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Ghana's Electricity Long-Term Capacity Expansion Plans and It's Role in the Proposed West African Power Pool

Brian H. Bowen
F.T. Sparrow

PURDUE UNIVERSITY
Power Pool Development Group
West Lafayette

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Summary

This report is based on the February13, 2001, demonstration version of the ECOWAS regional electricity trade model. Parameter values come from the ECOWAS Data Set #4 (February 2001). This data set marks an important stage of progress in the regional analysis but accurate data submission with reliable exchange rates into US dollars remains a major activity in the development of the West Africa regional electricity policy analysis work.

At this early stage of the ECOWAS regional modeling the Ghana national case study shows how the country's long-term electricity generation capacity expansion plans are very dependent upon good water supplies and are highly sensitive to natural gas costs. The total costs for Ghana's electricity planning period, 2001 to 2020, is of the order of $1300 million to $1800 million. Ghana saves 40% of its total costs with a free trade scenario. Whatever the level of electricity trade Ghana always appears to build as much new combined cycle generation capacity as possible, 2310MW. The existing international transmission line load carrying capability is increased threefold in the free trade scenario in which both electricity energy as well as power reserves are traded.

Fuel costs, operational costs, capital costs, and generation capacity expansion proposals are model inputs all needing further attention.

1. Costs to Ghana with partial autonomy and full autonomy

Two scenarios are considered. The first is with 50% autonomy factors for energy trade in MWh and trade of reserves in MW. Secondly the scenario is one of full autonomy with energy and power autonomy factors both set at 100%. The total cost to Ghana with the free trade scenario amounts to $1351 millions for the 20 year planning horizon and increases to $1895 millions with the no trade scenario, a 40% increase (Table 1). In both scenarios the maximum amount of new combined cycle (CC) capacity (natural gas) is built (2310MW, Table 3). A large part of the total costs to Ghana is in the fuel cost of the natural gas. Both scenarios use a cost of $3.2 per million Btu for Ghana, while allowing a 50 cents shipment cost from Nigeria. Gas costs in Nigeria are left at the $2.7 per million Btu level, as specified by ECOWAS, for the Data Set #3 demonstration scenarios. The CC stations have natural gas cost of nearly one billion dollars (958 million) for the 20 years with no trade allowed (Table 1).

Table 1 Ghana's Expansion Costs for the Period 2001 to 2020

COSTS (FpNCC = $3.2 per 10^6Btu) (Present Value)	**AFs = 0.5**	**AFs = 1.0**
ECOWAS Total Cost ($ $10^{6\text{ present value}}$)	20,112	26,620
Ghana Total Cost ($ $10^{6\text{ present value}}$)	1,351	1,895
Capital Cost of New Combined Cycle Capacity ($ $10^{6\text{ present value}}$)	364	561
Capital Cost of Existing hydropower expansion ($ $10^{6\text{ present value}}$)	122	24
Capital Cost of New hydropower stations ($ $10^{6\text{ present value}}$)	250	207
Expansion cost for existing transmission lines ($ $10^{6\text{ present value}}$)	22	6
Natural Gas Fuel costs ($ $10^{6\text{ present value}}$)	563	958
Water costs (existing & new hydro) ($ $10^{6\text{ present value}}$)	32	32

2. Existing electricity infrastructure

Ghana's existing thermal capacity is 550MW and its existing hydropower capacity is 1072MW. There are plans for the construction of four new hydropower stations and, with the employment of the West African Gas Pipeline (WAGPL) there are plans for large generation expansions with combined cycle stations. A summary of Ghana's existing stations are listed in Table 2. All of the values of parameters in the demonstration model are noted in Tables 8 and 9, in the Appendix.

Table 2 The Existing and Proposed Generation Stations in Ghana

Ghana Station (Data received Dec14, 2000)	**MW**	**Type**
TAPCOtakoradi-1 (Existing thermal)	330.0	PGO
TICOtakoradi-2 (Existing thermal)	220.0	PGO
TICOtakoradi-3 (Proposed combined cycle)	330.0	PGNCC
TEMA (Proposed combined cycle)	1980.0	PGNCC
Akosombo (Existing hydropower)	912.0	H
Kpong (Existing hydropower)	160.0	H
Bui (Proposed new hydropower)	400.0	HN
Juale (Proposed new hydropower)	87.0	HN
Pwalugu (Proposed new hydropower)	48.0	HN
Hemang (Proposed new hydropower)	93.0	HN

3. Ghana's growth in electrity demand and expansion plan

With a growth rate of 7% in the first half of the planning horizon and a 5% growth in the second decade then the peak demand levels of electricity expected for the country are shown in Table 3.

