

Strategic National Energy Plan

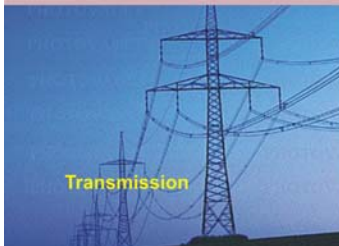
2006 - 2020



Annex II of IV

ELECTRICITY

*Energy Commission, Ghana
July, 2006*



Strategic National Energy Plan 2006 – 2020

Annex Two of Four

ENERGY SUPPLY TO THE ECONOMY

Electricity

***Energy Commission
July, 2006***

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PREFACE

THE ENERGY COMMISSION is required by law to prepare, review and update periodically indicative national plans to ensure that all reasonable demands for energy are met in a sustainable manner. In conformity with this mandate, the Commission has developed and elaborated a Strategic National Energy Plan (SNEP) for the period 2006 – 2020.

The goal of SNEP is to contribute to the development of a sound energy market that would provide sufficient, viable and efficient energy services for Ghana's economic development through the formulation of a comprehensive plan that will identify the optimal path for the development, utilisation and efficient management of energy resources available to the country.

In developing and elaborating the SNEP, the Energy Commission has since 2000 conducted empirical studies and workshops. Series of stakeholders' consultative meetings were held where Working and Issue discussion groups were formed for the various energy and economic sectors. Members of the discussion groups were drawn from major institutions representing the various sectors of the economy. For sectors where data were not available or outdated, consultants were engaged to collect the data to update and as well fill the missing gaps. Based upon an assessment of the existing institutional framework and energy demand and supply situation, issues papers on the various energy sub-sectors were also prepared by consultants which served as discussion documents at stakeholders' consultative meetings. Consultants' reports were reviewed at the Working Group level and finally by a Technical Committee.

The energy sector is broadly divided between demand for energy and supply of energy to the economy. The draft SNEP document was therefore divided into two volumes to facilitate ease of discussion:

- Volume One covered the Demand Sectors of the Economy, namely Residential (household); Commercial & Services; Agriculture & Fisheries; Industry and Transport*
- Volume Two covered the supply-side of the energy sector, namely, electricity; petroleum; woodfuels and renewables. Volume Two was further divided into three parts; Part I - Electricity; Part II – Petroleum; and Part III – Woodfuels and Renewables.

* Within the national economic statistics framework, Transport is a subsector of Commercial & Services. However, the energy utilisation in the transport sector has a significant impact on the economy necessitating it to be treated as a separate demand sector.

The SNEP documents were placed at the website of the Energy Commission to solicit for comments from the wider general public. Key stakeholders were further invited to discuss the draft documents and provide comments as well. The Stakeholder meeting for the Volumes Two Part 1 - Electricity was held on February 15, 2005. It was followed by stakeholder meetings for the Volumes Two Part III – Woodfuels & Renewables and Volumes Two Part II – Petroleum held on 18 January and 26 January, 2006 respectively. Volume One was discussed alongside Volume Two.

About 49 key organisations cutting across the related sector ministries and governmental committees, agencies and regulatory bodies, private and state enterprises, non-governmental institutions, trade unions, consultancy and advocacy groups, educational and research institutions participated in the stakeholder meetings. Individual experts in their personal capacities also attended the meetings. Besides, the specialised stakeholders and the individual experts, the cross-section of the press representing the print and electronic media and from both the public and private media houses actively participated in all the deliberations.

The list of institutions which participated in the SNEP process including the press is also available as an Appendix to the SNEP document.

All comments have been incorporated in the main unified SNEP document titled **STRATEGIC NATIONAL ENERGY PLAN AND *POLICY RECOMMENDATIONS***. The previous Volumes One and Two have been reorganised and presented as Annexes to the main document as follows:

- Annex I of IV: SNEP Energy Demand Sectors of the Economy
- Annex II of IV: SNEP Electricity Plan
- Annex III of IV SNEP Petroleum Plan
- Annex IV of IV: SNEP Traditional Woodfuels & Renewables Plan

The Energy Commission acknowledges the financial support, expert guidance and advice that it received from the Royal Danish Government through DANIDA[#] in the early stages of the development of the SNEP. The Danish support, which ended in 2003, was administered by Ramboll, a Danish consultancy firm.

The efforts of the Ramboll and the core professional staff of the Energy Commission who worked on the SNEP are hereby acknowledged.

Executive Secretary

[#] Danish International Development Agency

Background

Institutional set-up

1. There are six public institutions involved in the power sub-sector. These are the Ministry of Energy (MOE), Energy Commission (EC), Public Utility Regulatory Commission (PURC), Volta River Authority (VRA), Electricity Company of Ghana Limited (ECG) and the Northern Electricity Department (NED), a department of the VRA (Table 1) Under an on-going Power Sector Reform, ECG and NED are expected to be merged to form one distribution company. The transmission function is to be separated from the generation and other responsibilities of the VRA. Energy Foundation is a private-public sector partnership to promote energy efficiency and conservation countrywide.

Table1: Institutions in the electricity sub-sector

INSTITUTION	MAIN FUNCTIONS
Ministry of Energy	Government mouthpiece and responsible for energy policy formulation
Energy Commission	Energy Policy Advisory, planning, technical regulation & monitoring.
PURC	Electricity Tariff Regulation
VRA	Electricity Generation and Transmission
ECG	Electricity Distribution (Southern Sector ¹)
NED	Electricity Distribution (Northern Sector ²)
Energy Foundation	Promotion of energy efficiency and conservation

Reform in the Electricity subsector

2. An efficient and sustainable power sub-sector needs open and competitive markets. However, where markets are imperfect, electricity prices may not accurately reflect the full economic and social costs and it is not likely to attract the needed private capital for the timely expansion of the nation's capacity. If power producers come at all, they may not choose the most efficient and sustainable options.
3. To ensure fair play to all sides of the equation; protecting consumers and ensuring financial viability of the utilities, the power sector reform was initiated to create the

¹ Greater Accra, Ashanti, Central, Eastern, Western and Volta Regions.

² Brong Ahafo, Northern, Upper East and West Regions.

enabling environment to attract private capital to the power sector, increase efficiency and strengthen the financial performance of the public utilities.

4. The objectives of the Power Sector Reform include:
 - Securing sustained, efficient and affordable electric power for domestic, commercial, industrial and other uses in Ghana.
 - Attracting significant private sector participation or investment in the power sector.
 - Removing real or perceived monopolistic structures in the sector and thereby create market conditions that would make for competition for services.
 - Achieving transparency in the regulation of power utilities.
5. The establishment of the power sector regulators; PURC and the Energy Commission is part of the reform. Though the reform started in the mid 1990s, it has not been completed. Efforts to privatise and restructure the public utilities into separate generation, transmission and distribution have been the most challenging aspects of the reform. An office to see its implementation has been set up and is located in the Ministry of Energy.

Generation

6. Under the reform a New VRA – a state running entity – running only on the hydropower plants would be carved out of the existing VRA. An entirely new thermal power generator would also be carved out of the present VRA to deal only in thermal power generation.

Transmission

7. A new transmission utility company would be set up to operate the transmission system as a public transmission utility.

Distribution

8. The reform advocates one national entity for electricity Distribution Company in Ghana. The new state distribution company would be a merger of VRA-NED and the existing ECG.

Existing Generation

9. The existing power plants are the Akosombo and Kpong hydro power stations, the Takoradi Thermal Power Station, the Tema diesel power station and the Ghana (Osagyefo) Power Barge at Effasu in the Western Region.
10. VRA operates the Akosombo and Kpong hydro plants as a cascade of hydro plants, and thus their electricity outputs are directly related. Akosombo and Kpong hydropower had delivered, on the average, a total firm electricity of 5,815 Gigawatt hours (million units of electricity) annually from 1990 – 2004. Maximum generation of 6,851 Gigawatt-hours occurred in 1997.

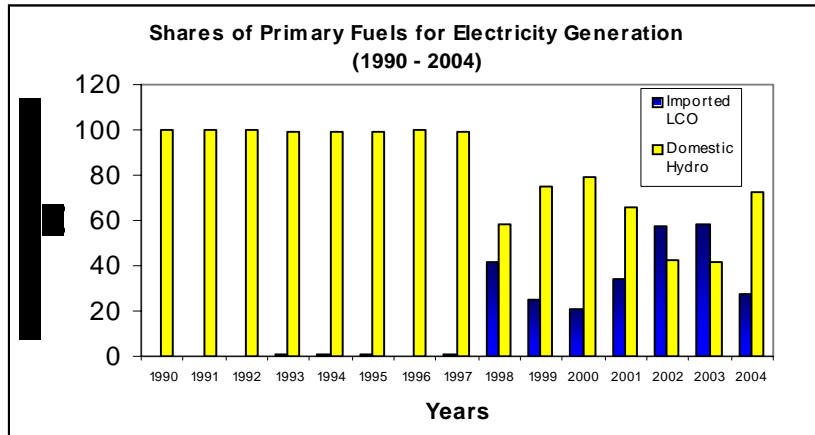
11. The Takoradi Thermal Power Station is located at Aboadze, near Takoradi, the Western Regional capital. It consists of two blocks of generating plants; 330 Megawatt combined cycle plant and 220 Megawatt open or single cycle plant. The 330 Megawatt plant usually referred to as Takoradi 1 (T1) is registered under the name Takoradi Power Company (TAPCO). TAPCO is wholly owned by the VRA. The 220 Megawatt plant usually referred to as Takoradi 2 (T2) is registered under the name Takoradi International Company (TICO). TICO is jointly owned by TAPCO (10 %) and CMS of Michigan, United States of America (90%).
12. VRA has a 30 Megawatt installed capacity (37.5 MVA) diesel station at Tema. The Tema diesel plant was installed between 1961 and 1963 and had run continuously till 1966. Thereafter, it was used as standby till 1979. The station has since been operated as a contingency plant only until 2005 when its pump was completely burnt due to a fire outbreak at the Tema Harbour³.
13. The Ghana (Osagyefo) Power Barge constructed in the late 1990s is a 125 Megawatt open cycle plant comprising two modern 62.5 Megawatt gas turbines. The gas wells intended to fuel the barge have not as yet been drilled or developed. The barge has therefore not been fuelled or operated ever since its arrival in the country. Neither has it been connected to the grid.

Electricity supplied since 2000

Grid Electricity

13. Electricity statistics compiled so far cover grid electricity since information on decentralised and individual generation is very limited. The primary fuel for electricity generation had largely been hydro until 1998 when the thermal power station at Aboadze commenced operations. The main fuel for the thermal power station at Aboadze has been light crude oil (LCO) but it also uses distillate oil for start-up and shut-down of the turbines.

³ VRA Letter of January 13, 2006 referenced EXR/041/004/02/ to the Energy Commission



Generation Balance

15. Primary electricity generation was about 7,224 Gigawatt-hour in 2000 but dropped to 5,901 Gigawatt-hour in 2003 (table 2).
16. The electricity production comprised mainly hydro emanating from Akosombo and Kpong hydroelectric power stations. There was however a drop in the hydro share from about 91.5 percent in year 2000 to almost 66 percent in 2003. Whilst the hydro share of primary energy dropped, the thermal component rose from about 8.5 percent in 2000 to about 34 percent in 2003.
17. Thermal generation is largely crude oil based coming from the Takoradi Thermal Power Station at Aboadze, near Takoradi in the Western Region.
18. Electricity import is primarily from neighbouring la Cote d'Ivoire, to the west of Ghana. Export is largely to Togo and Benin, also neighbouring countries to the east of Ghana.

Year	2000	2001	2002	2003	2004
	Gigawatt-hours				
Generation	7,223	7,859	7,296	5,900	6,039
<i>Hydro</i>	91.5%	84%	69%	66%	72.9%
<i>Thermal</i>	8.5%	16%	31%	34%	27.1%
Net import	472	160	534	339	213
<i>Total import</i>	864	462	1,145	940	878
<i>Total export</i>	392	302	611	601	665
Losses	229	259	368	333	205
<i>Transmission</i>	229	259	368	333	205
<i>Miscellaneous⁴</i>	23.2	32.1	44.7	45.4	30.9
Final supply	7,442.5	7,727.5	7,416	5,858	6,016

Standby and Embedded Generation

19. There is a significant amount of standby generation capacity owned by some industries and commercial establishments, which are intended for operations during extended periods of blackouts or brownouts. Even though, there is no information on the total installed capacity of these standby generators countrywide, total electricity generated annually could be estimated from recorded hours of power outages and the quantity of the industrial and commercial share of diesel consumption (table 3).

Table 3: Diesel Generation by the Industrial and Commercial Sectors

	2000	2001	2002	2003	2004
Hours of black outages	NA	704	501	485	NA
Estimated own generation in Gigawatt-hours	NA	138-194	101-145	103-149	NA
Equivalent in diesel consumption in 1000 tonnes	NA	45-64	33-48	34-49	NA

Solar Electricity Generation

20. Solar energy for electricity in Ghana was providing vital services in otherwise remote and off-grid rural locations in the country.⁵ This was largely via photovoltaic but was insignificant in terms of primary energy share.

⁴ Energy used at generating stations and substations

⁵ Solar electricity worldwide is either by solar thermal technologies utilising concentrator, or by photovoltaic using semiconductor cells.

21. Solar power systems mostly installed by public institutions in remote areas of the country number over 5000. The installed capacity of almost one megawatt generates between 1-2 Gigawatt-hour per annum.

22. The applications are as follows:

SOLAR PV SYSTEMS	Installed Capacity	Generation
	Kilowatt	Gigawatt-hour
Rural Solar home systems	450	0.70 – 0.90
Urban solar home systems	20	0.05 – 0.06
Systems for schools	15	0.01 – 0.02
Systems for lighting health centres	6	0.01 – 0.10
Vaccine Refrigeration	42	0.08 – 0.09
Solar Water Pumps	120	0.24 – 0.25
Telecommunication	100	0.10 – 0.20
Battery charging stations	10	0.01 – 0.02
Grid connected systems	60	0.10 – 0.12
Solar streetlights	30	0.04 – 0.06
Total	853	1.34 – 1.82

Biomass Power Generation

23. Some large sawmills and oil palm mills (e.g. the Benso, Twifo, Kwae Oil Palm Mills) have also been known to operate Combined Heat and Power (CHP) plants based on biomass wastes to generate essentially steam for their operations and some amount of electricity to supplement their grid electricity supply. Notable ones are the:

Plant location	Installed capacity	Average annual production
Kwai Oil Mills	420 kW	1.50 GWh
Benso oil mills	500 kW	1.90 GWh
Twifo Oil mills	610 kW	2.10 GWh
Juaben Oil mills	424 kW	1.50 GWh

Grid Load Balance

24. Average peak demand on the VRA generation and transmission system was about 921 Megawatt in 2000 but dropped to about 781 Megawatt in 2003 due to suspension of VALCO smelter operations that year. The average demand was 635 Megawatt in 2003 if power exports to neighbouring countries were excluded (table 4).

Table 4: VRA Peak Demand Profile from 2000 – 2004 in Megawatt (MW)

	2000	2001	2002	2003	2004
Average Power Demand in MW	920.6	949.9	963.6	780.9	789.7
<i>Export excluded</i>	<i>803.9</i>	<i>811.5</i>	<i>793.4</i>	<i>635.0</i>	<i>642⁶</i>
Maximum Peak Power generated in MW	1,161.0	1,181.2	1,226.5	1,134.8	1,137
Load factor	79.3 %	80.4 %	78.6 %	68.8 %	69.5%

Source: Adapted from VRA data, 2005

25. The load factor averaged 79 percent per annum when VALCO was in operation but less than 70 percent in 2003 when the smelter suspended operations.

Investments

26. The major public investments in the Power subsector since 2000 is estimated at US \$470-480 million (table 5).

Table 5: Major Power investments; since 2000

	PROJECT	US \$ million
1.	Retrofit of the Akosombo hydrogenation plants from 912 MW to 1020 MW installed capacity	130
2.	Construction of the Takoradi International Company (TICO) – 220 MW	110
3.	Installation of second 161 kV line from Prestea to New Obuasi to improve transmission network reliability	7
4.	Upgraded capacity: second bulk supply point for Accra	8
	Total	255

Source: VRA, ECG, 2006

27. The West Africa Gas Pipeline project was estimated to cost about \$590 million and was expected to be completed by end of 2006⁷.

⁶ Energy Commission's own estimation

⁷ The Ministry of Energy reported that there had been some delays and for that matter the pipeline is now expected to be completed by end of first quarter of 2007.

