# INTEGRATED POWER SECTOR MASTER PLAN FOR GHANA

## EXECUTIVE SUMMARY

**MARCH, 2023**

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# Integrated Power Sector Master Plan for Ghana

## Executive Summary (Vol1)

**March, 2023**

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# FOREWORD

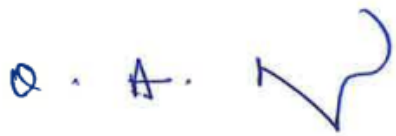
The 2023 Ghana Integrated Power Sector Master Plan (IPSMP) is an output of months of work by the Energy Commission and various energy sector agencies in Ghana, with financial support from the United States Agency for International Development (USAID) through the West Africa Energy Project (WAEP). In 2018, the first IPSMP was developed in close collaboration with Ghana energy sector agencies, led by the Energy Commission (EC), Ghana Grid Company (GRIDCo) and the Ministry of Energy (MoEn). This 2023 IPSMP is the second update of the 2018 IPSMP.

The vision of the IPSMP is to plan for a resilient grid power system that reliably meets Ghana's growing power demand in a manner that supports sustainable socio-economic development.

The IPSMP indicates that there is enough capacity (4,763 MW) to meet both demand at peak and the planned reserve margin of 18% up to 2025, therefore additional conventional thermal generation will not be needed until 2026. However, intermittent renewable energy sources will have to be added to help reduce generation cost in the medium term due to their comparatively low operational cost and help reduce fossil fuel dependency.

The Government of Ghana (GoG) is currently pursuing the Energy Sector Recovery Programme (ESRP) with the objective of curtailing the financial drain and averting such further occurrences going forward. The immediate objective of the ESRP is to provide a clear and comprehensive roadmap of strategic actions, reforms, and policies that would instil discipline into the energy sector to ensure financial viability and sustainability. For the medium term, the ESRP provides a guiding framework to ensure good governance practices in the energy sector, by establishing a strong linkage between energy sector planning and timely procurement of energy infrastructure investments. These investments are expected to be supported by competitive, transparent, and fair procurement processes for acquiring new generation resources to ensure that electricity costs are as low as possible, which can translate into consumer tariffs that are as low as possible while being cost-reflective.

The Energy Commission, together with the Power Planning Technical Committee (PPTC), will continue to lead in updating the IPSMP on a regular basis (at least every two years). The IPSMP will form the basis for the development of the power sector going forward.



Ing. Oscar Amonoo-Neizer

Executive Secretary, Energy Commission

March 2023

# ACKNOWLEDGEMENTS

The 2023 Integrated Power Sector Master Plan (IPSMP) was updated by the Energy Commission and the Power Planning Technical Committee (PPTC) with financial support received from USAID Ghana, through West Africa Energy Programme (WAEP).

The Energy Commission wishes to express its gratitude to ICF, the developer of IPM for extending the validity of the license at no cost. Also, we acknowledge the support and feedback received from USAID's local Energy Team (Mark Newton and Dorothy Yeboah Adjei) during the update of the IPSMP.

The Energy Commission and the PPTC team also acknowledge the important role played by officials from the Ministry of Energy in their sustained support for the 2023 update of the IPSMP.

The Energy Commission would like to thank the management and officials of the key stakeholder institutions—VRA, BPA, GRIDCo, ECG, NEDCo, EPC, PURC, GNPC, and GNGC—for their active participation in various activities associated with the updating of the 2023 IPSMP by dedicating resources and necessary data for the power sector modelling. They allowed their technical staff to work and provided the necessary data for the power sector modelling.

**Stakeholder Institutions Participating in the IRRP Process**

Volta River Authority (VRA)
Bui Power Authority (BPA)
Ghana Grid Company, Ltd. (GRIDCo.)
Electricity Company of Ghana (ECG)
Northern Electricity Distribution Company (NEDCo.)
Enclave Power Company (EPC)
Public Utilities Regulatory Commission (PURC)
Ghana National Petroleum Corporation (GNPC)
Ghana National Gas Company Ltd. (GNGC)

The PPTC Committee (see below) was established from these agencies, and these members contributed their time generously to ensure that the 2023 IPSMP was successfully updated in an inclusive manner. These stakeholder institutions are duly commended. All other stakeholders who provided data and specific suggestions that helped to shape the project and the update of the IPSMP are also duly acknowledged.

The 2023 Update of the IPSMP report was based on analysis of Ghana's power system as of the end of 2022 using ICF's power planning modelling tool, the Integrated Planning Model (IPM®).

**Power Planning Technical Committee**

| Name | Institution |
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| Ing. Mohammed T. Tampuri | Northern Electricity Company Limited |
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| Mr. Ebenezer Baiden | Electricity Company of Ghana |
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**IPM Core Team**

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|---|---|---|
| Simpson Attieku | EC | Energy Planning |
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# VOLUME 1: ABRIDGED OF INTEGRATED POWER SECTOR MASTER PLAN

The IPSMP was developed by the Energy Commission in collaboration with the Power Planning Technical Committee and with financial support from the United States Agency for International Development under the West African Energy Programme (WAEP). The IPSMP is a long-term capacity expansion plan. It assesses current and future challenges and opportunities in the country's power sector and develops a resilient generation capacity expansion plan that adequately meets the electricity demand forecast at the least cost.

