Guide to Electric Power in Ghana

First Edition

RESOURCE CENTER FOR ENERGY ECONOMICS AND REGULATION
INSTITUTE OF STATISTICAL, SOCIAL AND ECONOMIC RESEARCH
UNIVERSITY OF GHANA, LEGON

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Preface

This 'Guide to Electric Power in Ghana' is published by the Resource Center for Energy Economics and Regulation (RCEER) which is based at the Institute of Statistical, Social and Economic Research (ISSER), University of Ghana. It is published for two key reasons: first, the guide will provide comprehensive facts on Ghana's electric power sector. In doing so it provides the basics, history, regulations and policies affecting electric power generation in Ghana. The document evaluates the future prospects of the industry, discussing at length major issues and challenges facing electric power generation in Ghana, particularly financing. It also assesses the role of consumers and their critical contribution towards the maintenance of the sector.

Secondly, it was envisaged that the process of putting together this guide will promote greater collaboration between RCEER and all stakeholders. As a newly established center, RCEER seeks to collect, store, process and disseminate data and knowledge on the energy sector; conduct research to support energy sector development and governance; develop teaching material for both academic and professional audience; and educate the public on energy related issues.

This 'Guide to Electric Power in Ghana' has six chapters. Chapter one discusses consumption, expenditure and revenue patterns of electricity and the entire electric power system in Ghana. Chapter two emphasises the basics of electricity, while Chapter three generally details the phases of power generation in Ghana and states the case for developing additional power generation facilities. Chapters four and five trace the policies and regulatory developments that influence electric power generation in Ghana as well as discuss reforms currently being undertaken within the industry to address major challenges. The final chapter summarises the major issues and looks at new technologies for the future development of electric power generation in Ghana and neighbouring countries.

Following a lot of consultation, considerable information and data have been assembled for the guide. The guide has been prepared to meet the needs of policy makers, practitioners, academics, media practitioners and the general public. Additionally, the guide serves as easy reference material for many who ordinarily would find it difficult to gain access to such information.

A number of individuals and organizations have contributed immensely to make this publication possible. We express our appreciation to USAID which funded the project. We also thank Dr. Michelle Foss and Dr. Gurcan Gulen, both of the Center for Energy Economics, University of Texas, Austin, USA for their comments and assistance. We also thank Mrs Korantema Adi-Dako for her editing work and Mrs Helen Sunnu for her typesetting work.

Prof. Ernest Aryeetey
Director, ISSER and Chairman, RCEER Steering Committee

1. Facts on Ghana's Electric Power

1.1 Who uses electricity in Ghana

With a customer base of approximately 1.4 million, it has been estimated that 45-47 percent of Ghanaians, including 15-17 percent of the rural population, have access to grid electricity with a per capita electricity consumption of 358 kWh. All the regional capitals have been connected to the grid. Electricity usage in the rural areas is estimated to be higher in the coastal (27 percent) and forest (19 percent) ecological zones, than in the savannah (4.3 percent) areas of the country. In 2004, Ghanaians consumed 5,158 gigawatthours (GWh) of electricity. It is estimated that about half of this amount is consumed by domestic (or residential) consumers for household uses such as lighting, ironing, refrigeration, air conditioning, television, radio and the like. Commercial and industrial users account for the rest. The majority of the customers are in service territories of the Electricity Company of Ghana (ECG) and the Northern Electrification Department (NED) and they are regulated (Table 1.1). However, there are also deregulated consumers such as mines, and aluminum companies, which account for one third of total consumption. One industrial entity, VALCO, can account for most of this amount when it is operating normally.

Residential consumers comprise middle and high-income urban consumers. This consumer-class typically uses a number of high energy consuming household appliances and items such as air conditioners, fridges, water heaters, electric cookers in addition to a substantial amount of lighting equipment and bulbs for the houses. The majority of the rest of the residential consumers use electric power for lighting.

Table 1.1: **ECG and NED Customer population and energy consumption, 2004**

Customer	Number of Customers	Energy Consumption (GWh)
ECG	1,200,000*	4,818
NED	188,344	340
TOTAL	1,388,344	5,158
*Includes active customers, non-active customers and bulk customers.		

The major characteristic residential arrangement is the "compound house" multi-house phenomenon – essentially a number of households living in a compound and sharing basic amenities including one electricity metering system.

Apart from residential consumers who are considered to be "small" users, other consumers whose consumption is not considered large by virtue of their activities are the non-residential consumers as well as small industrial concerns which are known as special load tariff customers (SLT's). Non-residential consumers comprise offices, banks and other small businesses. Since the 1980's, the government has pursued a policy of extending electricity to the rural communities. The objective of this is to encourage the use of electricity for productive use for cottage industries and eventually the growth of these industries into bigger consumers which will become a source of employment and economic growth for the communities they are situated in.

1.2 Electricity and population growth

In Ghana, electricity consumption has been growing at 10 to 15 percent per annum for the last two decades. It is projected that the average demand growth over the next decade will be about six percent per year. As a result, consumption of electricity will reach 9,300 GWh by 2010. The projected electricity growth assumption has profound economic, financial, social and environmental implications for the country. The aspirations of developing countries for higher living standards can only be satisfied through sustained development of their electric power markets as part of their basic infrastructure. Electricity demand will grow much faster than overall economic growth (4-5 percent per year) or than population growth (which is less than two percent a year) because continuing urbanization will allow newly urbanized segments of the population to expand their electricity consumption manifold.

Urbanization in Ghana is expected to increase from around 40 percent in 2000 to about 55 percent in 2012 and eventually to 60 percent by 2020. A little more than a third of the urban population lives in Greater Accra and is expected to reach around 40 percent by 2020. A considerable percentage of household expenditure goes into energy. Energy sources in urban areas are more diversified than in rural areas, since access to a variety of commercial fuels and appliances are higher in the urban areas than in the rural areas. Often the cost of alternatives is higher in the rural areas than it is in the urban where incomes are lower.

Clearly, with the Ghanaian economy growing, increasing urban populations will consume more electricity. The Energy Commission (EC) estimates that residential demand may reach anywhere between 7,000 and 13,000 GWh by 2020 depending on the rate of economic growth and urbanization. The residential sector is not the only segment expected to grow; commercial and industrial consumption will grow as well to 3,000 to 10,000 GWh by 2020 according to the EC. If VALCO is fully operational, an additional 2,000 GWh should be expected. In order to meet this increasing demand, new power generation as well as transmission and distribution facilities will have to be built.

Ghanaian governments have been pursuing a national electrification policy. Still, more than half of the population remains without access to grid-based electricity. It is very expensive to build long-distance transmission lines to serve small communities, especially when these communities are relatively poor and cannot afford to pay rates high enough to cover the cost of these services. Moreover, there is weak or no evidence of increased economic activity in communities that benefited from the national electrification scheme. Smaller scale and locally installed generation systems using solar panels, batteries and the like can be more affordable.

Nevertheless, rural electrification will continue to be a challenge for Ghana.

1.3 Organisations

There are several key entities in the Ghanaian electric power industry. They will be discussed and referred to in later chapters in more detail. In this section, we provide a short introduction to each of these entities.

The Ministry of Energy: Ultimate body responsible for development of electricity policy for Ghana.

The Volta River Authority (VRA): State-owned entity that is responsible for generation and transmission of electricity in Ghana. VRA operates the largest generation facility in Ghana, the Akosombo hydroelectric plant.

The Electricity Company of Ghana (ECG): State-owned entity that is responsible for distribution of electricity to consumers in southern Ghana, namely Ashanti, Central, Greater Accra, Eastern and Volta Regions of Ghana. ECG is the entity that consumers interact with when they receive and pay their bills or when they have service questions (billing, metering, line connection etc.).

The Northern Electrification Department (NED): A subsidiary of VRA and responsible for power distribution in northern Ghana namely, Brong-Ahafo, Northern, Upper East and Upper West Regions.

The Public Utilities Regulatory Commission (PURC): Independent agency that calculates and sets electricity tariffs, educates customers about electricity services as well as energy efficiency and conservation and ensures the effectiveness of investments.

The Energy Commission: Independent agency that licenses private and public entities that will operate in the electricity sector. EC also collects and analyses energy data and contributes to the development of energy policy for Ghana.

The Private Generators: Domestic or international entities that build power generation facilities in Ghana. They sell their electricity to VRA or ECG.

The Energy Foundation: a Ministry of Energy – Private Enterprises Foundation (PEF) initiative, which was set up in 1997 to promote energy efficiency and conservation programmes. Initial activities focused primarily on provision of technical support to industries, introduction of compact fluorescent lamps (CFLs) countrywide and public education.

1.4 Electric power system

The physical equipment of an electric power system includes generation which makes electricity, a transmission system that moves electricity from the power plant closer to the consumer and local distribution systems which move electric power from the transmission system to most consumers. See Appendix 1 for a map of the Ghanaian electric power system.

Generation

Electric power plants use coal, lignite, natural gas, fuel oil, and uranium to make electricity. In addition, renewable fuels include moving water, solar, wind, geothermal sources and biomass.

The type of fuel, its cost, and generating plant efficiency can determine the way a generator is used. For example, a natural gas generator has a high marginal cost but can be brought on-line quickly. Coal, lignite, and nuclear units have lower marginal costs but cannot be brought on-line quickly. They are used primarily to provide the base load of electricity.

Costs for fuel, construction and operations and maintenance vary greatly among types of power plant. For example, renewable generation plants such as solar or wind, have virtually no fuel costs but are expensive to manufacture and install. Nuclear and coal fueled plants have low fuel costs but can be more expensive to construct and maintain. Coal and lignite units also incur additional costs for meeting air quality standards. Natural gas plants have higher fuel costs than coal or nuclear, but have lower initial construction costs.

Ghanaian generators have an installed capacity of more than 1,650 megawatts. About 1,100 MW is hydroelectric and 550 MW is thermal capacity burning light crude oil.

Capacity vs. Actual Generation – In 2003, total demand was 8,500 gigawatthours (GWh). Electricity from hydroelectricity facilities provided 6,500 GWh. The rest of our electricity is generated from thermal power plants burning light crude oil, which is imported. Electricity is usually dispatched first from hydroelectricity stations because it is cheaper per kWh to generate power at these facilities as long as water is available.

Storing Electricity – Unlike water and natural gas, electricity cannot be easily stored. This is a fundamental challenge of the electric power system. There is no container or large "battery" that can store electricity for indefinite periods (see following). Energy is stored in the fuel itself before it is converted to electricity. Once converted, it has to go out on the power lines.

Electricity Storage Technologies - Compressed air, pumped hydroelectric, advanced batteries and superconducting magnetic energy storage are the four main technologies being studied for possible electricity storage. Compressed air and pumped hydro are used in some locations around the world.

Transmission System

Power plants are located at one point and electricity must be moved from that point to the consumer. The transmission system accomplishes much of this task with an interconnected system of lines, distribution centers, and control systems.

As of December 2003, the existing transmission network system comprised 36 substations and approximately 4000 circuit km of 161 kV and 69 kV lines. This includes 129 km of double circuit 161kV interconnection to Togo and Benin. There is also a single circuit, 220 km of 225 kV intertie with La Côte d'Ivoire's network.

Local Distribution Systems

Most homes and businesses use 120- and 240-volt electric power while industries often use much higher voltages. Large commercial and industrial customers may bypass the local distribution system, receiving electricity at high voltage directly from the transmission system.