Projections up to 2020

Generation Projections

28. The electricity projections for three economic scenarios are as follows:

GROSS ELECTRICITY SUPPLY REQUIREMENT* in Gigawatt –Hours (GWh)						
Year	Business-as-usual, or Low economic growth		Moderately high economic growth		GPRS High economic growth	
	<i>Without Valco</i>	<i>Valco 3–4 potlines in 2006-7 5 potlines onwards</i>	<i>Without Valco</i>	<i>Valco 3 potlines in 2006 4 potlines in 2007 5 potlines in 2008-12 6 potlines onwards</i>	<i>Without Valco</i>	<i>Valco 3 potlines in 2006 4 potlines in 2007 5 potlines in 2008-12 6 potlines onwards</i>
2006	5,900	8,478-9,156	6,886	9,022	7,804	9,900
2007	7,282	9,920-10,598	9,143	12,100	11,004	13,960
2008	7,666	10,862-11,540	9,618	13,000	11,570	14,900
2009	8,073	11,675-12,354	13,161	16,660	18,248	21,540
2010	8,502	11,168-12,846	13,848	17,484	19,194	22,500
2011	8,904	12,626-13,304	14,488	18,243	20,072	23,370
2012	9,325	13,108-13,786	14,600	18,500	20,144	24,650
2013	9,768	13,615-14,294	14,990	19,500	20,210	24,770
2014	10,233	14,150-14,828	15,676	20,200	21,120	25,620
2015	10,721	14,730-15,408	16,398	20,900	22,074	26,600
2016	11,234	15,321-16,000	17,155	21,660	23,077	27,600
2017	11,773	15,944-16,623	17,951	22,598	24,130	28,630
2018	12,340	16,600-17,280	18,787	23,613	25,235	29,948
2019	12,934	17,291-17,970	19,666	24,682	26,398	31,394
2020	13,560	18,036-18,714	20,590	25,815	27,620	32,915

*This includes transmission and distribution losses.

Load Projections

29. Assuming a load factor range of 0.7 – 0.8 for the country, average load forecasts are as follows⁸:

AVERAGE PEAK DEMAND PROJECTIONS in Megawatt			
Year	BAU or Low economic growth	Moderately high economic growth	High economic growth
2006	1132.8	1209.0	1451.8
2007	1313.3	1407.3	1616.9
2008	1381.1	1494.9	1749.7
2009	1456.2	1591.6	1898.4
2010	1532.2	1691.4	2050.8
2011	1601.3	1786.7	2206.5
2012	1674.5	1888.5	2377.8
2013	1741.4	1986.7	2555.9
2014	1812.1	2091.8	2752.8
2015	1886.8	2199.2	2963.6
2016	1965.8	2313.7	3197.5
2017	2049.4	2435.9	3457.6
2018	2137.8	2566.3	3738.3
2019	2231.2	2705.3	4044.7
2020	2330.1	2853.7	4387.8

The above load forecast is for Ghana demand only and does not include exports to other countries.

Technical Limitations and Supply Shortfalls

Limitations

30. VRA operates the Akosombo and Kpong hydro plants as a cascade of hydro plants meaning their electricity production from the two is linked. The Akosombo and Kpong plants had delivered, on the average, a total firm electricity of about 6,000 Gigawatt hours (million units of electricity) annually in the past⁹.

⁸ The recorded load factors for 2003 and 2004 were 0.69 and 0.70 respectively.

⁹ The average generation from Akosombo and Kpong plants from 1990-2004 was 5,815 GWh (VRA source, 2006)

31. The Volta River Authority (VRA) forecasts a firm hydro electricity production of 4,800 Gigawatt-hours per annum at 98 percent reliability for 2005 – 2008 due to the present lake levels. It would however not be too ambitious to use 5,200 Gigawatt-hour per year as average for 2008 onwards to 2020. This is because the period 2005 - 2020 covers two ‘eleven year’ sunspot cycles, which could yield a cycle of heavy rains and droughts.
32. The TAPCO thermal plant has sometimes had operational problems with its steam turbine component¹⁰. Without an operative steam turbine, the system works as a simple or open cycle mode, which is less efficient than the combined cycle. For instance, in 2003, TAPCO generated only at about 45% of its rated capacity. The technical problems however are not insurmountable. The Takoradi International Company (TICO) plant or T2 is technically the same as the TAPCO plant except that the steam turbine component has not been installed, hence its 220MW installed capacity.
33. TICO is said to be in good condition but less efficient (due to its simple cycle operation mode) in electricity conversion and consequently, more expensive to operate; it consumes about 2 barrels of oil for every Megawatt-hour (thousand units of electricity) generated compared to TAPCO which consumes about 1.35 barrels per Megawatt-hour. In practice and in particularly humid and hot climate like Ghana, it is almost impossible to take advantage of the full output of the thermal plants, i.e. 220 and 330 Megawatt power from the TICO and TAPCO plants respectively.
34. In addition, technically, the thermal plants are designed to undergo mandatory shutdown for a period of about two months each year for regular maintenance and servicing, meaning each plant has 85 percent maximum availability every year. In view of this maintenance requirement the maximum electricity obtainable from the TAPCO and the TICO plants are about 2,457 Gigawatt-hours and 1,638 Gigawatt-hours per year respectively.

¹⁰The TAPCO plant (or T1) was commissioned in 1999. It comprises two 110 Megawatt combustion turbines and one 110 Megawatt steam turbine making a total of 330 Megawatt of gross installed capacity. The plant can use both crude oil and natural gas. It can also take distillate oil like diesel but that would be more expensive to run on. In operation, the two combustion turbines consume the fuel and convert it into energy. The excess or escaping heat from the two turbines is hot enough to heat water into superheated steam, which is used to drive the steam turbine. The three generating units combining to work together as one is what is referred to as the combined cycle mode. This design-mechanism makes it more efficient in its use of fuel compared to if it has been without the steam turbine. Efficiency in generating electricity is about 44 percent when on crude oil and about 47 percent when on natural gas.

35. The Tema 30 MW diesel station is currently inoperable due to a fire break at the Tema Harbour in 2005 which completely burnt the pump house of the plant. Hitherto, it had been in service well in excess of its economic lifetime, even though it had seen some rehabilitation. Generation was just 138 Megawatt-hour in 2000, 22.6 Gigawatt-hours in 2002 and 18.56 Gigawatt-hours in 2003¹¹.
36. The 125 MW Effasu Power Barge is convertible to a 187.5 Megawatt combined cycle system by addition of a 62.5 Megawatt steam turbine and generator. The barge can deliver a maximum of 931 Gigawatt-hour per year when in full operation. The fuel is primarily natural gas but it can also run on distillate oil.
37. Ghana, through VRA, has the capability of contracting power import of 200-250 MW from neighbouring la Cote d'Ivoire. The Ghana – la Cote d'Ivoire contract is basically an exchange agreement; flexible to allow supply both ways when the need arises.
38. Even though, opportunity exists for renewing the contract, long-term development programme of la Cote d'Ivoire up to 2020 is uncertain. Nevertheless, such an import facility can make available an average of 1,000 Gigawatt-hour of electricity every year.
39. The power plants on the drawing board are a combined cycle natural gas thermal power station earmarked for Tema vicinity and the Bui hydropower project. The Tema natural gas thermal plant is likely to commence when the West Africa Gas Pipeline project is commissioned.
40. The Government of Ghana has set up a committee to look into the development of Bui hydro project since 2001. The Bui gorge on the Black Volta River, was being developed by the former Soviet Union as part of the Volta River development programme in the 1960s, but was halted just after the change of government. Since then, the gorge has been marked out as a national reserve to prevent human resettlement.
41. The Bui hydro project has two main variants – a 200 Megawatt or a 400 Megawatt plant. However, the projected electricity output is the same; about 946 Gigawatt-hour every year. However, by virtue of size, the Bui-400 has wider environmental risk than the Bui-200. Bui-400 is estimated to inundate about 383 square kilometres of the

¹¹ Diesel generating plant of this size when new would consume between 240 – 250 tonnes of diesel per Gigawatt-hour (i.e. for every million units of electricity generated) and produce between 300 – 350 Gigawatt-hours per annum.

reserve and displace about 2,200 – 3,000 persons. These issues have attracted some environmental concerns.

42. Bui-400 Megawatt was earlier favoured for capacity reasons during peak hours, but, with the expected completion of the West Africa Gas Pipeline project by 2007 which will deliver a cheaper fuel, natural gas, to the 550-660 MW Takoradi Thermal Power Station, capacity as reason for the Bui-400 Megawatt should no more be a priority.
43. Snapshot of the status of the power plants discussed are as follows (table 6):

Table 6: Status of Existing and Envisaged Central Power Plants in Ghana

Plant	Year installed	Status	Installed or Gross capacity Megawatt	Available net capacity Megawatt	Firm Energy Yield Gigawatt-hour
Akosombo Hydro	1965/1972	Operating	1038	1020	4800 (6100)
Kpong Hydro	1982	Operating	160	148	
Takoradi T1	1997-2000	Operating	330	300	2234
Takoradi T2	2000	Operating	220 (330) ¹²	210 (320)	1638
Tema Diesel	1961/62	Unavailable	30	0	0
Power Barge	2000	Not commissioned	125	0	930
Tema Gas thermal	Not yet	Not built	330/900 ¹³	0	2500/6702
Bui Hydro	Not yet	Not built	200/400	0	960
			Total (maximum in brackets)		13,032 (18,534)

Produced by Energy Commission and edited by VRA, 2006

VRA grid supply shortfalls

44. In 1993, domestic electricity consumption was projected to grow by about 2.4 percent annually up to 2010¹⁴. Actual consumption however, from 1993 to 1997 grew at a rate of 4.3 percent per year. Consumption growth was over 10 percent per annum in 1996 and 1997¹⁵. Load growth of both ECG and NED has averaged 7 percent per annum since 2000.
45. Supply capability depends upon local generation capability and import availability from la Cote d'Ivoire. For instance, VRA estimated Ghana's primary electricity

¹² When TICO is retrofitted with the 110 MW heat recovery steam generator unit.

¹³ Capacity could go even up to 1000 MW depending upon investment climate and the interest of the stakeholders.

¹⁴ Energy and Ghana's Socio-economic Development, 1993, Ministry of Energy, Ghana, p.3

¹⁵ Energy RoadMap for Ghana: from Crisis to the fuel for Economic Freedom, Report by a U.S Interagency Team, in response to a request by the Government of Ghana, August, 1998.

demand to be between 7,747 – 7,921 GWh for 2000 increasing to between 9,124 – 9,763 GWh by 2003. Its low-case demand forecast could hardly be met in 2000; the actual generation was 7,222 GWh and the net import to supplement local demand was about 472 GWh bringing the total local primary supply to 7,694 GWh. In 2003, with VALCO out of the equation, VRA ‘energy demand’ forecast was 7,155 GWh. Yet, it was only able to supply about 6,462 GWh (i.e. including imports).

46. In addition to VRA’s handicaps, the country has not made timely investment in new capacities and infrastructure to significantly offset the seemingly annual occurrence of shortfalls.

Network limitations

47. Besides generation limitations, there are also transmission and distribution bottlenecks. The national electrification drive has so far been based on grid connection but the capacity of the transmission system has almost being over-stretched and the distribution network is limited and over-aged. Both need expansion and improvement to remove transmission and distribution constraints, to reduce system losses and increase service reliability.

Transmission

48. Transmission losses for instance had averaged 3% in the period 1990 – 2001. It rose to 4.9% in 2003 but dropped back to 3% in 2004. VRA’s long-term projection is 3% per annum and PURC benchmark is 2.8% per annum. The increased losses in 2003 could be attributed to the overloading of the coastal line from the west to the east, and other lines, which are operated close to their thermal limits.
49. In order to transmit the required generation efficiently there will be the need to expand the transmission infrastructure by:
 - i. Enhancing supply reliability and improving voltage stability in the entire northern transmission network, since its capacity will be exceeded with the growing load and the additional power plants coming on line. It includes
 - Construction of a 161kV line from Kumasi to Sunyani
 - Construction of a 161kV line through Tumu-Han-Wa to close the northern loop.
 - ii. Upgrading transmission system-wide reactive power compensation capability.
 - iii. Upgrading and expanding transmission circuits, both local and international.
 - iv. Establishing interconnection linking Ghana to Burkina Faso and to facilitate efficient regional power market under the West Africa Power Pool protocol. *It*

includes a construction of a 330 kV line link to the Nigerian transmission network.

- v. Installing a third Bulk Supply Point for Accra, in the short term and a fourth by 2020, if the quality of power supply (reliability and voltage stability) is to be improved and sustained in the nation's capital.
- vi. Installing a second Bulk Supply Point for Kumasi by 2008 and a third by 2020.
- vii. Expanding Bulk Supply Points at Takoradi and Tamale between 2015 - 2020.
- viii. Expanding bulk supply points to other regional capitals.

Cost

50. The total cost of the transmission network expansion is estimated at:
 - US\$ 100-200 million for the low or business as usual economic growth scenario;
 - US\$ 170-270 million for moderately high growth scenario; and
 - US\$ 500-700 million for GPRS high economic growth scenario.

The wide variation in cost is dependent on the kind of transmission technology and as to whether Bui is going to be built or not.

Siting generating stations inland

51. GPRS high economic growth scenario will necessitate constructing more power plants. The coast is the most likely location for any potential natural gas, oil, coal and nuclear power plant since the sea facilitates convenient transportation of fuel by marine vessels. Besides, the sea presents a large water body for cooling as well as quenching fire in times of fire accident.
52. Over 90 percent of the peak demand is concentrated in southern to middle Ghana; from the coast to Ashanti Region. Considering that all the international ports and the major market are found in this area, the status quo is not likely to change by 2020 irrespective of the economic scenarios, unless there is a significant change of circumstances.
53. Transmission losses however, increase when electricity is wheeled from the south (where it is produced presently) to the mid regions of the country and then to the north. At present, there is no power station beyond the geographical latitude of Akosombo hydropower generating station, which can act as a potential fulcrum to balance the transmission system inland. So, such a long distance transmission translates into significant losses and stability problems for the transmission network

and consequently, will demand additional reinforcement for balancing, otherwise a transmission voltage higher than the current 161 kV will be required.

54. Thus, instead of congesting the coast with the additional thermal power plants, it is worth considering constructing some power stations inland close to major demand segments inland in the case of the high economic growth scenario or by implementing the Bui hydroelectric Project. In addition, constructing a gas pipeline for a thermal power plant inland will potentially facilitate the development of a secondary gas market in Kumasi and its environs.
55. **The challenge however is to find suitable locations inland where there is stable geology and large water bodies but near the major demand segments where a central thermal power plant (330 MW and above) can be built.**

Distribution

56. Under the Power Sector Reform, ECG is to absorb NED to form single national distribution company. A major argument advanced for the creation of the new national utility company is that NED operational area is largely rural and financially disadvantaged, but ECG operates in a well-resourced largely urban south. Consequently, the merger of the two is expected to improve upon the financial returns of the existing ECG. In spite of the relatively rich resources of the south (ECG's operational area), the company has been running at a loss. Sales growth of ECG in 1999 and 2000 were 3.1 percent and 2.8 percent respectively. Return on capital employed and asset turnover in 2000 were 0.87 percent and 0.63 percent respectively.
57. Benchmarks for a healthy distribution utility are on the average
 - 10 percent for the Sales growth,
 - 12 percent for the return on capital employed, and
 - 5 percent for the Asset Turnover.
 - 10 percent for Interest cover but ECG's interest cover in 2000 was less than 5 percent.
58. Debt/equity ratio has been over 300 percent and net loss margin in 2000 was about 70 percent compared to sector averages of 50 percent and 8 percent respectively. ECG debtors' ratio ranges between 6 - 7 months compared to average of 2 months expected of a healthy distribution company. Present records of the company show marginal improvements over the year 2000 figures.
59. The high system losses of ECG averaging 26 percent per annum is not helping matters. For instance, ECG's average revenue yield per unit of electricity purchased in 2002 and 2003 against end user tariff of 7.8 US cents per unit and 8.2 US cents per unit respectively were only 4.6 and 5.3 US cents correspondingly. Average revenue collection on unit basis though, increased from about 58 in 2000 and 2001 to 65 units in 2003 (table 7).

