POWER AFRICA TRANSACTIONS AND REFORMS PROGRAM

ADVISORY BRIEFING PAPER

UPDATED GHANA GAS MARKET REVIEW SUBMITTED TO THE MINISTRY OF PETROLEUM

(FINAL REPORT)

December 15, 2015

This publication was produced for review by the Unites States Agency for International Development. It was prepared by Nexant as subcontractor to Tetra Tech under USAID Contract No. AID-623-C-14-00003

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1. INTRODUCTION

The nascent and dynamic nature of Ghana's emerging natural gas market requires regular assessments of the country's natural gas balance. This report presents an updated review of Ghana's natural gas market, incorporating available data and information on the latest gas demand, supply, and infrastructure developments, as of December 2015. The planning horizon used in this market review runs from 2015 to 2030.

The report covers existing and projected supplies of natural gas by source, including both indigenous and imported gas supplies transported through the West African Gas Pipeline (WAGP). It is based on the Ghana National Petroleum Corporation's (GNPC) latest long-term supply forecasts issued in December 2015.

The gas demand-side analysis is focused on the existing and projected gas demand by the power sector in Ghana's two main regions with thermal electricity generation capacity, namely Takoradi in the Western Region and Tema in the Greater Accra Area. This gas demand is based on the electricity generation demand forecasts produced by Nexant in its "*Electricity Demand Forecasting and Suppressed Demand Estimation Study*" submitted to the Ministry of Power in July 2015, and revised in August 2015 to extend the study period to 2030.

Based on this projected electricity demand, the present report on the Updated Gas Market Review for Ghana provides estimates of the potential levels of projected natural gas supply deficit nationally and regionally (for the Takoradi and Tema areas separately) over the 2015 to 2030 period. It then presents sensitivity results considering high and low cases, reflecting a combination of extreme gas supply and demand situations, as well as an additional scenario including a proposed coal-fired power plant project, as requested by the Volta River Authority (VRA).

Finally, the report addresses the issue of gas infrastructure availability to process and transmit the gas supplies required by the country's gas consumption centres in Takoradi and Tema, and how gas infrastructure can be developed to address the above determined gas imbalances. This includes the recently developed Western Corridor Gas Infrastructure Development Project (WCGIDP) and the Ghana segments of the West African Gas Pipeline (WAGP), with the possibility of using WAGP on "Reverse Flow" basis. The report lists also proposed LNG import projects that have been announced as an option to meet national and regional gas supply imbalances.

2. PURPOSE AND METHODOLOGY OF THE GAS MARKET REVIEW

This report aims to determine Ghana's potential gas demand during the 2015-2030 period (the Gas Demand) using the following approach:

(i) Determine the projected Thermal Electricity Demand (ThED) from the projected Total Electricity Demand (TED). The ThED is calculated by deducting the electricity demand expected to be served by Hydro and Renewable Energy from the TED;

(ii) Analyse the country's existing and projected Electricity Generation Capacity (EGC) and verify that the ThED can actually be served, including consumption peaks, for each year of the 2015-2030 period;

(iii) Determine the volumes of gas necessary to serve the projected Thermal Electricity Demand. Gas volumes in average MMscfd are calculated from the annual ThED in GWh using average gas and power plants characteristics (heat rate and efficiency factor, respectively); and

(iv) Determine the projected gas supply imbalances nationally and per region (Greater Accra and Western, or Tema and Takoradi respectively) according to their respective projected thermal power generation capacities and recommend ways to mitigate gas surpluses or deficits when and where they exist.

2.1. Input Data

(i) *Electricity Demand*

Electricity Demand (both TED and ThED) data used in this Gas Market Review (GMR) report are those coming from the "*Electricity Demand Forecasting and Suppressed Demand Estimation Study*" dated July 2015 produced by Nexant under the USAID-funded Power Africa Technical Assistance Program and submitted to the Ministry of Power in July 2015, and revised in August 2015 to extend the study period to 2030.

(ii) *Generation Capacity*

The power plants' (existing, under construction, fast track, and planned projects) generation capacity data used in this GMR report are based on information provided by the Volta River Authority and the Ministry of Power (MoP).

It is worth noting that the review of available dependable capacity aims only to:

a) Verify that there is enough existing and potential generation capacity to meet the ThED, including peak loads, and
b) Determine a weighted average efficiency factor in the calculation of the projected gas demand.

It is also important to clarify that the projected gas demand is not calculated from the dependable capacity (MW) of selected power plants using a load factor, but directly from the projected annual thermal electricity generation requirements (or ThED) in GWh consistent with the country's economic growth projections.

(iii) *Gas Supply Sources*

The existing and projected supplies of indigenous gas by source are based on the Ghana National Petroleum Corporation's (GNPC) latest long-term supply forecasts issued in December 2015. It should be noted that the projection data provided by GNPC have been retained on the basis that these have been produced by GNPC and the international oil and gas companies operating in Ghana's upstream sector as GNPC's partners. Nexant is not in a position to audit or provide a better set of gas supply forecasts since this type of upstream analyses is beyond Nexant's areas of expertise and outsourcing this work would be very costly.

Regarding Nigerian natural gas imports via the West African Gas Pipeline (WAGP), Nexant has taken into account historic supplies from Nigeria and its contractual commitments in the projection of future WAGP gas supply.

2.2. Translating from Thermal Electricity Demand to Gas Demand

The calculation steps that have been taken to translate projected ThED to projected gas demand are as follows:

(i) ThED denoted in MWh is divided by the system wide weighted average thermal efficiency of all thermal (gas-fired) power plants denoted in percentage on an annual basis to determine the gross energy level required in MWh. The estimated system wide weighted average thermal efficiency levels adopted for the calculations are presented in the table below.

Table 1: System Wide Weighted Average Thermal Efficiency
(Percentage)

	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
TE	37%	38%	39%	41%	41%	41%	41%	41%	41%	41%	42%	42%	42%	42%	42%	42%

Thermal efficiency for existing thermal power plants are supplied by VRA, while for future thermal power plants, an efficiency factor of 45% and 30% has been assumed for CCGT and OCGT units respectively.

(ii) The gross energy level requirement is then divided by 293 to convert it from energy unit (MWh) to volumetric unit (MMscf), using the natural gas calorific value assumption of 1 000 Btu\scf[1], hence the annual gas demand volume is derived.

(iii) The annual gas demand volume in MMscf is then divided by the number of days in a year to arrive at the average daily gas volume in MMscfd.

(iv) The nationwide gas demand volume is then split according to the proportion of thermal (gas-fired) electricity generation capacity each region (Greater Accra and Western Region, or Tema and Takoradi) possesses, giving an approximated gas demand per region used for the determination of regional gas balances.

2.3. Gas Balances

Because of the geographical location of electricity generation capacity and gas supply sources, gas balances are analysed on a regional basis (Greater Accra and Western Regions, respectively) in addition to the nationwide balance.

Mitigation of gas supply imbalances is considered using existing infrastructure (WCGIDP) or additional infrastructure (WAGP Reverse Flow) to transport potential surplus gas supplies produced in the West to the East. In the long-term, depending on financial viability conditions, a new onshore West-to-East gas pipeline and LNG imports facilities could be considered too as options to address supply imbalances as they emerge.

[1] 1 MWh = 3.4 MMBtu

3. PROJECTED NATURAL GAS DEMAND

3.1. Key Assumptions

In the foreseeable future, natural gas demand in Ghana is expected to be limited to use by the power sector only. The projected total demand for gas in this GMR report does not include other sectors' gas demand such as gas for heat or for the development of compressed natural gas (CNG) applications. The potential development of these gas-consuming segments has not been investigated because of a lack of data. Neither relevant market surveys nor credible analyses on non-power gas uses have been conducted to assess the potential non-power gas demand.

In order to establish the power sector's potential level of natural gas demand, two major elements would have to be considered:

- Electricity generation forecasts
- Electricity generation mix

In order to incorporate the results of the latest analyses on electricity demand, this updated gas market review has adopted the electricity generation forecasts from the "Electricity Demand Forecasting and Suppressed Demand Estimation Study", produced by Nexant in July 2015 and revised in August 2015 to extend the study period to 2030.

With respect to the projected electricity generation mix, Nexant had numerous exchanges with the Volta River Authority (VRA) and the Ministry of Power (MoP) after issuing the draft GMR report in August 2015. Both VRA and MoP have provided Nexant with feedback and updated data and information on the projected electricity output from non-thermal sources and on future developments in thermal electricity generation capacity.

3.2. Electricity Generation Forecasts

The Electricity Demand Forecasting and Suppressed Demand Estimation Study has adopted an econometric approach to estimate (domestic) electricity demand as well as electricity generation requirements.

The **base case** forecasts are presented in the figure and table below.

Figure 1: Electricity Demand & Generation Requirement Forecasts [2]

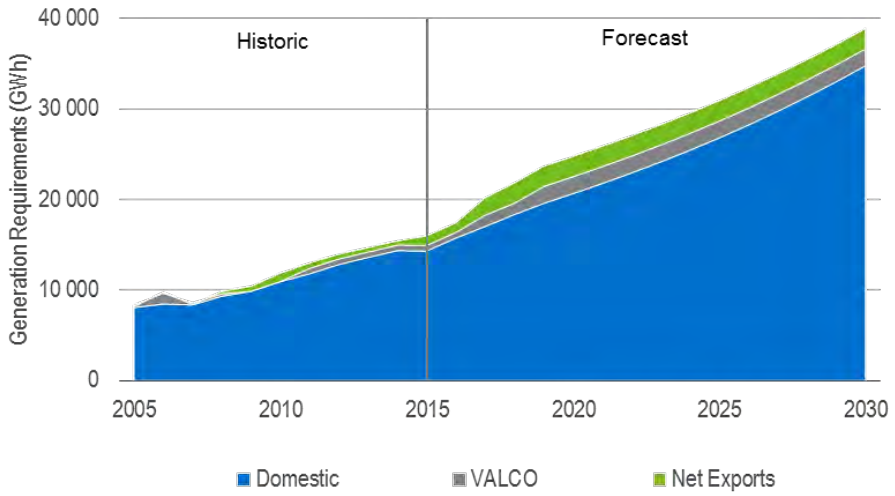


Table 2: Electricity Demand & Generation Requirement Forecasts
(GWh)

	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Domestic	14 318	15 764	17 046	18 363	19 593	20 672	21 794	22 959	24 181	25 472	26 830	28 262	29 772	31 364	33 042	34 810
VALCO	620	620	1 240	1 240	1 860	1 860	1 860	1 860	1 860	1 860	1 860	1 860	1 860	1 860	1 860	1 860
Net Exports	1 059	1 063	1 929	2 247	2 251	2 251	2 251	2 251	2 251	2 251	2 251	2 251	2 251	2 251	2 251	2 251
TOTAL	15 997	17 447	20 215	21 850	23 704	24 783	25 905	27 070	28 292	29 583	30 941	32 373	33 883	35 475	37 153	38 921

[2] Domestic includes system usage and transmission losses.