***Table 1.2:* Ghana electricity system capacity supply and demand balance**

Generation Source	Effective Capacity (MW)	Percent of Total Available Effective Capacity	Installed Capacity (MW)	percent of Installed Capacity
Hydro:				
Akosombo	**850**		**1020**	
Kpong	**120**		**160**	
Total Hydro	**970**	**56**	**1180**	**55**
Thermal:				
TAPCO	**320**		**330**	
TICO	**220**		**220**	
TDS	**15**		**35**	
OECF Barge	**0**		**125**	
Total Thermal	**555**	**32**	**710**	**33**
Imports	**200**	12	**250**	12
Total Installed Capacity Including Imports			**2140**	**100**
Total Available Effective Capacity	**1725**	**100**		**81**
System Coincident Peak Demand*	**1200**	**70**		**56**
Reserve Margin	**525**	**30**		**25**

*VRA System Peak Without VALCO @ 3 Pot-Lines

TAPCO - Takoradi Power Company
TICO - Takoradi International Company
TDS - Tema Diesel Station

Substations on the transmission system receive power at higher voltages and lower them to 24,900 volts or less to feed the distribution systems. The distribution system consists of the poles and wires commonly seen in neighborhoods. At key locations, voltage is again lowered by transformers to meet customer needs.

Customers on the distribution system are categorized as industrial, commercial and residential. Industrial use is fairly constant, both over the day and over seasons. Commercial use is less constant and varies over seasons. Residential and commercial use are more variable, sometimes changing rapidly over the day in response to occupant needs, appliance use and weather events.

As of December 2003, the entire distribution system comprised 8,000 km of sub-transmission lines, 30,000 km of distribution networks with 22 bulk supply points and 1,800 MVA of installed transformer capacity.

1.5 How much does it cost and how much do we pay?

Since most of the electricity is generated from hydro facilities that were built several decades ago, the cost of generation has been pretty low (about 2-2.5 US cents per kWh). But, as demand grew and VRA had difficulty supplying electricity during years of low rainfall, new thermal plants were built in the late 1990s. These plants have costs ranging from 4.5 to 8 US cents per kWh, and sometimes higher, depending on the cost of imported fuels such as light crude oil. As a result, the average cost of generation increased from about 2 US cents per kWh in the mid-1990s to about 6 US cents in 2002. However, tariffs to end-users have not always reflected these costs due to government's subsidized tariff policy.

Electricity supply is divided into bulk electricity (transmission level) and final electricity (distribution level). Average bulk electricity price was below 4 US cents per kWh in the early 1990s until 1998 when it went up to between 4.0 to 4.5 US cents per kWh, below the cost of generation.

After its establishment in 1997, the Public Utilities Regulatory Commission (PURC) started setting electricity tariffs, in consultation with key stakeholders comprising the generators, distributors and representatives of major consumers. 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 has been effected once in 2003 and twice in 2004 with the latest adjustment in 2004 affecting only the Bulk Supply Tariff (BST) and the Distribution Service Charge (DSC). 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 addition of thermal generation has pushed up the End User Tariff to about 8.2 US cents per kWh: a BST of about 4.8 US cents (including a 'postage stamp' transmission charge of about 0.9 US cents) and a DSC of about 3.4 US cents.

There are different tariffs for industrial, commercial (non-residential) and residential customers. The tariff for residential customers has a lifeline tariff for low consumption, which was set at 100 kWh per month maximum in 1989/90 but was downgraded to 50 kWh per month maximum by the year 2000, which is still high compared to some neighbouring countries (for example, 20 kWh for Benin and 40 kWh in Togo). The lifeline tariff is about US $1.5 (about 13,000 cedis) per month. The Government of Ghana subsidizes the lifeline consumers to the tune of about US $1 per month but it has been unable to make regular and timely remittances to the utilities. The total subsidies owed by the Government to the distribution utilities by end of 2003 ranged from US $400,000–1,400,000.

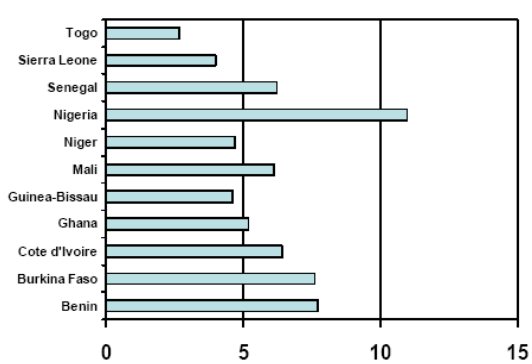
The average tariff for final electricity in general, was below 5 US cents per kWh until 1998 when it shot up to between 5.2 - 8.2 US cents per kWh. Above 8 US cents per unit, though relatively low compared to some neighbouring countries, it is not attractive to induce high level commercial and industrial usage. At the same time, industrial customers subsidize residential consumers. These policies are hampering the development of an industrial base in Ghana that can compete in regional and global markets and fuel economic growth.

There are a number of other challenges in fixing the distortions in electricity tariffs. First, utilities need to improve their operational efficiencies so that they can be financially sound while lowering tariffs for consumers of electricity. A second and related challenge concerns the average tariff collection efficiency, which has ranged from 75 to 85 percent. PURC has a benchmark of 95 percent. Although utilities are called upon to improve their customer relations and service quality; consumers have the duty to procure legal connections and to pay their bills regularly. Otherwise, the electricity system cannot be expanded reliably to meet the growing demand.

1.6 Electric power and Ghana’s neighbours

West Africa's total installed electric generating capacity was 9.4 gigawatts (GW) at the beginning of 2001, the majority of which was thermal (about 59 percent). Ghana is the second largest electricity market after Nigeria both in terms of generation capacity and consumption in the region, followed by La Côte d’Ivoire.

Figure 1.1: **Average annual growth in electricity demand, 2003-2012**



Total electricity generation for the region in 2001 was 33.8 terawatthours (TWh), with Nigeria (15.7), Ghana (8.8) and La Côte d'Ivoire (4.6) being the largest generators. In 2001, total regional electricity consumption was 31.8 TWh, led by Nigeria's 14.6 (45.8%). Ghana (8.8, 27.8%), and La Côte d'Ivoire (3.0, 9.4%) were the next largest electricity consumers.

There are roughly 234 million potential electricity consumers in the region. Only about 33 percent of them have access to electricity. Demand for electric power in the region is expected to grow by five percent annually over the next 20 years, and much faster in some countries (see Figure 1.1). Based on the existing capacity of 10,000 megawatts, the region needs to increase its generating capacity by about 17,000 megawatts by 2023 to keep up with demand. Most of the countries in the region have small power utilities; the largest three are in Nigeria (2,800 MW), Ghana (1,600 MW) and La Côte d’Ivoire (1,200 MW). All others have less than 450 MW of capacity.

The electric power transmission system of Ghana is connected to its neighbours, La Côte d’Ivoire on the west by a 226-kV transmission line and Togo and Benin on the east by a 161-kV transmission line. Ghana also supplies electric power to Burkina Faso in the north through a low voltage distribution network. A high voltage transmission system between Ghana and Burkina Faso is being developed. In 2002, La Côte d’Ivoire exported 1,563 GWh of electricity (worth about $77 million), of which 111 GWh went to Burkina Faso and another 233 GWh was transmitted across Ghana to Togo and Benin. Also in 2002, Ghana exported an additional 170 GWh of electricity to Togo and Benin.

Under the leadership of the Economic Community of West African States (ECOWAS), there is an effort to create a regional power pool, starting with Nigeria, Benin, Togo, Ghana, La Côte d'Ivoire, Burkina Faso and Niger which are already interconnected. The project, known as the West African Power Pool (WAPP), also aims to increase energy trade in the region and to promote foreign investment in the electricity sector.

If this regional approach to electricity sector development is successful, countries in the region are expected to save about $3-5 billion over 20 years. The WAPP is now an ECOWAS priority project for the New Partnership for African Development (NEPAD). A more detailed discussion on WAPP is provided in Section 6.5.

2. The Basics of Electric Power

2.1 Introduction

Electricity travels fast, cannot be stored easily or cheaply, and cannot be switched from one route to another. These three principles are basic to the operation of an electric power system. Electricity is almost instantaneous. When a light is turned on, electricity must be readily available. Since it is not stored anywhere on the power grid, electricity must somehow be dispatched immediately. A generator is not simply started up to provide this power. Electric power must be managed so that electricity is always available for all the lights, appliances and other uses that are required at any particular moment.

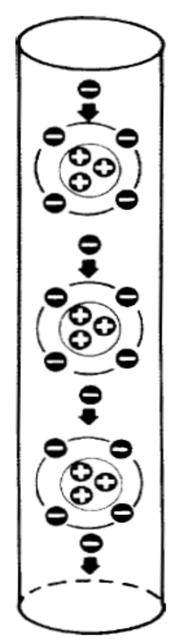
Electricity travelling from one point to another follows the path of least resistance rather than the shortest distance. With long distances of interconnected wires, electricity may travel miles out of any direct path to get where it is needed. As a result of these three principles, designing and operating an electrical system is complex and requires constant management.

Energy is used in diverse ways and the most commonly utilized form of energy is heat. Energy may be obtained either directly or indirectly from energy sources; electrical energy or electricity, for instance, is always invariably produced indirectly from a myriad of primary energy sources. Electricity is one of the key types of energy; it is made up basically of the flow of tiny particles of matter called electrons. Practically everything on this earth, including humans, contains electrons and therefore can be described as partly electrical.

2.2 Defining and Measuring

Electricity is simply the flow or exchange of electrons between atoms. The atoms of some metals, such as copper and aluminum, have electrons that move easily. That makes these metals good electrical conductors. Electricity is created when a coil of metal wire is turned near a magnet (Diagram 1). Thus, an electric generator is simply a coil of wire spinning around a magnet. This phenomenon enables us to build generators that produce electricity in power plants.

Diagram 1
Electric Current



When a metal wire, such as copper, is passed through a magnetic field, electrons are exchanged from atom to atom. This forms a moving stream or *current* of electricity.

The push, or pressure, forcing electricity from a generator is expressed as volts. The flow of electricity is called current. Current is measured in amperes (amps).

Watts are a measure of the amount of work done by electricity. Watts are calculated by multiplying amps by volts. Electrical appliances, light bulbs and motors have certain watt requirements that depend on the task they are expected to perform. One kilowatt (1,000 watts) equals 1.34 horsepower.

The *watt (W)* represents the unit of measure of electric power or rate of doing work. Large amounts of electric power are denoted as follows:

1. **Kilowatt (kW):** equal to 1,000 W
2. **Megawatt (MW):** equal to 1,000,000 W or 1,000 kW
3. **Gigawatt (GW):** equal to 1,000,000,000 W; 1,000,000 kW or 1,000 MW
4. **Terawatt (TW):** equal to 1,000,000,000,000 W; 1,000,000,000 kW; 1,000,000 MW or 1,000 GW.