Table 3 Ghana's Peak Demands for 2001 to 2020

Year	2005	2010	2015	2020
PEAK DEMAND (MW) (From input files)	1508	2018	2830	3612

To meet these demand levels there are major expansions in the combined cycle plants added in both trade scenarios. There is a maximum expansion, of 2310MW, with the two new CC stations in Ghana (Table 4). 150MW of new hydropower capacity is added to the existing hydro stations and with free trade the totally new hydropower stations have a much larger increase in capacity, 444MW as compared with 158MW with no energy trade. The gains from trade justify the construction of the more expensive hydropower sites.

Table 4 Ghana and the Regional ECOWAS Optimal Generation Expansions for 2001 to 2020

	AFs = 0.5	**AFs = 1.0**
New Combined Cycle Expansion (MW)	2,310	2,310
New Hydropower Expansion (MW)	444	158
Existing hydropower Expansion (MW)	150	150
Existing transmission expansions (MW)	With Cote D'Ivoire - 1088 With Togo – 1157	With Cote D'Ivoire - 269 With Togo - 377

As expected there is a much larger expansion of the international transmission lines when free trade is encouraged. The line to Togo is expanded by 1157MW with free trade as compared with a 377MW expansion with no electricity energy trade.

4. Expansion of Ghana's Combined Cycle plants (natural gas)

The WAGPL permits the use of natural gas in Ghana. This efficient form of electricity generation combined with moderate capital investment costs is an important major development for Ghana. Table 5 shows the pattern of CC expansions in Ghana for the 20 year planning horizon. The bulk of the CC expansion is calculated to take place during the 2016 to 2020 time period. With free trade 330MW of expansion takes place in the first 15 years. More expansion, as a result from no imports, of the CC takes place during these first 15 years but still the most intensive construction period for Ghana, from the optimization analysis, takes place in the longer term time period.

Table 5 Ghana's Optimal Expansion Plan for Combined Cycle Expansions (New Natural Gas Stations)

	2001 - 2005	2006 - 2010	2011 - 2015	2016 - 2020
Combined Cycle Expansions (MW) **AFs = 50%**	161	0	169	1980
Combined Cycle Expansions (MW) **AFs = 100%**	81	344	710	1176

5. Sensitivity of Regional Fuel Costs & Optimal New Generation Expansions

The total costs for Ghana are significantly affected by the cost of imported natural gas from Nigeria. Whatever the cost however of this fuel there is always a maximum amount of CC new generating capacity added. When the cost of the gas becomes equivalent to the cost of unused energy ($140 per MWh) then the new CC stations are not used for generation. This takes place once the cost of gas reaches $17 per million Btu (Table 6). The upper and lower levels for the cost of natural gas in the USA are $2 per million Btu and $4 per million Btu.

Table 6 Costs for Ghana's Natural Gas at Different Rates for 2001 to 2020 (AF = 50%)

Natural Gas Rates FpNCC ($\$/10^6$ Btu)	3.2	5.5	16.0	17.0
Total Gas Cost for 2001 to 2020 ($\$\ 10^6$)	401	358	990	0
MWh Supplied for 2001 to 2020 (10^6 MWh)	14.94	8.31	7.90	0
New Combined Cycle constructed (MW)	2310	2310	2310	2310

With heat rates of nearly 8 (10^6Btu/MWh), Table 8B, and gas costs of 3.2 ($/million Btu) then the cost of fuel is about $25/MWh (8 x 3.2). The cost of natural gas, in Ghana, supplied for Data Set #4 is $5.5 per million Btu. As the cost of gas increases so too its use is decreased as shown in Table 6. The cost of gas in Ghana cannot be disconnected from the cost in Nigeria and so the $2.7 cost per million Btu, in Nigeria, is maintained in the model until data validation is received from Nigeria.

3. Electricity Trade for 2000 to 2010

For the 20 year planning horizon Ghana is a net importer of electricity with all of it's imports coming from Togo (Table 7). About half of the total imports during the 20 year period are used domestically and the other half are wheeled to Cote D'Ivoire. There is a switch in the flow of trade with electricity trade tending to travel more from east to west and this is as a result of the increased generating capacity from the use of natural gas and the WAGPL project. A more detailed analysis of the energy flows across the region should take place once the Nigeria data and expansion plan becomes more reliable.