Table 7: Revenue performance of ECG

		2000	2001	2002	2003	2004
A	End User Tariff in US cents per unit	2.6	5.2	7.8	8.2	8.2
B	Units purchased from VRA in %	100	100	100	100	100
C	System losses in %	27	26	26	26	26
D=b - c	Units billed to customers in %	73	74	74	74	74
E	PURC Benchmark in %	82	82	82	82	82
f=d x a	Actual customer billing in US \$	1.9	3.8	5.8	6.1	NA
f=e x a	Expected customer billing in US \$	2.1	4.3	6.4	6.7	NA
G	Revenue collection efficiency in %	79	79	80	87	NA
H	PURC Benchmark in %	95	95	95	95	95
i=f x h	Expected revenue to be collected	1.8	3.6	5.5	5.8	NA
j=f x g	Actual Revenue collected	1.5	3.0	4.6	5.3	NA
K=j ÷ a	Units revenue collected	57.7	57.7	58.9	64.6	NA

Source: Adapted from ECG data, 2004

60. Average revenue yield per unit of electricity purchased enhances if ECG were to achieve PURC performance benchmark.
61. The constraints in cash flow are largely responsible for the non-economic performance of the country's power utility operations. It is therefore difficult to envisage an improvement in performance when resource-trapped NED is merged with ECG.
62. Last but not least, NED professional staff are staff of VRA. VRA salaries on the average are significantly higher than ECG. Merging ECG with NED therefore raises the issue of salary disparity.
63. Merging the two entities to become one credit worthy company without addressing the salary disparity as well as the bottlenecks within ECG that are militating against its optimal performance could therefore be dicey.
64. Deterioration of distribution infrastructure has also led to supply bottlenecks and consequently, higher technical losses; 11 – 15 percent. Improving the efficiencies in distribution and consequently lowering the technical losses can achieve substantial gains. Efficiency improvement projects by the utilities include:
 - i. Installation of system monitoring and data acquisition systems like SCADA¹⁶ to improve operations in Accra, Tema, Kumasi and other major load centres.

¹⁶ Supervisory Control and Data Acquisition System

- ii. Modernisation of technical and commercial operations including installation and expansion of wide-area network.
- iii. Reinforcement of medium voltage network and construction of new substations in Accra and other major load growing centres.
- iv. Replacement and upgrading of over-aged and overloaded distribution networks.

Cost

- 65. Total cost of upgrading and expanding the distribution network to achieve the benchmark service levels could cost not less than US\$650 million by 2020. Total cost could exceed US\$900 million by 2020 for High economic growth scenario.

Commercial losses in distribution

- 66. The large system losses of the utilities are largely commercial due to theft, unpaid bills and undue delayed payments. Credit meters apparently allow individual customers to delay bill payment and some eventually never to be paid due to debtors relocating or absconding.
- 67. Introducing more pre-paid meters and eventually phasing out credit meters in urban centres would reduce the delays in payments as well as other commercial losses.

VALCO factor

- 68. VALCO has been unique in the sense that in normal operation it accounts for 35 – 37 percent of total national electricity consumption. It therefore provides a large base load against which existing and future thermal capacity can be planned and operated cost-effectively, taking cognisance of the ongoing West African gas pipeline project. The higher the consumption of the natural gas the cheaper the gas becomes.
- 69. Primary aluminium production in general is energy-intensive. Old smelter plants utilise about 16 – 17 Megawatt-hours to produce one tonne of aluminium from alumina. Today's smelters use between 14 – 15 Megawatt-hours of electricity per tonne. Electricity intensity of production at VALCO average 16.2 Megawatt-hour per tonne. Absence of pollution charges in Ghana however, has eliminated the incentive for VALCO to improve its efficiencies further to the 15 Megawatt-hour per tonne level. VALCO smelter, when in full operation 'pumps' about 300,000 tonnes of carbon dioxide per year into the atmosphere¹⁷.

¹⁷ 1.6 – 2.2 tonnes of carbon dioxide per tonne of primary aluminium is produced depending upon the technology.

70. Aluminium smelting worldwide is very sensitive to electricity pricing. Typical European smelters of similar capacities as VALCO producing between 160,000 – 180,000 tonnes of aluminium per year operated at average prices of 2.5 US cent per unit of electricity in 2002. Plants of over 200, 000 – 250,000 tonnes capacity operated at prices ranging from 3 US cents to as high as 5 US cents per unit of electricity. VRA bulk electricity tariff to VALCO until 2003 was 1.65 – 1.80 US cents per unit of electricity whilst the PURC approved supply tariff to other bulk customers was about 4.5 US cents per unit of electricity. This implies a recurrent subsidy to VALCO to the tune of about US\$ 40-60 million in 2002. Break-even price of electricity for aluminium smelter¹⁸ with maximum capacity of 200,000 tonnes such as VALCO range from 3.8 – 4.0 US cents per unit of electricity, where the low-side is due to efficiency improvement. Thus VALCO can operate at 4.0 US cents per unit of electricity if it can improve its operational efficiency from 16.2 Megawatt-hour per tonne to at least 15.0 Megawatt-hour per tonne. The other option is to expand production capacity by additional pot, i.e. to 240,000 tonnes per annum. Operating at higher than 4.0 US cents per unit of electricity is cost competitive for aluminium prices of US\$1,900 per tonne and above. Average aluminium prices in 2005 was over of US\$3,500 per tonne
71. VALCO recommenced smelter operations in 2005 with one-two potlines. It projects to activate a 5th potline by 2008. A sixth potline is planned for 2013. VALCO electricity demand is expected to increase from about 2000 GWh to about 3,300 GWh when all the five potlines are activated. The demand will jump to over 4000 GWh when it adds a sixth potline¹⁹.
72. These future developments of VALCO have been factored into the load and electricity projections for the GPRS high and moderate economic growth scenarios.

Electricity Tariffs

73. PURC sets the tariff, in consultation with key stakeholders comprising the generators, distributors and the representatives of major consumers. Electricity supply is divided into bulk electricity (transmission level) and final electricity (distribution level). The country runs a block end user tariff system for electricity reaching all classes of consumers. The sum of the BST and the DSC is the End User Tariff (EUT) charged by the distribution companies. The End User Tariff is classified largely into industry, commercial (non-residential) and residential customers.

¹⁸ VALCO has a capacity of 200,000 tons but operated between 150,000-160,000 regularly per annum at an average alumina spot market price of between \$410-412 per tonne. Aluminium prices were US\$1,400 – 1,500 per tonne by end of 2003. At an average aluminium price above US\$3,500 per tonne in 2005 and with world annual growth of 7 -8 percent, it makes economic sense to operate even at two potlines

¹⁹ From VALCO's Projected Power Requirement for 2006 – 2015.

74. Average tariff collection efficiency had ranged from 75 – 85 percent compared to PURC benchmark of 95 percent. Average bulk electricity price was below 4 US cents per unit in the early 1990s until 1998 where it went up to between 4.0 to 4.5 US cents per unit. In 1998 drought upstream of the Volta lake reduced the hydropower generation capability of the country by about 50 percent. This compelled the Government to enter into agreement with private power producers to supply electricity under emergency. In order to allow ECG to recover the higher costs incurred due to the emergency power operations, PURC approved a surcharge end-user tariff of about 8.5 US cents per unit of electricity. The surcharge was soon to decline in its real value due to the rapid depreciation of the cedi in the years that followed. To restore the real economic value of the tariff, the PURC developed a transition plan to trigger a gradual adjustment to economic cost recovery by 2003. The automatic price adjustment formula of the Transition Plan was effected once in 2003 and twice in 2004.
75. The addition of thermal generation pushed up the End User Tariff to about 8.2 US cents per unit of electricity as of 2004. The End User Tariff comprised a BST of about 4.8 US cents per unit of electricity including a ‘postage stamp’ transmission charge of about 0.9 US cents per unit of electricity and a DSC of about 3.4 US cents per unit of electricity as of 2004. The tariff for Residential customers has a lifeline tariff for low consumption, which is based on per monthly consumption compared to per unit consumption. The lifeline tariff was at 100 units per month maximum in 1989/90 but was downgraded to 50 units per month maximum by the year 2000, though high compared to some neighbouring countries²⁰. The lifeline tariff was about US \$1.5 per month as of 2004 and the Government subsidised the lifeline consumers to the tune of about US \$1 per month but was unable to make regular and timely remittances to the utilities. The total subsidies owed by the Government to the distribution utilities by 2004 ranged from US \$400,000 – 1,400,000.
76. Average tariff for final electricity in general, was below 5 US cents per unit until 1998 when it shot up to between 5.2 - 8.2 US cents per unit. Above 8 US cents per unit, though relatively low compared to some neighbouring countries, it is not attractive to induce high level commercial and industrial usage²¹. In spite of the existing tariff being at a level comparable with what is pertaining in some developed countries, the utility companies still claim they are unable to break even. Moreover,

²⁰ Lifeline tariff is 20 kWh for Benin and 40 kWh in Togo as of end of 2003.

²¹ Products from South Africa have competitive advantage because of low electricity cost. In South Africa since 2000, final electricity sale price for Commercial, Manufacturing, and Agriculture customers has averaged 2.4, 1.3 and 2.4 US cents per kWh respectively. Bulk electricity to the mining industries has averaged 1.3 US cents per kWh (*Source: Electricity Supply Statistics for South Africa, 2000 – 2003*).

industrial customers subsidise residential consumers, a practice which must be reviewed if electricity is emphasised for wealth creation.

76. As the demand for electricity grows, the supply from hydro, which forms the bulk of the total supply, is dwindling. Hydropower so far, has been the least cost generation option. The thermal generation is largely crude oil based but this is expected to be displaced by natural gas in 2007. Thus, shift towards thermal generation introduces higher generation cost into the generation mix.

Expansion plans for meeting the generation requirements

78. Three alternative expansion plans that have been identified for meeting the supply requirements are:
- Option One is an expansion plan based primarily on natural gas and with renewable energy making a 10 percent contribution by installed capacity by 2020.
 - Option Two is an expansion plan based on natural gas, Bui hydropower project and 10 percent renewable energy contribution by installed capacity by 2020.
 - Option Three is an expansion plan based on natural gas, Bui Hydropower project, nuclear power and 10 percent renewable energy contribution by installed capacity by 2020.
79. A 10 percent contribution of renewable energy in the generation mix is the optimum proportion that will maintain the average generation costs of all the options at about the same level.
80. Assuming a reference option of largely thermal comprising installed capacities of 68-69 percent gas turbine based on natural gas and 31 – 32 percent hydropower, the change in generation cost due to the 10 percent renewable energy composition in the generation is found to be insignificant, if the average delivery price of the gas is above US\$5 per mm BTU by 2020²². The change will however be significant should the average crude oil prices fall below US\$30 per barrel.
81. Since the nation has exceeded the business-as-usual economic growth rate, the moderately high economic growth scenario based on 5 – 7 percent GDP growth per annum is used for the expansion plan. The upper ceiling of the load forecast represents a real GDP growth of about 7 percent per annum, which could be assumed as the lowest threshold for the high economic growth scenario.

Option One

82. Option One besides the existing power plants comprises:
- i. The 125 MW Effasu barge. *The Barge can be converted into 187 MW combined cycle Gas turbine plant*

²² Natural gas at US\$5.00 is equivalent to about US\$29 per barrel of crude oil. Under the WAGP agreement, the price of the natural gas has been indexed to the world crude oil price but capped at US\$30 per barrel equivalent price.

- ii. The planned 330 MW Tema Gas Thermal Station could be expanded to 660 MW by 2020.
- iii. An additional 660 MW Gas thermal Station, an improved version of the existing Takoradi Thermal Power Station taking advantage of new technologies, will be built in Takoradi.²³
- iv. There is inclusion of Renewables (excluding the traditional large hydro plants such as Bui), starting with a share of about 5% by 2008 increasing to about 9% by 2015 and eventually up to 10% by 2020.
- v. Embedded generation is highly advocated to encourage private sector investment and participation in the power generation industry. Even though, the renewables will largely come on line through embedded generation, investment in small natural gas co-gensets in the range of 1-3 MW is encouraged and envisaged by 2015.

Option Two

83. Option Two has the same configuration as Option One except that instead of another 660 MW CCGT thermal station in the vicinity of Takoradi, only 330 MW CCGT power station is proposed due to introduction of the Bui hydropower project.
- i. To compensate for the downsizing of the thermal capacity, Bui hydro power plant is being advocated for and is expected to be commissioned by 2012.
 - ii. The location of Bui provides a natural fulcrum for the national transmission network between the south and the northern zone. This balancing effect has the advantage of reducing total transmission losses, particularly, during power transmission from the south²⁴ to the north.
 - iii. However, instead of 400 MW Bui hydropower project, 200 MW plant is built to reduce negative environmental impact.
 - iv. The inclusion of Bui increases the hydropower composition in the generation mix from 43% in Option One to 51% in Option Two. The corresponding reduction in thermal composition is from 49% in Option One to 41.2% in Option Two.
 - v. Due to relatively low electricity generation output of Bui hydropower compared with gas thermal generation, private investors are encouraged to come on line with embedded gas-fired generation by 2015 to offset demand outstripping supply.

²³ Siting the next 660 MW thermal Plant near Takoradi could encourage industrial spread between Takoradi – Tema coastal corridor, instead of allowing most of the industries to be concentrated in Tema.

²⁴ Where most of the generation plants are situated.

- vi. Even though, the Bui hydropower project will inundate part of the Bui forest reserve, with careful planning, the negative environmental impact could be significantly minimised²⁵.

Option Three

- 84. Option Three has the same configuration as Option 2 except that the additional 330 MW CCGT gas thermal station for Takoradi is eliminated from the expansion plan.
 - i. Instead, a 335 MW nuclear light water reactor (IRIS-335) plant comprising between 2.3-2.5% of the generation is included in the plan. This small unit nuclear reactor will be financially manageable compared to a 600 MW advanced light water plant, which cost between US\$1-1.3 billion to install; about twice the cost of the former. The 335 MW plant could be expanded as more experience is gained in its operation and more finances become available.
 - ii. Nuclear is slated for 2018 for the following reasons:
 - EIA stage, seeking IAEA approval and sourcing for finance could take at least, 3 years.
 - Feasibility stage covering geophysical and geological studies for site selection and engineering designs could take at least, another 3 years, whilst construction to operation stage could take at least, 6 years.
 - It is the most complex of all power plants, even though, generation cost could be lower in the long term. Beside the power plant itself, a strict and specialised infrastructure is required to handle fuel arrivals and temporary wastes and spent rods before being shipped out of the country.
 - In addition, it is also the most difficult project to secure funding for.
 - iii. Option Three further reduces the thermal composition of the generation mix from about 48% in 2015 to about 43 % by 2020.

Fuel supply options to the Osagyefo Power Barge

- 85. Extending the WAGP to Effasu at the moment appears to be the most reasonable option in the medium to long term, because developing the Tano fields assuming funds are available today, will take between 3 – 5 years. The extension could help

²⁵ It should be noted that the Bui national park was created in anticipation of the construction of the Bui project. This was to avoid the Akosombo experience, by preventing settlements in the gorge and environs. To recall, the construction of the Akosombo dam unsettled about 80,000 people, flooded hectares of farm lands and cocoa plantations which comprised 7% of the real Gross national product (GNP) at that time.

- increase the consumption of the WAGP natural gas and consequently reduce the unit cost of the WAGP gas at the gate.
86. Natural gas could also be brought from la Cote d'Ivoire²⁶ to fire the Osagyefo Barge and at less or almost the same period it would take to develop the Tano gas fields. The regional nature of the project however could enhance la Cote d'Ivoire's chances of getting connected to the WAGP project²⁷.
 87. Technically, the barge could be moved to Tema and get connected to the WAGP instead of extending the latter to Effasu and could be the quicker option. However, preparing the site at Tema to receive the barge could cost about US\$ 50 million which is about the cost of installing a new 100MW single cycle gas turbine plant. Furthermore, considering that infrastructure²⁸ has been laid at Effasu, the indigenes, the opinion leaders and their chiefs have been promised the project assuring them of job creation, they in turn having embraced the project, the social cost could be immense and repercussion uncertain taking cognisance of the civil unrest in the neighbouring country – la Cote d'Ivoire. A compensation package deemed adequate for the communities would have to be worked out through careful negotiation with the aggrieved communities.
 88. In the context of ECOWAS, extending the WAGP to Effasu will draw closer the dream of having a pipeline stretching from Nigeria to Gambia and eventually serving all the ECOWAS member countries. Therefore, a decision based not only on technical feasibility, but social and in the regional context appears to be more sustainable.
 89. The second favourable option is the development of the Tano fields as originally envisaged by GNPC²⁹ for the barge. Development of the Tano fields has the following advantages:
 - i. The associated oil deposit will help deflate the cost of the project.
 - ii. Secondly, since the gas is raw, potential exists to separate the heavy molecular formulae during its exploitation to process into LPG for the domestic market.