A 60-W incandescent bulb will, for example, require 60 watts of electric power to operate or light up. On the other hand, a 3-kW electric kettle will need 3,000 watts of electric power to boil water. The *kilowatt-hour (kWh)* is the basic unit of measure of the amount or quantity of electricity (electric energy) used. A kilowatt-hour is equal to one kilowatt of electric power supplied to or taken from an electrical power system for one hour. It represents the amount of work done by one kilowatt in one hour. Other representations of electric energy utilized are the following:

1. **Watt-hour (Wh):** equal to one-thousandth of 1 kWh or (1kWh/1,000)
2. **Megawatt-hour (MWh):** equal to 1,000,000 Wh or 1,000 kWh
3. **Gigawatt-hour (GWh):** equal to 1,000,000,000 Wh; 1,000,000 kWh or 1,000 MWh
4. **Terawatt-hour (TWh):** equal to 1,000,000,000,000 Wh; 1,000,000,000 kWh; 1,000,000 MWh or 1,000 GWh.

The kilowatt-hour (kWh) is also known as one unit of electricity. If a 100-W bulb burns continuously for 10 hours, then 1 unit or 1 kilowatt-hour of electricity has been used. This is described in mathematical form as:

100-W x 10 hours = 1000 Wh = 1 kWh = 1 unit of electricity.

Most electric plants generate kilowatts (kW) or megawatts (MW) of electric power while the energy production could be in billions of units or kilowatt-hours (kWh).

The average electricity customer in Ghana uses about 350 kWh annually, with large differences between industrial users and residential users as well as between urban users and rural users. The world average for electricity consumption is about 2,900 kWh per person. In high income countries, average consumption is more than 8,000 kWh per person.

Electricity is generated and usually transmitted as alternating current (AC). The direction of current flow is reversed 60 times per second, called 60 hertz (Hz). Because of the interconnection within the power grids, the frequency is the same throughout the grid. Operators strive to maintain this frequency at 60 Hz.

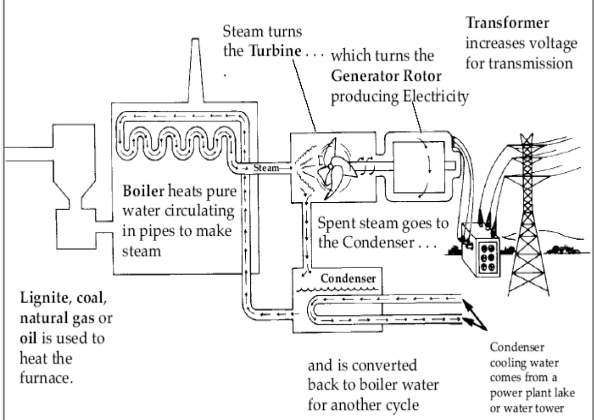
Higher voltages in many instances can be transmitted more easily by direct current (DC). High voltage direct current (HVDC) lines are used to move electricity long distances.

2.3 Generating Electricity

There are many fuels and technologies that can generate electricity. Usually a fuel like coal, natural gas, or fuel oil is ignited in the furnace section of a boiler. Water piped through the boiler in large tubes is superheated to produce heat and steam. The steam turns turbine blades which are connected by a shaft to a generator. Nuclear power plants use nuclear reactions to produce heat while wind turbines use the wind to turn the generator. A generator is a huge electromagnet surrounded by coils of wire which produces electricity when rotated (Diagram 2).

Diagram 2

Steam Turbine Electric Power Plant



Electricity generation ranges from 13,000 to 24,000 volts. Transformers increase the voltage to hundreds of thousands of volts for transmission. High voltages provide an economical way of moving large amounts of electricity over the transmission system.

Types of Generators

Steam Turbine

Uses either fossil fuel or nuclear fuel to generate heat to produce steam that passes through a turbine to drive the generator; primarily for base load but some gas-fired plants are also used for peak loads; range in size from 1 to 1,250 megawatts.

Combustion Turbine

Hot gases are produced by combustion of natural gas or fuel oil in a high pressure combustion chamber; gases pass directly through a turbine which spins the generator; used primarily for peak loads but combined cycle plants are used for base load; generator is generally less than 100 megawatts; quick startup suitable for peaking, emergency, and reserve power.

Hydroelectric Generating Units

Flowing water used to spin a turbine connected to a generator; range in size from 1 to 700 megawatts; can start quickly and respond to rapid changes in power output; used for peak loads and spinning reserve, as well as baseload.

Internal Combustion Engines

Usually diesel engines connected to the shaft of a generator; usually 5 megawatts or less; no startup time; operated for periods of high demand.

Others

Geothermal, solar, wind, and biomass; many different technologies; range widely in size and capabilities.

2.4 Transmission and Distribution

Once electricity is given enough push (voltage) to travel long distances, it can be moved onto the wires or cables of the transmission system. The transmission system moves large quantities of electricity from the power plant through an interconnected network of transmission lines to many distribution centers called substations. These substations are generally located long distances from the power plant. Electricity is stepped up from lower voltages to higher voltages for transmission.

High voltage transmission lines are interconnected to form an extensive and multi-path network. Redundant means that electricity can travel over various different lines to get where it needs to go. If one line fails, another will take over the load. Most transmission systems use overhead lines that carry alternating current (AC). There are also overhead direct current (DC) lines, underground lines, and even under water lines.

All AC transmission lines carry three-phase current - three separate streams of electricity travelling along three separate conductors. Lines are designated by the voltage that they can carry. Voltage ratings are usually 345 kilovolt (kV) for primary transmission lines and 138 kV and 69 kV for sub-transmission lines. Transmission voltages in Ghana are presently 69,000 volts, 161,000 volts and 220,000 volts. It is envisaged to operate 330,000 volts transmission lines along parts of the coastal corridor of the country by 2008. Sub-transmission voltages are 33,000 volts and 34,500 volts. Apart from the reduced level of voltage, a sub-transmission system is similar to a transmission network.

Even though higher voltages help push along the current, electricity dissipates in the form of heat to the atmosphere along transmission and distribution lines. This loss of electricity is called line loss. The loss will be higher if the lines are not well maintained by the utilities. Around the world, best utility practices lower the technical line loss during transmission and distribution to 7-8 percent. In Ghana, this ratio was about 14 percent in 2001 (11 percent during distribution and three percent during transmission). It is also estimated that there is about 14 percent of non-technical losses that are associated with illegal connections and unpaid consumption.[1]

Switching stations and substations are used to (1) change the voltage, (2) transfer from one line to another, and (3) redirect power when a fault occurs on a transmission line or other equipment. Circuit breakers are used to disconnect power to prevent damage from overloads.

Control centers coordinate the operation of all power system components. One or more utilities can make up a control area. To do its job, the control center receives continuous information on power plant output, transmission lines, ties with other systems, and system conditions. In Ghana, VRA and ECG manage their control centers as the main transmission and distribution providers.

2.5 Transmission Constraints

There are some important constraints that affect the transmission system. These include thermal limits, voltage limits, and system operation factors.

Thermal/Current Limits

Electrical lines resist the flow of electricity and this produces heat. If the current flow is too high for too long, the line can heat up and lose strength. Over time it can expand and sag between supporting towers. This can lead to power disruption. Transmission lines are rated according to thermal limits as are transformers and other equipment.

Voltage Limits

Voltage tends to drop from the sending to the receiving end of a

[1] Transitional Plan for Electricity Rate Adjustment 2001-2002 prepared by the PURC.

transmission line. Equipment (capacitors and inductive reactors) is installed to help control voltage drop. If voltage is too low, customer equipment and motors can be damaged.

System Operation Constraints

Power systems must be secure and reliable. Operating constraints are needed to assure that this is achieved.

Power Flows: Electricity flows over the path of least resistance. Consequently, power flows into other systems' networks when transmission systems are interconnected. This creates what are known as loop flows. Power also flows over parallel lines rather than the lines directly connecting two points-called parallel flows. Both of these flows can limit the ability to make other transmissions or cause too much electricity to flow along transmission lines thus affecting reliability.

Preventive Operations: The primary way of preventing service failures from affecting other areas is through preventive operations. Some standards and guidelines developed by the utility or regulator or another entity are usually desired. Operating requirements include (1) having a sufficient amount of generating capacity available to provide reserves for unanticipated demand and (2) limiting power transfers on the transmission system. The guidelines recommend that operations be able to handle any single contingency and to provide for multiple contingencies when practical. Contingencies are identified in the design and analysis of the power system.

System Stability: The two types of stability problems are maintaining sychronization of the generators and preventing voltage collapse. Generators operate in unison at a constant frequency of 60 Hz. When this is disturbed by a fault in the transmission system, a generator may accelerate or slow down. Unless returned to normal conditions, the system can become unstable and fail.

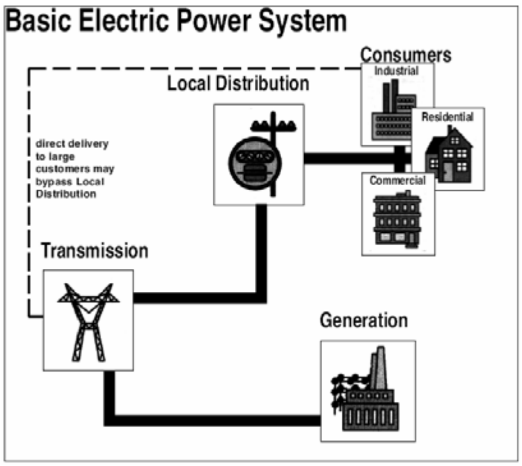
Voltage instability occurs when the transmission system is not adequate to handle reactive power flows. Reactive power is needed to sustain the electric and magnetic fields in equipment such as motors and transformers, and for voltage control on the transmission network.

2.6 Distribution

The distribution system is made up of poles and wire seen in neighborhoods and underground circuits. Distribution substations monitor and adjust circuits within the system. The distribution substations lower the transmission line voltages to 34,500 volts or less. In Ghana, the median voltage is 11,000 volts. The voltage is then further reduced by distribution transformers (substations) to the utilization voltages of 415 volts three-phase or 230 volts single-phase supply required by most users.

Substations are fenced yards with switches, transformers and other electrical equipment. Once the voltage has been lowered at the substation, the electricity flows to homes and businesses through the distribution system. Conductors called feeders reach out from the substation to carry electricity to customers. At key locations along the distribution system, voltage is lowered by distribution transformers to the voltage needed by customers or end-users.

Apart from voltage magnitude, distribution systems differ in other ways from transmission networks. The distribution network has more feeders or wires and more sources of power supply than the transmission network.



The structure or topology of its network is also different: this may be either radial overhead feeder as are often used in rural areas or loop/ring format that are the norm in urban areas. Ring circuits are usually interconnected to form networks used for enhancing reliability of supply to customers. Radial feeders are cheaper than ring or loop circuits but are less reliable as there is only one path between the substation and the customer. A failure of any component along the path results in complete loss of power delivery. Ring systems however provide two paths between the sources of power (substations or service transformers) and every customer. Here, each loop is designed such that service can be maintained regardless of a break at any point on the loop.

The effectiveness of a distribution system is measured in terms of service continuity or reliability, service quality in terms of voltage stability and lowest cost possible. Distribution systems also face similar cost constraints for transmission networks but to a much lesser extent.

Customers at the End of the Line

The ultimate customers who consume electricity are generally divided into three categories: industrial, commercial, and residential. The cost of serving customers depends upon a number of factors including the type of service (for example, if service is taken at high or low voltage) and the customer's location with respect to generating and delivery facilities.

Industrial

Industrial customers generally use electricity in amounts that are relatively constant throughout the day. They often consume many times more electricity than residential consumers. Most industrial demand is considered to be base load. As such it is the least expensive load to serve. Industrial loads are expected to remain within certain levels over time with relatively little variation. Major industrial customers may receive electricity directly from the transmission system (rather than from a local distribution system).