Table 7   Electricity Trade (GWh energy total) for Ghana, 2001 - 2020

	AFs = 0.5
Electricity Exports (GWh)	
To – Togo	3,500
To – Cote D'Ivoire	64,150
Electricity Imports (GWh)	
From - Togo	119,000

Appendix

Table 8A Existing Ghana Thermal Stations

Station Name	Station Code #	PGOinit (MW)	Oexpcost ($/MW)	PGOexpstep (MW)	PGOmax (MW)	FORPGO (%)	UFORPGO (%)	Crfi (%/yr)	VarOM0 ($/MWh)	HRO 10^6Btu/ MWh
TAPCOtakoradi-1	Gha Stat1	330.0	0	0	0	0.09	0.06	0.1056	2.3	1*
TICOtakoradi-2	Gha Stat2	220.0	0	0	0	0.09	0.06	0.178	2.3	1*

(Iindicates Purdue added/changed value; Data Set #3 - August 2000)*

Table 8A (Continued) Existing Ghana Thermal Stations

Station Name	Station Code #	Fuel cost FpO ($/MWh)	Fuel escalation (fpescO (%/yr)	Decay rate (%/yr)	Resthm (%)	Min usage Pgmin (MWh/yr)	Forced decommissioning (AT period ty)
TAPCOtakoradi-1	Gha Stat1	44	1.02*	0.01	0.1	2,000,000	-
TICOtakoradi-2	Gha Stat2	68	1.02*	0.01	0.1	1,400,000	2003

Table 8B Proposed/New Ghana Thermal Stations

Station Name	Station Code #	FGCC ($)	NCCexpcost ($/MW)	NCCexpstep (MW)	PGNCCinit (MW)	PGNCCmax (MW)	FORNCC (%)	UFOR NCC(%)	Crfni (%)	OMCC ($/MWh)
TICOtakoradi-3 (CC)	Gha Stat1	120,000,000	-	-	330.0	0.0	0.09	0.06	0.178	2.3
TEMA (CC)	Gha Stat2	280,000,000	727,000	330.0	330.0	1650.0	0.09	0.06	0.178	2.3

Table 8B (Continued) Proposed New Ghana Thermal Stations

Station Name	Station Code #	FixOMCC ($/MW/yr)	HRNCC (10^6Btu/MWh)	FpNCC ($/$10^6$Btu)	FpescNCC (%)	DecayNCC (%)	AtCC (%)	MinCC (MWh/yr)
TICOtakoradi-3	Gha Stat1	20,000*	7.981	3.2*	0.01*	0.01	2003	2,200,000
TEMA	Gha Stat2	36,000	7.981	3.2*	0.01*	0.01	-	2,200,000

Table 9A Existing Ghana Hydropower Stations

Station Name	Existing hydro Station code #	Hoinit (MW)	HOVcost ($/MW)	Hoexpstep (MW)	HOVmax (MW)	HOLF (MWH/yr)	FORoh (%/yr)	Crfih (%/yr)	VarOMoh ($/MWh)
Akosombo	Gha Stat 1	912.0	730 000	30	150	5,100,000	0.04	0.085	0.2*
Kpong	Gha Stat 2	160.0	0	0	0	1,037,000	0.04	0.0	0.2*

Table 9A (Continued) Existing Ghana Hydropower Stations

Station Name	Existing hydro Station #	DecayHO (%/yr)	Reshyd (%)	MinH (MWh/yr)	FdecomH (Period)
Akosombo	Gha Stat 1	0.01	0.19	4 000 000	-
Kpong	Gha Stat 2	0.01	0.19	816 000	-

Table 9B Proposed/New Ghana Hydropower Stations

Station Name	Existing hydro Station code #	HNinit (MW)	HNFcost ($)	HNVcost ($/MW)	HNVmax (MW)	HNexpstep (MW)	HNLF (MWh/yr)	FORNH (%)	Crfnh (%/yr)
Bui	Gha Stat 1	400.0	484,000,000	0	0	0	962,900	0.04	0.12042
Juale	Gha Stat 2	87.0	340,280,000	0	0	0	385,000	0.04	0.10086
Pwalugu	Gha Stat 3	48.0	199,230,000	3,500,000	100*	10*	160,000	0.04	0.10086
Hemang	Gha Stat 4	93.0	158 000 000	0	0	0	336 000	0.04	0.10086

Table 9B (Continued) Proposed/New Ghana Hydropower Stations

Station Name	Existing hydro Station code #	FixOMnh ($/yr)	VarOMnh ($/MWh)	DecayHN (%/yr)	AtHn (Period)	BefHN (Period)	AftHN (Period)	MinHN (MWH/yr)
4. Ghana								
Bui	Gha Stat 1	2 520 000	0.2*	0.001*	-	-	-	904 000
Juale	Gha Stat 2	1 140 000	0.2*	0.01	-	-	-	298 000
Pwalugu	Gha Stat 3	640 000	0.2*	0.01	-	-	-	145 000
Hemang	Gha Stat 4	790 000	0.2*	0.01	-	-	-	300 000