Comparatively, the natural gas from WAGP has to be dry to avoid the potential safety and operational problems associated with the condensation of liquids in the pipeline³⁰.

²⁶ Kudu and Ibex fields in la Cote d'Ivoire, near the Tano fields in Ghana.

²⁷ La Cote d'Ivoire envisages joining the WAGP in the long term.

²⁸ Estates have been built, the harbour for the barge has been readied, and the national transmission network has been extended to barge site.

²⁹ Ghana National Petroleum Corporation

³⁰ It is therefore not practical for bottling to supplement local LPG demand.

90. In the short term and for it to be operated for few days, the barge could be readied and made part of the country's power reserve by filling the barge's storage system and the four (4) bulk road tankers procured for it with distillate oil. Even though, it could easily come on line, in times of crisis but would be the most expensive option. It is not sustainable since the trucks would have to make a number of trips if the barge is to operate for a number of days.

Selected Power Generation Technologies

91. Detailed assessment of the technical feasibility including an evaluation of the costs and a demonstration of the overall net benefits accruing to the economy is provided in the supporting document to the SNEP titled Least Cost Assessment of Power Generation Technologies and Demand-Side Appliances: An Integrated Resource Planning Approach³¹
92. The assessment of power generation technologies carried out by the Commission as part of the SNEP suggests that coal-fired steam turbines and combined cycle gas turbine running on natural gas are the most competitive sources of centralised grid electricity, followed by simple-cycle gas turbines.
93. For decentralised grid systems, electricity from closed engineered landfill³² power plant is the least expensive, combined heat and power (CHP) based on sawdust and wood residues is next followed by wind based power.
94. The most expensive means of generating grid power is by grid connected solar photovoltaic (PV) system, followed by waste incineration and wood plantation in that order.
95. Even though, conventional thermal plants based on natural gas would provide the least expensive grid power, infusing indigenous renewable energy based electricity besides the traditional hydropower in the generation mix helps to improve the balance of payments and also reduces the greenhouse gas emissions of the country, recalling that Ghana is a signatory to the Kyoto Protocol.
96. Extracting and utilising the gas generated from landfill sites create a significant benefit for the environment as the methane (gas) a very potent greenhouse gas is prevented from entering the atmosphere. Wind and solar power systems however do not emit any harmful gases or particulates into the environment. Solar power also emits no noise during operation making it ideal for office and wildlife environments.
97. Whilst conventional thermal generating systems are most sensitive to fuel prices, renewable energy technologies including hydropower are the least sensitive to variations to fuel prices. Renewable energy technology like biomass-fired CHP plants, landfill, waste-to-energy (incinerators), could have highest supply security, since once they are installed or constructed; fuel is largely indigenous. Hydropower plants may be threatened by severe droughts in their catchments, solar resource is assured almost daily, even though, intensity may vary.

³¹ Published by the Energy Commission, 2004. Also, see the Bibliography for more reference materials.

³² Excludes cost of constructing the landfill

98. Indigenous natural gas once discovered and exploited could on the other hand, provide high supply security to the thermal plants, since it would shield the latter from external influences.
99. Biomass plantation-based power production has the highest job creation, mainly since labour will be needed for the plantation and its management. Local employment generated from the investment costs would only last during the construction period, whereas employment generated from operation and maintenance as well as fuel costs would last during the lifespan of the power plant in question.
100. Nuclear technology including the power plants and the fuel would be the most difficult to acquire and thus provides the least security of supply in terms of external factors. However, once acquired and installed, it tends to have high security of supply; smaller quantities of fuel can last far longer periods than the same quantity of oil or natural gas. Another major drawback with nuclear power technology is that it would be the most difficult to attract funding, due to nuclear proliferation concerns, long construction periods and long pay-back times.

Renewables for the Energy mix

Landfills

101. Tapping power from closed landfills will be encouraged. Even though, usually in the ranges of 1 – 2 MW installed capacities per site, it is potentially the cheapest source of grid electricity for closeby communities. Engineered landfills are proposed for all regional centres and large urban centres where they could serve as sources of supplementary power to the centralised grid for these urban communities.

Wind

102. Ghana has some wind resources that could be tapped to supplement her energy requirements. For now, the potential is confined to the coastline and the most economic exploitation based on current technology is at 50 metre-height with average wind speeds between 6.0 – 6.3 metres per second (m/s). The corresponding wind power density range from 185 - 210 Watt per square metre at 1.225 kilogramme per cubic metre (kg/m³) air density. 300 – 400 MW power can reliably be tapped for now and the maximum energy that can theoretically be tapped from the available wind for electricity using today's technology is about 500 – 600 Gigawatt-hours every year³³. 200 MW providing about 400 GWh per year is conservatively being proposed.

³³ A theoretical maximum installation is expected to be in the order of 100 – 200 units with a spacing of at least 500 m in one line, corresponding to about 300 – 400 MW

Solar energy

103. Solar energy particularly for electricity, and to some smaller extent crop drying and water heating has seen some use over the years. It is estimated that photovoltaic electric (PV) systems installed in the country are well over 5000 with installed capacity of about one megawatt generating between 1.2 – 1.5 Gigawatt-hours every year.
104. A promotional programme like “Solar power for every home’ can target urban homes with a minimum of 100Wp system for basically lighting per home with some incentives. An advantage is that individuals will be investing in power reserves for the country with their own finances, whilst public funds could be used to support rural electrification. A government programme to provide a set of solar-television systems (each consisting of a solar power unit and a television set) for basic schools in off-grid locations is commendable, since it offers pupils in deprived schools the opportunity to participate in the Presidential Special Initiative for Distance Education based on radio and television.

Agro biofuel wastes

105. Biomass for electricity generation would come from logging and wood processing residues, agrofuels and municipal by-products, as well as plantations. Almost 2 million tonnes of wood residues are available in the country annually for energy and other purposes and this is expected to reach 2.5 million tonnes as the Agriculture sector grows, increasing to about 3 million tonnes by 2020. For electricity, most reliable data suggests that at least 95 Megawatt capacity providing about 600 Gigawatt-hours annually could be tapped from farm-wastes, sawmill and logging residues between now and 2010.

Small – minihydros

106. Small to mini-hydro sites total around 25 MW but dispersed over 70 sites with Dayi River cascades (2,000 – 5,300 kWp) in the Volta Region as the most attractive. Small–mini-hydro could be promoted as decentralised power systems for commercial agricultural projects and tourist sites. It could also be tied to the grid to serve as supplementary power units. The small hydropower proposed for development is the Dayi River cascades which can be developed and connected into the distribution grid.

Generation Mix

107. Generation mix of the expansion options by installed capacity is as follows:

Average generation mix by installed capacity of the expansion plans			
	Option 1	Option 2	Option 3
Hydropower	39 - 41 %	46 - 49 %	44 - 46 %
Thermal	51 %	43 - 46 %	41 - 43 %
Nuclear	0 %	0 %	3 - 8 %
Renewables	8 - 10 %	5 - 11 %	7 - 8 %

Job Creation

108. Construction of the Bui hydropower project could create as many as 21,000 jobs. The development of the Tano gas fields and the construction of the nuclear power plants will also create significant number of jobs. These make the Option Three the highest job creator. The infusion of renewable energy technologies in general creates most of the operation and maintenance jobs due to their higher local content, decentralised and localised nature.

Greenhouse Gas Emissions

109. Option One gives the highest carbon dioxide emissions due to the large thermal component in its generation mix.

Costs

110. Option Three tends to be the most capital intensive due to the inclusion of the Bui hydropower and the nuclear power projects.
111. Snapshot of the cost, job creation potential and the carbon dioxide emissions of the options by 2020 are as follows:

	Option 1	Option 2	Option 3
Cost in billion US dollars	5.7 – 6.8	6.1 – 6.2	6.5 – 6.6
Investment in power plants	33–37%	43–45%	46–48%
Operation, maintenance, fuel	73–77%	55–57%	52–54%
Transmission cost in billion US dollars		0.17 – 0.27	
Distribution cost in billion US dollars		0.65 – 0.90	
Direct jobs created during construction in man-years	18,500-24,500	43,000 – 44,000	54,100 – 57,000
Direct jobs created during operation and maintenance in man-years³⁴	247,000	277,000	286,000
Carbon dioxide emissions during operation in million tonnes	85 - 86	72 - 77	68 - 73

Assumptions

112. Technical assumptions used for the expansion plan is as follows:
- The Takoradi Thermal Power Station (TTPS) presently at 550 MW installed capacity will be expanded to 660 MW by 2008.
 - The WAGP project bringing natural gas from Nigeria will be completed by end of 2006.
 - The TTPS will switch fully to natural gas by mid 2007.
 - The old 30MW Tema diesel plant is decommissioned³⁵.
 - Ghana's existing contractual net power exports to Togo, Benin and Burkina Faso are met through imports from la Cote d'Ivoire.

³⁴ Rounded to the nearest 1000

³⁵ Besides, the fire outbreak at Tema Harbour in 2005 destroyed the pump house.

- Net electricity imports to supplement local demand after 2007 will not be necessary if local generation is adequate to meet demand and contractual export to Togo and Benin.
- The targeted reserve margin for the country will still be 25% maximum as envisaged by VRA, but the optimal operational range could be between 15 – 25%.
- Renewables are included and make up 10% by installed capacity by 2020 in all the options.

The Power Sector Reform

113. It is commendable that the Government has passed the enabling legislation for the creation of the new entities and also, the modification of mandates of the existing entities to facilitate the implementation of the power sector reform.
114. It is recommended that the New VRA manages the Volta Lake and secures the integrity of large hydropower dams in the country.
115. Large hydropower projects compare to thermal, takes relatively longer time to construct, require relatively larger infrastructure development, involves environmental issues that could be controversial such that they hardly attract private investors without Government participation, unless the rate of return is relatively very high. High rate of return on the other hand makes the intended generation costs of the hydropower projects very uncompetitive. The technical lifetime of the hydropower plants is about 50 years compared to the usual economic lifetime of 20 – 30 years used for most analysis. They could become very attractive in the long run when their investments have been paid for. In addition, construction of hydro plants creates more jobs and they have less operation and maintenance costs than thermal plants.
116. However, without an entity such as new VRA, it will be almost impossible to develop the remaining hydropower resources. The new VRA with hydro as focus has the advantage to look for overseas development assistance, governmental loans and government (public)-private partnership investment funding.
117. Furthermore, it should be emphasised that without the transmission ownership separated from VRA system ownership and an Independent System Operator appointed, it will be very difficult to envisage a fair competition for would-be future generators. Consequently, the expected private sector participation in power generation could hardly be realised without an Independent System Operator.

**STRATEGIC PLAN FOR
THE ELECTRICITY
SUBSECTOR
and
Policy Recommendations**

Strategic Plan for the Electricity Subsector

Security of Supply

Objective: To produce adequate, high quality, reliable and efficient power supply to meet economic and social development needs of Ghana and for export.

Strategic Target:

Secure and increase future energy security by diversifying sources of supply, including increasing access to renewable energy technologies so as to achieve 10 percent penetration in terms of installed capacity by 2020³⁶.

Policy

1. It is recommended that:

- i. Government facilitates the timely completion of the West African Gas Pipeline project*
- ii. Government ensures the speedy resolution of fuel to the ‘Osagyefo’ Power Barge.*
- iii. Government speeds up the development of the Bui hydropower project.*
- iv. Government supports the development of renewable energy for power generation.*
- v. Government explores various options including decentralised and mini-grid systems for reducing the cost of supplying utility power to the rural communities.*

Implementation measures

- a) Create incentives to attract private sector investment including, wherever relevant and appropriate, access to loans on concessionary terms, financial instruments, government, guarantees and or grants for infrastructure investment.
- b) Promote the entry of multiple players into the generation market by encouraging private and public investors to take advantage of the opening up of the generation market.
- c) Timely implement the power sector reform strategy already outlined for the sub-sector.
- d) Government scouts for overseas development assistance for the development of the Bui dam since that looks more favourable than private capital. Bui

³⁶ Computation for renewable energy share shall not include existing hydropower stations of Akosombo and Kpong generation stations.

besides the energy it provides, has the potential to balance the entire transmission network from south to the north and in the process reduce transmission losses. It will also create thousands of jobs during construction and operation.

- e) PURC resolve feed-in tariff for embedded generation to allow existing biomass co-generation plants to be integrated into the grid system.
- f) Energy Commission issues licence for the operation of renewable energy large power plants in the country.
- g) Ministry of Energy and the Energy Commission jointly undertake pre-feasibility study of coal nuclear power plants to prepare the initial ground work for the possibility of including “clean coal” and nuclear power in the grid power supply mix in the foreseeable future.

Universal Electrification

Objective: National goal is to achieve 100% universal electrification by 2020. The present level of access to electricity for households is estimated to be over 50%. Connection however has largely been by grid.

Strategic Target:

To achieve 30% penetration of rural electrification via renewable energy technologies by 2020.

Policy

2. It is recommended that:

- i. *The universal access to electrification via the National Electrification Scheme be by both grid extension and decentralised minigrid and microgrid energy systems including renewable energy.*
- ii. *Government sustains its commitment to achieving the National Electrification Scheme objective of 100% universal electrification by 2020.*
- iii. *Government ensures that sufficient funding is available for the National Electrification Scheme.*
- iv. *Government establishes a Rural Electrification Board with a Rural Electrification Fund to manage and coordinate the rural electrification component of the National Electrification Scheme.*
- v. *Government supports local agencies to solicit funding from the international donor facilities such as the Global Environment Facility and the Clean Development Mechanism.*

- vi. *Government encourages instituting energy planning and management committee at the community level in rural areas as structures to support rural electrification.*
- vii. *Government supports the issue of favourable feed-in tariffs for electricity from embedded generation, particularly renewable energy, to promote distributed generation systems in the country.*

Implementation measures

- a) Consider the possibility of encouraging District Assemblies to provide electricity services to their off-grid communities via mini-grids and micro-grids through alternative distributed generation sources such as biomass but other than traditional (petroleum) diesel.
- b) Integrate the supply of electricity to rural areas with other social infrastructure e.g. water, road network etc.
- c) Ensure that the Self Help Electrification Programme (SHEP) and the National Electrification Programme (NEP) are part of an integrated rural development programme of the District Assemblies.
- d) Rural electrification is seen to be providing energy services for social enterprises but also to support economic (wealth creation) activities. Therefore establish a Rural Electrification Board, a Rural Electrification Fund and a transparent mechanism for funds disbursement to bring down costs of equipment and materials through the provision of grants and loans for rural electrification schemes.
- e) Government legislates **0.1-0.2 cents per kWh** of existing hydro generation for rural electrification to augment existing levy on the tariff for rural electrification to support the proposed Rural Electrification Fund. Or,
- f) Government **adjust the existing hydropower tariff** to that of the thermal plant running on natural gas and use the incremental difference to fund the Rural Electrification. In this case there would be nothing like preferential hydropower sales to VALCO or any industry customer in the de-regulated market. Natural gas thermal generation tariff would be the benchmark for baseload electricity sales.
- g) Also, efforts should be doubled to tap the numerous ‘green credits’ available worldwide such as the Clean Development Mechanism (CDM) into the country for rural electrification via decentralised renewable energy systems.

The Power Transmission System

Objective: To facilitate bulk transportation of power to where it is needed and as the main artery for facilitating the long-term vision of 100 percent universal electrification of the country.

Preamble

Transmission losses sum up least when the country's electricity generation is mainly from the Akosombo and Kpong hydropower stations since they are located in the east. Transmission losses however, go up when generation is largely thermal since the power has to be wheeled from the thermal station at Aboadze in the west to the east where demand is greater. The losses are greater than expected due to over-loading of coastal lines, which are close to their transfer limits. It thus makes economic sense to site future power stations at locations along the east coast where for obvious reasons most of the industries are located, specifically within Accra – Tema coastal segment. The high demand within Tema-Accra coastal stretch also makes the coast the most favourable location for future thermal power plants.

Future industries are also likely to be attracted to the east for the power supply reason as well. However, over concentration of power plants and industries in the east could give rise to serious balancing problems in the national transmission system and in addition threaten the coastal environment unless stricter environmental policies are enforced. Thus, to enhance the dynamic stability of the transmission network and also to keep losses to the optimum minimum, there will be the need for deliberate industrial policy to develop the western segment of the coast and consequently encourage future industries to go there. Reinforcement of the coastal line will also be required.

It is recommended that the government expedite the establishment of the Electricity transmission Utility. Without the transmission ownership separated from VRA system ownership and an Independent System Operator appointed quickly, it would be very difficult to envisage immediate and active private sector participation in power generation.