The followings are key assumptions behind the forecasts:

- Domestic consumption includes electricity marketed by the Electricity Company of Ghana (ECG) and the Northern Electricity Distribution Company (NEDCo) as well as directly sales to mines and other industrial consumers. Compound annual growth rate (CAGR) for the domestic portion is estimated at 6.1 percent between 2015 and 2030.
- According to VRA, Ghana is projected to ramp up gradually its exports of electricity to its total contractual export level of 1 314 GWh by 2018 and 937 GWh by 2019 to both Communauté Electrique du Bénin (CEB) of Togo and Société Nationale d'Electricité du Burkina (SONABEL) of Burkina Faso. Potential electricity exports to Nigeria have not been taken into account due to the lack of legally binding commercial agreements in place. It should also be noted, however, that electricity prices are low in Nigeria, whilst gas prices are substantially higher in Ghana than in Nigeria. This would affect the competitiveness any potential export deal.
- In this report's base case, VALCO is assumed to operate one potline between now and the end of 2016, adding another one in 2017 and 2018, and eventually operating three potlines from 2019 onwards. This reflects the assumption used in Nexant's July\August 2015 Electricity Demand Forecasting and Suppressed Demand Study. Sensitivity runs have been included in Section 7 of the report to assess the impact of different potline assumptions.

Total electricity generation requirements are expected to increase from the current level of 16 TWh to just below 25 TWh by 2020, and eventually reaching 39 TWh by 2030.

3.3. Electricity Generation Mix

The next step in establishing the power sector's potential gas demand level would require an analysis of Ghana's electricity generation mix between thermal and non-thermal sources. Non-thermal sources, such as hydro, operate as base load, and are supplemented by thermal power plants to fulfil all electricity demand and generation requirements.

It should be noted that all existing and future thermal power plants in Ghana are capable of operating on natural gas. Some of the existing plants are operating on light crude oil (LCO) or diesel due to the lack of gas supply availability. Forecasts of electricity output from non-thermal sources are deducted from the total generation requirements presented above in order to derive the level of electricity required to be generated from thermal power sources, i.e. thermal generation requirements. This then enables the estimation of the power sector's projected gas demand.

The following assumptions have been made for non-thermal power generation sources:

- *Akosombo and Kpong Hydroelectric Power Plants*: According to VRA, electricity output from the two hydroelectric power plants combined are estimated at 3 900 GWh for 2015 and eventually rises to 5 300 GWh by 2018. The low level of output before 2018 is due to the rehabilitation of water level in the reservoir, which translates into an average load factor of around 40 percent, eventually increasing back to just below 60 percent when normality resumes.
- *Bui Hydro Power Plant*: According to VRA, this hydroelectric plant is expected to generate 723 GWh of electricity annually in the long term.
- *Hemang Hydro Power Plant*: Confirmation of the current status of this project is difficult to obtain. According to the Ministry of Power, engineering, procurement and construction (EPC) contract for this project has been awarded, and is assumed to come on-stream in 2022 with 60 MW of capacity. This plant is assumed to have a load factor of 60 percent and 315 GWh of annual electricity output.
- *Juale Hydro & Pwalugu Plants*: No information is available on these two hydro power plant projects. Therefore, they have not been included in this final version of the report.
- *Solar Renewables*: It should be noted that the Government of Ghana has a regulation that restricts the capacity of solar electricity generation to a maximum of 20 MW per location. As a result of this, all candidate projects have been aligned to reflect this regulation. This includes the BXC project that is currently in the commissioning phase, several projects at advanced stage and what may come out of the current competitive bidding process undertaken by the MoP and the EC with the support of GIZ. All solar electricity generation capacity is based on a load factor of 35 percent.
- *Wind Renewables*: one advanced stage wind power project is included in this study with an initial capacity of 50 MW in 2019, ramping up to a full capacity of 175 MW by 2030. The plant load factor is assumed to be 33 percent.

- *Biomass Renewables*: biomass power offers tariffs generally higher than wind and solar, but is attractive in rural areas for its substantial job creation capacity. Therefore, one biomass project has been included in this study, with an initial capacity of 30 MW in 2020, and gradually increasing to 90 MW from 2028 onwards. The plant's projected load factor has been assumed at 80 percent.

Overall, the Renewables (RE) industry in Ghana is still in its definitional phase. Numerous projects have been proposed with various merits. In the immediate future, RE success depends on several factors, including: the ability of developers to meet the annually adjusted Feed-In Tariff; the Government's policy with regards to credit enhancement; and the continuing trend of RE towards lower costs, particularly Solar. Also, it is affected by the limitation of project size by ECG to 20 MW to ensure integration in the grid, with only 5 projects planned as current target.

In this context, projecting the share of RE in the energy mix is not easy. Nevertheless we chose to assess the RE forecast on an initial batch of five 20 MW projects, to be completed in the next five years; and the global improvement of RE competitiveness versus thermal in the long run, with national target of 10% of installed capacity (or 6% of energy mix) almost achieved in 2030.

Based on all the assumptions listed above, the mix of electricity generation from different sources in Ghana is projected to be as follows:

Figure 2: Projected Electricity Generation Mix

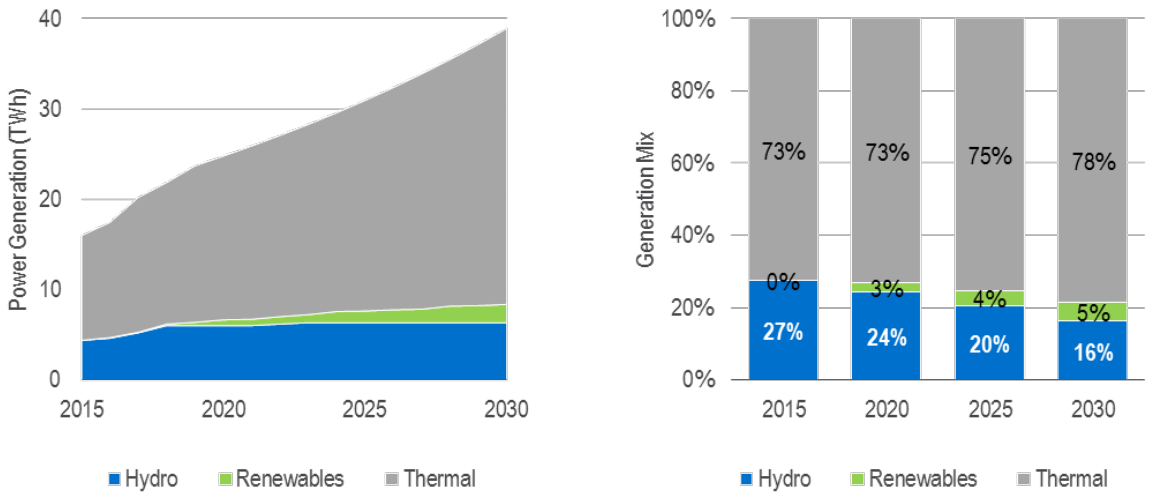


Table 3: Projected Electricity Generation Mix

(TWh)

	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Hydro	4.4	4.6	5.2	6.0	6.0	6.0	6.0	6.2	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3
Renewables	0.0	0.1	0.1	0.2	0.4	0.6	0.7	0.8	0.9	1.2	1.3	1.4	1.5	1.8	1.9	2.0
Thermal	11.6	12.8	14.9	15.7	17.3	18.1	19.2	20.1	21.1	22.0	23.3	24.6	26.1	27.3	28.9	30.5
TOTAL	16.0	17.4	20.2	21.9	23.7	24.8	25.9	27.1	28.3	29.6	30.9	32.4	33.9	35.5	37.2	38.9

The forecast figures and table above show that the total electricity generation requirement (including suppressed demand)[3] from thermal plants is projected to increase from 11.6 TWh in 2015 to 18.1 TWh in 2020, growing further to 30.5 TWh by 2030. As a result, the share of thermal generation is projected to increase from 73 percent in 2015 to 78 percent by 2030. As mentioned earlier, all existing and future thermal power plants in Ghana are expected to be able to run on natural gas, so all thermal electricity output will be translated into natural gas demand here.

Installed thermal electricity generation capacity in Ghana, as of the end of 2014, was 1 250 MW. Apart from the Sunon Asogli power plant in Tema, which only runs on natural gas, all other thermal power plants have dual fuel capability to run on natural gas, as well as on light crude oil (LCO) and\or diesel. Therefore, if natural gas supplies and the required gas infrastructure to transport this gas are reliably and timely available, all power plants would be able to run on natural gas (based on above-mentioned assumptions). The same would also apply to many proposed\planned thermal power plants.

[3] Estimated at 16% of total demand in 2014 and then decreasing gradually between 2015 and 2020.

3.4. Thermal Power Generation Capacity

The following sub-sections identify the thermal power plants (existing, under construction, fast track, and planned) in each region which have the potential to serve the projected Thermal Electricity Demand (ThED).

3.4.1. Tema

There were almost 570 MW of installed thermal (gas and liquids) electricity generation capacity in Tema as of the end of 2014. As noted earlier, all power plants are capable of running on gas.

The following table shows existing, under construction, fast track, and planned thermal power projects.

Table 4: Thermal Power Plants in Tema

Name	Status	Year Available	Nameplate Capacity	Dependable Capacity	Turbine Type	Fuel
(-)	*(-)*	*(Year)*	*(MW)*	*(MW)*	*(-)*	*(-)*
TT1PP	Existing	2009	110	100	OCGT	LCO, NG
TT2PP	Existing	2010	50	45	OCGT	DFO, NG
VRA MRP	Existing	2007	80	75	OCGT	DFO, NG
Sunon Asogli Phase 1	Existing	2010	200	180	CCGT	NG
Cenit Energy	Existing	2012	126	110	OCGT	LCO, NG
Trojan Power	Existing	2015	25	25	OCGT	DFO, NG
VRA KTPP OC Phase 1	Existing	2015	115	110	OCGT	DFO, NG
TT2PP-X	Existing	2015	38	35	OCGT	DFO, NG
Sunon Asogli Phase 2a	Under Construction	2016	180	160	CCGT	NG
Sunon Asogli Phase 2b	Under Construction	2017	180	160	CCGT	NG
VRA KTPP OC Phase 2	Under Construction	2016	115	110	OCGT	DFO, NG
VRA KTPP ST Addition	Under Construction	2018	115	110	ST	Steam
CenPower	Under Construction	2017	348	330	CCGT	NG, LCO, DFO
Karpower Barge	Fast Track	2016-2025	225	213	CCGT	HFO, NG
ST for TT1PP & CEL	Planned	2018	110	100	ST	Steam

Note: Some open cycle plants have been converted to CCGT plants by adding steam turbines. However, in order to show the correct timing of these conversions, the phasing of these open cycle and steam turbines are shown separately in the above table.