The modelling for the IPSMP is based on the Integrated Planning Model (IPM®), which was used to develop the previous versions of the IPSMP. IPM is a dynamic, linear programming model that relies on sectoral and zonal data to simulate the operations of any power system for mid- and long-term planning horizons.

This Version of the IPSMP report highlights the following:

(i) Goals and objectives of the IPSMP;

(ii) Key findings and recommendations of the IPSMP; and

(iii) Recommendations for future planning and procurement.

## 1 VISION AND OBJECTIVES OF THE IPSMP

The primary objective of the IPSMP is to identify a **long-term Least-Regrets power sector resource plan** that will meet Ghana's future electricity demand, through an optimisation of existing and future power plants and other energy systems, as well as transmission capability. The Least-Regrets resource plan is based on an evaluation of the resilience of the Ghana power system to potential risks, including fuel prices and availability, hydrological changes, economic growth, policy and regulatory changes, and climate change.

The vision of the IPSMP is to develop "*a resilient power system to reliably meet Ghana's growing power demand in a cost-effective manner that supports the country's sustainable development*".

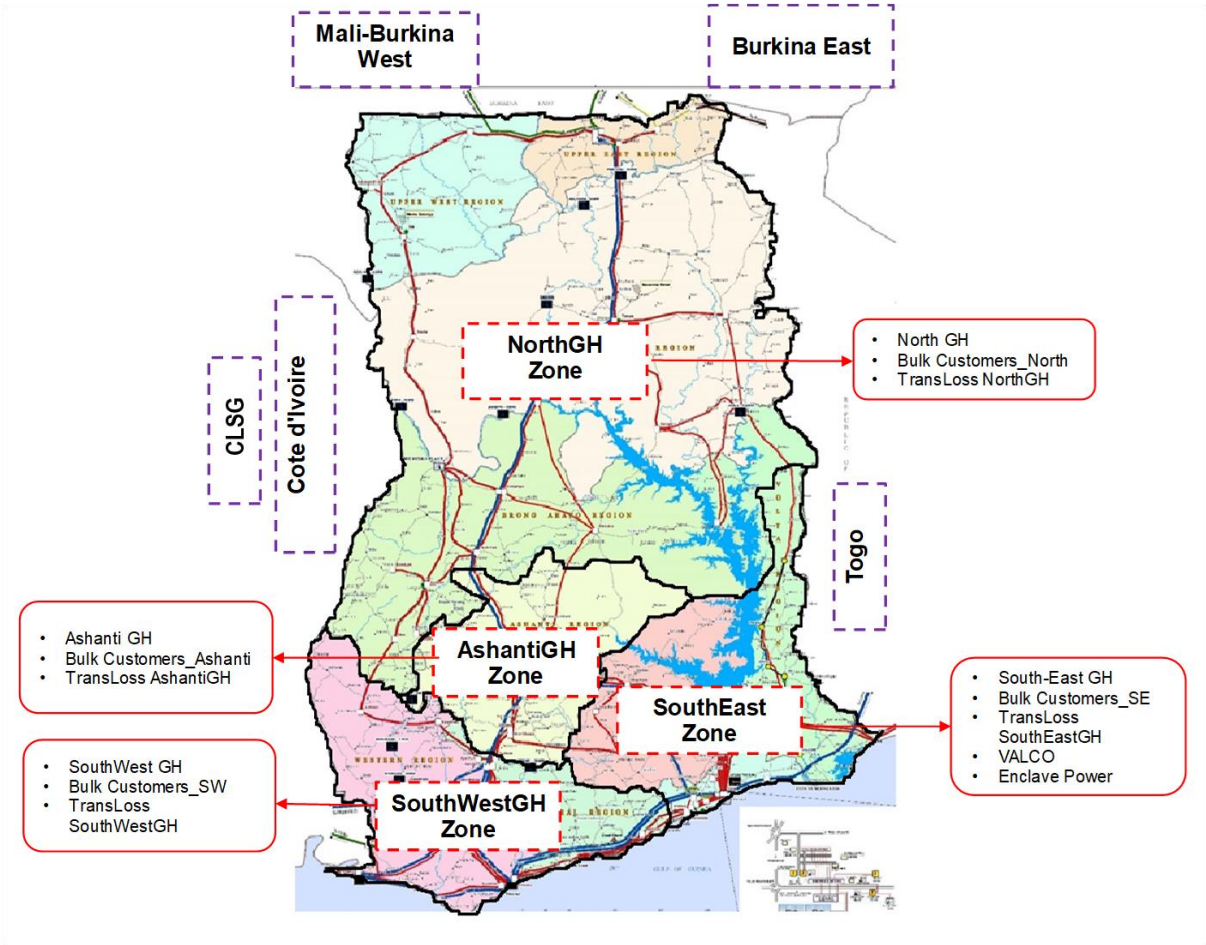
The specific objectives that define the course to realising this vision are:

1. Achieve cost-competitiveness in power generation and delivery;
2. Reliably meet local demand and exports in a timely manner;
3. Increase resilience of the power system;
4. Ensure positive economic impacts through job creation and GDP growth;
5. Meet Ghana's local environmental and climate change commitments;
6. Promote and implement sustained energy efficiency and demand-side management (DSM) programmes; and
7. Support secondary objectives beyond current universal access goals (e.g., productive uses of electricity, household-level connection, mini-grids).