Policy

3. It is recommended that:

- i. *Government encourages future industries to be sited in the west coast of the country.*
- ii. *Government improves the basic industrial infrastructure within the Sekondi –Takoradi - Cape Coast coastal segment to make it equally attractive for industrialisation as in the east.*
- iii. *Government looks for suitable locations for future power plants inland and mark them out as national reserves.*
- iv. *Government conducts feasibility study on extension of the WAGP from the coast to a suitable location near Kumasi*
- v. *Government facilitates the upgrading and expansion of the transmission and the distribution networks.*

- vi. *Energy Commission in consultation with the Independent System Operator and the Transmission Utility develops:*
- *The Grid Code for transparent access, information and despatch; and*
 - *Rules for the operation of the transmission system.*

Implementation measure

- a) Government help set up the Independent System Operator and the Transmission Utility as soon as possible.
- b) Assets of the transmission network of VRA – including the Volta Load Despatch Centre at Tema and Engineering and the System Planning Division at Akuse transferred to the Electricity Transmission Utility.
- c) Government financially assists the Transmission Utility to expand transmission network.
- d) Energy Commission develops standards of performance, codes of practice and regulations of electric transmission.

Distribution and Tariff

Preamble

Under the Power Sector Reform, ECG is proposed to absorb or merged with NED to form single national distribution company. Total system losses had ranged from 24 – 26 percent for both ECG and NED. NED operational area is largely rural, sparsely populated and poorly resourced, whilst ECG's is largely urban, relatively densely populated and highly resourced. Average salary of NED professional staff is higher than that of ECG. It may therefore not be healthy to merge the two entities without addressing salary disparity issue and the bottlenecks within ECG that are militating against its optimal performance.

Policy

4. It is recommended that:

- i. *Government ensures that ECG is put on a sound management footing before it is made to absorb NED into a new ECG*
- ii. *ECG explores innovative ways to reduce their high system losses including ways of improving collection from customers with credit meters.*
- iii. *Government promulgates the standards of performance, codes of practice and regulations for electricity distribution.*
- iv. *PURC resolves quickly the issue of favourable feed-in tariffs for electricity from embedded generation, particularly renewable energy, to allow*

distributed generation systems to be hooked to the distribution grid network.

Implementation measures

Introduce private participation into the management of new ECG to improve technical, financial and commercial operations.

Cost of Unserved Energy

Presently, economic costs of power outages to the various economic sectors of the country are not officially known. Knowing the high cost of unserved energy endured by the economic sectors will encourage the nation to invest in measures to reduce power outages to the barest minimum.

Policy

5. It is recommended that:

Energy Commission, PURC in consultation with the utilities compute cost of unserved energy at all the load centres in the country.

Tracking and reducing bill defaults

Even though, introducing more pre-paid meters can significantly reduce the default and delay in payments, a system whereby individual customer is made the target of identification instead of the meter for the bill payment is likely to reduce drastically cases of customers absconding with unpaid bills. For instance, prospective customer is issued with identification number based on his/her Social Security number and a bank account. For those without Social Security numbers and bank accounts, their birthday or baptismal certificates are used, so that the individual is billed based on any of the above being used as personal identification number (PIN). In this case, if such a customer defaults say in Accra and moves to Tamale in the Northern Region, the debt will still be following that individual since past records will pop up whenever the individual applies or tries to apply for a new meter (or connection) in any new residency the individual finds him or herself. For the distribution companies to effect this arrangement, there should be in place a centralised computer system where information on all individual customers are stored.

Policy

6. It is recommended that:

- i. Government supports nationwide computerisation of all bills into one billing network.*
- ii. Government supports the distribution companies to adopt a more efficient system to track bill defaulters.*

Appendices

Appendix 1 A Electricity Expansion Plan; Generation mix by installed capacity 2006 – 2008

Appendix 1 B Electricity Expansion Plan; Generation mix by installed capacity 2009 – 2012

Appendix 1 C Electricity Expansion Plan; Generation mix by installed capacity 2013 – 2015

Appendix 1 D Electricity Expansion Plan; Generation mix by installed capacity 2016 – 2020

Appendix 2 A Electricity Expansion Plan: Option 1; Gas + 10% Renewables

Appendix 2 B Electricity Expansion Plan: Option 2; Gas + Bui Hydro +10% Renewables

Appendix 2 C Electricity Expansion Plan: Option 3; Gas + Bui Hydro + Nuclear + 10%
Renewables

Appendix 3 A Capacity Plan: Option 1; Thermal + 10% Renewables

Appendix 3 B Capacity Plan: Option 1; Option 2; Thermal + Bui Hydro +10% Renewables

Appendix 3 C Capacity Plan: Option 3; Thermal + Bui Hydro + Nuclear + 10% Renewables

Appendix 4 A Transmission map of Ghana – 2015

Appendix 4 B Transmission map of Ghana – 2020

List of Participants

Bibliography

APPENDIX 1 – A

ELECTRICITY EXPANSION PLAN – GENERATION MIX BY INSTALLED CAPACITY 2006 – 2008							
SOURCE	PLANT	OPTION 1		OPTION 2		OPTION 3	
		Total	Percent	Total	Percent	Total	Percent
Hydropower		1180	54%	1180	54%	1180	54%
	Akosombo & Kpong	1180		1180		1180	
	Bui hydro 200 - 400 MW	0		0		0	
Thermal		895	41%	895	41%	895	41%
	Tapco	330		330		330	
	Tico	330		330		330	
	Tema diesel	0		0		0	
	Effasu Barge	125		125		125	
	330MW Tema GT 1	110		110		110	
	330MW Tema GT 2	0		0		0	
	Embedded Gas Gensets	0		0		0	
Renewables		105	5%	105	5%	105	5%
	Biomass, solar, minihydro, etc	5		5		5	
	Wind	100		100		100	
	Municipal Solid Wastes	0		0		0	
	Landfills	0		0		0	
Nuclear		0	0%	0	0%	0	0%
	Light water reactor – IRIS-335	0	0	0	0	0	0
TOTAL		2180		2180		2180	

2006 – 2008	Option 1	Option 2	Option 3
Cost in US \$ billion	1.0-1.4	1.0 – 1.4	1.0 – 1.4
Investment	48%	48%	48%
Operation & Maintenance	52%	52%	52%
Job creation potential			
Construction	4,120	4,120	4,120
Operation & Maintenance	10,310	10,310	10,310
Total	14,430	14,430	14,430

APPENDIX 1 B

ELECTRICITY EXPANSION PLAN – GENERATION MIX BY INSTALLED CAPACITY 2009 - 2012							
SOURCE	PLANT	OPTION 1		OPTION 2		OPTION 3	
		Total	Percent	Total	Percent	Total	Percent
Hydropower		1180	43.0%	1380 (1580)	51.0% 54.4%	1380 (1580)	51.0% 54.4%
	Akosombo & Kpong	1180		1180		1180	
	Bui hydro 200 - 400 MW	0		200 (400)		200 (400)	
Thermal		1335	49.0%	1115	41.3% 38.4%	1115	41.3% 38.4%
	Tapco	330		330		330	
	Tico	330		330		330	
	Tema diesel	0		0		0	
	Effasu Barge	125		125		125	
	330MW Tema GT 1	330		330		330	
	330MW Tema GT 2	220		0		0	
	Embedded Gas Gensets	0		0		0	
Renewables		208	7.6%	208	7.7% 7.2%	208	7.7% 7.2%
	Biomass, solar, minihydro, etc	7		7		7	
	Wind	200		200		200	
	Municipal Solid Wastes	0		0		0	
	Landfills	1		1		1	
Nuclear		0	0	0	0	0	0
	Light water reactor – IRIS-335	0	0	0	0	0	0
	TOTAL	2723	100%	2703 (2903)	100%	2803	100%

2009 – 2012	Option 1	Option 2	Option 3
Cost in US \$ billion	1.2 - 1.5	1.5 – 1.7	1.5 – 1.7
Investment	35%	48%	48%
Operation & Maintenance	65%	52%	52%
Job creation potential			
Construction	3,404	25,000	25,000
Operation & Maintenance	6,034	36,000	36,000
Total	10,438	61,000	61,000

APPENDIX 1 C

ELECTRICITY EXPANSION PLAN – GENERATION MIX BY INSTALLED CAPACITY 2013 - 2015							
SOURCE	PLANT	OPTION 1		OPTION 2		OPTION 3	
		Total	Percent	Total	Percent	Total	Percent
Hydropower		1180	36.3%	1380 (1580)	42.6% 45.9%	1380 (1580)	42.6% 45.9%
	Akosombo & Kpong	1180		1180		1180	
	Bui hydro 200 – 400 MW	0		200 (400)		200 (400)	
Thermal		1775	54.6%	1565	48.3% 45.5%	1565	46.8% 45.5%
	Tapco	330		330		330	
	Tico	330		330		330	
	Tema diesel	0		0		0	
	Effasu Barge	125		125		125	
	330MW Tema GT 1	330		330		330	
	330MW Tema GT 2	330		330		330	
	Embedded Gas Gensets	0		120		120	
	3rd 330MW Takoradi CCGT	330		0		0	
	4th 330MW Takoradi CCGT	0		0		0	
Renewables		294	9.1%	294	9.1% 8.5%	294	9.1% 8.5%
	Biomass, solar, minihydro, etc	10		10		10	
	Wind	200		200		200	
	Municipal Solid Wastes	80		80		80	
	Landfills	4		4		4	
Nuclear		0	0	0	0	0	0
	Light water reactor – IRIS-335	0	0	0	0	0	0
	TOTAL	3249	100%	3239 (3439)	100%	3239 (3439)	100%

2013 – 2015	Option 1	Option 2	Option 3
Cost in US \$ billion	1.2 – 1.4	1.3 – 1.4	1.3 – 1.4
Investment	40%	52%	52%
Operation & Maintenance	60%	48%	48%
Job creation potential			
Construction	5,000	5,000	5,000
Operation & Maintenance	135,000	135,000	135,000
Total	140,000	140,000	140,000

APPENDIX 1 D

ELECTRICITY EXPANSION PLAN – GENERATION MIX BY INSTALLED CAPACITY 2016 - 2020							
SOURCE	PLANT	OPTION 1		OPTION 2		OPTION 3	
		Total	Percent	Total	Percent	Total	Percent
Hydropower		1180	31.2%	1380	37.8%	1380	37.8%
	Akosombo & Kpong	1180		1180	41.0%	1180	41.0%
	Bui hydro 200 MW	0		200 (400)		200 (400)	
Thermal		2225	58.8%	1895	51.8%	1565	42.8%
	Tapco	330		330	49.2%	330	40.5%
	Tico	330		330		330	
	Tema diesel	0		0		0	
	Effasu Barge	125		125		125	
	330MW Tema GT 1	330		330		330	
	330MW Tema GT 2	330		330		330	
	Embedded Gas Gensets	120		120		120	
	3rd 330MW Takoradi CCGT	330		330		0	
	4th 330MW Takoradi CCGT	330		0		0	
	Renewables		380	10.0%	380	10.4%	380
Biomass, solar, minihydro, etc		25		25	(9.9%)	25	(9.9%)
Wind		200		200		200	
Municipal Solid Wastes		140		140		140	
Landfills		15		15		15	
Nuclear		0	0	0	0	335	9.1%
	Light water reactor – IRIS- 335	0	0	0	0	335	8.7%
	TOTAL	3785	100%	3655	100%	3660	100%
				(3855)		(3860)	

2016 – 2020	Option 1	Option 2	Option 3
Cost in US \$ million	2.3 – 2.5	2.3 – 2.4	2.7
Investment	26%	26%	37%
Operation & Maintenance	74%	74%	63%
Job creation potential			
Construction	6,027	6,027	20,000
Operation & Maintenance	95,616	95,616	105,000
Total	101,643	101,643	125,000

APPENDIX 2A ELECTRICITY EXPANSION PLAN: OPTION 1; THERMAL + 10% RENEWABLES

YEAR	Required Generation GWh	Peak Demand Range MW	POWER PLANT	PLANT FEATURES					Gross Installed Capacity MW	Reserve Margin	REMARKS
				Generation GWh		Installed Capacity MW	Availability				
				Max	Optimal		MW	Percent			
2005	6,400 – 7,500	1,200 – 1,400	Akos&Kpg hydro	6,100	5,200	1,198	1,168	97%	1,885	16%	Assumed Valco comes on line with 2 pots by end '05.
			Tapco (oil)	2,234	500	330	220 - 280	67-85%			
			Tico (oil)	1,638	200	220	200	90 %			
			Tema diesel	210	0	30	15	50 %			
			Osagyefo Barg	930	0	125	0	0 %			
			<i>Import</i>	1,000	1,000	100	100	100%			
2006	6,800 – 9,000	1,200 – 1,500	Akos&Kpg hydro	6,100	4,000	1,198	900	60-70%	1,855	23%	Tema diesel is retired./ Bui EIA shd complete.
			Tapco (oil → gas)	2,234	1,000	330	220 - 280	67-85%			
			Tico (oil → gas)	1,638	500	220	200	90 %			
			Tema diesel	210	0	30	0	0 %			
			Osagyefo Barg	930	0	125	0	0 %			
			<i>Import</i>	2,000	2,000	200	200	100%			
2007	9,100 – 12,100	1,400 – 1,600	Akos&Kpg hydro	6,100	4,200	1,198	1,000	70-80%	1,856	22%	WAGP is complete./ Commence Tico upgrade / Begin to construct new 330MW CCGT./ Install some renewables. / Bui finances must be secured. First wind come on line
			Tapco (oil → gas)	2,234	2,234	330	260–280	70–85%			
			Tico (oil → gas)	2,457	2,000	330	220–280	70–85%			
			Osagyefo Barg	930	400	125	100-106	70-80%			
			Mini-small hydro/solar	2	2	1	1	NA			
			<i>Import</i>	2,000	2,000	200	200	100 %			
2008	9,600 – 13,000	1,500 – 1,750	Akos&Kpg hydro	6,100	5,000	1,198	1,168	97%	2,130	20%	Effasu barge shd come on line. All old plants near peaking. Import not necessary First 110 MW Tema CCGT and first woodwaste bio-cogen plant come on line. Valco could operate 5 pots Bui construction should start
			Tapco + Tico gas	5,000	4,900	660	560-600	70-80%			
			Osagyefo Barg	930	930	125	106-110	80-85%			
			Wind farm	98-100	98-100	50	10-11	21-22%			
			Tema CCGT Ist stge	819	819	110	90-100	80-85%			
			Mini-small hydro/solar	2	2	1	1	NA			
			BioCogen-Woodwastes	30	27	4	3	70-80%			

YEAR	Required Generation GWh	Peak Demand Range MW	POWER PLANT	PLANT FEATURES					Gross Installed Capacity MW	Reserve Margin	REMARKS
				Generation GWh		Installed Capacity MW	Availability				
				Max	Optimal		MW	Percent			
2009	13,100 – 16,700	1,600 – 1,900	<i>Existing as of 2008</i> Tema CCGT 2nd stage Mini-small hydro/ solar	1,638	1,392-1,400	220	187-200	70-85%	2,130	18%	Total mini-small hydro/solar goes up. 2 nd Gas turbine of Tema CCGT comes on line. Initiate plans to tap landfill power.
				4	4 - 2	2	2	NA			
2010	13,800 – 17,500	1,700 – 2,050	Tema CCGT 3 rd stage Wind farm	2,500	2,457–2,500	330	280-300	70-85%	2,461	18%	Tema 330 MW CCGT is complete. Total wind farm expands to 160 MW.
				315	313-315	160	35-37	22-23%			
2011	14,400 – 18,250	1,780 – 2,100	Tema CCGT 4 th Stage Mini-small hydro/ solar 1 st Landfill (<i>Accra</i>)	3,300	3,276-3,300	440	374-400	70-85%	2,572	19%	Expand 330MW Tema CCGT to 660MW. First 110MW comes on line. Initiate plans to develop municipal waste power. 1 st landfill comes on line.
				6	3 - 6	3	3	NA			
				17	16 - 17	1	1	95%			
2012	14,600 – 18,500	1,880 – 2,200	Tema CCGT 5 th Stage Wind farm 1 st Landfill (<i>Kumasi</i>)	4,100	4,095-4,100	550	467-500	70-85%	2,723	20%	Windfarm expands./Tema CCGT gets 2 nd 110MW on line. /Construction of MSW plant on going.
				395	392-395	200	44-46	22-23%			
				17	16-17	1	1	95%			
2013	14,990 – 19,500	1,980 – 2,280	Tema CCGT 6 th Stage 1 st Municipal Solid Wastes (<i>Accra–Tema</i>) 1 st Landfill (<i>Ta'di</i>)	5,000	4,914-5,000	660	561-600	70-85%	2,854	21%	Tema 330MW expansion to 660MW completes. 1 st MSW plant comes on line. / Landfill expands to other major cities.
				150	149 - 150	20	4	15–20%			
				17	16 - 17	1	1	95%			
2014	15,670 – 20,300	2,092 – 2,300	2 rd CCGT (Ta'di) 1 st Stge	819	819	110	90-100	80-85%	2,989	24%	Kumasi gets MSW plant. 2 nd 660MW CCGT plant is built near Takoradi. 1 st 110MW unit comes on line. Valco operates 6 th potline
			1 st Municipal Solid Wastes MSW (<i>Kumasi</i>)	150	149 - 150	20	4	15–20%			
			Landfill (<i>Tamale</i>)	17	16 - 17	1	1	95%			
			Landfill (<i>Cape Coast</i>)	17	16 - 17	1	1	95%			
			Mini-small hydro/ solar	6	3 - 6	3	3	NA			