If all the above-listed power plants are to run on natural gas, the existing plants would have a collective peak gas demand of 126 MMscfd in 2014; with future capacity additions, total peak gas demand for Tema power plants could potentially reach 378 MMscfd by the end of this decade.

3.4.2. Takoradi

There were 682 MW of installed thermal power capacity in Takoradi as of the end of 2014.

The following table shows existing, under construction, fast track, and planned thermal power projects.

Table 5: Thermal Power Plants in Takoradi

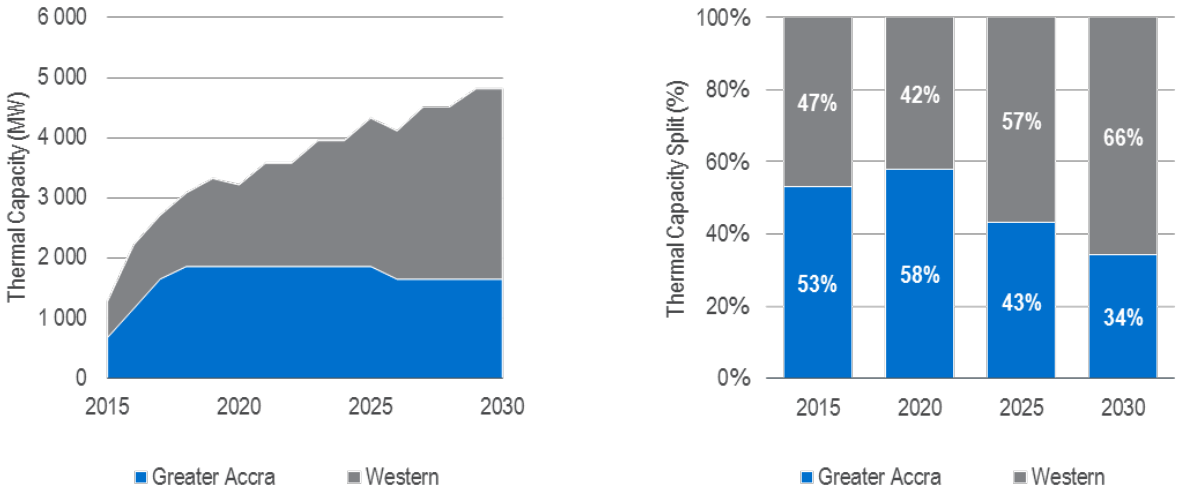
Name	Status	Year Available	Nameplate Capacity	Dependable Capacity	Turbine Type	Fuel
(-)	*(-)*	*(Year)*	*(MW)*	*(MW)*	*(-)*	*(-)*
TAPCO	Existing	1999	330	300	CCGT	NG, LCO
TICO OC	Existing	2000	220	200	OCGT	NG, LCO
TICO ST	Existing	2015	110	100	ST	Steam
Takoradi 3	Rehabilitating	2016	132	120	CCGT	NG, LCO
Takoradi 4	Under Construction	2018	186	165	CCGT	NG, LCO
Ameri	Fast Track	2016	250	230	CCGT	HFO, NG
GPGC TEI & Trifigura	Fast Track	2016-2019	110	107	CCGT	NG
Amandi	Planned	2019	240	240	CCGT	NG, LCO
Jacobsen	Planned	2021	360	360	CCGT	NG, LCO
GH1K Phase 1a	Planned	2023	375	375	CCGT	NG
GH1K Phase 1b	Planned	2025	375	375	CCGT	NG
VRA Globeleq	Planned	2027	450	400	CCGT	NG, DFO, LCO
VRA EDF	Planned	2029	330	300	CCGT	NG, DFO, LCO

Note: Some open cycle plants have been converted to CCGT plants by adding steam turbines. However, in order to show the correct timing of these conversions, the phasing of these open cycle and steam turbines are shown separately in the above table.

If all power plants above are to run on natural gas, the existing plants would have a collective peak demand for gas of close to 150 MMscfd in 2014; with future capacity additions, Takoradi's total gas demand for power could potentially reach 345 MMscfd by the beginning of the next decade.

Taking into account the projected level of electricity required to be generated by gas-fired thermal power plants, a summary of generation capacity by location is presented in the figure below.

Figure 3: Gas-Fired Power Generation Capacity by Location in Ghana



3.4.3. Meeting Peak Load Requirements

The figure below illustrate in a snapshot how the power capacity requirements (peak demand) for the whole country over the planning period could be met by existing, under construction, fast track, and planned electricity generation projects, all sources combined.

Figure 4: Peak Demand vs Capacity Additions

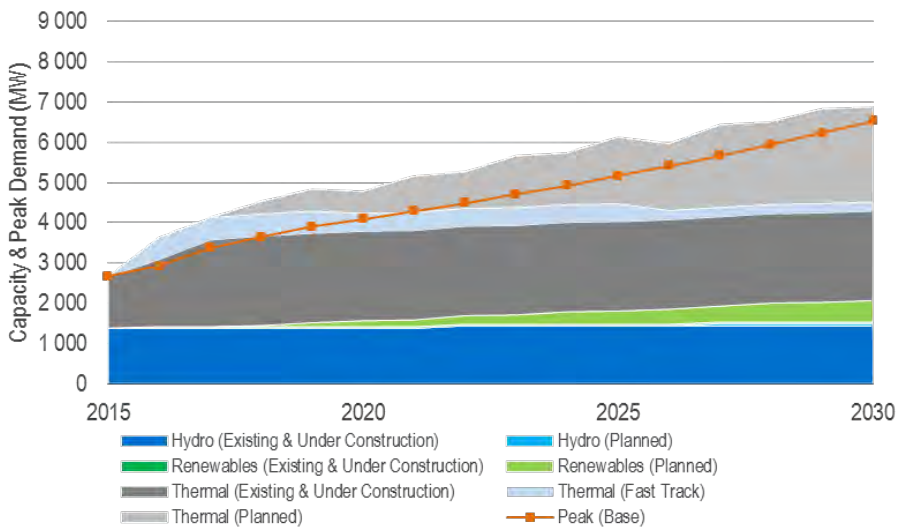


Table 6: Dependable Power Generation Capacity

(MW)

	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Hydro (Existing & Under Con.)	1 380	1 380	1 380	1 380	1 380	1 380	1 380	1 440	1 440	1 440	1 440	1 440	1 440	1 440	1 440	1 440
Hydro (Planned)	0	0	0	0	0	0	0	0	0	0	0	0	57	57	57	57
Renewables (Existing & Under Con.)	3	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37
Renewables (Planned)	0	0	0	30	100	150	170	215	235	310	330	375	395	470	490	535
Thermal (Existing & Under Con.)	1 280	1 670	2 160	2 225	2 225	2 225	2 225	2 225	2 225	2 225	2 225	2 225	2 225	2 225	2 225	2 225
Thermal (Fast Track)	0	550	550	550	550	443	443	443	443	443	443	230	230	230	230	230
Thermal (Planned)	0	0	0	310	550	550	910	910	1 285	1 285	1 660	1 660	2 060	2 060	2 360	2 360
TOTAL	2 663	3 637	4 127	4 532	4 842	4 785	5 165	5 270	5 665	5 740	6 135	5 967	6 444	6 519	6 839	6 884

The table below shows how projected peak demand could be met with existing, under construction, fast track, and planned capacities, under the study's Base Case.

Table 7: Peak Demand and Capacity Additions

(MW)

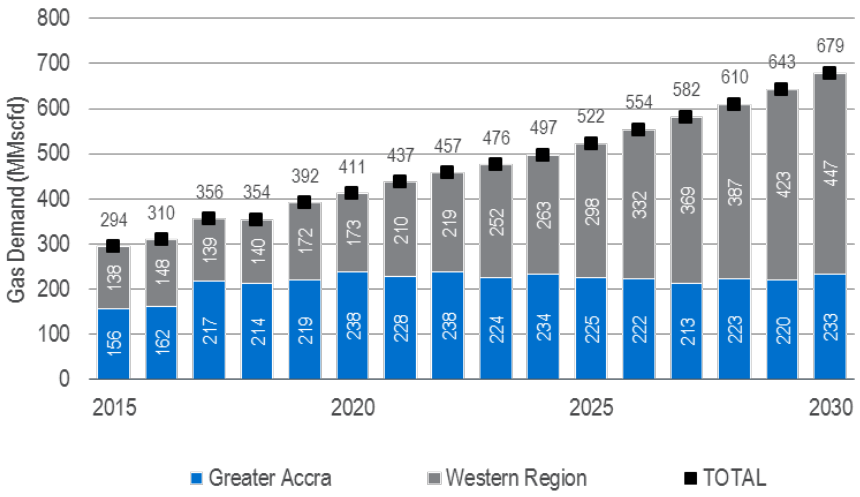
	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Peak Demand - Base	2 673	2 932	3 371	3 644	3 902	4 088	4 298	4 491	4 711	4 932	5 166	5 412	5 671	5 945	6 233	6 537
Existing	2 663	2 783	2 783	2 463	2 463	2 463	2 463	2 463	2 463	2 463	2 463	2 463	2 463	2 463	2 463	2 463
Under Construction	0	304	794	1 179	1 179	1 179	1 179	1 239	1 239	1 239	1 239	1 239	1 239	1 239	1 239	1 239
Fast Track	0	550	550	550	550	443	443	443	443	443	443	230	230	230	230	230
Surplus/Deficit	-10	705	756	548	290	-3	-213	-346	-566	-788	-1 021	-1 480	-1 739	-2 013	-2 301	-2 605
Planned	0	0	0	340	650	700	1 080	1 125	1 520	1 595	1 990	2 035	2 512	2 587	2 907	2 952
Surplus/Deficit	-10	705	756	888	940	697	867	779	954	807	969	555	773	574	606	347

3.5. Natural Gas Demand Projections

In this section, this report now moves on to converting the projected thermal electricity generation requirements into a projection of potential natural gas demand, based on the earlier analysis. The following assumptions have been made for the estimation of potential gas use by power plants:

- Calorific Value of Natural Gas. According to data supplied by Ghana Gas, it is assumed that on average there are 1 000 British Thermal Units (Btu) per standard cubic foot (scf).
- Thermal Efficiency of Power Plants. Data on power plant thermal efficiencies have been provided by VRA. Wherever not provided by VRA, thermal efficiency is assumed at 30 percent for open cycle gas turbines (OCGT) and 45 percent for combined cycle gas turbines (CCGT).