The IPSMP vision and objectives are aligned with the Government of Ghana's policies in the power sector, and they were developed in a collaborative process led by the Energy Commission.

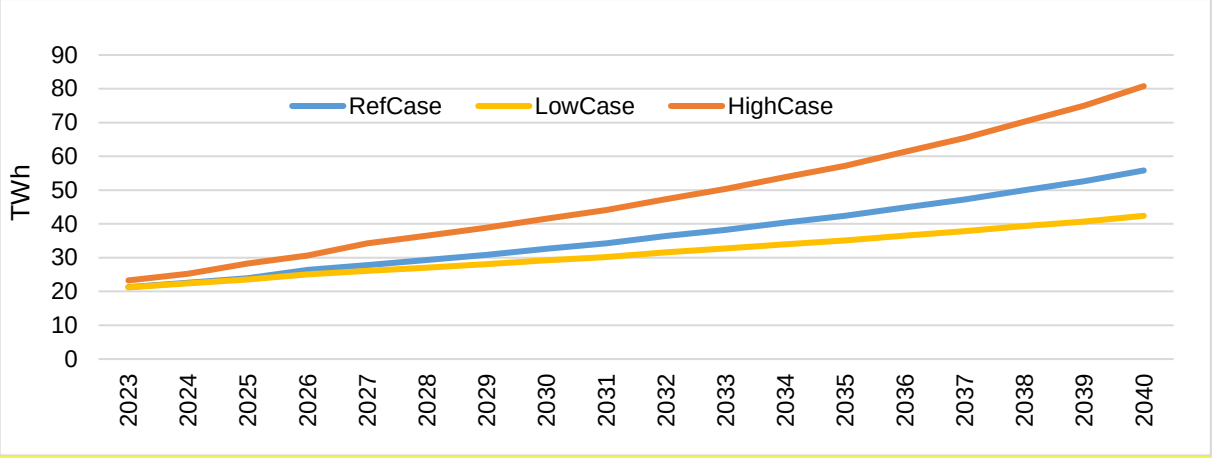
# 2 MODELLING ASSUMPTIONS

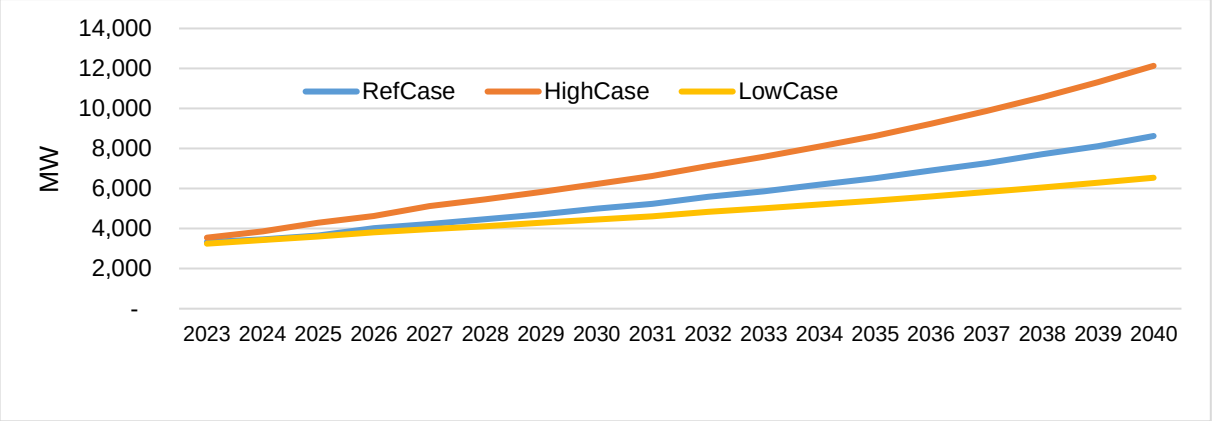
Current transmission constraints within and across some segments or corridors of the Ghana transmission grid system were used as a guide to segregate the electricity demand into four zones for the modelling (See ES Figure 1). For each of these zones, energy and peak demand forecasts were exogenous inputs that were estimated.




**ES Figure 1: Ghana Zones and Modelling Regions**

Given that any demand forecast can never be predictive (given the high range of uncertainty in underlying factors), it is important to develop various sensitivities to the reference demand forecasts. For the IPSMP, two different demand cases were developed—a high and a low demand case—relative to the Reference Case. The aggregated energy demand and peak demand forecasts, and their respective high and low cases are in ES Figure 2.




