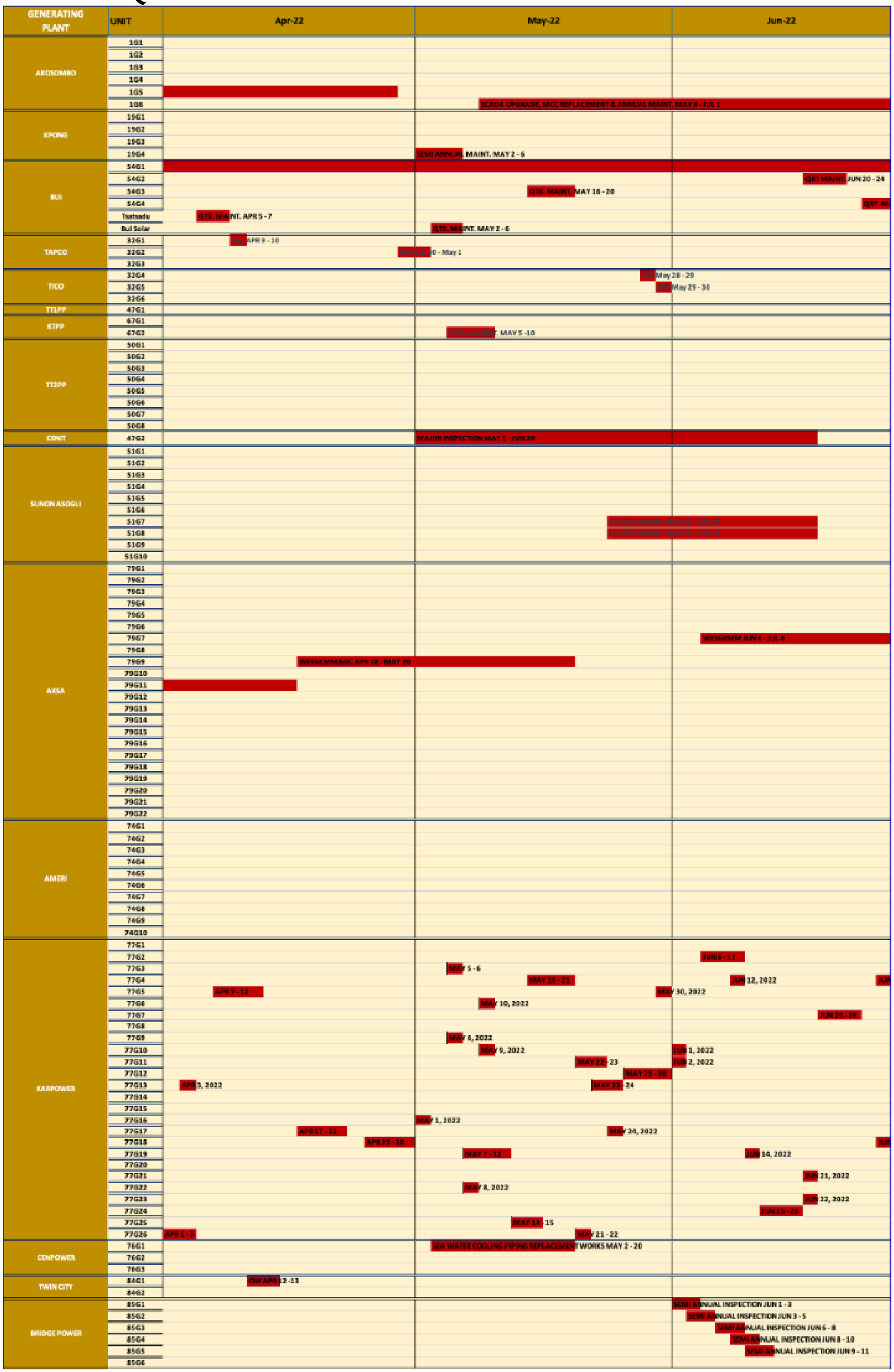
Load Forecast: Energy (GWh)	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
ECG	15,817.28	16,769.21	17,574.25	18,660.07	19,891.59	21,444.87	23,289.07	25,237.75	27,383.47	29,712.61
NEDCo	1,903.73	2,163.66	2,428.94	2,610.71	2,795.55	2,963.82	3,127.44	3,286.94	3,553.66	3,842.02
ENCLAVE POWER COMPANY	283.80	384.48	407.37	421.10	448.56	466.87	494.33	512.64	540.10	558.41
MINES	1,406.06	1,628.14	1,991.68	2,118.46	2,425.63	2,482.30	2,492.19	2,500.27	2,490.51	2,490.51
DIRECT	379.25	595.79	745.44	811.83	845.24	924.64	925.21	1,044.04	1,110.33	1,110.92
VALCO	765.39	1,371.47	1,371.47	1,371.47	1,371.47	2,437.78	2,437.78	3,087.85	3,087.85	3,087.85
CEB(Togo/Benin)	650.00	650.00	743.59	743.59	743.59	743.59	743.59	743.59	743.59	743.59
SONABEL(Burkina)	1,051.20	1,314.00	1,314.00	1,314.00	1,384.80	1,454.04	1,526.74	1,603.08	1,683.23	1,683.23
CIE(Cote d'Ivoire)	252.00	-	-	-	-	-	-	-	-	-
EDM(Mali)	-	-	-	-	-	352.15	469.54	586.92	645.61	704.30
Network Usage	11.07	12.08	12.90	13.62	14.52	16.15	17.24	18.74	20.02	21.33
LOSSES	1,058.71	1,094.23	1,173.92	1,260.51	1,429.03	1,633.98	1,716.44	1,893.70	2,024.01	2,156.69
Total	**23,578.51**	**25,983.05**	**27,763.55**	**29,325.35**	**31,349.97**	**34,920.18**	**37,239.57**	**40,515.52**	**43,282.39**	**46,111.48**