Figure 5: Natural Gas Demand Projections



As shown in the figure above, potential gas demand is expected to increase relatively steadily throughout the forecast period, at 5.7 percent CAGR. Gas demand is forecasted to almost double the projected 2015 level of 294 MMscfd, over a decade, to 582 MMscfd by 2027.

The split of projected natural gas demand between Tema and Takoradi is almost equal in 2015 and 2016, but as thermal power capacity starts to build up in Takoradi, the region is expected to be the bigger gas consumer from 2023 onwards.

4. PROJECTED NATURAL GAS SUPPLY

4.1. Indigenous Gas Supplies

Ghana's sources of indigenous gas supplies, for both associated and non-associated gas, include the following producing or being developed hydrocarbon fields.

- Greater Jubilee (Jubilee, Mahogany, Teak) – associated gas
- Tweneboa-Enyenra-Ntomme (TEN) - associated and non-associated gas
- Sankofa Gye Nyame (SGN) - non-associated gas

Following the submission of the Draft Gas Market Review report in August 2015, meetings were held between GNPC and Nexant to seek clarification on data and information provided by GNPC for the Draft Gas Market Review report and to obtain an updated set of long term indigenous gas supply forecasts for three considered scenarios.

In this Final Gas Market Review report, the GNPC Mid Case is used as the Base Case for the analysis, whilst the other two cases are used in the low and high sensitivity runs.

As shown in Figure 6 below, according to GNPC's mid case forecasts, the marketed gas production from the Jubilee field is expected to average around 100 million standard cubic feet per day (MMscfd) between 2015 and 2030, with a peak of 127 MMscfd in 2028, followed by a rapid decline to 50 MMscfd in 2030[4].

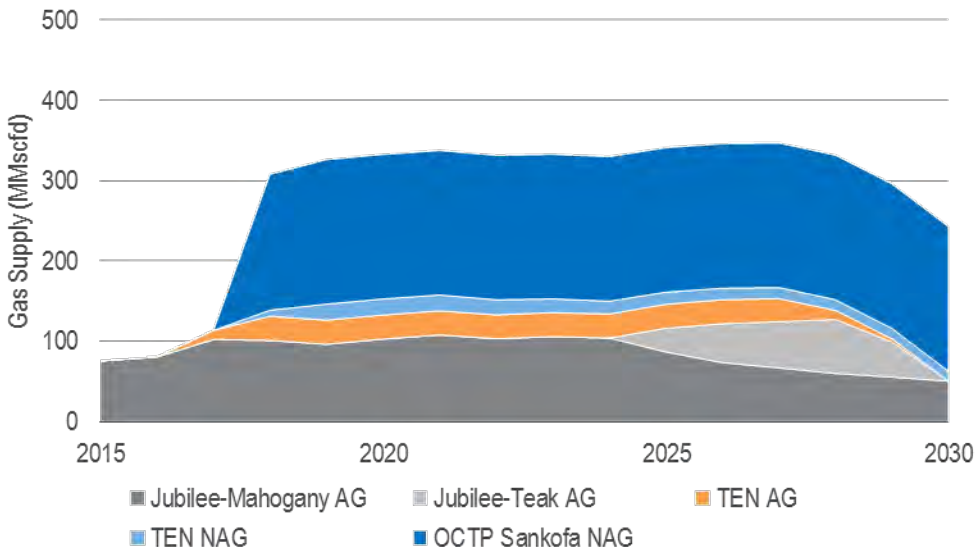
Both associated gas (AG) and non-associated gas (NAG) will be produced from the TEN fields, under the mid case, AG will be produced at the level of 30 MMscfd between 2018 and 2027, whilst 20 MMscfd of NAG will be produced between 2019 and 2022, output then declines to 12 MMscfd by 2030.

GNPC's mid case projections for natural gas production from the SGN fields show a production level of 169 MMscfd during the first year of production in 2018. It then reaches an impressive plateau level of 180 MMscfd from 2019 until 2030.

[4] In this analysis, the last planning horizon year is 2030. GNPC's forecasts go beyond this date to 2036.

The figure and table below illustrate the Ghana's projected gas supply profiles provided by GNPC.

Figure 6: Base Case Indigenous Natural Gas Supply



4.2. Imported Gas Supplies

With respect to pipeline gas imports from Nigeria through WAGP, Nigeria's (N-Gas) contractual commitment to Ghana's foundation customer, the Volta River Authority (VRA), is a total of 123 MMscfd. Unfortunately, due to problems of gas supply availability and gas infrastructure constraints in Nigeria, as well as accidents on the pipeline route, this contractual level has never been achieved (except on some days). The average volume of Nigerian gas delivered to Ghana remains well below the contractual volume.

Therefore, as a result of all the uncertainties affecting the issue of future deliverability of Nigerian gas through WAGP, a projected daily flow rate of 60 MMscfd, over the whole planning period from 2015 to 2030, has been assumed in the Base Case. This flow rate represents the historic average gas flow rate delivered through the WAGP during non-Force Majeure periods.

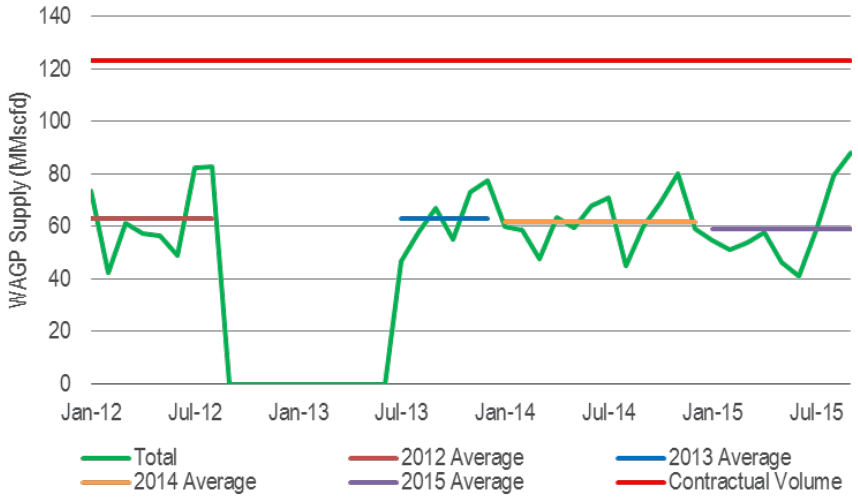
For the Low Case, an average flow rate of 40 MMscfd is assumed. This rate is close to the lowest level of daily flow rate in any given month between 2012 and 2015, excluding the non-operating period (see figure below); whilst for the High Case, this level is assumed to be the contractual level of 123 MMscfd.

Since its commissioning, deliveries of Nigerian gas supplies to Ghana through the West African Gas Pipeline recorded the following two phases of Force Majeure (FM):

- August 2012 to July 2013 – FM declared due to an accident that stopped pipeline operation
- July 2013 to present – FM declared for insufficient gas supplies from Nigeria

Figure 7: Historic Nigerian Gas Imports via WAGP

Date: January 2012 – September 2015)



Note: The period from August 2012 to date (December 2015) has been declared force majeure.

Table 8: Base Case Natural Gas Supply

(MMscfd)

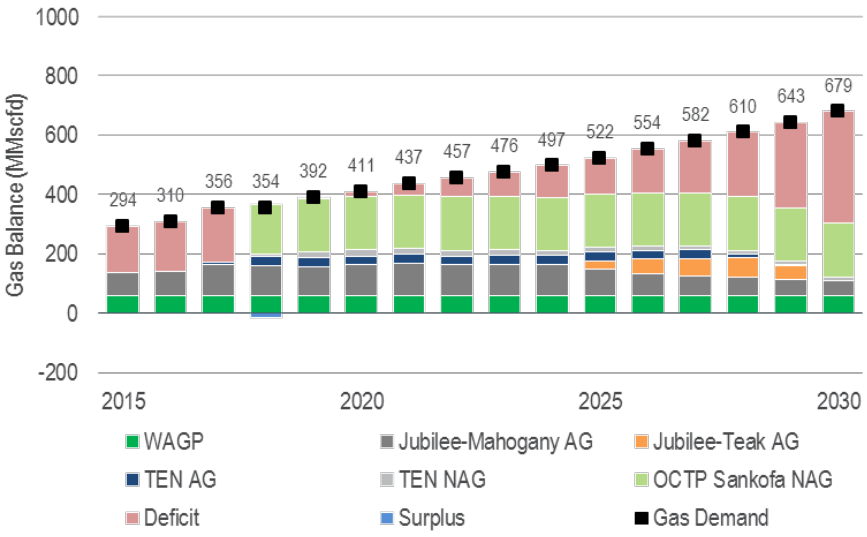
	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
WAGP	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60
Jubilee-Mahogany AG	76	81	102	101	96	103	108	103	106	104	87	74	67	60	56	50
Jubilee-Teak AG											29	48	58	67	44	
TEN AG		0	11	30	30	30	30	30	30	30	30	30	29	11	4	0
TEN NAG		0	0	8	20	20	20	19	17	16	15	14	14	13	13	12
OCTP Sankofa NAG				169	180	180	180	180	180	180	180	180	180	180	180	180
TOTAL	136	141	174	368	386	393	398	392	393	390	401	406	407	392	356	303

5. NATURAL GAS BALANCE RESULTS & SUPPLY OPTIONS

5.1. Nationwide Gas Balance

The projected natural gas balances for Ghana nationwide, as shown in the figure below, are derived from the potential gas supply and demand estimates presented in the previous sections. Based on assumptions listed in this report and for the Base Case, the estimated resulting gas balance suggests that, apart from the initial period between 2015 and 2017, continuous and significant levels of natural gas supply deficits are expected to start occurring after 2020. The deficit level is projected to widen from 65 MMscfd in 2022 to 379 MMscfd by 2030.

Figure 8: Natural Gas Balance Projections



5.2. Regional Gas Balance

It is important, however, to take into account the locations of all the potential gas demand and supply points, as highlighted below:

- Natural gas supply in Ghana consists of domestic or indigenous production and pipeline imports from Nigeria through the WAGP. Pipeline imports from Nigeria can be delivered to both the Tema area in the east and Takoradi in the west; while all domestic gas resources are located in offshore areas of the western region. Hence, coverage of delivery zone is presently limited to locations served by the Western Corridor Gas Infrastructure Development Project (WCGIDP).
- Natural gas demand in Ghana is again split between the east (Tema) and the west (Takoradi). Demand in the western region can be served by both domestic production and pipeline imports from Nigeria; while presently demand in Tema can only be served by WAGP pipeline gas imports from Nigeria. So, it is assumed that all WAGP gas from Nigeria will be allocated to Tema to meet at least part of its gas needs.