**ES Figure 2: Energy and Peak Demand Forecasts**

Other modelling parameters that were considered for the IPSMP are as follows:

- High-level Assumptions
  - Year maps
  - Financing
- Demand
  - Hourly demand
  - Import and Export
- Supply
  - Existing and firmly planned capacity
    - Unit types, cost, operational characteristics and constraints
  - Cost and performance of new generation options
    - Unit types, cost, operational characteristics and constraints
  - Renewable energy resources and renewable energy penetration assumptions
  - Sensitivities
  - Reserve margins
  - Fuel supply and price
    - Natural gas volume and infrastructure
    - Price and volume sensitivities
    - Conventional fuels (liquid fuels, coal, nuclear)
- Transmission

# 3 MODELLING APPROACH FOR DETERMINING LEAST-REGRETS STRATEGY

The selected Integrated Planning Model (IPM®), optimises demand-side options, generation, and transmission options simultaneously, and is well suited for scenario analysis.

To select a robust and resilient solution for expanding Ghana's power sector in the future, several different strategies and sensitivities were developed (see adjacent box). Five different strategies were developed and each of them was tested against 11 different sensitivities (ES Figure 3). Specific results or metrics from all of the strategy-sensitivity combinations were evaluated to determine the Least-Regrets solution. The sets of evaluated metrics were related to cost, resilience, reliability, local environment, land use area used for power generation, and climate change.

A **strategy** is a set of modeling assumptions about policy framework and technology/fuel decisions, which are conditions under Ghana's control.

**"Sensitivities"** test the performance of the various strategies under changing conditions (e.g., load forecasts, technology cost/availability, fuel and renewable resources), which are not fully under Ghana's control.

| | |
|---|---|
| **S1 Unconstrained** | Reference Case assumptions on demand, technology costs, gas resource availability, RE bounds, TTCs, build 50MW small hydro, Build 150 MW CC in Ashanti. No other technology-specific constraints on build options |
| **S2** Diversify with **Nuclear** | Reference case demand assumptions on demand, technology cost, gas resource availability, RE bounds, TTCs, build 50 MW small hydro and 150 MW CC, Diversify fuels by building a 1000 MW nuclear power plant in 2031 in SouthWest GH |
| **S3** Diversify Geographically | Reference case demand assumptions on demand, technology cost, gas resource availability, RE bounds, TTCs, build 50 MW small hydro, Build 150 MW CC in Ashanti, Build additional 180 MW combined cycle plant in Ashanti by 2027 and 2550 MW SouthEast by 2029 |
| **S4** Renewable Energy Master Plan | Reference case demand assumptions on demand, technology cost, gas resource availability, RE bounds, TTCs, build 50 MW small hydro and 150 MW CC Implementation of on-grid utility-scale RE capacities identified in the Renewable Energy Master Plan (REMP) |
| **S5** Enhanced G-NDC's | Reference case assumption on demand, technology costs, gas resource availability, TTCs, build 50 MW small hydro and 150 MW CC. Constrain CO2 emissions to half of unconstrained strategy emissions strategy emissions. |

| # | Sensitivity |
|---|---|
| 1 | Reference Assumptions |
| 2 | High Demand Growth |
| 3 | Low Demand Growth |
| 4 | High Fuel Prices |
| 5 | Low Fuel Prices |
| 6 | Limited Gas Supply |
| 7 | Greater Domestic Fuel Supply |
| 8 | Limited Water Inflows for Hydro |
| 9 | Higher RE Capital Costs |
| 10 | Lower RE Capital Costs |
| 11 | Lower Capital Cost for Conventional Resources |