YEAR	Required Generation GWh	Peak Demand Range MW	POWER PLANT	PLANT FEATURES					Gross Installed Capacity MW	Reserve Margin	REMARKS
				Generation GWh		Installed Capacity MW	Availability				
				Max	Optimal		MW	Percent			
2015	16,400 – 20,900	2,200 – 2,500	2 rd CCGT (Ta'di) 2 nd & 3 rd	2,500	2,457–2,500	330	280-300	70-85%	3,249	24%	Sekondi-Takoradi gets MSW plant. 1 st 330MW block of the 2 nd 660MW Ta'di CCGT is complete.
			2 nd Municipal S. Wastes - (Accra-Tema)	300	295 - 300	40	8	15–20%			
			Municipal Solid Wastes - (Sekondi-Ta'di)	150	149 - 150	20	4	15–20%			
2016	17,150 – 21,660	2,310 – 2,600	2 rd CCGT (Ta'di) 4 th Stage	3,300	3,276-3,300	440	374-400	70-85%	3,380	24%	Tamale gets MSW plant. Construction of 2 nd 330MW block of 2 nd 660MW Ta'di CCGT. 1 st 110MW comes on line.
			Municipal Solid Wastes - (Tamale)	150	149 - 150	20	4	15–20%			
			Landfills (Winneba, Obuasi)	17	16 - 17	2 x 0.5	1	95%			
2017	17,950 – 22,600	2,430 – 2,700	2 rd CCGT (Ta'di) 5 th & 6 th	5,000	4,914-5,000	660	561-600	70-85%	3,628	26%	Expand landfill power to other regional centres.
			2 nd Municipal Solid Wastes (Kumasi)	300	295 - 300	40	8	15–20%			
			Landfills (K'dua Ho, Sunyani)	60	51 - 60	3 x 1	3	95%			
			Mini-small hydro/ solar	8	6 - 8	4	4	NA			
			BioCogen-Woodwastes	40	35-40	4	3 - 4	70-80%			
2018	18,780 – 23,620	2,560 – 2,860	Distributed Gas turbines	900	820 - 900	120	100-110	80-85%	3,751	24%	Introduce distributed Gas turbines for embedded generation.
			2 nd landfill (Accra),	40	34-40	2	2	95%			
			2 nd landfill (Kumasi)	40	34-40	2	2				
			2 nd landfill (Ta'di)	40	34-40	2	2				
2019	19,670 – 24,680	2,700 – 3,000	Municipal Solid Wastes - (Cape Coast)	150	149 - 150	20	4	15–20%	3,776	20%	Cape Coast gets MSW plant
			Mini-small hydro/ solar	10	8 - 10	5	5	NA			
2020	20,590 – 25,820	2,850 – 3,150	Landfills (Bolga, Wa Nkawkaw, Techiman, Ash-Manpong)	35	33 - 35	2 x 1	2	95%	3,785	17%	Expand landfill power to other large district centres.
			Bio-cogen woodwastes	120	95 - 120	15	9 - 12	70 – 80%			

APPENDIX 2B ELECTRICITY EXPANSION PLAN: OPTION 2; THERMAL + BUI HYDRO + 10% RENEWABLES

YEAR	Required Generation GWh	Peak Demand Range MW	POWER PLANT	PLANT FEATURES					Gross Installed Capacity MW	Reserve Margin	REMARKS
				Generation GWh		Installed Capacity MW	Availability				
				Max	Optimal		MW	Percent			
2005	6,400 – 7,500	1,200 – 1,400	Akos&Kpg hydro	6,100	5,200	1,198	1,168	82%	1,885	16%	Valco came on line with 2 pots by end '05. /
			Tapco (oil)	2,234	500	330	220 - 280	67-85%			
			Tico (oil)	1,638	200	220	200	85 %			
			Tema diesel	210	0	30	15	50 %			
			Osagyefo Barg	930	0	125	0	0 %			
<i>Import</i>	<i>1,000</i>	<i>1,000</i>	<i>100</i>	<i>100</i>	<i>100%</i>	<i>1,983</i>	<i>17%</i>				
2006	6,800 – 9,600	1,200 – 1,500	Akos&Kpg hydro	6,100	4,000	1,198	900	60-70%	1,855	16%	Tema diesel is retired./ Bui EIA shd complete.
			Tapco	2,234	1,000	330	220 - 280	70-85%			
			Tico	1,638	500	220	200	85 %			
			Tema diesel	210	0	30	0	0 %			
			Osagyefo Barg	930	0	125	0	0 %			
<i>Import</i>	<i>2,000</i>	<i>2,000</i>	<i>200</i>	<i>200</i>	<i>100%</i>	<i>1955</i>	<i>17%</i>				
2007	9,100 – 12,100	1,400 – 1,600	Akos&Kpg hydro	6,100	4,20	1,198	1,168	70-80%	1,966	22%	WAGP is complete./ Commence Tico upgrade / Begin to construct new 330MW CCGT./ Install some renewables. / Bui finances must be secured.
			Tapco (oil → gas)	2,234	2,234	330	260–280	70–85%			
			Tico (oil → gas)	2,457	2,000	330	220–280	70–85%			
			Osagyefo Barg	930	400	125	100-106	70-80%			
			Mini-small hydro/solar	2	2	1	1	NA			
<i>Import</i>	<i>2,000</i>	<i>2,000</i>	<i>200</i>	<i>200</i>	<i>100 %</i>	<i>2,066</i>	<i>25%</i>				
2008	9,600 – 13,000	1,500 – 1,750	Akos&Kpg hydro	6,100	5,000	1,198	1,168	81%	2,130	20%	Effasu barge shd come on line. All old plants near peaking. Import not necessary First 110 MW Tema CCGT and first woodwaste bio-cogen plant come on line. Valco could operate 5 pots Bui construction should start
			Tapco + Tico gas	5,000	4,900	660	560-600	70-80%			
			Osagyefo Barg	930	930	125	106-110	80-85%			
			Wind farm	98-100	98-100	50	10-11	21-22%			
			Tema CCGT Ist stge	819	819	110	90-100	80-85%			
			Mini-small hydro/solar	2	2	1	1	NA			
			BioCogen-Woodwastes	30	27	4	3	70-80%			

YEAR	Required Generation GWh	Peak Demand Range MW	POWER PLANT	PLANT FEATURES					Gross Installed Capacity MW	Reserve Margin	REMARKS
				Generation GWh		Installed Capacity MW	Availability				
				Max	Optimal		MW	Percent			
2009	13,100 – 16,700	1,600 – 1,900	Existing as of 2008 Tema CCGT 2nd stage Mini-small hydro/ solar	1,638	1,392-1,400	220	187-200	70-85%	2,130	17%	Total mini-small hydro/solar goes up. 2 nd Gas turbine of Tema CCGT comes on line. Initiate plans to tap landfill power.
				2	2	1	1	NA			
2010	13,800 – 17,500	1,700 – 2,050	Tema CCGT 3 rd stage	2,500	2,457– 2,500	330	280-300	70-85%	2,461	17%	Tema 330 MW CCGT is complete. Total wind farm expands to 160 MW.
			Wind farm	315	313-315	160	35-37	22-23%			
2011	14,400 – 18,250	1,780 – 2,100	Bui hydro at 200MW Mini-small hydro/ solar 1 st Landfill (<i>Accra</i>)	1,000	900-1,000	200	200	25-27%	2,662	22%	Bui-200MW comes on line. / Initiate plans to develop municipal waste power. / 1 st landfill comes on line.
				6	3 - 6	3	3	NA			
				17	16 - 17	1	1	95%			
2012	14,600 – 18,500	1,880 – 2,200	Wind farm 1 st Landfill (<i>Kumasi</i>)	395	392-395	200	44-46	22-23%	2,703	20%	Windfarm expands. /Tema CCGT gets 2 nd 110MW on line. / Construction of MSW plant on going.
				17	16-17	1	1	95%			
2013	14,990 – 19,500	1,980 – 2,280	Tema CCGT 4th stage 660MW	3,300	3,276-3,300	440	375-400	80-85%	2,934	20%	Tema 330MW expansion to 660MW commences. Ist 110MW comes on line. /1 st MSW plant comes on line. / Landfill expands to other major cities.
			1 st Municipal Solid Wastes (<i>Accra-Tema</i>)	150	149 - 150	20	4	15–20%			
			1 st Landfill (<i>Ta'di</i>)	17	16 - 17	1	1	95%			
			Bui increases to 300MW	1,000	900-1,000	300	300	23-25%			
2014	15,670 – 20,200	2,092 – 2,300	Tema CCGT 5th stage 660MW	4,100	4,090– 4,100	550	467-500	80-85%	3,069	23%	Kumasi gets MSW plant. Tema CCGT expands to 550MW. Valco operates 6 th potline
			1 st Municipal Solid Wastes MSW (<i>Kumasi</i>)	150	149 - 150	20	4	15–20%			
			Landfill (<i>Tamale</i>)	17	16 - 17	1	1	95%			
			Landfill (<i>Cape Coast</i>)	17	16 - 17	1	1	95%			
			Mini-small hydro/ solar	6	3 - 6	3	3	NA			

YEAR	Required Generation GWh	Peak Demand Range MW	POWER PLANT	PLANT FEATURES					Gross Installed Capacity MW	Reserve Margin	REMARKS
				Generation GWh		Installed Capacity MW	Availability				
				Max	Optimal		MW	Percent			
2015	16,400 – 20,900	2,200 – 2,500	Tema CCGT 6th stage	5,000	4,900–5,000	660	561-600	80-85%	3,339	24%	Tema 330MW CCGT expands to 660MW. Introduce distributed Gas turbines for embedded generation. Sekondi-Takoradi gets MSW plant.
			Distributed Gas turbines	900	820 - 900	120	100-110	80-85%			
			2 nd Municipal S. Wastes - (Accra-Tema)	300	295 - 300	40	8	15–20%			
			Municipal Solid Wastes - (Secondi-Ta'di)	150	149 - 150	20	4	15–20%			
2016	17,150 – 21,660	2,310 – 2,600	Municipal Solid Wastes - (Tamale)	150	149 - 150	20	4	15–20%	3,360	21%	Tamale gets MSW plant.
			Landfills (Winneba, Obuasi)	17	16 - 17	2 x 0.5	1	95%			
2017	17,950 – 22,600	2,430 – 2,700	2 nd Municipal Solid Wastes (Kumasi)	300	295 - 300	40	8	15–20%	3,388	19%	Expand landfill power to other regional centres.
			Landfills (K'dua Ho, Sunyani)	60	51 - 60	3 x 1	3	95%			
			Mini-small hydro/ solar	8	6 - 8	4	4	NA			
			BioCogen-Woodwastes	40	35-40	4	3 - 4	70-80%			
2018	18,780 – 23,620	2,560 – 2,860	3 rd CCGT (Ta'di) 1 st stage	819	819	110	90-100	80-85%	3,501	17%	A new 330MW CCGT plant is built near Takoradi. 1 st 110MW unit comes on line.
			2 nd landfill (Accra),	40	34-40	2	2	95%			
			2 nd landfill (Kumasi)	40	34-40	2	2				
			2 nd landfill (Ta'di)	40	34-40	2	2				
2019	19,670 – 24,680	2,700 – 3,000	3 rd CCGT (Ta'di) 2 nd stage	1,638	1,392-1,400	220	187-200	70-85%	3,636	16%	2 nd 110MW unit of the new Ta'di CCGT comes on line. Cape Coast gets MSW plant.
			Muni. S. Wastes (C. Coast)	150	149 - 150	20	4	15–20%			
			Mini-small hydro/ solar	10	8 - 10	5	5	NA			
2020	20,590 – 25,820	2,850 – 3,150	3 rd CCGT (Ta'di) 3 rd stage	2,500	2,457–2,500	330	280-300	70-85%	3,755	15%	3 rd 330MW Ta'di CCGT is complete. Expand landfill power to other large district centres.
			Landfills (Bolga, Nkawkaw Wa, Techiman, Ash-Manpong)	35	33 - 35	2 x 1	2	95%			
			Biocogen -woodwastes	120	95 - 120	15	9-12	70–80%			

APPENDIX 2C ELECTRICITY EXPANSION PLAN: OPTION 3; THERMAL + BUI HYDRO + NUCLEAR + 10% RENEWABLES

YEAR	Required Generation GWh	Peak Demand Range MW	POWER PLANT	PLANT FEATURES					Gross Installed Capacity MW	Reserve Margin	REMARKS
				Generation GWh		Installed Capacity MW	Availability				
				Max	Optimal		MW	Percent			
2005	6,400 – 7,500	1,200 – 1,400	Akos&Kpg hydro	6,100	5,200	1,198	1,168	82%	1,885	16%	Assumed Valco comes on line with 2 pots by end '05.
			Tapco (oil)	2,234	500	330	220 - 280	67-85%			
			Tico (oil)	1,638	200	220	200	85 %			
			Tema diesel	210	0	30	15	50 %			
			Osagyefo Barg	930	0	125	0	0 %			
			Import	1,000	1,000	100	100	100%			
2006	6,800 – 9,600	1,200 – 1,500	Akos&Kpg hydro	6,100	4,000	1,198	900	60-70%	1,855	23%	Tema diesel is retired./ Bui EIA shd complete.
			Tapco	2,234	1,000	330	220 - 280	70-85%			
			Tico	1,638	500	220	200	85 %			
			Tema diesel	210	0	30	15	0 %			
			Osagyefo Barg	930	0	125	0	0 %			
			Import	2,000	2,000	200	200	100%			
2007	9,100 – 12,100	1,400 – 1,600	Akos&Kpg hydro	6,100	4,200	1,198	1,000	70-80%	1,966	22%	WAGP is complete./ Commence Tico upgrade / Begin to construct new 330MW CCGT./ Install some renewables. / Bui finances must be secured. First wind come on line
			Tapco (oil → gas)	2,234	2,234	330	260–280	70–85%			
			Tico (oil → gas)	2,457	2,000	330	220–280	70–85%			
			Osagyefo Barg	930	400	125	100-106	70-80%			
			Mini-small hydro/solar	2	2	1	1	NA			
			Import	2,000	2,000	200	200	100 %			
2008	9,600 – 13,000	1,500 – 1,750	Akos&Kpg hydro	6,100	5,000	1,198	1,168	81%	2,130	20%	Effasu barge shd come on line. All old plants near peaking. Import not necessary First 110 MW Tema CCGT and first woodwaste bio-cogen plant come on line. Valco could operate 5 pots Bui construction should start
			Tapco + Tico gas	5,000	4,900	660	560-600	70-80%			
			Osagyefo Barg	930	930	125	106-110	80-85%			
			Wind farm	98-100	98-100	50	10-11	21-22%			
			Tema CCGT Ist stge	819	819	110	90-100	80-85%			
			Mini-small hydro/solar	2	2	1	1	NA			
			BioCogen-Woodwastes	30	27	4	3	70-80%			