Based on the points made above, gas balances for Tema and Takoradi areas would be as follows:

Figure 9: Projected Gas Balance for Tema
Base Case

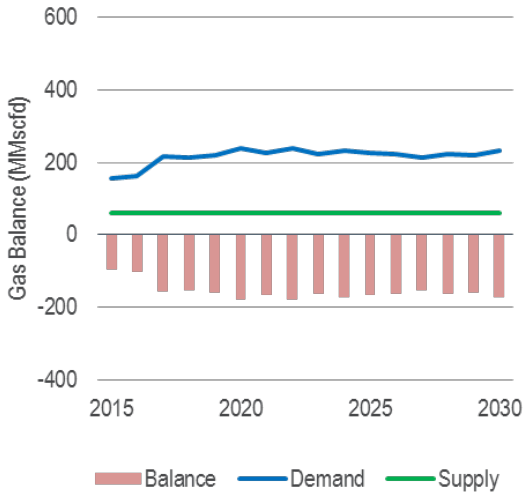
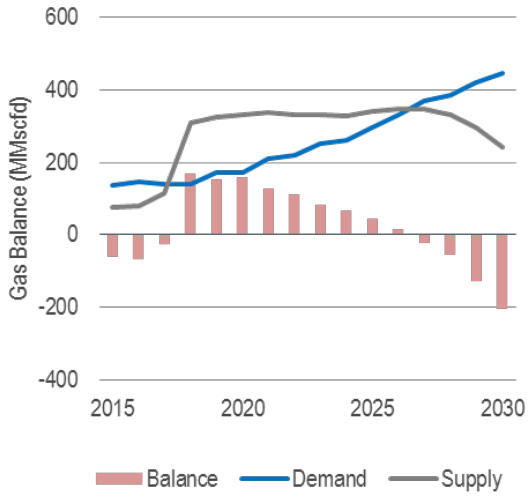


Figure 10: Projected Gas Balance for Takoradi
Base Case



The following table summarizes the nationwide and regional gas balances.

Table 9: Base Case Gas Balance Summary
(MMscfd)

	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Tema	-96	-102	-157	-154	-159	-178	-168	-178	-164	-174	-165	-162	-153	-163	-160	-173
Takoradi	-62	-67	-25	168	154	160	128	113	81	67	44	15	-22	-55	-127	-204
Nationwide	-159	-169	-182	14	-5	-18	-40	-66	-83	-107	-121	-148	-175	-218	-287	-377

As illustrated above, even if all gas pipeline imports from Nigeria, assumed at 60 MMscfd in the Base Case, are to be allocated to Tema, a persistent gas supply deficit would still be expected in Tema throughout the forecasted period. This deficit would fluctuate between 96 and 178 MMscfd. However, if supplies from Nigeria reach their contractual level of 123 MMscfd and are all dispatched to Tema, the gas supply deficit would be reduced to between 33 and 115 MMscfd.

Indigenous gas production in Ghana is expected to be sufficient to supply all natural gas demand in Takoradi up till 2026, in fact the balance shows a regional surplus of gas available. Then the projected supply deficit is projected to rise from 22 MMscfd in 2027 to 204 MMscfd by 2030.

The natural gas balances show that Tema would have a relatively more pressing case to receive additional natural gas supplies in order to satisfy existing and future potential gas demand.

Therefore, a number of actions would need to be considered to address the potential gas supply deficits that could emerge and increase rapidly in size, as shown above.

These actions would be as follows:

- A reverse free flow in the WAGP system, which could initially transfer from the western region a volume of 50 MMscfd on a best endeavor basis. Then, when Sankofa gas comes on stream, a reverse flow in the WAGP system with compression at Takoradi would be required. This could transfer from the Western Region a volume of about 150 MMscfd on a firm capacity booking basis.
- An alternative to the WAGP reverse flow above would be an onshore or offshore pipeline from Aboadze to Tema, subject to detailed feasibility studies and fulfillment of financing criteria of such onshore or offshore gas pipeline project.

In addition, there are the possibilities that LNG imports could be made available and that more gas reserves could be proved up in Ghana to address the projected long-term gas supply deficits.Furthermore, in the long-term, new gas pipeline imports from different suppliers (other than N-Gas) in Nigeria through WAGP could become an option.

Finally, one could also consider generating bulk electricity in one enclave, where indigenous gas supplies are available, and transmit electricity to the western region of Ghana. This would require a reinforcement of the electricity transmission system between Takoradi and the Greater Accra area, including Tema.

6. NATURAL GAS INFRASTRUCTURE

6.1. Existing and Under Development

The cost-effective development of a country's gas market for the utilization of its indigenous gas resources and imported gas supplies, whenever and wherever relevant, depends on the timely and adequate availability of reliable gas infrastructure.

At present, Ghana's gas infrastructure consists of the following listed by chronological order:

- Ghana segments of the West African Gas Pipeline (WAGP) linking Tema and Takoradi
- Western Corridor Gas Infrastructure Development Project (WCGIDP)

The first free flow of gas reached Ghana in December 2008, whilst gas through the WCGIDP system arrived at Takoradi in November 2014. A new WCGIDP pipeline is under development to link Essiama on the coast to Prestea.

Within the context of this updated Ghana Gas Market Review, the commissioning of the Atuabo gas processing plant and the gas transmission pipeline from Atuabo to Aboadze near Takoradi constitutes a major milestone not only for the development of Ghana's gas industry and market, but essentially for the much needed expansion of the country's thermal gas-fired power capacity.

As more supplies and additional demand of gas materialize, as outlined in this report, the capacity of the country's existing gas infrastructure, including the WAGP segments, will need to be re-assessed to meet the related increasing gas processing and transportation requirements.

6.2. Potential New Gas Infrastructure Projects

The infrastructure of the WCGIDP is adequately meeting the present needs of the western region's market, but with the development of new sources of supply like the TEN and Sankofa fields, there will be a need, for example, for additional processing facilities, whether at Atuabo or somewhere else on the western coast. There are also the options (WAGP reverse flow or new onshore pipeline link) to evacuate surplus gas produced in the west to the high consumption centers in the east.

6.2.1. WAGP Reverse Flow

The proposed project of developing a new onshore gas pipeline link to the West African Gas Pipeline's Regulating & Metering Station (WAGP RMS) at Takoradi, in order to establish a reverse flow to transport surplus gas supplies from Takoradi to Tema, has been approved by the Cabinet of the Government of Ghana and confirmed by the Minister of Petroleum in August 2015.

In relation to this project, Ghana Gas has completed the design of the 1.5 km interconnecting pipeline from its gas system (WCGIDP) to the WAGP RMS. WAPCO has also completed the FEED for the modifications work within the WAGP RMS.

On a free flow basis and at existing pressure differentials, nearly 50 MMscfd gas could flow from Takoradi to Tema. If compression is added, the potential transportation capacity could be about 150 MMscfd.

The funding and consequently implementation of this reverse flow project have not been decided yet. But the Government of Ghana is keen to implement this gas pipeline link between the Western and Eastern regions.

The alternative to this reverse flow project would be, as indicated earlier, a new onshore gas pipeline that would have to be laid over a distance of approximately 250 km. This option would be a costly one to fund at the moment.

Therefore, the reverse flow is presently the Government's priority option and it is planned to be commissioned before gas supplies from the Sankofa field come on-stream in 2018.

6.2.2. LNG Import Facilities

In the long-term, with the decline of existing and about to be developed fields, additional imports of gas could be required over this Gas Market Review's retained planning horizon. The problems that have marred (and are still marring) imports of Nigerian gas through the WAGP have pushed to the front another form of gas imports: liquefied natural gas or LNG.

Over the last two years, more than half a dozen of LNG import projects have been proposed\submitted to the Government of Ghana, most of them consisting of a Floating Storage & Regasification Unit (FSRU) to be moored off Ghana's eastern (Tema) and western (Takoradi) coasts. To the best of Nexant's knowledge, the following are the publicly announced LNG import projects.

1. Quantum Power Ghana Gas Ltd
2. West Africa Gas Ltd led by the Sahara group
3. Ghana 1000 project led by Endeavor Energy and General Electric (GE)
4. Volta River Authority (VRA) and Gasol, via the port of Cotonou in Benin
5. Ghana National Gas Company and African Power Generation Limited (AfGen)
6. Brakfields Power Generation Limited
7. Newstars Terminal Limited
8. Rotan Gas Limited

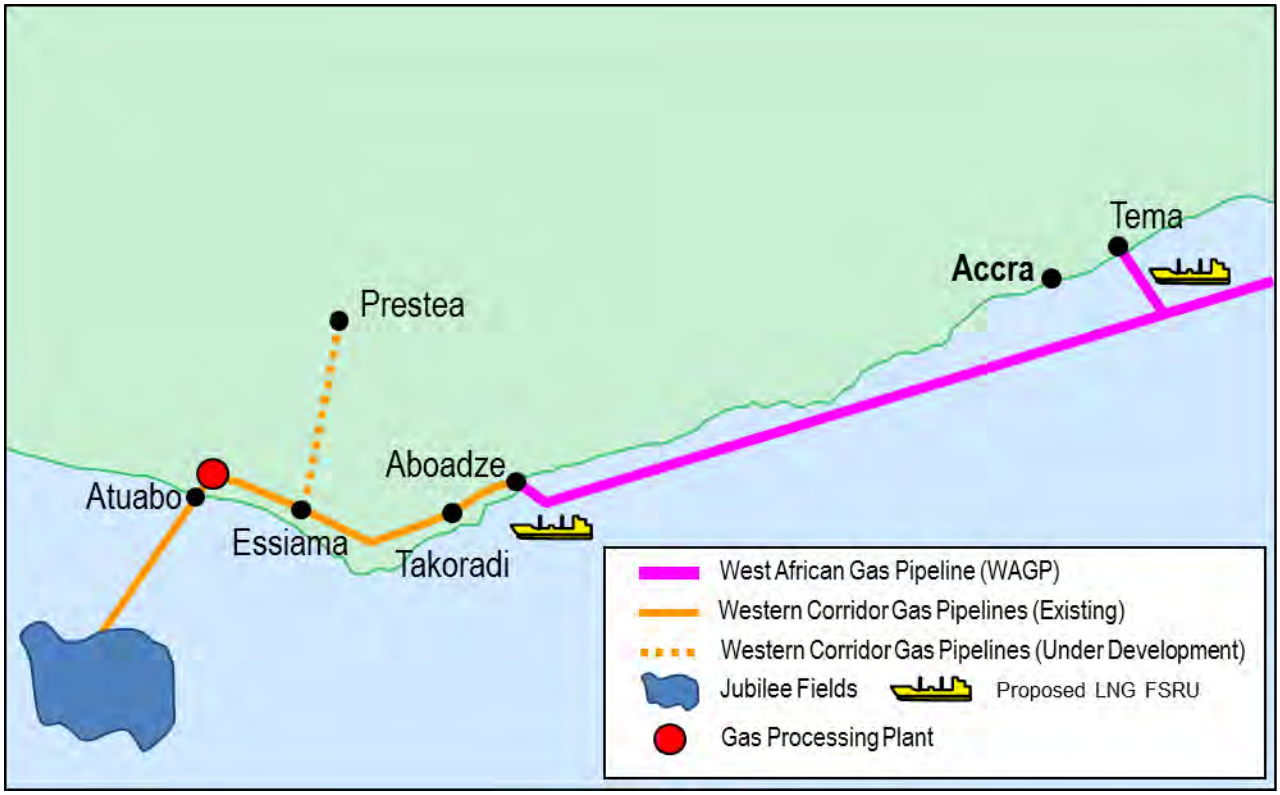
The status of each of the above-listed proposed projects is unknown. Therefore, this list does not mean that these projects would be implemented or not. The implementation or not of any of these proposed LNG import schemes, and especially their timing, would very much depend on a number of factors. These factors would include, *inter* alia, the expected long-term situation of Ghana's gas supply\demand balance, as analyzed in Section 5 and Section 7; the proposed project sponsors; LNG import project competitiveness; financing of such import projects; and, the availability of new or incremental sources of gas imports, such as additional supplies of gas from Nigeria.