**ES Figure 3: Strategies and Sensitivities Evaluated for the IPSMP**

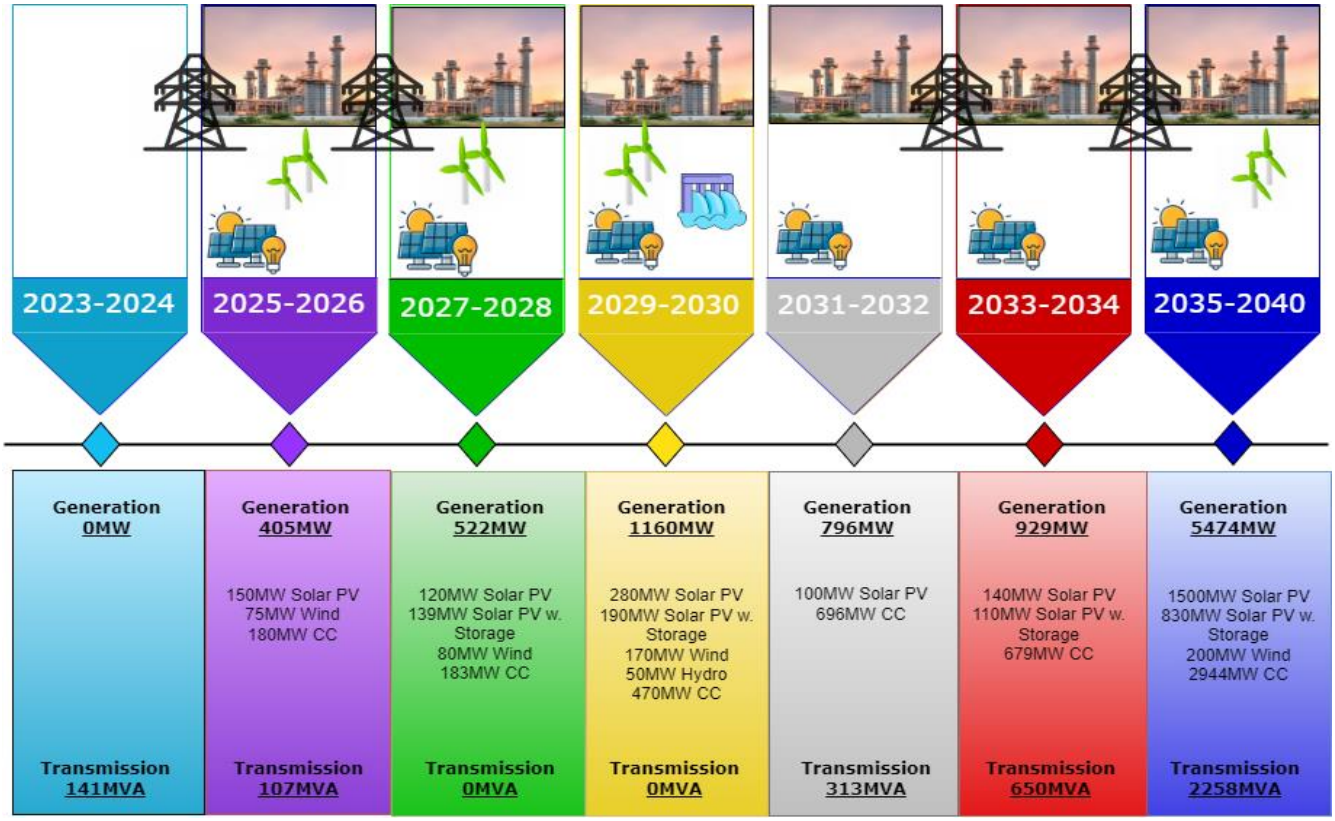
Investment costs (i.e. capital costs to be invested) and the total system costs (future capital, operations and maintenance, and fuel costs) were determined to be the most important criterion in

the Ghanaian context. Therefore, the least-cost strategy was evaluated against other metrics, to assess whether it remains a valid strategy for Ghana—i.e., whether the other metrics disqualify the least-cost strategy, or not. If disqualified, the next low-cost strategy would be selected for evaluation.

# 4 KEY FINDINGS AND RECOMMENDATIONS

The primary findings from the modelling and the recommendations associated with these findings are outlined below:

1. **Diversify Geographically Strategy (Strategy III)** is more resilient and conforms to government policy of diversifying generation capacity geographically, and it also performs relatively well under all the other metrics for the whole 18-year planning period except the cost metric where the Unconstrained Strategy (Strategy I) performs better. Hence, the Diversify Geographically Strategy is deemed as the most favourably ranked strategy and therefore it qualifies as the ***Least-Regrets* Strategy** for the 2023 IPSMP**.** The build plan indicated by this strategy is outlined in ES Figure 4.




**ES Figure 4: 2023 Least-Regrets Generation and Transmission Additions (Reference Case Demand)**

- The average cumulative 18-year total system costs are about $234 million USD higher than the lowest strategy, which is the Unconstrained strategy. However, the Least regret strategy performs very well under investment cost, resilience metrics and land use.
- the local reserve metric with the highest share of generation in the NEDCo and Middlebelt areas in both the 10-year and 18-year period recording resilience of about 78%. Natural gas is the primary conventional fuel used in this strategy, and if the cost of natural gas is lower than what is assumed, then the total system cost of this strategy will be considerably lower than what is shown in the current analysis. Natural gas for the power sector is primarily supplied by domestic natural gas resources and imports from Nigeria through WAGP.
- Solar PV and wind costs are expected to decline enough to be built economically by the mid-2020s. Solar PV generation in the northern region and the creation of a generation

enclave in Kumasi (Ameri, AKSA) also reduce transmission losses and mitigates voltage stability issues around Kumasi.

- Additional studies, however, is needed to fully assess the impact of grid integration of renewables, including the need for ancillary services, in light of policy goals and the expected cost decline of specific technologies.
- Ghana's Wholesale Electricity Market is expected to support the provision of ancillary services.
- Energy efficiency measures could reduce the Reference case power demand by nearly 7% in 2030, purely due to customers making economic decisions to save money by deploying energy-efficient lighting, air-conditioners, and industrial motors. Increased efficiency reduces consumer costs and engenders a more productive economy.