YEAR	Required Generation GWh	Peak Demand Range MW	POWER PLANT	PLANT FEATURES					Gross Installed Capacity MW	Reserve Margin	REMARKS
				Generation GWh		Installed Capacity MW	Availability				
				Max	Optimal		MW	Percent			
2009	13,100 – 16,700	1,600 – 1,900	<i>Existing as of 2008</i> Tema CCGT 2nd stage Mini-small hydro/ solar	1,638	1,392-1,400	220	187-200	70-85%	2,130	17%	Total mini-small hydro/solar goes up. 2 nd Gas turbine of Tema CCGT comes on line. Initiate plans to tap landfill power.
				2	2	1	1	NA			
2010	13,800 – 17,500	1,700 – 2,050	Tema CCGT 3 rd stage	2,500	2,457– 2,500	330	280-300	70-85%	2,461	17%	Tema 330 MW CCGT is complete. Total wind farm expands to 160 MW. Nuclear feasibility study must commence.
			Wind farm	315	313-315	160	35-37	22-23%			
2011	14,400 – 18,250	1,780 – 2,100	Bui hydro at 200MW	1,000	900-1,000	200	200	25-27%	2,662	22%	Bui-200MW comes on line. / Initiate plans to develop municipal waste power. / 1 st landfill comes on line.
			Mini-small hydro/ solar	6	3 - 6	3	3	NA			
			1 st Landfill (<i>Accra</i>)	17	16 - 17	1	1	95%			
2012	14,600 – 18,500	1,880 – 2,200	Wind farm	395	392-395	200	44-46	22-23%	2,703	20%	Windfarm expands. /Tema CCGT gets 2 nd 110MW on line. / Construction of MSW plant on going.
			1 st Landfill (<i>Kumasi</i>)	17	16-17	1	1	95%			
2013	14,990 – 19,500	1,980 – 2,280	Tema CCGT 4th 660MW	3,300	3,276-3,300	440	375-400	80-85%	2,934	20%	Tema 330MW expansion to 660MW commences. Ist 110MW comes on line. /1 st MSW plant comes on line. / Landfill expands to other major cities.
			1 st Municipal Solid Wastes (<i>Accra–Tema</i>)	150	149 - 150	20	4	15–20%			
			1 st Landfill (<i>Ta'di</i>)	17	16 - 17	1	1	95%			
			Bui increases to 300MW	1,000	900-1,000	300	300	23-25%			
2014	15,670 – 20,200	2,092 – 2,300	Tema CCGT 5th 660MW	4,100	4,090– 4,100	550	467-500	80-85%	3,069	23%	Construction of Ghana's first nuclear plant commences. Kumasi gets MSW plant. Tema CCGT expands to 550MW. Valco adds 6 th potline
			1 st Municipal Solid Wastes MSW (<i>Kumasi</i>)	150	149 - 150	20	4	15–20%			
			Landfill (<i>Tamale</i>)	17	16 - 17	1	1	95%			
			Landfill (<i>Cape Coast</i>)	17	16 - 17	1	1	95%			
			Mini-small hydro/ solar	6	3 - 6	3	3	NA			

YEAR	Required Generation GWh	Peak Demand Range MW	POWER PLANT	PLANT FEATURES					Gross Installed Capacity MW	Reserve Margin	REMARKS
				Generation GWh		Installed Capacity MW	Availability				
				Max	Optimal		MW	Percent			
2015	16,400 – 20,900	2,200 – 2,500	Tema CCGT 330? 660MW	5,000	4,900–4,900	660	561-600	80-85%	3,339	24%	Tema 330MW CCGT expands to 660MW. Introduce distributed Gas turbines for embedded generation. Sekondi-Takoradi gets MSW plant.
			Distributed Gas turbines	900	820 – 900	120	100-110	80-85%			
			2 nd Municipal S. Wastes - (Accra-Tema)	300	295 – 300	40	8	15–20%			
			Municipal Solid Wastes - (Sekondi-Ta'di)	150	149 – 150	20	4	15–20%			
2016	17,150 – 21,660	2,310 – 2,600	Municipal Solid Wastes - (Tamale)	150	149 – 150	20	4	15–20%	3,360	21%	Tamale gets MSW plant. Construction of Ghana's first nuclear plant on-going
			Landfills (Winneba, Obuasi)	17	16 – 17	2 x 0.5	1	95%			
2017	17,950 – 22,600	2,430 – 2,700	2 nd Municipal Solid Wastes (Kumasi)	300	295 – 300	40	8	15–20%	3,388	19%	Expand landfill power to other regional centres.
			Landfills (K'dua Ho, Sunyani)	60	51 – 60	3 x 1	3	95%			
			Mini-small hydro/ solar	8	6 – 8	4	4	NA			
			BioCogen-Woodwastes	40	35-40	4	3 - 4	70-80%			
2018	18,780 – 23,620	2,560 – 2,860	Nuclear – light water reactor	4,000	3,900-4,000	335	285-300	85-90%	3,726	22%	First nuclear power comes on line. Assume Westinghouse (USA) IRIS – 335 (335MW)_
			2 nd landfill (Accra),	40	34-40	2	2	95%			
			2 nd landfill (Kumasi)	40	34-40	2	2				
			2 nd landfill (Ta'di)	40	34-40	2	2				
2019	19,670 – 24,680	2,700 – 3,000	Municipal Solid Wastes - (Cape Coast)	150	149 – 150	20	4	15–20%	3,751	19%	Cape Coast gets MSW plant
			Mini-small hydro/ solar	10	8 – 10	5	5	NA			
2020	20,590 –	2,850 –	Landfills (Bolga, Nkawkaw Wa, Techiman, Ash-Manpong)	35	33 - 35	2 x 1	2	95%	3,760	15%	Expand landfill

APPENDIX 3 A CAPACITY PLAN : Option 1: Thermal with 10% Renewables by installed capacity

	2005	2006	2007	2008	2009	2010	2011	2012
POWER PLANTS								
a. Akosombo Hydro	1,020	1,020	1,020	1,020	1,020	1,020	1,020	1,020
b. Kpong Hydro	160	160	160	160	160	160	160	160
c. Tapco_oil	330	330	0	0	0	0	0	0
c. Tapco_gas		0	330	330	330	330	330	330
d. Tico_oil	220	220	0	0	0	0	0	0
d. Tico_gas		0	220	330	330	330	330	330
e. Tema diesel	30	0	0	0	0	0	0	0
f. Wind turbines				50	100	160	160	200
g. Effasu Power gas Barge	125	125	125	125	125	125	125	125
h. Tema 330 MW gas thermal				110	220	330	330	330
h. 2nd Tema 330MW gas thermal						0	110	220
I. Embedded Generation - gas turbine								
j. 2nd 660MW CCGT at Takoradi								
k. Biomass, solar, minihydro, etc			1	5	6	6	7	7
I.Municipal solid wastes								
m.Landfill power							1	1
Total	1,885	1,855	1,856	2,130	2,291	2,461	2,572	2,723
VRA expected Import	100	200	200	0	0	0	0	0

Legend

Green: No installation

Yellow: Standby - back up / reserve installations. Or yet to be connected to the grid.

	2013	2014	2015	2016	2017	2018	2019	2020
POWER PLANTS	Installed Capacity in Megawatts (MW)							
a. Akosombo Hydro	1,020	1,020	1,020	1,020	1,020	1,020	1,020	1,020
b. Kpong Hydro	160	160	160	160	160	160	160	160
c. Tapco_oil	0	0	0	0	0	0	0	0
c. Tapco_gas	330	330	330	330	330	330	330	330
d. Tico_oil	0	0	0	0	0	0	0	0
d. Tico_gas	330	330	330	330	330	330	330	330
e. Tema diesel	0	0	0	0	0	0	0	0
f. Wind turbines	200	200	200	200	200	200	200	200
g. Effasu Power gas Barge	125	125	125	125	125	125	125	125
h. Tema 330 MW gas thermal	330	330	330	330	330	330	330	330
h. 2nd Tema 330MW gas thermal	330	330	330	330	330	330	330	330
I. Embedded Generation - gas turbine						120	120	120
j. 2nd 660MW CCGT at Takoradi	0	110	330	440	660	660	660	660
k. Biomass, solar, minihydro, etc	7	10	10	10	15	15	20	25
l. Municipal solid wastes	20	40	80	100	120	120	140	140
m. Landfill power	2	4	4	5	8	11	11	15
Total	2,854	2,989	3,249	3,380	3,628	3,751	3,776	3,785
<i>VRA Import</i>	<i>0</i>	<i>0</i>	<i>0</i>	<i>0</i>	<i>0</i>	<i>0</i>	<i>0</i>	<i>0</i>

Legend

Green: No installation

APPENDIX 3 B CAPACITY PLAN : Option 2: Thermal + Bui Hydro + 10% Renewables by installed capacity

	2005	2006	2007	2008	2009	2010	2011	2012
POWER PLANTS								
a. Akosombo Hydro	1,020	1,020	1,020	1,020	1,020	1,020	1,020	1,020
b. Kpong Hydro	160	160	160	160	160	160	160	160
c. Tapco_oil	330	330	0	0	0	0	0	0
c. Tapco_gas		0	330	330	330	330	330	330
d. Tico_oil	220	220	0	0	0	0	0	0
d. Tico_gas		0	220	330	330	330	330	330
e. Tema diesel	30	0	0	0	0	0	0	0
f. Wind turbines				50	100	160	160	200
g. Effasu Power gas Barge	125	125	125	125	125	125	125	125
h. Tema 330 MW gas thermal				110	220	330	330	330
h. 2nd Tema 330MW gas thermal							0	0
i. Embedded Generation - gas turbine								
j. Bui Hydro at 200MW							200	200
k. 2nd 660MW CCGT at Takoradi								
l. Biomass, solar, minihydro, etc			1	5	6	6	7	7
m. Municipal solid wastes								
n. Landfill power								1
Total	1,885	1,855	1,856	2,130	2,291	2,461	2,662	2,703
<i>VRA expected Import</i>	<i>100</i>	<i>200</i>	<i>200</i>	<i>0</i>	<i>0</i>	<i>0</i>	<i>0</i>	<i>0</i>

Legend

Green: No installation

Yellow: Standby - back up / reserve installations. Or yet to be connected to the grid.

	2013	2014	2015	2016	2017	2018	2019	2020
POWER PLANTS	Installed Capacity in Megawatts (MW)							
a. Akosombo Hydro	1,020	1,020	1,020	1,020	1,020	1,020	1,020	1,020
b. Kpong Hydro	160	160	160	160	160	160	160	160
c. Tapco_oil	0	0	0	0	0	0	0	0
c. Tapco_gas	330	330	330	330	330	330	330	330
d. Tico_oil	0	0	0	0	0	0	0	0
d. Tico_gas	330	330	330	330	330	330	330	330
e. Tema diesel	0	0	0	0	0	0	0	0
f. Wind turbines	200	200	200	200	200	200	200	200
g. Effasu Power gas Barge	125	125	125	125	125	125	125	125
h. Tema 330 MW gas thermal	330	330	330	330	330	330	330	330
h. 2nd Tema 330MW gas thermal	110	220	330	330	330	330	330	330
i. Embedded Generation - gas turbine			120	120	120	120	120	120
j. Bui Hydro at 300-400MW	300	300	300	300	300	300	300	300
k. 2nd 660MW CCGT at Takoradi						110	220	330
l. Biomass, solar, minihydro, etc	7	10	10	10	15	15	20	25
m. Municipal solid wastes	20	40	80	100	120	120	140	140
n. Landfill power	2	4	4	5	8	11	11	15
Total	2,934	3,069	3,339	3,360	3,388	3,501	3,636	3,755
<i>VRA Import</i>	<i>0</i>	<i>0</i>	<i>0</i>	<i>0</i>	<i>0</i>	<i>0</i>	<i>0</i>	<i>0</i>

Legend

Green: No installation

APPENDIX 3 C CAPACITY PLAN : Option 3: Thermal + Bui Hydro + Nuclear + 10% Renewables by installed capacity

	2005	2006	2007	2008	2009	2010	2011	2012
POWER PLANTS								
a. Akosombo Hydro	1,020	1,020	1,020	1,020	1,020	1,020	1,020	1,020
b. Kpong Hydro	160	160	160	160	160	160	160	160
c. Tapco_oil CCGT	330	330	0	0	0	0	0	0
c. Tapco_gas CCGT		0	330	330	330	330	330	330
d. Tico_oil SCGT	220	220	0	0	0	0	0	0
d. Tico_gas SCGT / CCGT		0	220	330	330	330	330	330
e. Tema diesel	30	0	0	0	0	0	0	0
f. Wind turbines				50	100	160	160	200
g. Effasu Power gas Barge	125	125	125	125	125	125	125	125
h. Tema 330 MW gas thermal				110	220	330	330	330
h. 2nd Tema 330MW gas thermal								
i. Embedded Generation - gas turbine								
j. Bui Hydro at 200MW							200	200
k. Nuclear light water reactor - IRIS 335								
l. Biomass, solar, minihydro, etc			1	5	6	6	7	7
m. Municipal solid wastes								
n. Landfill power								1
Total	1,885	1,855	1,856	2,130	2,291	2,461	2,662	2,703
<i>VRA expected Import</i>	<i>100</i>	<i>200</i>	<i>200</i>	<i>0</i>	<i>0</i>	<i>0</i>	<i>0</i>	<i>0</i>

Legend

Green: No installation

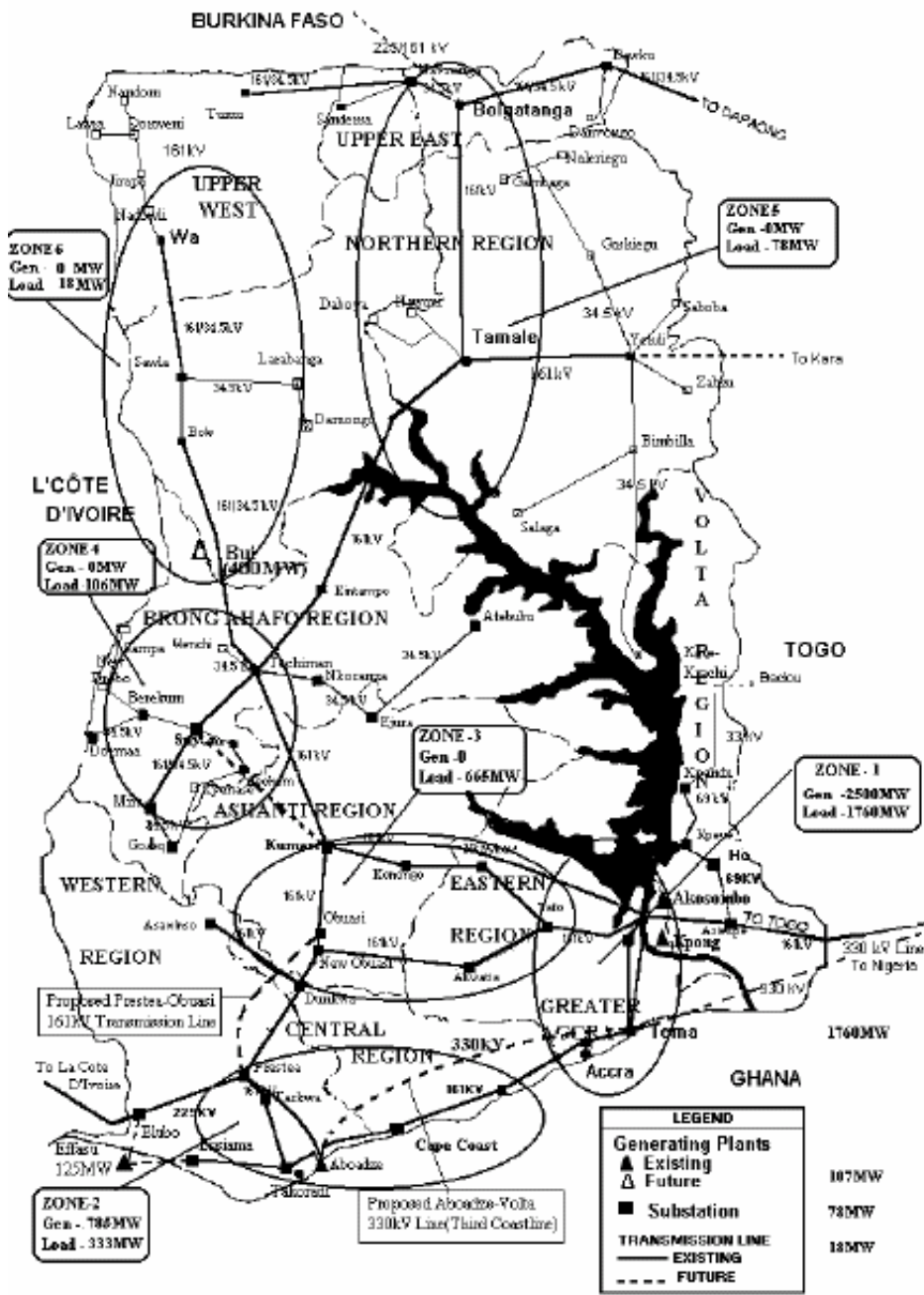
Yellow: Standby - back up / reserve installations. Or yet to be connected to the grid.