The following figure provides a schematic of the existing, under development and planned new gas infrastructure projects, under discussion or proposed.

Regarding proposed LNG import infrastructure, most of the schemes seem to indicate a preferred choice of Tema as an LNG import site.

Figure 11: Natural Gas Infrastructure

Existing & Potential



7. NATURAL GAS MARKET SCENARIOS & SENSITIVITIES

7.1. High and Low Deficit Scenarios

7.1.1. Assumptions

In order to gain a better understanding of how Ghana's gas balance may potentially evolve in the future under conditions different from the base case analysed in the previous sections, two sensitivity scenarios: high and low deficit cases, have been developed to examine the impact of extreme situations using the same approach depicted previously. Assumptions adopted for the high and low demand cases are shown below.

High Electricity Demand Scenario Assumptions

- CAGR of domestic demand between 2015 and 2030 at 7.7 percent.
- Ghana to fulfil full contractual export commitments to CEB and SONABEL by 2018 and 2019.
- VALCO would operate at the level of two potlines in 2017 and 2018, three potlines between 2019 and 2021, and four potlines from 2022 onwards.

Low Electricity Demand Scenario Assumptions

- CAGR of domestic demand between 2015 and 2030 at 5.5 percent.
- Ghana would never fulfil full contractual export commitments to CEB and SONABEL, and exports remain at the level of 1 000 and 690 GWh respectively from 2015 and 2016 onwards.
- VALCO would only operate at the level of one potline throughout the forecast period.

Figure 12: Electricity Demand Scenarios

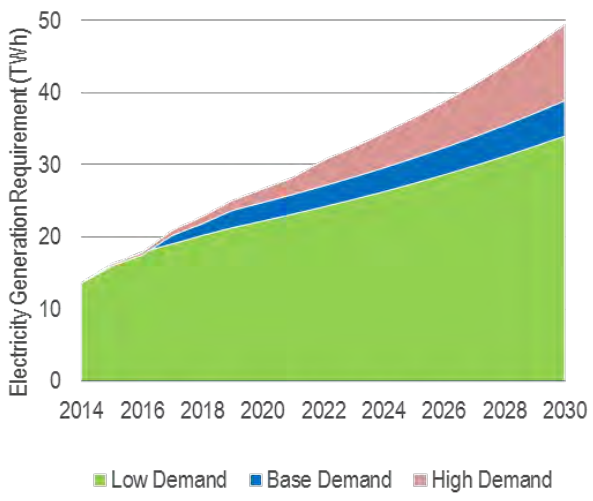
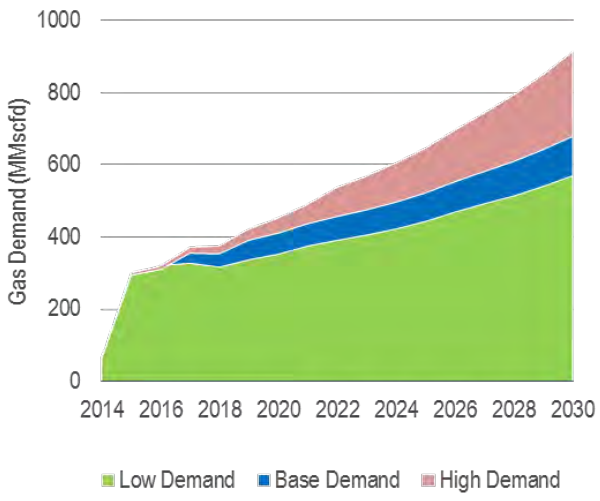


Figure 13: Natural Gas Demand Scenarios



The sensitivity analysis uses also the high and low gas projected supply cases, developed by the Ghana National Petroleum Corporation (GNPC), as outlined below.

High Supply Scenario Assumptions

- OCTP (Sankofa) gas supply peaks at 204 MMscfd from 2019 through to 2030.
- No gas supply from the Teak oil reservoir over the outlook horizon. Oil production is assumed to come onstream in 2031, with all gas produced is re-injected, blowdown from 2038.
- WAGP gas supply at 123 MMscfd.

Low Supply Scenario Assumptions

- OCTP (Sankofa) gas supply peaks at 171 MMscfd from 2019 through to 2030.
- WAGP gas supply at 40 MMscfd.

Figure 14: GNPC Natural Gas Supply Scenarios

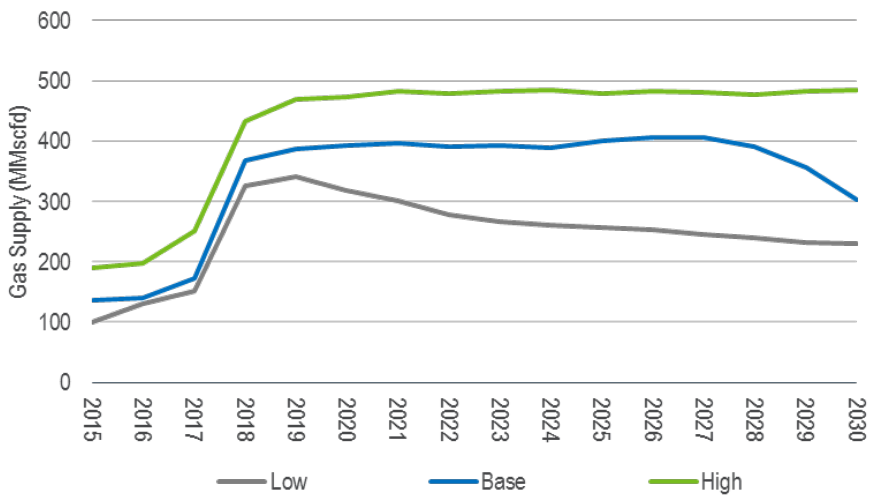


Figure 15: High Gas Supply Scenario

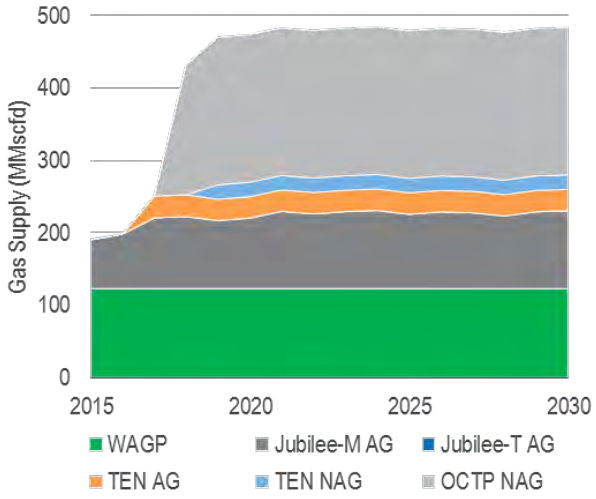
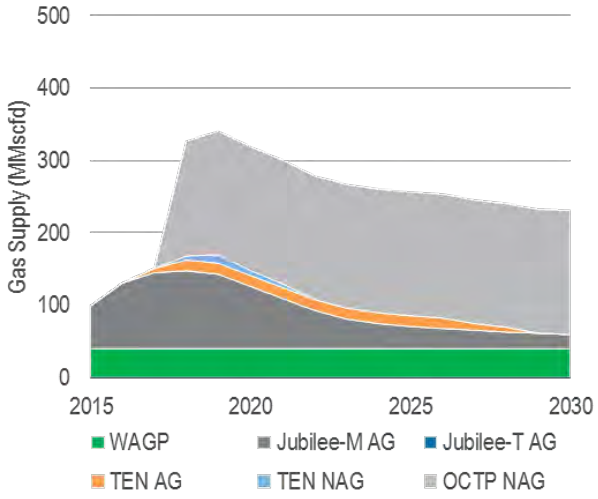


Figure 16: Low Gas Supply Scenario



The two sensitivity scenarios combine and contrast the following extreme cases:

- High Deficit Case: When high electricity\gas demand interacts with low gas supply
- Low Deficit Case: When low electricity\gas demand interacts with high gas supply

7.1.2. Nationwide Sensitivity Results

The following figures illustrate the resulting gas balance for each of the two scenarios.