**Recommendation 1**

- Prioritise the use of indigenous resources (small hydro and other renewables, as well as indigenous natural gas) in power generation.
- Develop new competitively procured solar PV and wind capacity in a slow and gradual manner to increase RE penetration and increase know-how on integration of variable RE plants.
- Build dispatchable small hydropower plants capable of providing additional non-power benefits (such as irrigation, river transportation, flood control, fisheries, etc.).
- As prices of solar PVs with storage decline, consider solar PVs with storage for the middle-to-north of the country, to enhance grid stability.
- Continue to promote energy efficiency uptake to save consumer costs in the street lighting, commercial, industrial, and residential sectors through consumer awareness, access to low-cost finance, and implementation and enforcement of standards and building codes.

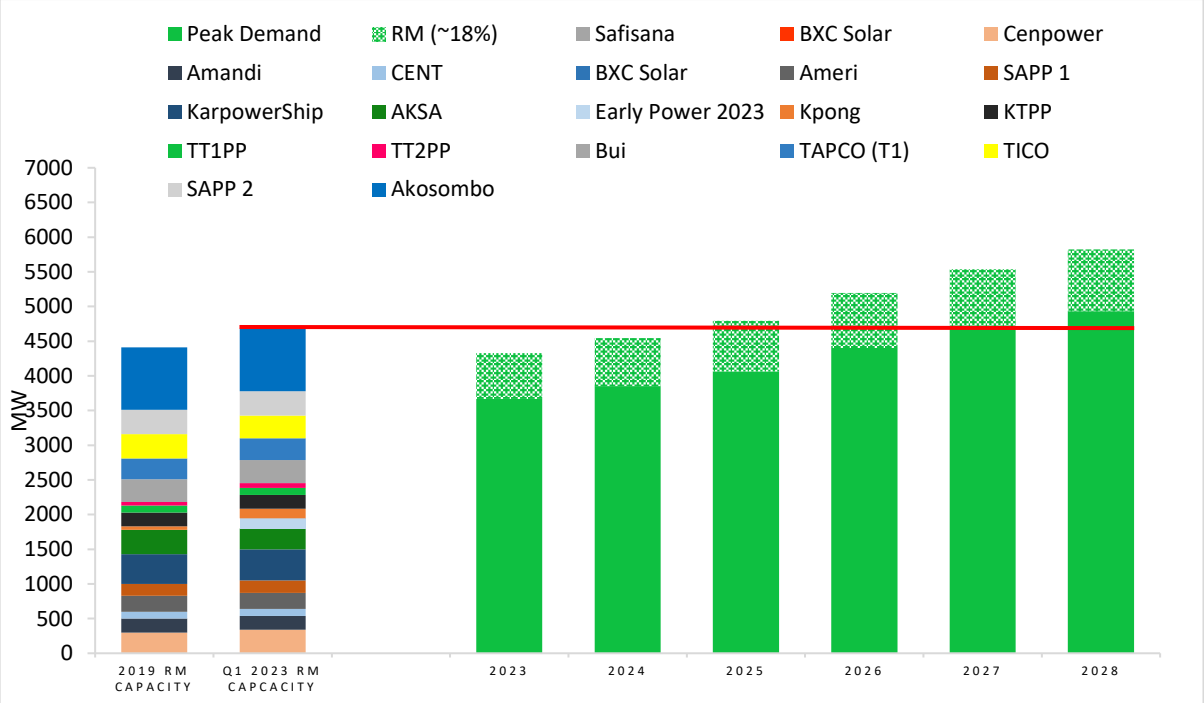
2. There is enough capacity (4,763 MW) to meet both demand at peak and the planned reserve margin of 18% for 2023 (4,328 MW) and 2024 (4,547 MW). (see ES Figure 5 and 6).

- Although there is enough capacity in the short-term, developing and installing *competitively procured* intermittent renewable energy will be added to help reduce generation cost in the medium term due to their comparatively low operational cost, and reduce fossil fuel dependency in 2025 and is consistent with the Least-Regrets strategy.
- Over the next 10 years (2023–2032), based on the Least-Regrets Strategy under the Reference Case demand projection, a cumulative sum of about 1,485 MW of renewable energy (solar PV, wind, Solar PV with Storage, and small hydropower) and combined cycle capacity of about 1,490 MW will be needed.