Commercial

Commercial loads are similar to industrial in that they remain within certain levels over intermediate periods of time. Examples of commercial customers are office buildings, warehouses, and shopping centers.

Residential

Residential electrical use is the most difficult to provide because households use much of their electricity in the morning and evening and less at other times of the day. This is less efficient to provide and therefore a more expensive use of the utility's generators. Over time as homeowners buy new appliances and change lifestyles, the expected loads also change. Examples of residential loads are individual residences.

2.7 The Electric Power Industry

Organizations that generate, transmit or distribute electricity are called *(public) utilities* due to the fact that they have the capacity to satisfy essential human wants which lead to enhancement of the quality of life. Utilities may be vertically integrated in which case electric power generation, transmission and distribution are performed by one organization. The Volta River Authority (VRA), a government owned utility, is largely responsible for electricity generation and transmission in Ghana and it can be described as being partially integrated. Limited generation is also undertaken by a private company, the Takoradi International Company (TICo), a joint venture ship between VRA and CMS Energy Inc. of the USA.

Two nationally owned utilities are responsible for electric power distribution in the country. These are the Electricity Company of Ghana (ECG) and the Northern Electricity Department (NED), the latter being a directorate of the VRA. The Electricity Company of Ghana delivers power to customers in the southern half of the country comprising Ashanti, Western, Central, Eastern, Volta and Greater Accra Regions while the Northern Electricity Department has responsibility for supplying power to customers in the northern half of the country consisting of the Brong Ahafo, Northern, Upper East and Upper West Regions.

There are four electric utilities in the country, namely VRA, ECG, NED and TICO. The Public Utilities Regulatory Commission (PURC) and the Energy Commission (EC) are two government agencies that regulate the utilities for the public good rather than private interests. The PURC is an independent body with primary responsibility for setting the tariffs that utilities charge their customers. The EC on the other hand is tasked with licensing and regulating the technical operations of the utilities. Both regulatory agencies also ensure fair competition in the power market, enforce standards of performance for the provision of services to customers and protect both customer and utility interests.

Electric energy policy formulation is the preserve of the Ministry of Energy while the Energy Foundation, a non-governmental agency, has been very active in promoting energy efficiency measures.

3. History of Electric Power in Ghana

3.1 Introduction

There are three main periods of electricity in Ghana. The first, "**Before Akosombo**", refers to the period before the construction of the Akosombo Hydroelectric Power Plant in 1966. This is a period of isolated generation facilities with low rates of electrification. The second period, "**the Hydro Years**", covers the period from 1966 to the mid eighties, the Volta Development era. The Volta Development includes the Akosombo Hydroelectric Plant commissioned in 1966 and the Kpong Hydroelectric Plant, completed in 1982. By the mid-eighties, demand for electricity had exceeded the firm capability of the Akosombo and the Kpong Hydro Power Plants. The third period, "**Thermal Complementation**", from the mid eighties to date is characterised by efforts to expand power generation through the implementation of the Takoradi Thermal Power Plant as well as the development of the West African Gas Pipeline to provide a secure and economic fuel source for power generation. There have been efforts to link the power facilities of Ghana with neighbouring countries including the implementation of the Ghana-Togo-Benin transmission line as well as the Ghana - La Côte d'Ivoire interconnection carried out during the second period. As the economies of Ghana and its neighbours continue to grow, there are many challenges remaining in meeting the increasing demand for electricity in the region while at the same time pursuing policies of fuel diversification, grid integration and sector restructuring.

3.2 Before Akosombo (1914 to 1966)

Before the construction of the Akosombo hydroelectric plant, power generation and electricity supply in Ghana was carried out with a number of isolated diesel generators dispersed across the country as well as stand-alone electricity supply systems. These were owned by industrial establishments such as mines and factories, municipalities and other institutions (e.g. hospitals, schools etc.).

The first public electricity supply in the country was established in Sekondi in 1914. The Gold Coast Railway Administration operated the system which was used mainly to support the operations of the railway system and the ancillary facilities which went with its operations such as offices, workshops etc. In 1928, the supply from the system was extended to Takoradi which was less than 10 km away. This system served the needs of railway operations in the Sekondi and Takoradi cities.

In addition to the Railways Administration, the Public Works Department (PWD) also operated public electricity supply systems and commenced limited direct current supply to Accra in 1922. On November 1, 1924, the PWD commenced Alternating Current supply to Accra. The first major electricity supply in Koforidua commenced on April 1, 1926 and consisted of three horizontal single cylinder oil-powered engines. Other municipalities in the country which were provided with electricity included Kumasi where work on public lighting was commenced. On May 27, 1927, a restricted evening supply arrangement was effected and subsequently, the power station became fully operational on October 1, 1927.

The next municipality to be supplied with electricity in 1927 was Winneba where with an initial direct current supply, the service was changed to alternating current (AC) by extending the supply from Swedru. During the 1929-30 time frame, electricity supply of a limited nature was commenced in the Tamale township. Subsequently in 1938, a power station operating on alternating current was commissioned. In 1932, a power station was established in Cape Coast and subsequently another station was opened at Swedru in 1948. Within the same year, there was a significant expansion of the electricity system and Bolgatanga, Dunkwa and Oda had electricity power stations established. The first major transmission extension of the electricity network in Ghana is believed to be the 11 kV overhead extension from Tema to Nsawam which was put into service on May 27, 1949. Subsequently a power station was commissioned at Keta in 1955.

On April 1, 1947, an Electricity Department within the Ministry of Works and Housing was created to take over the operation of public electricity supplies from the PWD and the Railways Administration. One of the major power generation projects undertaken by the Electricity Department was the construction of the Tema Diesel Power Plant. The plant was built in 1956 with an initial capacity of 1.95 MW (3x 650 kW units). This was expanded in 1961-64 to 35 MW with the addition of ten 3 MW diesel generators and other units of smaller sizes. Subsequently, three of the original units were relocated to Tamale and the others used as a source of spare parts for the ten newer units. The plant when completed was the single largest diesel power station in Black Africa and served the Tema Municipality. In addition, through a double circuit 161-kV transmission line from Tema to Accra, the Tema Diesel Plant supplied half of Accra's power demand.

The total electricity demand before the construction of Akosombo cannot be accurately determined due to the dispersed nature of the supply resources and the constrained nature of electricity supply. Most of the towns served had supply for only part of the day. In addition to being inadequate, the supply was also very unreliable. There was therefore very little growth in electricity consumption during the period. Total recorded power demand of about 70 MW with the first switch on of the Akosombo station can be used as a proxy for the level of electricity demand in the country just prior to the construction of Akosombo.

3.3 The Hydro Years (1966 – Mid 1980's)

Akosombo Hydroelectric Project

The history of the Akosombo Hydroelectric Project is linked with efforts to develop the huge bauxite reserves of Ghana as part of an integrated bauxite to aluminium industry. The project was first promoted by Sir Albert Kitson, who was appointed in 1913 by the British Colonial Office to establish what is known as the Geological Survey Department. In 1915, while Sir Kitson was on a rapid voyage down the Volta River he identified the hydro potential of the Volta River and later outlined a scheme for harnessing the water-power and mineral resources of the then Gold Coast in an official bulletin.

The idea was later taken up by Duncan Rose, who came across Kinston's proposals in the bulletin and became interested in the idea of a hydroelectric aluminium scheme. Efforts to develop the scheme further intensified in the 1950's with the implementation of engineering studies by Sir William Halcrow and Partners on the possibility of producing power from the Volta River by constructing a dam at Ajena in the Eastern Region of Ghana. The Halcrow report, which was published in 1955 covered the climate and hydrology of the Volta Basin, evaporative studies, flood control, geology, power plant design and project cost estimates in detail.

An independent assessment of the Halcrow report by Kaiser Engineers in 1959 recommended the construction of the dam at Akosombo instead of Ajena as proposed in the Halcrow report. This meant a complete redesign of the dam and the power plant. The major advantage in relocating the dam was that the width of the gorge at the proposed crest elevation of 290 feet was only 2,100 feet compared with 3,740 feet at the Ajena site. However, at the Akosombo site, the maximum depth to bedrock was minus 80 feet as compared to minus 40 feet at the Ajena site.

The Volta River Authority (VRA) was established in 1961 with the enactment of the Volta River Development Act, 1961 (Act 46) and charged with the duties of generating electricity by means of the waterpower of the Volta river and by other means, and of supplying electricity through a transmission system. The VRA was also charged with the responsibility for the construction of the Akosombo dam and a power station near Akosombo and the resettlement of people living in the lands to be inundated as well as the administration of lands to be inundated and lands adjacent thereto.

Construction of the Akosombo dam formally commenced in 1962 and the first phase of the Volta River Development project with the installation of four generating units with total capacity of 588 MW each was completed in 1965 and formally commissioned on January 22, 1966. In 1972, two additional generating units were installed at Akosombo bringing the total installed capacity to 912 MW.

By 1969, the Volta Lake, created following the completion of the Akosombo dam, had covered an area of about 8,500 km^2 and had become the world's largest man made lake in surface area. It can hold over 150,000 million m^3 of water at its Full Supply Level (FSL) of 278 feet NLD and has a shoreline length of about 7,250 km. The Lake is about 400 km long and covers an approximate area of 3,275 square miles, i.e., 3 percent of Ghana. The drainage area of the Lake comprises a land area of approximately 398,000 km^2, of which about 40 percent is within Ghana's borders. The other portions of the Volta Basin are in Togo, Benin, Mali and la Côte d'Ivoire. The average annual inflow to Lake Volta from this catchment area is about 30.5 MAF (37,600 million m^3).

Kpong Hydroelectric Project

In 1971, VRA commissioned Kaiser Engineers of USA to prepare a planning study, "*the Ghana Power Study: Engineering and Economic Evaluation of Alternative Means of Meeting VRA Electricity Demands to 1985*", which recommended the construction of the Kpong Hydroelectric Project, with the dam located upstream of the Kpong Rapids and the Power Station at Penu, about 18 kilometers upstream of Kpong.

Other options studied included the Bui Hydroelectric Plant on the Black Volta, expansion of the Akosombo Plant with the installation of additional units and development of the Pra, Tano and lower White Volta rivers. Thermal options, including steam turbine plants and gas turbine plants were also considered, in addition to the possibility of supply from Nigeria through the Ghana-Togo-Benin (then Dahomey) transmission line. These options, however, were found to be less economic than the Kpong hydroelectric development. The study also recommended that thermal plants, which could be deployed faster than the Kpong plant, should be considered for implementation in the event of a significant increase in demand.

In 1974, VRA commissioned Acres International of Canada to carry out a review of the Kaiser Study. Following the review, the plant site was changed to Akuse. A major benefit of the change was the drowning of the Kpong rapids as a result of the dam construction. This eliminated the terrible insect, simulium damnosum, the agent of river blindness.

The Kpong Hydroelectric Plant was successfully commissioned in 1982 and gave an additional 160 MW of installed capacity to the existing hydroelectric capacity.

Demand for Electricity during the Volta Development Period

By 1967, a year after the Akosombo Hydroelectric Plant was commissioned, most of the major electricity consumers were switched off diesel-powered electricity supply and served from Akosombo. The major customers of power were an aluminum smelter and a national electricity distribution company established in 1967.