Figure 17: Projected Nationwide Gas Balance
High Deficit Case

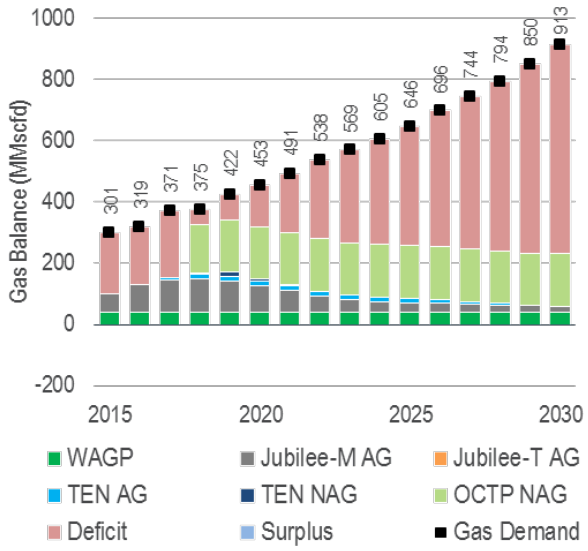
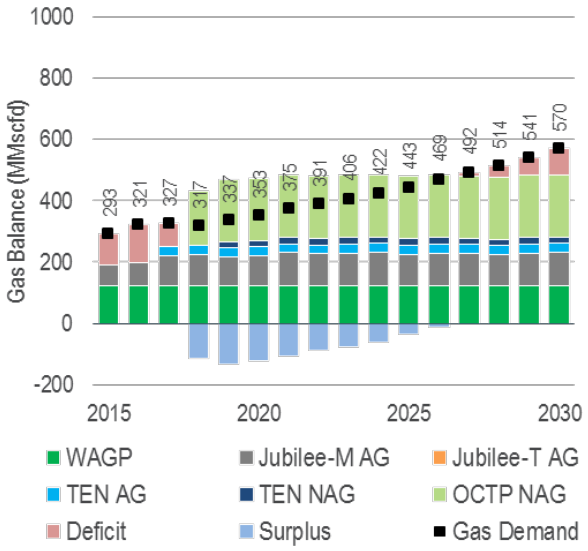


Figure 18: Projected Nationwide Gas Balance
Low Deficit Case



As illustrated in the figures above, under the high deficit case, the gas supply deficit is projected to be between 188 and 221 MMscfd in the near future (2015-2017). But, as oil and gas fields come on-stream towards the end of this decade, this deficit is expected to be reduced to below 100 MMscfd in the two subsequent years (2018 and 2019), followed by a gradual widening to 683 MMscfd by 2030. Hence, deficits are expected throughout the forecast period.

On the other hand, under the low gas supply deficit case, apart from the short period up until 2017, supply surpluses are expected throughout most of the forecasting period, in fact a surplus averaging 84 MMscfd is estimated between 2018 and 2026.

7.1.3. Regional Sensitivity Results

The figures below illustrate the projected regional gas balance for Tema and Takoradi, assuming that all WAGP supplies would be allocated to fuel power plants in Tema, while domestic gas supplies would be limited to use by power plants in Takoradi\Aboadze only.

Figure 19: Projected Gas Balance for Tema
High Deficit Case

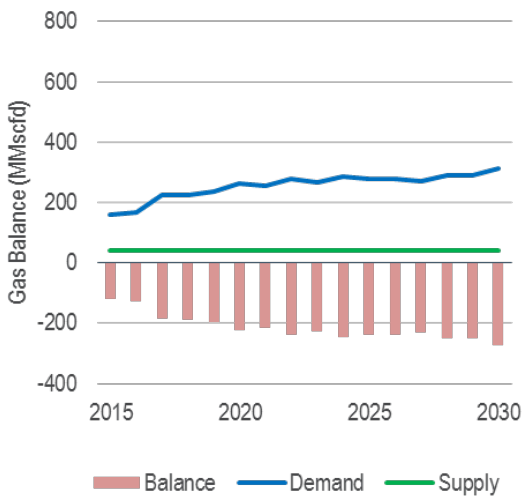


Figure 20: Projected Gas Balance for Takoradi
High Deficit Case

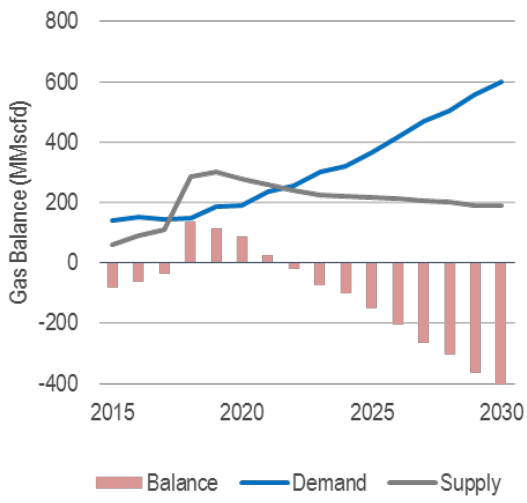


Figure 21: Projected Gas Balance for Tema
Low Deficit Case

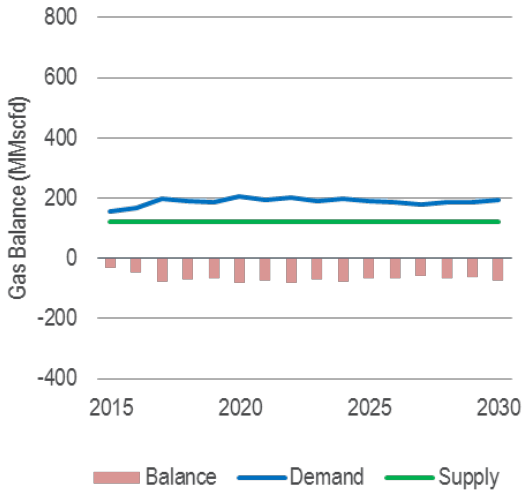
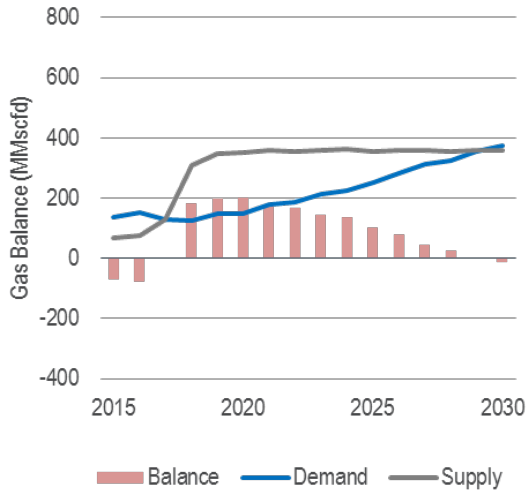


Figure 22: Projected Gas Balance for Takoradi
Low Deficit Case



In all cases, Tema is expected to experience a continuous shortage of gas supply, averaging 216 MMscfd and 66 MMscfd throughout the forecast period under the high and low deficit scenarios respectively.

The situation in Takoradi would be slightly different, under the low deficit scenario, when domestic production start coming on-stream over the remaining period of this decade, a gas surplus averaging 114 MMscfd would emerge between 2017 and 2029; while under the high deficit case, a surplus would only be expected between 2018 and 2021 averaging 92 MMscfd. This is followed by a widening of the supply deficit, which would eventually reach 410 MMscfd by 2030.

The following tables summarise the nationwide and regional gas balances for the sensitivity scenarios depicted above.

Table 10: High Deficit Case Gas Balance Summary (MMscfd)

	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Tema	-120	-127	-187	-187	-197	-222	-215	-240	-228	-245	-238	-239	-232	-250	-251	-273
Takoradi	-82	-61	-34	138	115	88	25	-19	-74	-100	-152	-204	-266	-303	-366	-410
Nationwide	-202	-188	-221	-49	-82	-134	-190	-259	-302	-345	-390	-443	-498	-554	-618	-683

Table 11: Low Deficit Case Gas Balance Summary

	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Tema	-33	-45	-77	-68	-66	-81	-72	-81	-68	-76	-68	-65	-57	-65	-62	-72
Takoradi	-70	-78	0	184	199	202	180	169	145	138	104	79	46	28	4	-14
Nationwide	-102	-123	-76	116	134	121	108	89	77	62	36	13	-11	-37	-58	-86

7.2. Coal Power Generation Sensitivity

Subsequent to the submission of the Draft Gas Market Review report in August 2015, VRA enquired about the inclusion of VRA's planned coal power project. As a result of this, a sensitivity scenario is considered in this subsection including VRA's coal power project under the base case assumptions.

7.2.1. Assumptions

The following information were supplied by VRA to Nexant for the inclusion of the coal project:

- The project sponsors are VRA and Shenzhen Energy Group Company, i.e. Sunon Asogli Power Plant's project developer.
- Generation capacity of the coal-fired power plant is planned at 2 x 350 MW in the first phase, while configuration for the second phase has not been determined yet, which can be 2 x 600 MW, 4 x 350 MW, or 3 x 500 MW, largely dependent on potential electricity demand.
- For Phase 1, target date for final investment decision is March 2016; engineering, procurement, construction (EPC) contract award is planned for August 2016; and, project start date scheduled for late 2019;
- For Phase 2, EPC contract award will depend on the projected electricity demand.
- Availability and load factors are planned to be 90 percent and 85 percent respectively.
- The coal-fired power plant will have a dedicated coal handling facility (port) as part of the plant's infrastructure.
- Shenzhen Energy Group Company has contacted two coal mining companies in South Africa and MoUs have been signed for potential coal supplies. The company is also planning to contact coal producers in Colombia.
- The estimated capital expenditure of this coal-fired power project is $1.3 billion.

7.2.2. Nationwide Electricity Supply Mix (incl. coal-fired power plant)

The figure below illustrates Ghana's potential electricity supply mix when VRA's coal-fired power project is included under the base case's conditions.

Figure 23: Projected Electricity Generation Mix – Coal-fired Power Plant Sensitivity Case

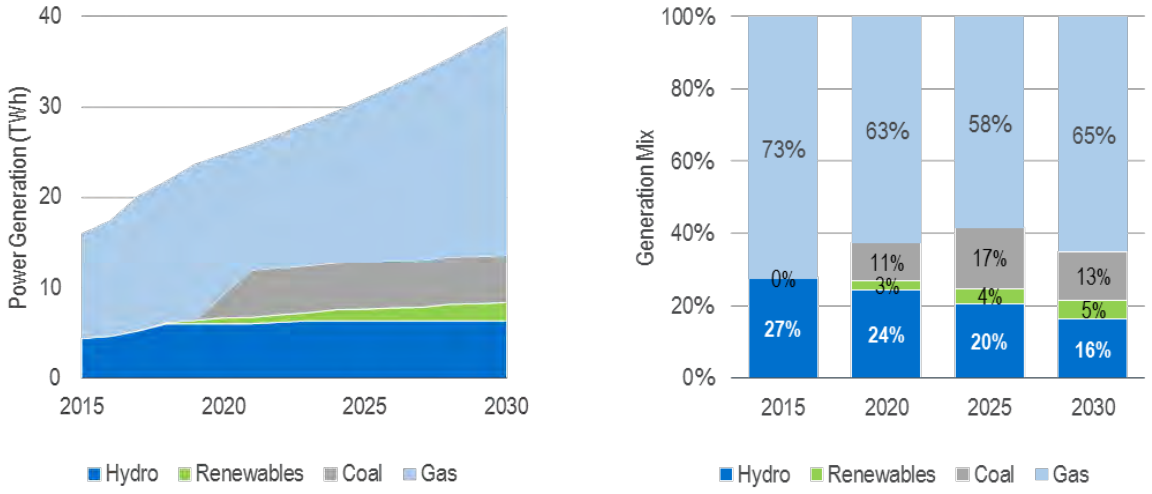


Table 12: Projected Electricity Generation Mix for Coal Generation Sensitivity Case
(TWh)