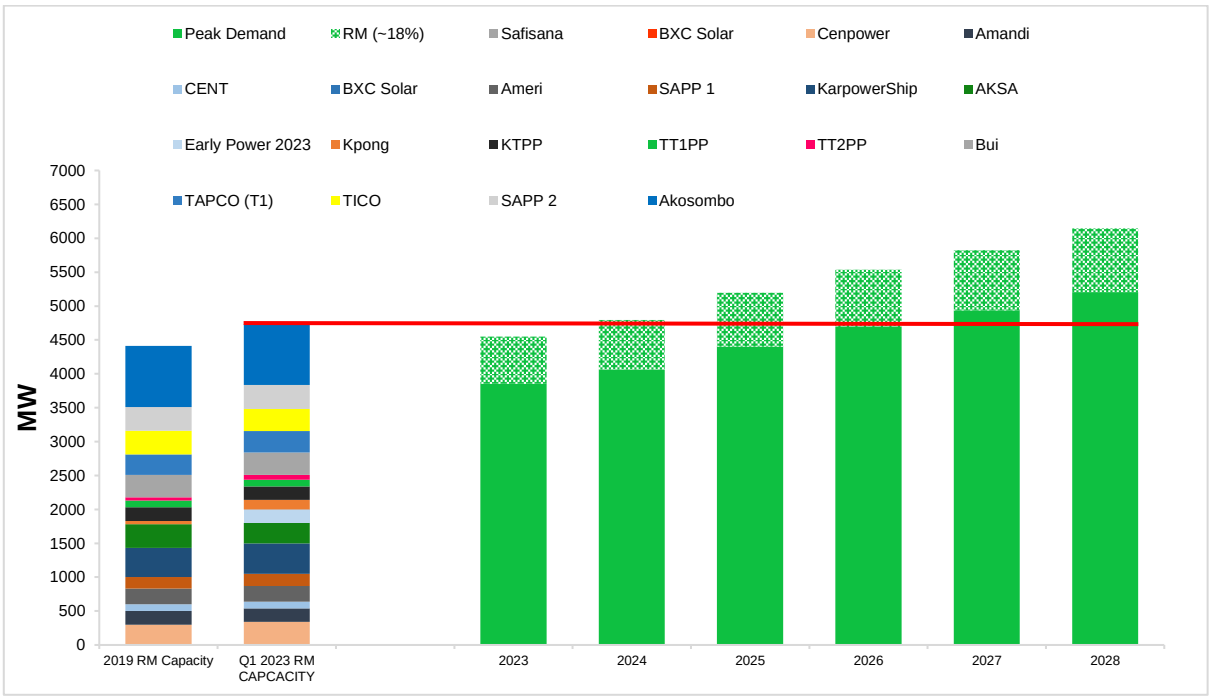
– New solar PV and wind power plants need to be economically competitive with natural gas-based power plants in the long run. Therefore, the economics of renewable energy technologies is affected by the delivered cost of natural gas. The capital cost of new solar PV and wind plants should be low enough to displace the marginal cost of generation from gas-based power plants.

**Recommendation 2**

- New thermal plants should come online in 2025. However, the 175 MW AKSA power plant, to which PPA has been signed with the off-taker, ECG, and is expected to come online in 2025 should be used to fill the 150 MW additional capacity required in 2026 in the Ashanti model region
- Timing for new power plants may be influenced by whether TAPCo, and T3 would be retired or refurbished, and the timeframe for the refurbishment.
- Considering the time for procurement, design, construction and commissioning of power plants, the procurement of all additional capacities required in 2028 should be initiated now.
- Implement the wholesale electricity market, as soon as possible, to increase dispatch efficiency and lower generation costs.
- Evaluate and implement options to increase natural gas supply reliability for existing and under-construction power plants.
- Continue to support development of competitively procured RE projects.




**ES Figure 5: Medium-Term Supply-Demand Balance for Reference Electricity Demand**




**ES Figure 6: Medium-Term Supply-Demand Balance for High Case Electricity Demand**

3. The need for conventional power plants is dependent on the amount of installed RE capacity, EE penetration, and expected demand growth in the future.
   - From 2023 to 2032, about 1,530 MW of thermal capacity is needed, and an additional 3,623 MW is needed to meet rising demand from 2033 to 2040.
   - These thermal capacity needs can be met by either nuclear or gas plants, but these technologies tend to displace each other.

– Nuclear power is an option beyond 2030, but its development is dependent on policy and economics. Nuclear plants are more expensive to build than gas plants and require greater regulatory oversight.

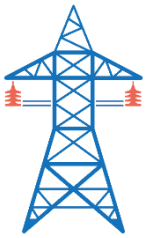
**Recommendation 3**

- Assess demand growth, taking into consideration the impact of Energy Efficiency (EE) and demand side management (DSM).
- Continue to resource Nuclear Power Ghana in delivering the first nuclear power plant
- The Standard and Labelling program should cover all electrical appliances and equipment.

4. Additional transmission builds and/or new local generation capacity are needed beyond the mid-2020s to improve grid stability and reliability, particularly in the Middle Belt and NEDCO regions.
   – Transmission builds lower overall system cost and allows for greater export opportunities.
   – Reliability improves upon completion of current transmission projects including the 330kV Aboadze-Prestea-Kumasi-Tamale-Bolgatanga line.
   – Integrating variable RE capacity up to 10-15% of total system capacity improves reliability of supply in the northern part of the country during off-peak hours, and reduces system losses.

**Recommendation 4**

- Conduct additional transmission analyses to confirm specific transmission builds and improvements in the 2020s, particularly towards the Middle Belt
- Facilitate the integration of variable REs into the grid in the northern zone through use of modern technologies and operational changes.
- Give more attention to the proposed project to close the eastern corridor loop from Kpandu-Kadjebi to Yendi through Juale (with or without the Juale hydropower plant) to increase reliability in the NEDCo zone.