The smelter was owned by the Volta Aluminum Company (VALCO), a company incorporated in Ghana. In 1962, VALCO signed a Master Agreement with the Government of Ghana, which included a Power Supply Agreement for the supply of power from Akosombo to the 200,000-tonne aluminum smelter. VALCO thus served as the anchor customer for VRA and the first phase of the Volta Development. Construction of the VALCO smelter commenced in 1964 and was completed in 1967 and connected to the VRA transmission system.

In 1967, the Electricity Corporation of Ghana (ECG), established by the Electricity Corporation of Ghana decree of 1967 (NLCD 125) and Executive Instrument No. 59 dated June 29, 1967 vested all assets and liabilities of the former Electricity Department in ECG.

Total domestic load (excluding VALCO) supplied from the grid in 1967 was approximately 540 GWh with an associated peak demand of about 100 MW. Domestic consumption in 1967 was therefore less than 20 percent of the installed capacity at the Akosombo Station.

Between 1967 and 1976, domestic consumption more than doubled, growing from about 540 GWh to about 1,300 GWh. The average annual growth rate was about 10 percent. This was followed by a period of relatively stagnant domestic consumption, 1977 to 1980, when domestic consumption remained around 1,350 GWh. From 1981, domestic consumption declined to a level of about 1,000 GWh in 1984. During this period, supply to VALCO was governed by the VRA – VALCO Power Supply Agreement. Figure 3.1 shows consumption of electrical energy from 1967 to 1985.

In 1972, VRA commenced supply of electricity to neighbouring Togo and Benin following the construction of a 205-kilometre 161-kV transmission line from Akosombo (Ghana) to Lome (Togo). The supply of electricity was governed by a Power Supply Agreement executed in 1969 between VRA and the Commutate Electricité de Benin (CEB), a power utility formed by the two countries, Togo and Benin. In 1983, the interconnected Ghana-Togo-Benin power system was expanded through the construction of a 220-kilometre transmission line from the Prestea Substation in Ghana to the Abobo Substation in La Côte d'Ivoire.

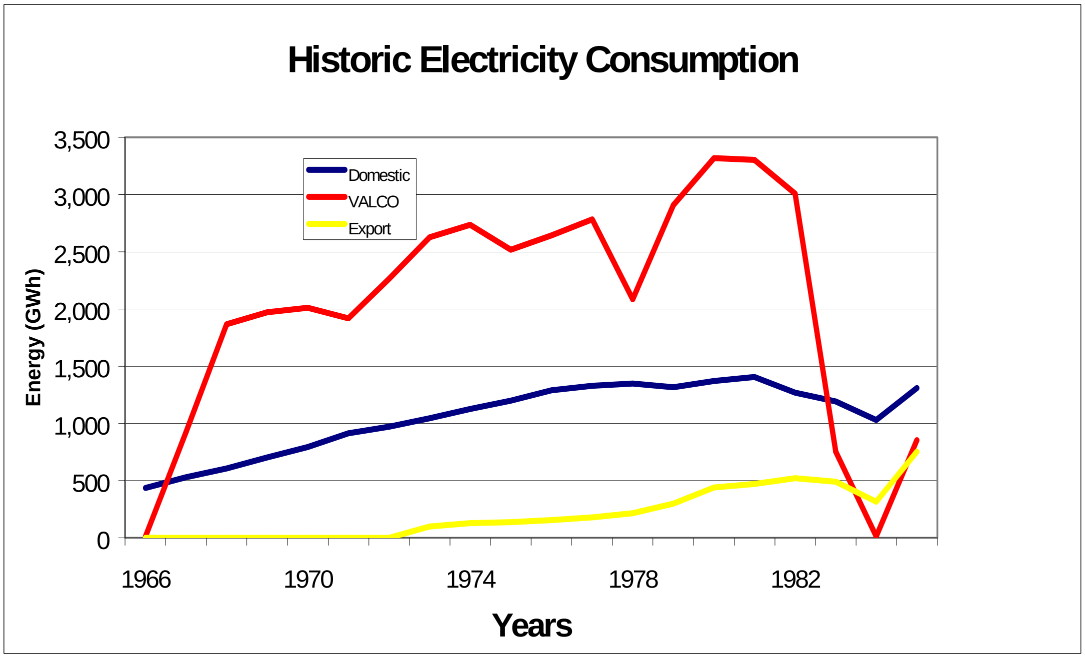
The decline in power consumption in the early eighties was compounded by the most severe drought in the recorded history of the Volta Basin, which occurred from 1982 to 1984. Total inflow into the reservoir over this three-year period was less than 15 percent of the long-term expected total. Electricity supply during this period was consequently rationed. Supply to VALCO was completely curtailed and export supplies to Togo and Benin were reduced.

3.4 Thermal Complementation – The Takoradi Thermal Power Plant

In 1983, following the drought, VRA as part of its Generation and Transmission planning process undertook a comprehensive expansion study, the ***Ghana Generation Planning Study*** (GGPS).. The engineering planning study which was completed in 1985 confirmed the need for a thermal plant to provide a reliable complementation to the hydro generating resources at the Kpong and Akosombo power plants. A major consideration for complementing the hydro sources was the natural and inherent characteristic of the Volta River to have highly variable flows from year to year. The Volta River had shown over 10:1 variation in flow between its highest inflow in 1963 and the lowest in 1983. Indeed this characteristic was not for the Volta River only. Nearly all the tropical rivers of the world have this cyclical variation in inflow over a certain periodicity.

The study concluded that by adding thermal complementation to the all-hydro system, the vulnerability of the power system in Ghana would be significantly reduced. This was because in times of insufficient rainfall resulting in low inflows into the Volta Lake, the thermal plants could be used to meet the shortfall in demand resulting from reduced hydro generation. In effect, the thermal generators were to serve as an insurance policy against poor hydrological years to meet the demand for electricity in Ghana.

Figure 3.1: **Consumption of electrical energy from 1967 to 1985**



In addition to thermal complementation, the study also recommended the rehabilitation of the 30-MW Tema Diesel Station as an immediate and short term measure to support the operation of the hydro plants and consequently reduce the risk of another exposure to poor rainfall and reduced power generation. The Tema Diesel plant faced delays in its rehabilitation but work was completed in 1993. Given its state and importantly, the cost of generation, the Tema Diesel plant has been used intermittently and is currently not in commercial operation.

Between 1985 and 1992, a number of studies were carried out to confirm the technical, economic and financial feasibility of introducing thermal plants within the generation mix. Although, the technical feasibility was easily established, it was extremely difficult to establish the economic and especially financial feasibility of the undertaking given the relatively low tariffs then being paid by VALCO and consumers in Ghana.

In addition, the late 1980s saw the beginning of significant increases in the demand for power in Ghana. This could largely be attributed to the impact of the Economic Recovery Programme embarked on by the Government in 1984/85. A study was also carried to determine the optimal technology for the thermal plants to be developed especially in the light of the profile of the rapidly growing power demand in Ghana. The study, named the ***Combustion Turbine Feasibility Study***, was completed in 1990. The Study recommended the addition of combustion turbine power plants in Ghana.

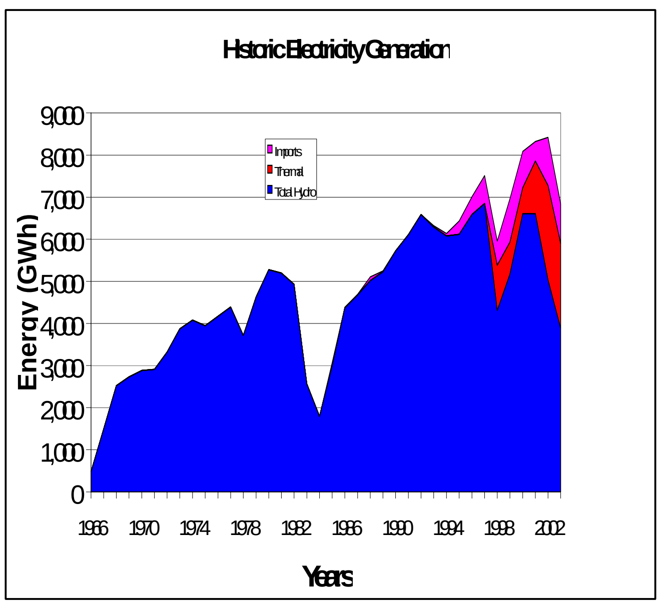
With the continued increase in demand for power, another study, ***Takoradi Thermal Plant Feasibility Study*** was finally completed in 1992 with a recommendation for the construction of a 600-MW plant, with an initial 300-MW combined cycle plant and a 100-MW Combustion Turbine unit to be commissioned by 1995. There were however, delays in financing approvals by the International Development Association, which eventually resulted in the first 330-MW tranche of the Takoradi Plant being commissioned in 1999. It is noted however that the first 110-MW combustion turbine unit went into commercial operation in December 1997 and the second in January 1998.

In 1998, the power system in Ghana experienced another crisis resulting in the rationing of power to consumers. The crisis was brought on largely by poor rainfall and consequently low inflows into the Volta Lake affecting power generation, and also the inability to obtain sufficient back up power from La Côte d'Ivoire.

In order to deal with the power shortage, the Government contracted two emergency power producers, namely, AGGREKO LTD and CUMMINS Ltd both of the UK to produce and sell into the distribution grid in Tema up to 30 MW each. This arrangement was ended in 2000 when the crisis was over and normal power generation had been restored. The power crises set the basis for the addition of power plants to the generation system in Ghana through the private sector for the expansion of the Takoradi Thermal Power Plant. In 1994, the Government launched a new policy framework for the development of the power sector. The policy envisaged the introduction of private sector participation in infrastructural development for the sector to meet growing demand.

In 1999, in line with Government's policy, the VRA entered into a joint venture arrangement with CMS Energy of USA to expand the Takoradi Thermal Power Plant Station to 550 MW with the addition of 2x110 MW Combustion Turbine plants. With the expansion of the Takoradi Thermal Power Plant, thermal generation increasingly started playing a major role within the power generation mix of Ghana. The two combustion turbine units were put into commercial operation in March and September 2000 respectively. Figure 3.2 shows the significant impact of low rainfall on the Ghanaian power system. Clearly, the addition of thermal generation capacity in recent years has been helpful but remains limited.

Figure 3.2: **Electricity generation in Ghana, 1966-2003**



3.5 Current Power System Facilities

The total installed generation capacity is 1,778 MW. This comprises:

- The Akosombo Hydroelectric Power Plant with an installed capacity of 1,038 MW. The Akosombo plant has been retrofitted with the replacement of the old turbine runners with new ones as well as electro-mechanical works aimed at restoring the plant to its original condition. The retrofit was completed in March.
- 160-MW Kpong Hydroelectric Power Plant
- 550-MW installed thermal capacity at the Takoradi Thermal Power Station and;
- 30-MW Diesel Power Plant at Tema.

A 125-MW Power Barge "the Osagyefo Power Barge" is also available and is currently berthed at Effasu Mangyea in the Western Region with arrangements ongoing to establish viable fuel sources for it. The Osagyefo barge was developed by the Ghana National Petroleum Corporation in order to utilize the natural gas available in the Tano oil and gas fields for power generation. The barge has been completed and is yet to go into commercial operation.

3.6 Need for Additional Generation

Domestic electric energy consumption in 2004 was 6,004 GWh. An additional 660 GWh was supplied to CEB. It is projected that the average local (Ghana) load growth over the next decade will be about six percent as a result of which local consumption of electricity will reach 9,300 GWh by 2010. There is also the potential for significant electricity exports and supply to VALCO when the smelter resumes operations.