	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Hydro	4.4	4.6	5.2	6.0	6.0	6.0	6.0	6.2	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3
Renewables	0.0	0.1	0.1	0.2	0.4	0.6	0.7	0.8	0.9	1.2	1.3	1.4	1.5	1.8	1.9	2.0
Coal	0.0	0.0	0.0	0.0	0.0	2.6	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2
Gas	11.6	12.8	14.9	15.7	17.3	15.5	14.0	14.8	15.8	16.8	18.1	19.4	20.8	22.1	23.7	25.3
TOTAL	16.0	17.4	20.2	21.9	23.7	24.8	25.9	27.1	28.3	29.6	30.9	32.4	33.9	35.5	37.2	38.9

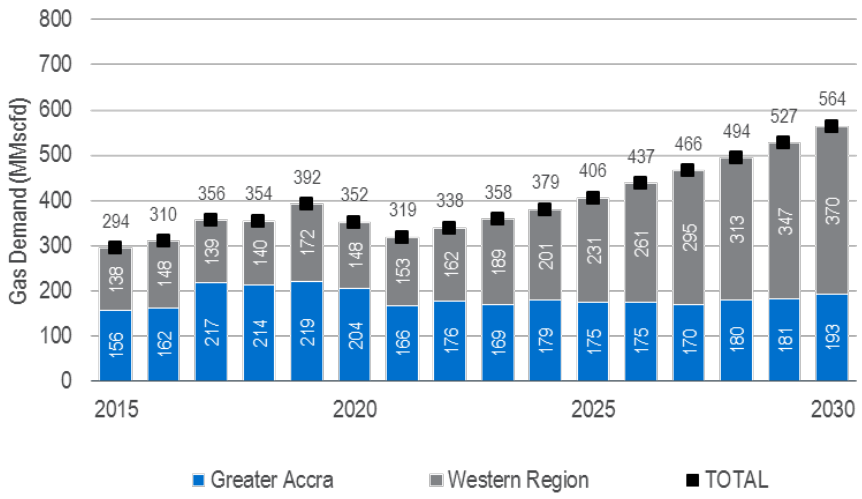
VRA's planned coal-fired power plant would generate 2.6 TWh of electricity per year when the first 350 MW of generation capacity comes on-stream and doubling to 5.2 TWh when the second identical unit starts operating the year after.

Non-thermal electricity output from hydro and renewables are not expected to differ from the base case's figures. Therefore, as expected, the introduction of coal-fired generation is expected to reduce the call on gas-fired thermal generation, reducing the potential level of natural gas demand, as illustrated in the following sub-section.

7.2.3. Gas Demand and Balance

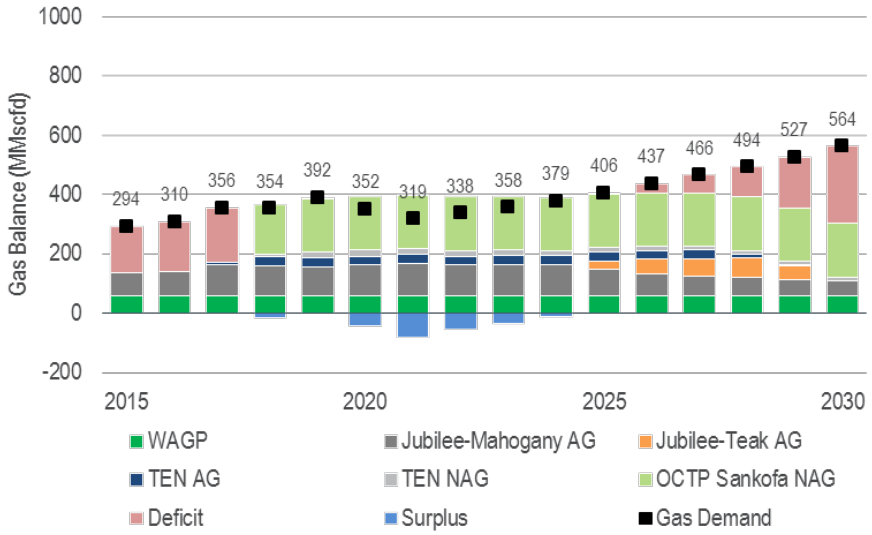
The figure below shows Ghana's gas demand projections when VRA's coal-fired power generation project has been included under the base case's assumptions.

Figure 24: Natural Gas Demand Projections – Coal Generation Sensitivity Case



As mentioned earlier, the introduction of a coal-fired power plant will reduce the call on gas-fired generation. Hence, a projected reduction of gas demand by just under 120 MMScfd would take place compared to the base case without coal-fired generation. This is expected to shift Ghana's countrywide gas balance from a deficit to a surplus for the period between 2020 and 2024, and deficits in the subsequent years are not as large as in the base case without coal-fired generation. There would be a deficit of 261 MMscfd under this case as opposed to 377 MMscfd under the normal base case by 2030, as illustrated in the figure below.

Figure 25: Natural Gas Balance Projections – Coal Generation Sensitivity Case



The figures below illustrate Ghana's regional gas balance in Tema and Takoradi when VRA's coal-fired power generation project has been included under the base case.

Figure 26: Projected Gas Balance for Tema
Coal Generation Sensitivity Case

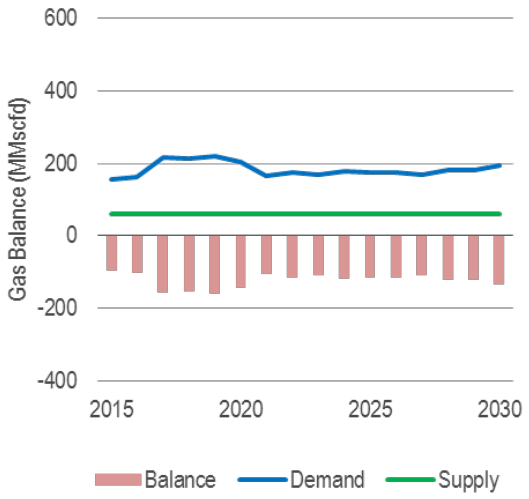
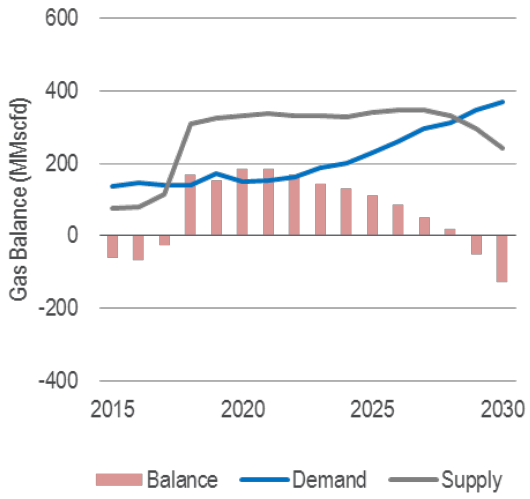


Figure 27: Projected Gas Balance for Takoradi
Coal Generation Sensitivity Case



Assuming the same supply priority and no pipeline link between the Western and Eastern regions, as in the base case, Tema would still exhibit a sustained level of gas deficit over the planning horizon, but at a reduced level from 2020 onwards, averaging 48 MMscfd less than the base case.

In Takoradi, the projected surplus period under the coal-fired generation would be prolonged for two more years to 2028, as opposed to 2026 in the base case without coal-fired generation, and with a high average supply surplus of 127 MMscfd, as opposed to 103 MMscfd in the base case. The annual levels of nationwide and regional surplus are shown in the table below.

Table 13: Base Case Gas Balance Summary
(MMscfd)

	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Tema	-96	-102	-157	-154	-159	-144	-106	-116	-109	-119	-115	-115	-110	-120	-121	-133
Takoradi	-62	-67	-25	168	154	185	185	170	144	129	110	85	52	19	-51	-128
Nationwide	-159	-169	-182	14	-5	41	79	53	35	11	-4	-30	-59	-102	-171	-261

8. CONCLUSIONS

Ghana's energy sector is undergoing some major transformation reflecting the country's short, medium and long-term economic development challenges and opportunities. The energy sector consists of two key subsectors closely interlinked: power and hydrocarbons. Ghana's entry into the club of African oil and gas producers is quite recent, less than five year old. Therefore, the analysis of its energy sector and projecting its potential during the next decades should be appreciated within this development perspective.

This 2015 Gas Market Review report, based on recent data and information, confirms the overall conclusions of previous assessments and provide detailed results on the impact of on-going and new natural gas supply and demand side developments.

It confirms that based on the country's presently estimated hydrocarbons' resource\reserve endowment and the projected rapidly growing demand for electricity to sustain its economic development path, Ghana is expected to remain a gas-short producer. This means that in the long-term it will have to rely on gas imports, unless some additional hydrocarbon discoveries are made and developed.

Over the 2015 - 2030 period, the projected national gas balance shows a gas supply deficit emerging and increasing in size from the beginning of next decade. A more detailed analysis of this balance, focused on Ghana's two main energy consuming regions, i.e. Takoradi (Aboadze) in the west and Tema in the east, indicates that the gas supply deficit is more pronounced and emerges much earlier in the eastern region if the two regions' gas infrastructure are not connected.

Hence, a number of gas supply and infrastructure options would need to be considered. These would include: first, a reverse free flow in the WAGP system; then when Sankofa gas comes on-stream, a reverse flow with compression at Takoradi; and, in the longer term potential LNG imports or additional imports from new suppliers in Nigeria.

The linking of Ghana's regional gas infrastructure would allow an optimal utilization of Ghana's indigenous gas supplies, supplemented potentially by gas imports. This would have a positive impact on the power sector's ability to generate electricity in a cost-effective way.

It is also critically important to be prepared for potential situations that would deviate significantly from the base case and evaluate the impact of such scenarios. Therefore, this report presents also the results of a high gas demand in a low gas supply environment scenario and the opposite situation with a low gas demand associated to a high case supply scenario. An additional scenario is also considered to assess the impact of VRA's newly announced coal-fired power project.

Finally, we would like to conclude this report by drawing attention to the fact that domestic energy pricing policies for electricity tariffs and gas prices would have a significant impact on the above-mentioned scenario outcomes (for the base case and sensitivities).

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