5. The creation of a generation enclave in Kumasi has provided an opportunity for gas to be consumed in the middle belt which can drastically reduce the financial obligations under the Sankofa take-or-pay agreement.
   – Gas supply estimates indicate that there will be insufficient gas to meet demand for power generation beyond 2025.
   – Additional domestic gas is projected to come in 2028 and supply of gas from LNG is scheduled to commence at the end of 2024.
   – Further assessment of the gas supply situation needs to be carried out in light of new additional domestic production before any determination for long-term LNG contracts.

**Recommendation 5**

- An LNG regasification and storage terminal are relevant to increase gas supply security, in case of domestic gas interruptions (due to maintenance or unplanned outages). However, gas delivered from such an LNG terminal will have higher

# 5 RECOMMENDATIONS FOR FUTURE PROCUREMENT


Least-cost generation is best achieved through procurement of investment in new generation and transmission by competitive bidding using a well-structured procedure to guide participants.

Future procurements of additional generation expansion to meet demand should be based on the supply-demand figures in the IPSMP. The timing, location, and size of the additional generation, as well as the type of technology or resource used, should also be consistent with the plan to ensure that the capacity procured meets demand without creating over-capacity.

All future procurement of power plants for the regulated market should be open, competitive and subject to approval by regulators. This will ensure that the procurement is aligned with the recommendations of the IPSMP, and the rules of the wholesale electricity market.

Bulk customers planning to procure their own supplies to meet their demand should provide information on their demand forecast and planned supply sources to the EC and PURC, to support the development of the IPSMP.

**Recommendation 7**

- All future procurement of power plants connected to the grid should be based on the recommendations of IPSMP.
- Competitively procure new transmission systems based on a Transmission Master Plan that is consistent with IPSMP results.
- Location, size, timing, and type of technology or resource for future procurement should all be laid out without creating over-capacity.
- Bulk and direct customers, who are in the deregulated market, may procure power generation on their own.
- Regulated DISCos should seek no-objection from the regulators, Energy Commission, and PURC to proceed with an acceptable competitive procurement process.
- The design of the Wholesale Electricity Market (WEM) and the development of the market rules and their implementation need to be expedited to provide price signals for the need and location of new generation and any required ancillary services in the long term.

# 6 OTHER RECOMMENDATIONS

The following recommendations on demand forecasting, transmission, and distribution are highlighted here for focused attention in the short term.

## Demand

- 
- Formulate and implement new policies and programmes that support the deployment of energy efficiency and conservation measures (e.g., the use of light-emitting diode [LED] lamps, more efficient air conditioners, and fridges/deep freezers) to help decrease the growth rate of electricity demand, and keep carbon footprints down while helping businesses and homes to save money.
- Continue and enhance collaboration between the various agencies (e.g., GRA/Customs, the Energy Commission, and Ghana Standards Authority) that implement DSM measures to effectively enforce the ban/control of the entry of substandard or non-energy efficient appliances at the country's points of entry.

## Transmission

- Prepare a Transmission System Master Plan consistent with the IPSMP.
- Upgrade the lines from the Western region (Aboadze) to the Middle Belt area, and the link between Tema/Akosombo and Aboadze to address transmission constraints and increase the reliability of the transmission network.
- Adopt, as a matter of policy, double circuits for high-voltage transmission lines to mitigate future right-of-way constraints in all-new high-voltage transmission and sub-transmission lines.
- Carry out an assessment of the aggregate effect of all variable REs (wind and solar) currently connected to the grid, to help in recommending mitigation measures for future variable RE projects.

- Arrange to procure and install weather forecasting stations in collaboration with the Ghana Meteorological Agency at the System Control Centre (SCC), GRIDCo substations, and request that RE developers install same at their RE plant sites, to help SCC predict the output of the various REs connected to the grid and assist in the overall dispatch process.

### Distribution

- Utilise information gathered from smart meters and automatic meter readers (AMR) to implement options to reduce commercial losses and improve the collection rate of distribution utilities. Analyses of the data will also provide the most recent data from these customers for future demand forecasting.
- Improve coordination between the Ministry of Energy and the distribution utilities in the extension of the grid to new communities and the connection of new customers.
- Improve inventory management of meters to avoid situations where some customers are put on a flat rate.
- Expand the scope of 2017 ECG's Accra Reliability Assessment study to cover more regional capitals and other ECG service areas to improve distribution planning.
- NEDCo needs to expand the scope of load flow analyses carried out in Tamale (2016) to include heavy load centres like Sunyani, Techiman, Wa, Bolgatanga and other towns and cities to improve distribution planning.
- Develop an integrated SCADA system across all utilities in Ghana.
- The deployment, operation and maintenance of solar PVs at the 33-kV and 11-kV voltage levels should be undertaken by the DISCo. However, GRIDCo should be informed or notified of the planning, construction, operation and maintenance stages since each stage has an impact on the NITS and dispatch decisions. Large (>20 MW) solar projects should be connected to the transmission grid at higher voltages.
- Carry out studies to determine localities where roof-top solar PV installations can result in significant technical loss reduction and improve value to the utilities.
- Distribution utilities should coordinate with MoE and harmonize GIS data collection and its use for planning, operations, and maintenance of distribution service assets, in order to save costs and avoid duplication of effort.


ENERGY COMMISSION