The firm capability of our hydro system of about 4,800 GWh represents about half of the projected domestic consumption for 2010. This implies that at least 50 percent of Ghana's electricity requirement will be provided from thermal sources by the year 2010.

On the basis of the studies carried out, the next generation addition is the completion of the expansion of the Takoradi power station. This involves the addition of 110-MW steam unit in order to complete the combined cycle arrangements for the TICO power plant.

In the medium to long term, up to 600 MW of additional generating capacity will be required by 2012. It is planned that this additional capacity will be met through the establishment of thermal as well as hydro plants such as the Bui Hydroelectric Plant. An attractive candidate for generation expansion is the 300-MW combined cycle thermal power plant to be located at Tema. The operation of this plant is intended to be synchronized with the delivery of natural gas through the West African Gas pipeline project.

Currently, the Takoradi Thermal Power Station is fuelled with light crude oil, the price for which has appreciated significantly on the world market. In order to secure a sustainable and cost-competitive fuel source, Ghana is involved in the West African

Gas Pipeline (WAGP) Project for power generation.

The West African Gas Pipeline (WAGP) Project involves the construction of a natural gas pipeline of about 600-kilometres to supply natural gas from Nigeria to meet the energy requirements of Ghana and other West African countries. The countries presently involved in the project with Ghana are Nigeria, Benin and Togo. The WAGP project will provide a source of clean fuel for VRA's thermal generating facilities and other future thermal plants, and is expected to deliver natural gas at relatively lower costs than light crude oil currently does.

It is expected that the first gas will be delivered to the Takoradi power station by the beginning of 2007.

In addition, Ghana is involved in the development of the West African Power Pool (WAPP), aimed at establishing a regional market for electricity trades. The WAPP is expected to allow the sharing of available energy resources and increase the reliability of electricity supply in the West African region

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4. Regulation and Policies

4.1 Introduction

Prior to 1997, the Government and the state-owned electricity utility organizations combined operational responsibilities with policy and regulatory issues. Almost a century after the commencement of a public electricity service in what was to become the modern Ghana, the country's electricity sector began a restructuring process in the mid 1990's, among other things, to overcome the limitations of the traditional set up. As far as utility regulation is concerned, perhaps the most dramatic change was the policy shift towards autonomous regulation of the sector by bodies that operate at arms length from government.

The current regulatory policy evolved as result of the restructuring of the electricity sector, itself a component of a broader national infrastructure and public institutional reform program. The structure of the electricity industry in Ghana is similar to the situation in most developing countries where service providers are state-owned monopoly organizations. Although the reform in the electricity sector is attributable to several factors it was prompted largely by multilateral donor agencies, fatigued from a decade and a half of concessionary financial support and considering reallocation of funds to other sectors. Some of the objectives of the reforms, which envisaged introduction of competition in supply as well as encouragement of private sector investment, necessitated transparency in regulation of the sector leading to the development of a sustainable electricity industry.

It is contended that the reform process and the resulting policy determinations, including the regulatory mechanisms, were a natural response to both the external demands and internal factors. Following the relative successes of restructuring elsewhere and the evolution of regulatory institutions, notably in Chile and Britain in the early 1980's and learning from the long established traditional American regulatory experience, the tone was set for Ghana and indeed most of the African continent to embrace reforms generally and also the concept of independent regulation.

Quite significantly, by the end of 1997, the sectoral structures had been well defined and established and the electricity industry positioned to advance. Two key regulatory institutions were duly created by acts of Parliament. These were the Public Utilities Regulatory Commission (PURC) established under the Pubic Utilities Regulatory Commission Act, 1997 (Act 538) and the Energy Commission (EC) established under the Energy Commission Act, 1997 (Act 541). As their names imply, the functions of these institutions are broader, but this synopsis is limited to their regulatory mandates regarding the electricity industry. The following structure was adopted under the revamped system: the Ministry of Energy is responsible for the broad policy direction of the electricity industry; the Energy Commission is responsible for indicative national planning, licensing of electricity utilities and technical standards; and the Public Utilities Regulatory Commission has responsibility for economic regulation, ensuring fair competition among utilities and monitoring quality of service.

4.2 History of electricity policy and regulation

There is a close linkage between the evolution of electricity policy and regulation and the development and growth of the industry from colonial times to the post independence era. In addition, the various institutional arrangements and the legal developments in the sector are useful in considering historical perspectives. As such the antecedents of the current electricity structure are summarized below.

Ghana's electricity supply dates back to 1914 when the Gold Coast Railways Administration started the first thermal power generation and public electricity supply in the municipalities of Sekondi and Takoradi. The development and growth of the industry was slow. From 1924, the Public Works Department which was to dominate the industry for a long time started operating diesel plants which had been installed in certain municipalities, notably in Accra, Kumasi, Koforidua, Winneba, Swedru and Cape Coast.

In 1947, the Electricity Department which later became the Electricity Division within the Ministry of Public Works was created as a separate entity to assume responsibility for the generation and supply of electricity from both the Railways Administration and the Public Works Department. After the take-over, and in the face of growing urbanization, a long term program was initiated to accelerate the supply of electricity to the other big towns and commercial centers.

To streamline the development and operations of the power stations and ensure speedy growth of the electricity industry, a prerequisite of an ambitious industrialization and national development drive, certain measures where initiated by the government. These included the enactment of the Volta River Development Act, 1961 (Act 46) which established the Volta River Authority (VRA) mandated to build and operate hydro power stations within the Volta Basin and to construct and operate the national electricity transmission system as well as the Electricity Act, 1961 (Act 48), which vested licensing and other regulatory powers in respect of electricity in the Minister responsible for Public Works.

The enactment of the Electricity Corporation Decree, 1967 (NLCD 125) and the repeal of the Electricity Act, established the Electricity Corporation of Ghana (ECG). For the next two decades, ECG was to remain the entity solely responsible for electricity supply and the distribution networks nationwide. In 1987, the corporation's sphere of operation was limited to the southern parts of Ghana which also had the greater concentration of customers. Service provision in respect of the sparsely populated northern parts of the country devolved on the Northern Electricity Department (NED) which was formed as the distribution arm of the VRA. This position had been in place until the radical changes introduced with the creation of the EC and

PURC with regulatory responsibility over the sector.

Before independence in 1957, the Electricity Supply (Control) Ordinance (Cap 66) provided the legal basis for regulating the electricity supply and distribution activities in Ghana. The regulatory authority was exercised by the Chief Electrical Engineer of the Public Works Department. The licensing, regulatory and operational framework for the industry was, however, redefined with the enactment in 1961 of two pieces of important sector legislation; the Electricity Act and the Volta River Development Act. Under the Electricity Act, the Minister responsible for Public Works was vested with licensing and other regulatory power for the electricity sector. In practice the regulatory function was performed by the Chief Electrical Engineer of the Ministry. The repeal of the Electricity Act and its replacement with the Electricity Corporation of Ghana Decree established the industry structure as it was known until the commencement of the electricity reform in the mid-1990's.

Both Acts effectively made the two state-owned electricity organizations, ECG and VRA, self regulatory monopolies with oversight by the Minister responsible for energy. ECG which was required to operate on a commercial basis was mandated to purchase electricity from VRA in bulk for distribution. Governmental control of the electricity industry is evident in the functions of the ECG and the composition of the governing board of ECG. Among the eight-member board, three were civil servants and the chief executive of a state-owned enterprise (SOE). Thus, the Principal Secretaries or holders of the most senior civil service positions in the Ministry with responsibility for Energy, the Ministry with responsibility for Finance as well as the Chief Executive of VRA constituted an overbearing government presence on the utility's board.

VRA on its part was also required to operate on a commercial basis and at a profit and was mandated to build and generate hydro electricity and supply it in bulk to various entities as well as to control and regulate the Volta Basin as the construction and operation of the national transmission system got underway. Indicative planning for the national electricity system was also undertaken by VRA.

Both utilities had the power to issue regulations in the form of subsidiary legislation. But the inherent arbitrariness in the system was compounded by the fact that these government monopolies had the ultimate power to fix their own tariffs. The shortcomings of that arrangement were self evident in the ensuing market failure that occurred. The absence of an independent regulator meant that decisions relating to regulation of services were made by the ministries, which were not insulated from political considerations.

Meanwhile, both VRA and ECG have been converted from their statutory corporation status to companies registered under the Companies Code, 1963 (Act 179) under the provisions of the related Statutory Corporations (Conversion to Companies) Act, 1993 (Act 461). This Act signified Government's strategy to encourage private participation and investments in various sectors of the economy, including the electricity sector.

The importance and necessity for an independent regulator in the energy sector was underscored by the Power Sector Reform Committee which was established in 1994 to look into ways of bringing about efficiency and to encourage private participation in the power sector. However the process towards the establishment of regulatory institutions, in particular the PURC, was accelerated by the imposition of tariffs by the utility companies which precipitated disaffection in the consuming public, resulting in the suspension of tariffs. The upshot was the establishment of PURC as the economic regulator and EC as the technical regulator and licensing authority.

4.3 Restructuring of electricity sector

Ghana's electricity sector has been significantly reformed in recent years. Several factors have driven the reforms. In June, 1994, the Government issued a Statement of Power Sector Policy which outlined electricity reform in Ghana. This statement of policy was driven by the indication given by the World Bank in a policy paper that it would no longer be in a position to provide funding for electricity sector projects in developing countries. Following the Government policy statement, the Minister of Energy initiated the power sector reform process to establish the required conditions in Ghana to improve operational efficiency of the utility companies and streamline tariff setting that would be transparent and independent of Government. These were prerequisites to securing private sector participation in the development of future electricity infrastructure. The World Bank provided suggestions for dealing with existing statutory restrictions to the entry into the sector by private investors owing to the dominant and powerful role of the VRA and ECG; these were insufficient regulation in terms of the lack of definition of the rules of practice and regulations intended to govern operations of the sector; unclear tariff setting criteria and unpredictable tariff setting regime; lack of transparency in market access and a nebulous government policy on measures for assisting investors in mitigating the risks posed by the unfavorable investment climate.

The objectives of the reform included structural changes within the sector to bring about competition in supply, transparency in the regulation of the sector operators, effective commercialization of operations of electricity utilities and encouragement of private investment in the development of the electricity sector. The industry structure envisaged under the reform was the unbundling of the sector with multiple generators of public private partnerships, a single transmission utility to be publicly owned, creation of distribution zones and the establishment of a transparent regulatory regime.

In 1997 two regulatory bodies were established to superintend electricity service provision, among their many functions. The PURC, established under Act 538, sets rates and monitors quality. The EC was established under Act 541 as the licensing authority of electricity utilities with further statutory responsibilities for technical standards and indicative planning.

Both bodies have power to issue regulations for the sector.

In accordance with the provisions of the Statutory Corporations (Conversion to Companies) Act, 1993 VRA and ECG have been converted into companies under the Companies Code. Additionally, the physical unbundling of VRA has occurred and there has been separation of hydro generation, thermal generation and transmission functions into separate organizations.

4.4 Current regulation of electric power in Ghana

The current regulatory framework for the electricity industry is provided by Acts 538 and 541 which established the PURC and EC respectively.

EC's regulatory mandates are:

- to receive and assess applications and grant licenses to public utilities for the transmission, wholesale supply and distribution of electricity;
- to establish and enforce, in consultation with PURC, standards of performance for the relevant public utilities;
- to promote and ensure uniform rules of practice for the transmission, wholesale supply and distribution of electricity.