APPENDIX B: GENERATOR PLANNED MAINTENANCE SCHEDULE

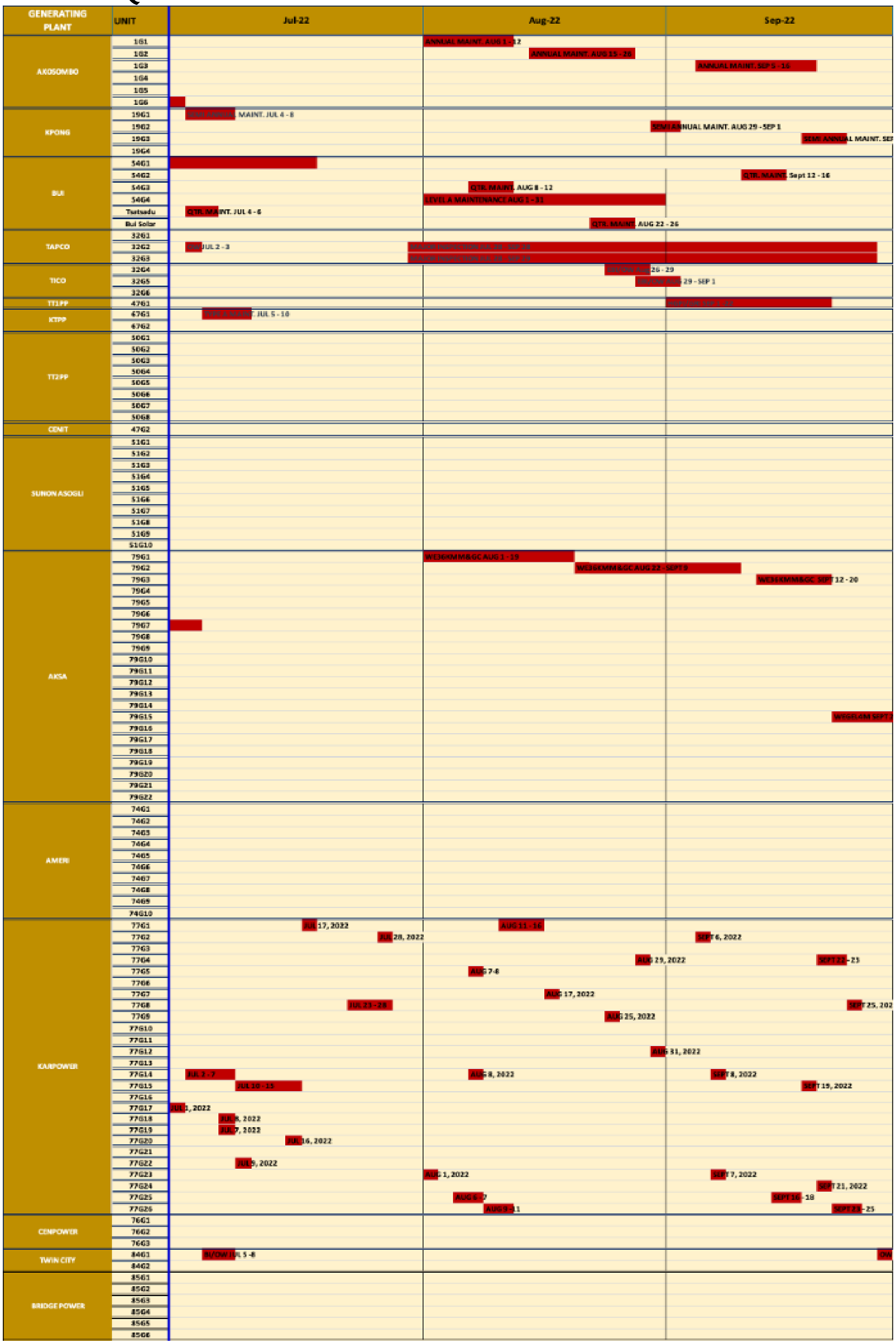
i. 1st Quarter 2022 Schedule:



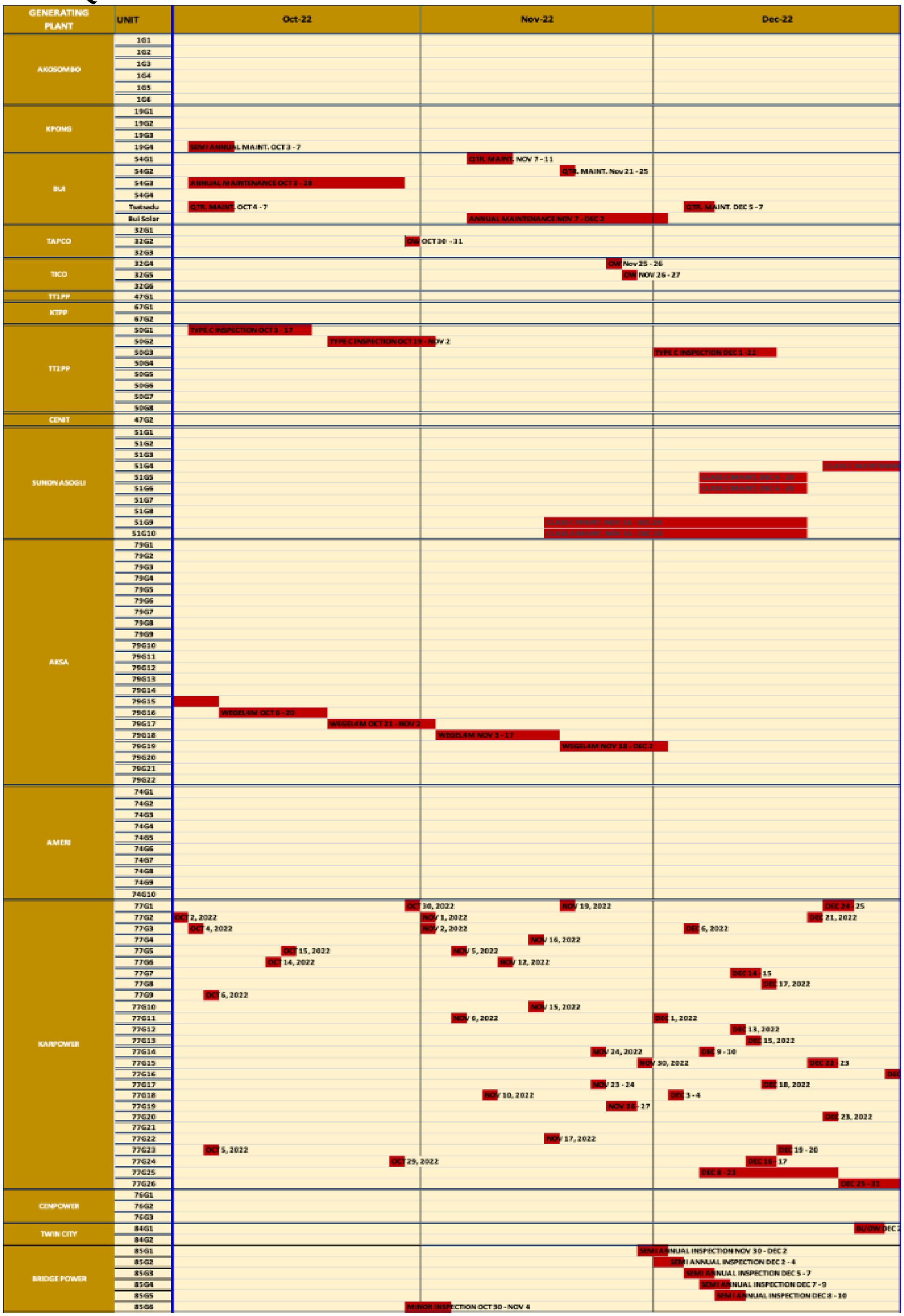
ii. 2nd Quarter 2022 Schedule:



iii. 3rd Quarter 2022 Schedule:



iv. *4th Quarter 2022 Schedule*



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