	2013	2014	2015	2016	2017	2018	2019	2020
POWER PLANTS	Installed Capacity in Megawatts (MW)							
a. Akosombo Hydro	1,020	1,020	1,020	1,020	1,020	1,020	1,020	1,020
b. Kpong Hydro	160	160	160	160	160	160	160	160
c. Tapco_oil	0	0	0	0	0	0	0	0
c. Tapco_gas	330	330	330	330	330	330	330	330
d. Tico_oil	0	0	0	0	0	0	0	0
d. Tico_gas	330	330	330	330	330	330	330	330
e. Tema diesel	0	0	0	0	0	0	0	0
f. Wind turbines	200	200	200	200	200	200	200	200
g. Effasu Power gas Barge	125	125	125	125	125	125	125	125
h. Tema 330 MW gas thermal	330	330	330	330	330	330	330	330
h. 2nd Tema 330MW gas thermal	110	220	330	330	330	330	330	330
i. Embedded Generation - gas turbine			120	120	120	120	120	120
j. Bui Hydro at 300-400MW	300	300	300	300	300	300	300	300
k. Nuclear light water reactor - IRIS 335						335	335	335
l. Biomass, solar, minihydro, etc	7	10	10	10	15	15	20	25
m. Municipal solid wastes	20	40	80	100	120	120	140	140
n. Landfill power	2	4	4	5	8	11	11	15
Total	2,934	3,069	3,339	3,360	3,388	3,726	3,751	3,760
VRA Import	0	0	0	0	0	0	0	0

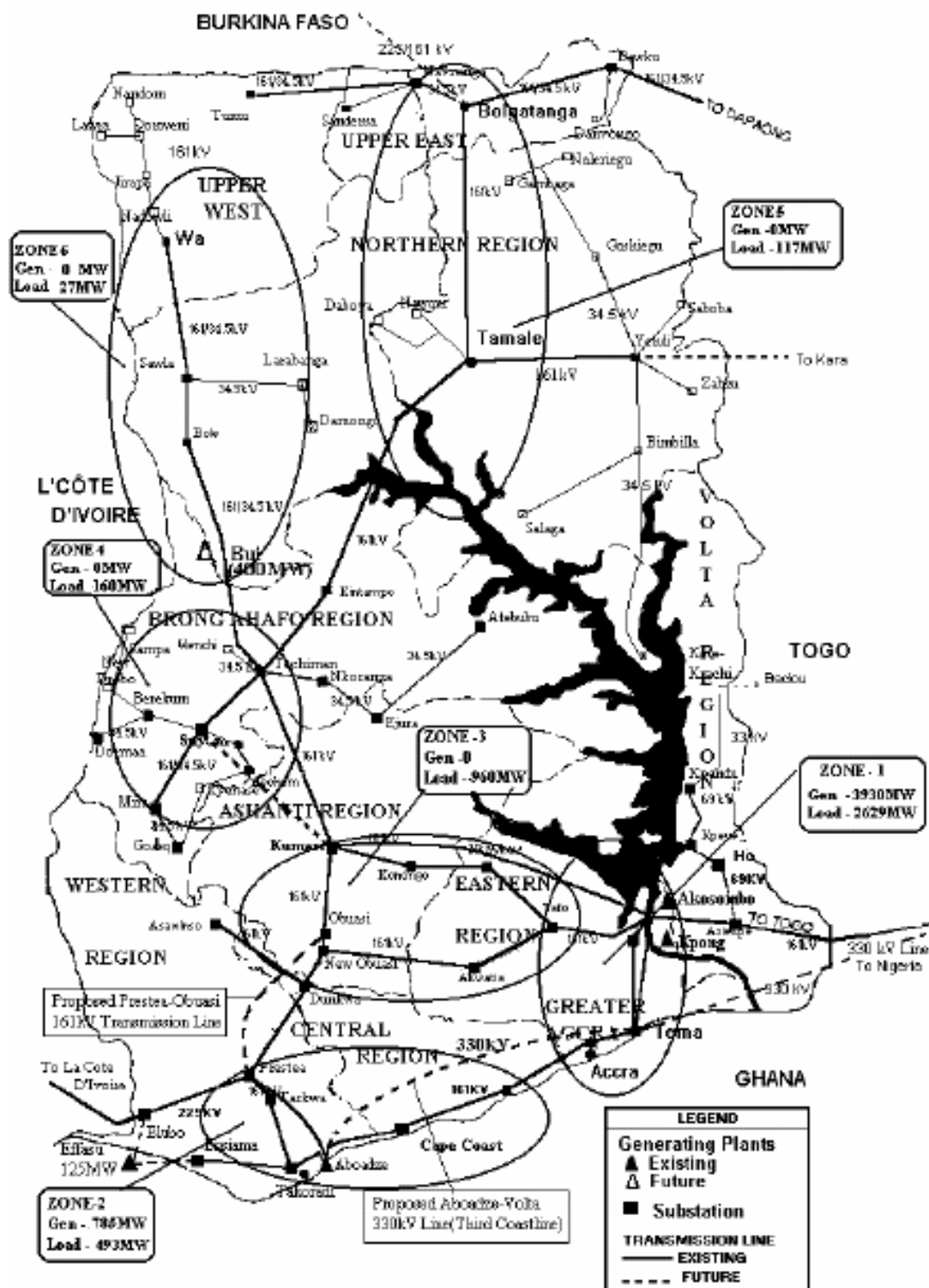
Legend

Green: No installation

APPENDIX 4 A: Transmission map of Ghana showing 2015 load and generation distribution in accordance with Moderately High Economic Growth Scenario.



APPENDIX 4 B: Transmission map of Ghana showing 2020 load and generation distribution in accordance with Moderately High Economic Growth Scenario.



LIST OF PARTICIPANTS

LIST OF INSTITUTIONS REPRESENTED AT THE STAKEHOLDER MEETINGS ³⁷			
	SNEP AREA PARTICIPATED		
	Electricity	Petroleum	Renewables
Ministries and Governmental Committees			
1. Ministry of Energy	•	•	•
2. Ministry of Finance & Economic Planning	0	•	•
3. Ministry of Environment and Science	•	•	•
4. Parliamentary Select Cmmttee. for Mines & Energy	•	0	0
5. Power Sector Reform Committee	•	0	0
6. Bui Hydro Development Committee	•	0	Not invited
Public Sector Bodies, Enterprises & Commissions			
1. Board of the Energy Commission	•	•	•
2. Public Utility Regulatory Commission (PURC)	•	0	0
3. National Petroleum Authority	Not invited	•	•
4. Environmental Protection Agency	•	•	•
5. Bank of Ghana	0	•	•
6. National Development Planning Commission	•	•	0
7. Ghana Atomic Energy Commission	•	Not invited	Not invited
8. Ghana National Petroleum Corporation	0	•	0
9. Bulk Oil Storage & Transport Company	•	•	0
10. Ghana Statistical Services	0	•	0
11. Electricity Company of Ghana	•	0	0
12. Volta River Authority	•	0	0
13. Tema Oil Refinery	•	•	0
Private sector (non-oil) energy companies			
1. NEK Ghana Ltd	0	Not invited	•
2. AESSEL Development Group Ltd	Not invited	Not invited	•
3. GHAESCO	Not invited	Not invited	•
4. Wilkins Engineering Ltd.	0	Not invited	•
5. Deng Solar Ltd.	0	Not invited	•
6. 'Pluck the Day' Solar Company	Not invited	Not invited	•
7. A1 Quality Engineering	0	•	Not invited
8. AngloGold Ashanti Ltd	•	0	Not invited
9. Volta Aluminium Company	•	0	Not invited
Oil Marketing Companies (OMCs)			
1. OMC Coordinator	0	•	0
2. Ghana Oil Company (GOIL)	Not invited	•	Not invited
3. Vanco Ghana Ltd.	Not invited	•	Not invited
4. Tema Lube Oil	Not invited	•	Not invited
5. Nasona Oil Company, Ltd	Not invited	•	Not invited
	•		
	0		
	<i>Attended</i>		
	<i>Absent</i>		

³⁷ Name of individuals are available at the Energy Commission.

LIST OF INSTITUTIONS REPRESENTED		Electricity	Petroleum	Renewables
NGOs/ Consultancy/Unions/Advocacy groups				
1.	Ghana Private Road Transport Union (GPRTU)	Not invited	•	Not invited
2.	Ghana Chamber of Mines	•	•	Not invited
3.	Association of Ghana Industries	•	0	0
4.	Energy Foundation	•	•	•
5.	KITE	Not invited	•	•
6.	Energy Research Group - Ghana	•	•	•
7.	Ghana Solar Energy Society	•	0	•
8.	Sustainable Environment Group	Not invited	0	•
9.	Jeavco	Not invited	0	•
10.	AESSEL Development Group Ltd.	Not invited	•	•
11.	Ghana Institution of Engineers	•	0	0
Educational & Research Institutions				
1.	Resource Center for Energy Economics & Regulation /ISSER	0	•	•
2.	Institute of Industrial Research of CSIR	•	0	•
3.	Dept of Physics, University of Ghana	0	•	•
4.	Dept of Physics, University of Cape Coast	•	0	0
5.	College of Engineering, KNUST	•	0	0
The Press				
Television				
1.	GTV - Ghana Broadcasting Corporation	•	•	Not invited
2.	TV3	•	•	Not invited
Print Media				
3.	Daily Graphic	•	•	•
4.	Ghanaian Times	•	•	•
5.	Business & Financial Times	•	•	•
6.	Daily Guide	•	•	•
Radio and FM stations				
7.	Ghana Broadcasting Corporation Radio	•	•	•
8.	JOY FM	•	•	•
9.	CITI FM	•	•	•
10.	TOP Radio	•	•	•
	•	<i>Attended</i>		
	0	<i>Absent</i>		
Note	Names of experts attending in their individual capacities are not included here but available at the Energy Commission			

BIBLIOGRAPHY

Energy Sector Technology Catalogue (*Energy Commission publication, 2004*).

A catalogue of both qualitative and quantitative descriptions of present and projected future energy technologies and appliances for Ghana's economy. The Catalogue is one of the key outputs of the SNEP and is to provide a reliable and acceptable technology database for planning exercises as well as a credible reference for the energy market in Ghana.

Least Cost Assessment of Power Generation Technologies and Demand-Side Appliances An Integrated Resource Planning approach (*Energy Commission publication, 2004*)

Assessment of power generation technologies and demand-side appliances using the Integrated Resource Planning (IRP) methodology. IRP is a planning tool that looks at the entire energy supply-demand chain on one scale. It allows both the supply-side technologies and Demand-Side Management programmes to be combined and ranked on one scale in the order of least cost option. Balancing the demand side with the supply side options provides an overview of the cheapest way to satisfy the need for energy services.

Indigenous Resource Catalogue (*Contract carried out by the Dept. of Mechanical Engineering, Kwame Nkrumah University of Science and Technology for the SNEP, 2003*)

This resource catalogue contains qualitative descriptions and quantitative estimates of the known energy resources of Ghana that could be exploited up to the year 2020. It is a database on reserves and production as well as technical, environmental and socio-economic features of each resource that could serve as a reference for policy planning.

Energy Balance and Environmental Impact Assessment Report (*Contract carried out by the Dept. of Economics, University of Ghana for the SNEP, 2002*)

An analysis of baseline data on primary energy production, import, conservation and usage. The results were used to prepare the energy balance of the base year and the disaggregation of the economic sectors for inputting into LEAP, the computer-modelling tool used for the projections. Also included in the report is an EIA of the Akosombo hydroelectric project.

Estimation of Woodfuel Demand in the Household Sector of Ghana (*Contract executed by the BRRI of CSIR, for the SNEP, 2003*)

A compilation and analysis of woodfuel consumption data for the household sector. The report provided the household sector input for the LEAP. The Building and Road Research Institute (BRRI) carried out the exercise for SNEP.

Economic Analysis of the Energy Sector (*Contract undertaken by Prof. Bartholomew Armah, a visiting researcher of the Institute of Economic Affairs, Ghana, 2003*)

This report provides the economic context for the formulation of the SNEP. The first part of the report describes the economic structure of Ghana and is followed by an analysis of the contribution of energy to the Ghanaian economy. The report also discusses the implications of the nation's development policies, namely the Ghana Poverty Reduction Strategy (GPRS) and the Coordinated Programme of Economic and Social Development (CPESD) on the country's long-term energy demand.

Policy Framework for Ghana's Energy Sector (*Ministry of Energy, 2001*)

A policy framework document outlining the vision of the Ministry of Energy and its main objectives for the energy sector.

ENERGY & GHANA'S SOCIO-ECONOMIC DEVELOPMENT: Issues, Strategies and Programmes in the Energy Sector under the Economic Recovery Programme (National Energy Board/Ministry of Fuel and Power, 1989, revised July, 1990) A policy document outlining the vision of the National Energy Board and the Ministry of Fuel and Power.

An Energy Roadmap for Ghana: from Crisis to the fuel for 'Economic Freedom' (*USAID, August, 1998*)

A report by a United States Government Interagency Team in response to a request from His Excellency the Vice President John Atta Mills, On behalf of the Government of Ghana. The team was in the country in 1998 during the power crisis that year.

2000 Population & Housing Census, March 2002

Special reports on Ghana's 2000 population census by the Ghana Statistical Services.

VRA Generation and Transmission System Master Plan

(Final Report -three volumes, July 2001)

A document prepared by the Acres International for the Volta River Authority (VRA), the power generation utility of Ghana. It provides power generation projections and capacity expansion largely based on thermal options from 2000 – 2020. Transmission expansion plans for VRA are also discussed. VRA owns and operate the national transmission network in addition, even though the latter is to be hived off into an independent transmission utility company under Ghana's Power Sector Reform.

The State of the Ghanaian Economy, 2000, 2001, 2002, 2003, 2004, 2005

A yearly publication by the Institute of Statistical, Social and Economic Research (ISSER) of the University of Ghana. Each year's edition is a commentary and or analysis of the performance of the economy during the previous year.

Sustainable Energy Scenarios for Ghana's Long -Term Development Plan (Vision 2020)

(Essandoh-Yeddu, Joseph and Johansson, Daniel, Chalmers University of Technology / Gothenburg University, Sweden, Department of Physical Resource Theory, 2001)

A Master of Science thesis that looks at sustainable energy pathways for Ghana's long term development.

The Economist Pocket World in Figures (Edition 2001, 2002, 2003, 2005)

An annual pocket editions published by The Profile Books Ltd of UK in association with The Economist. The annual booklet provides rankings on more than 200 topics and detailed statistical profiles of the world's major economies.

Tools and Methods for Integrated Resource Planning

(UNEP Collaborating Centre on Energy and Environment, RISØ National Laboratory³⁸, Denmark, 1997)

A teaching material on energy efficiency, end-use analysis, demand-side management and integrated resource planning (IRP).

LEAP

LEAP (Long range Energy Alternative Planning) is an integrated software developed by the Stockholm Environment Institute for energy and environment planning. It is an accounting modelling tool that can be used for energy projections as well as creating energy balances of production and usage for a given economy or region. It has a Microsoft DOS version (LEAP95) and a WINDOWS version (LEAP2000). For more information visit <http://forums.seib.org/leap>.

RETscreen ® International (Natural Resources Canada)

RETSCREEN is a trademark for RETScreen International and is a renewable energy awareness, decision-support and capacity building tool developed by the CANMET Energy Diversification Research Laboratory (CEDRL) of Natural Resource – Canada with major support from UNEP and the World Bank. The core of the tool consists of a standardised and integrated renewable energy project analysis software that can be used world-wide to evaluate the energy production, life-cycle costs and greenhouse gas emission reductions for various types of renewable energy technologies. Renewable energy technology (RET) projects are not routinely considered by planners and decision-makers at the critically important

³⁸ Now called UNEP Risoe

initial planning stage. The RETScreen® Renewable Energy Project Analysis Software has been developed to help address this barrier. For more information visit www.retscreen.net/ang.

MESSAGE (IAEA, Austria)

MESSAGE (Model for Energy Supply Strategy Alternatives and their General Environmental Impact) is a model designed for the optimisation of energy system. The model was originally developed at International Institute for Applied Systems Analysis (IIASA) but the latest version of the model has been acquired by the International Atomic Energy Agency (IAEA). For more information contact the IAEA, P.O. Box 100, Wagramer Strasse 5, A-1400 Vienna, Austria. Email Official.Mail@iaea.org.

Links to Energy Sector Regulatory Bodies in Ghana

Public Utilities Services Commission, www.purc.com.gh

Energy Commission, www.energycom.gov.gh.

National Petroleum Authority (*website not available yet*).....