PURC's regulatory mandates are:

- to provide guidelines on rates chargeable for electricity services;
- to examine and approve the rates;
- to protect the interests of consumers and providers of utility services;
- to monitor the standard of performance of the utilities;
- to promote fair competition.

In furtherance of its regulatory responsibilities, PURC has issued guidelines for setting tariffs in respect of generation, transmission and distribution of electricity. These guidelines provide a transparent and predictable mechanism for setting rates. In addition, an Automatic Adjustment Formula has been introduced to allow for quarterly revision of tariffs to reflect fluctuations in crude oil prices and foreign exchange rates, the hydro-thermal generation mix and changes in the consumer price index. With the automatic adjustment formula in place, major tariff reviews would take place every four years. The tariff review process is quite transparent and the public and consumers are involved through the public hearings system. Licensing decisions rendered by the EC are subject to appeals to the Minister of Energy or the courts but tariff decisions are not subject to appeal.

5. Major Electric Power Issues

5.1 Consumer issues

The use of electric power has become widespread in Africa; and Ghana is no exception. Over the last two decades, demand for electricity for various purposes including domestic and industrial uses has been increasing at a rate of 10-15 percent per annum. This has significant implications for the rate of economic development. While the use of electricity for domestic purposes (e.g., lighting, radio, television, ironing) will normally lead to improvement only in the lives of consuming individuals, productive use of electricity by industries (all things being equal) will lead to general macroeconomic improvement and a rise in the standard of living of the populace. The major consideration for Ghana is the ability of the country to match the rate of electricity demand with adequate supply as well as the proportion of energy produced which is consumed for productive use. It is estimated that about 50 percent of electricity produced in Ghana is consumed by domestic users. If this proportionate use can be changed in favour of industrial use and/or productive use then Ghana stands to gain.

In Ghana electricity customer groups comprise Residential, Non-Residential and Industrial customers. Each group has its requirements and needs. For most ordinary consumers electricity has become an important factor in their lives, particularly for lighting purposes. The main issues for ordinary consumers are (i) the price at which the electricity is bought, i.e., the bill they have to pay and the reliability of the service (ii) the level of tariff price in comparison to reliability, adequacy and safety of service being provided.

Residential Customers

As a large proportion of residential customers are low-income earners, the cost of electricity is critical for them. Therefore a pricing arrangement that will ensure that they can enjoy the use of electricity for their basic needs at an affordable price is important. The current "lifeline tariff" targets the rural and urban poor whose consumption is less than 50 kWh per month. The life-line tariff is typically 60-70 percent of the economic cost of supply.

Non-Residential Customers

This comprises major offices, banks and small businesses. For this group, the cost of energy is also important particularly for small businesses whose electricity cost is a significant component of their operating cost and who require lower energy costs to be more competitive in the market place to survive.

Industrial Customer Special Load Tariff Customers (SLT)

The major industries whose operations depend to a large degree on a reliable supply of power are also concerned about cost and reliability in order to ensure their competitiveness in the markets within which they operate.

5.2 Electric Power and Economic Development

Electricity, like other forms of energy, is a vital ingredient in the economic development of countries the world over. Not only is it a critical factor and cornerstone of the accelerated development and growth of any nation, it is also a measure of the standard and quality of life of a people. Without a safe, sustained, reliable and reasonably affordable supply of electricity to meet demand, a country can hardly make progress in its economic and social development.

Population growth and economic expansion are the major factors driving growth in the electric power industry. As the number of households grows and as more and more households add on electric appliances, electric power generation capacity has to keep up.

At the same time, electricity is an essential input for industrial and economic performance, although there are other things that are equally or more important. In general, when both household and economic growth are taken together, they account for most if not all of the net growth of electric generation capacity.

Growth in the electric power industry is also influenced both directly and indirectly by population growth and general economic performance. The direct effects come from demand for electricity as households are added or businesses and industries expand. The indirect effects come from the contribution that electricity makes to our life-styles and quality of life and technological development.

Electricity costs are important, but so are the costs for land, labor, materials, transportation and other factors. Usually, employment in electric utility services is only a small portion of total employment in an economy. However, we also have jobs tied to companies that provide equipment, materials and services to the electric power industry, and jobs in electric power services outside of the utility companies themselves.

Though the electricity supply industry Ghana contributes only 10 percent of its energy-supply mix, the industry is a key driver of economic growth and development, powering the country's industrial, commercial and urban development. The industrial, agricultural, mining and services sectors of the Ghanaian economy, which together account for 75 percent of the country's GDP, rely critically on the electricity industry for their survival. The electricity industry accounts for 14.7 percent of total energy share in the industrial sector, and 32.6 percent energy consumption in the formal manufacturing sector.[2] It also contributes 2.8 percent of real GDP and 10.65 percent of industrial GDP. With a customer base of approximately 1.4 million, it is estimated that 45-47 percent of Ghanaians including 15-17 percent of the rural population have access to grid electricity with a per capita electricity consumption of 358kWh while the average annual growth rate stands at 9.7 percent.[3] According to the Ministry of Mines

[2] Armah, B. 2002, Economic Analysis of the Energy Sector, Institute of Economic Analysis (IEA) Ghana

[3] ECG Management Support Services Contract 2004

and Energy (1996)[4] rapid growth in domestic demand for electricity, which averaged 10 percent per annum between 1985 and 1993, increasing further to 15 percent by 1995 was a result of positive economic growth and the National Electrification Programme embarked upon by the government during this period led to electricity demand gradually catching-up and eventually surpassing generation capacity.

5.3 Environment and Energy Policy Issues

Environmental concerns are a prominent part of every industry today and the electric power industry is no exception. Coal and lignite are taken from underground and strip mines. Natural gas wells are drilled to provide fuel to generate electricity. Power plants that use fossil fuels emit pollutants that are subject to emissions regulations. Transmission lines are spread across the state, affecting human and natural environments. These activities are monitored and regulated, but because of the size and scope of the industry there will continue to be concern about electric power and its environmental effects.

Fuel Choices

Power plants use various fuels that are linked to problems like acid rain, urban ozone depletion, global warming and waste disposal. Each fuel has environmental advantages and disadvantages. Coal, one of the lowest priced fuels, requires considerable treatment of emissions to meet environmental standards and its use triggers concerns about global warming. Natural gas, a more expensive fuel, burns cleaner than coal but can contribute to ozone formation in urban areas. Wind and solar power which require relatively high capital costs produce no direct emissions and have virtually no fuel cost but they can be unsightly or impact wildlife negatively. Nuclear power plants emit no combustion gases but have raised the issue of long-term disposal of spent fuel.

Ghana generates most of its power from hydroelectric facilities, which do not cause emissions of harmful elements into the atmosphere; but their large reservoirs have some impact on the environment by flooding large areas, causing people to move, changing the ecology and causing silt formation.

Air Pollution

Acid rain, urban ozone depletion, particulate emissions and global warming are the four primary air pollution concerns for the electric power industry. Power plants contribute relatively little to emissions of volatile organic compounds (VOCs - associated with ozone formation), carbon monoxide, nitrous oxide (a greenhouse gas and oxide of nitrogen), or methane (a greenhouse gas). Because of effective control devices, power plants contribute little to the problem of particulates.

Acid Rain: Acid rain refers to precipitation which has a high acidity level that poses a risk to human and ecosys-

[4] Load forecast studies suggest that peak demand on the Ghana system would double in 10 years requiring over 2000 MW of peak capacity compared to the present peak demand of 980 MW (Opam and Turkson, 2000)

tem health. SO_2 emissions from burning coal (or any fuel containing sulfur) reacts with water vapor and becomes an acid. The acids may mix with water, fall to the earth, or combine with dust particles. These may damage plants, marine life, or human health, including increasing mortality rates in humans. SO_2 is subject to federal and state air quality standards.

Urban Ozone: Power plants produce a substantial portion of NO_X as a product of combustion. These oxides react with VOC's in the presence of sunlight to produce ozone. Ozone has various nonfatal effects on human health and some types of vegetation. NO_X and VOCs are subject to federal and state air quality standards.

Global Warming: Greenhouse gases keep the earth's temperature within a certain range by capturing part of the sun's heating effect within the earth's atmosphere. Some fear that global warming will result from increased CO_2 levels (and other greenhouse gases) in the atmosphere, leading to increased temperatures, changes in precipitation and other harmful effects. CO_2 and NO_2 are two greenhouse gases produced by fossil fuel (coal, natural gas, and petroleum) power plants. Natural gas has about 60 percent of the carbon content of coal and, as such, produces less CO_2.

Particulates: Although power plants contribute relatively little to this problem, particulates are the subject of increasing concern for their impact on human health. Particulates are associated with other pollutants, such as SO_2 from power plants, and are likely to be subject to future air pollution control strategies.

Transmission Lines and Stations

Development of new transmission lines, expansion of existing lines, and construction of new distribution facilities are often met with public resistance. Environmental concerns are part of the reasons given for this resistance.

Transmission lines may require intrusion on natural areas, be visible from scenic areas or intrude on residential neighborhoods. They may destroy or disrupt wildlife habitats. Solar and wind power facilities supported by environmental groups have faced similar public reaction.

There has been ongoing public concern about the health effects of high voltage power lines. The National Research Council in the U.S. has found that there is "no conclusive and consistent evidence" that electromagnetic fields cause any human disease or harmful health effects. However, despite these findings, this issue will likely continue to be an environmental and health concern for the general public.

Related Energy Policy Issues

Environmental concerns are also linked to energy issues such as the use of alternative fuels to generate electricity and energy efficiency. Alternative fuels are defined in different ways, but are often simply alternatives to conventional fuels. There are usually environmental or energy-related benefits associated with alternative fuels. For example, natural gas used as a transportation fuel is considered an alternative that can be cleaner than conventional gasoline, but natural gas for power generation is not considered to be an alternative fuel (it is considered by many to be a cleaner fuel, however).

Alternatives for power generation include hydroelectric power, solar electricity, wind energy, biomass energy and geothermal power. The fuels for each of these are available at little or no cost; they are often renewable fuels; and they may produce little if any direct emissions. Proponents argue that the environmental costs of conventional electric power are not reflected in the cost of electricity produced. If these costs (externalities) were included, alternative fuel electricity would be very competitive.

Solar electric power can be produced through various technologies. Costs have declined substantially and in some applications, solar electricity is economically competitive. Solar panels and large solar arrays face environmental and community opposition similar to placement of other large electric power facilities.

Wind energy technology is available today at competitive prices (advanced wind turbines). Wind resources are fairly site specific.

Biomass energy is produced from conversion of plant and animal matter to heat or to a chemical fuel. It encompasses the widest range of technologies including converting garbage to methane, burning materials to produce heat to generate electricity and fermenting agricultural wastes to produce ethanol. Many biomass energy approaches rely on renewable fuels. Because of the differences in these technologies, it is difficult to generalize on the environmental issues associated with them.

Geothermal power relies on the heat energy in the earth's interior. Some resources cannot be used for electricity production. However, heat from these resources could be used as a substitute for heat from an electrical source. The economics and environmental effects of such applications limit their viability.

While the benefits of cleaner, alternative energy sources for electricity are appealing, they do pose operational considerations for the management of electricity services. For one thing, they are "intermittent" power sources (the sun does not shine at night, the wind is variable), and peak availability of alternative energy sources does not always coincide with peak demand. Options like solar and wind cannot provide consistent power production, in contrast to the coal and nuclear facilities that are usually used for "base load" (the units operate continuously providing a consistent power base). Many solar technologies tend to be implemented in conjunction with natural gas turbines. In addition, both solar and wind require large amounts of acreage when deployed for large-scale power generation.

Technological advances are such that some success in integrating wind-generated electricity has been achieved. Likewise, hydro facilities provide a readily available power reserve (interrupted only by periods of extreme drought). Solar poses more of a problem, because some form of storage is required. Scientists are experimenting with a variety of storage solutions, like letting daytime heat accumulate in fluids like molten salt so that turbines can continue to operate after sunset. However, it will be some time before the economics of utility-scale renewable technologies become favorable. The operating cost of new natural gas turbines has dropped by half or more during the past decade, so that electricity from most renewable energy technologies is usually 150 to 400 percent more expensive than natural gas-fired turbines with the range dependent upon the age of gas turbine and the price of natural gas. The cost of wind power, however, has fallen significantly to a range of 4 to 6 cents per kWh within the last decade and costs are expected to drop another 20 to 40 percent over the next 10 years.

What many renewable technologies (and some small scale technologies like natural gas microturbines and fuel cells) do offer are options for users in remote locations. An isolated community can distribute electricity to its residents "off-grid" (meaning that there does not have to be a connection to a transmission line). Or, excess power from location-specific generation, including co-generation, can be distributed "on grid." Distributed and off-grid generation bear significant implications for the future.

Energy Efficiency and Conservation

Energy efficiency and conservation are two sides of the same environmental and energy policy coin. The impacts of the environmental issues discussed above are all reduced by simply using less electricity. New electricity demand is met through energy savings rather than the provision of more electrical power.

Energy efficiency usually applies to technological improvements that reduce electricity needs, for example, more efficient electric motors, low energy lighting, improved insulation and high efficiency refrigeration. Co-generation can provide an energy efficient means to sequentially produce both power and useful thermal energy (steam/chilled water) from a single fuel. Technological improvements have substantially increased fuel efficiency and lowered capital costs during the last decade.

Reduced energy use also includes changes in operations and behavior that result in less electricity consumption; for example, turning out the lights when leaving a room or building.

Utilities can implement energy efficiency and conservation efforts through programs called demand-side management (DSM). Utilities help customers to reduce electricity use by providing energy audits and information on energy saving appliances and habits ("bill stuffers"). Other initiatives include offering rebates to customers who install energy saving appliances, compensating utilities that reduce electricity load through efficiency programs by allowing them to earn a higher rate of return or encouraging customers to reduce peak-period demand (i.e., installing devices that reduce a customer's load during daily peaks in demand).

However, many economists argue that if costs and benefits are correctly measured, electric utilities may be spending much more on efficiency programs than the value of benefits obtained. Other strategies, like marginal pricing which would force customers to pay more of what it actually costs to provide electricity, may be more effective for rationing electricity use. Retail electricity providers in restructured markets where retail choice is allowed have already started to provide energy services, which include inspection of the site, installation of energy efficient equipment and insulation, monitoring of energy usage, and so on. With the growing attention to efficiency and conservation, new businesses have emerged and existing ones have grown, creating numerous opportunities. These businesses include everything from companies that research, develop and manufacture energy saving devices (like lighting and building materials, automatic/remote thermostat controls, advanced real-time meters, storage devices, etc.) to those that provide independent audits and information services.

5.4 Financing and Operations

Electricity infrastructure (power generation plants, transmission and distribution lines, metering) is expensive to build, maintain and operate. Financing of these projects can be challenging. State companies that fail to recover their investments because of inefficiencies, inability to collect bills or charge cost-reflective tariffs cannot be expected to finance future expansion or maintenance. Regulated monopolies can secure financing more easily but they can invest more than necessary and inflate costs, and they will face similar challenges regarding tariffs and collection. Policies to make the electric power industry more competitive have big financial and operational impacts on these investments.

Electricity Investments and Technology

Transmission and distribution costs have been most heavily impacted over the years by inflation (which affects the cost of labor and materials), interest rates (which affect the costs for utilities to borrow money), dealing with environmental concerns (costs associated with environmental studies and mitigation) and other factors. In contrast, the costs associated with generation have generally declined due to technological improvements, including those for alternative electric energy sources, and lower costs for conventional fuels.

The impact of technological innovations has had a significant impact on generation costs. Improvements in natural gas turbine design have made gas much more competitive with coal. New turbines are essentially jet engines that use a pressurized mixture of gas and air to spin the turbine. New "combined-cycle" turbines take excess heat generated from the gas turbine and use it to power a conventional steam turbine. This combination has pushed turbine efficiencies beyond 50 percent, and continued improvements are expected in coming years. The new generation of turbines is relatively cheap, modular and can be brought on-line quickly. Gas derived from coal or biomass can also be used to drive combined-cycle turbines. Turbines using higher pressures and efficiency gains in performance are improving rapidly.

Because of the development of turbine technologies and improvements in alternative energy technologies (mainly in solar panel and wind turbine design), the costs of electricity generation from natural gas and alternative fuels are on a downward trend, while flexibility and ease of installation are on an upward trend.

Where investments of billions of dollars were a matter of course for nuclear and coal facilities, it is likely that the financial requirements of the electric power industry in the future will be much different. However, it is clear that for the electric utilities, especially those that have invested heavily in coal and nuclear facilities, the advent of cheaper, more flexible turbine design and generation alternatives means that financial pressure everywhere in the electric power industry is likely to increase.

Historically, financing of the operational activities of Ghana's electric power industry has been from government, either through multilateral or bilateral loan agreements. The first major government financing of operations of the country's electricity industry dates back to the early 1960's when the Government contributed £35 million as its equity investment in the Volta River Project. This was followed by several other loans and grants which were on-lent to both the Volta River Authority and the Electricity Company of Ghana. Despite Government efforts at financing the operations of the VRA and ECG, the two state-owned generation and distribution utilities have continued to incur huge debts which in turn undermined their operational capability. To address the problems posed by the high level of debt and also enhance the operational performance of the two companies, the Government in 1998 undertook restructuring and re-capitalisation of the VRA and ECG. Following the approval of tariffs by the Public Utilities Regulatory Commission in September 1998, the Government initiated action to deal with the mounting liabilities of the power utilities. To that end, the Government, the VRA and ECG each adopted Financial Recovery Plans which led to significant debt relief to the ECG amounting to US$ 95.6 million.[5] In addition, total debt relief amounting to US$88 million was also written-off by the Government.

As part of its macro-economic restructuring programme with the World Bank and IMF, the Government agreed to continue to provide the ECG with further debt relief annually up to 2008, while undertaking to secure further funding for the company to undertake critical short-term investments in the company's distribution system. These recipes, if observed and if the company is able to manage its operations prudently, should significantly improve the current financial position of ECG in the coming years. The government also granted the VRA total debt relief amounting to US$ 144.9 million under the Heavily Indebted Poor Countries (HIPC) Initiative Debt Relief programme, while discussions with International Development Association (IDA) are on-going on the preparation of a new Distribution Sector Upgrade Project; this is intended to inject a further US$105 million of support for Northern Electricity Department (NED). In addition, the Government continues to meet the US$ 10 million quarterly crude oil supply to Takoradi Thermal Power Plant. It is argued that these measures, especially the debt relief, have drastically reduced VRA's debt portfolio and raised its return on average net fixed assets (regulated

[5] The Government of Ghana under pressure from the World Bank and the IMF opted for the Heavily Indebted Poor Countries (HIPC) Initiative in 2000.

assets) in operation from negative (4.5 percent) in 2002 to 2.25 percent, in 2003. Available records show that, between 1997 and 2002, both the Volta River Authority and the Electricity Company of Ghana had recorded huge losses from their operations, details of which are shown in the Tables 5.1 and 5.2. For example, the total debt stock of the VRA including medium to long term and short-term loans as at December 31, 2002 amounted to 3,910.9 Billion cedis and 1,075.1 Billion cedis respectively.

***Table 5.1:* Financial performance of VRA, 1997-2002 (in ¢Billion)**

Year	1997	1998	1999	2000	2001	2002
Operating Profit/(Loss)	61.2	18.7	79.2	(257.9)	(220.0)	(582.5)
Net Profit/(Loss)	(58.6)	(105.2)	(283.2)	(983.3)	(329.7)	(1,269.1)

Source: Volta River Authority (VRA), Annual Reports and Accounts for 1997-2002

***Table 5.2*: Financial performance of ECG, 1997-2002 (in ¢Billion)**

Year	1997	1998	1999	2000	2001	2002
Operating Profit/(Loss)	(33.9)	6.0	17.3	(13.6)	152.9	(85.3)
Net Profit/(Loss)	(80.9)	(27.5)	(79.2)	(394.0)	110.1	(380.5)

Source: Electricity Company of Ghana (ECG), Financial Statements for 1997-2002

5.5 Performance of Ghana's Electric Power Industry

Ghana's electricity supply industry infrastructure comprises two hydroelectric dams, which until the late 1990's virtually supplied all of Ghana's electricity (99 percent), two thermal generating plants and a network of transmission and distribution infrastructure. The two hydroelectric plants, namely the Akosombo Generating Station and Kpong Generating Station both of which are owned and managed by the Volta River Authority (state-owned generating company) have installed capacities of 1020 MW and 160 MW respectively. The company also owns a 90 percent shareholding in a 330-MW Combined Cycle Gas Turbine (CCGT) (Takoradi Thermal Power Company, TAPCO) with CMS Energy of Michigan USA holding 10 percent and a further 10 percent equity holding in a 220-MW Simple Cycle Gas Turbine (SCGT) (Takoradi International Company), with the CMS Energy of Michigan USA holding the remaining 90 percent.

The Volta River Authority also owns and operates a high voltage transmission network infrastructure, which consists of 3,670 circuit kilometers of 161-kV lines, 133 circuit kilometers of 69-kV lines and 35 associated substations. Other transmission network assets owned by VRA include a 129-kilometer double circuit of 161-kV lines connecting Ghana to Togo and Benin and a single 220-kilometer line of 225kV line connecting La Côte d'Ivoire to the west of the country.

As part of the arrangements to expedite the Northern Grid Extension and System Reinforcement Project, the government in 1987 extended VRA's mandate to distribution of electricity in the northern part of Ghana. This led to the creation of the Northern Electricity Department (NED) as a subsidiary of the VRA to implement the northern distribution zone component of the National Electrification Project. As such, the VRA became a vertically integrated monopoly in generation, transmission and distribution of electricity. As a corporate body, the VRA has since its establishment in 1961 under the Volta River Development Authority Act, 1961 (Act 46) been operated as a quasi-enclave within Ghana enjoying a high degree of autonomy.[6]

The Electricity Company of Ghana (state-owned distribution utility) is the premier national distributor and retailer of electric power in the southern sector of Ghana. The company owns and manages the distribution network infrastructure. It has an installed transformer capacity of about 3,004 MVA and 6,149-km of sub-transmission lines, which are made up of 1,200 km of 33-kV sub-transmission lines, 450 km of 11-kV distribution circuits within the major urban centers and approximately 4,049 km of other lower voltage distribution circuits for retailing electricity. The total length of the company's distribution network is about 63,474 km.[7] Power supply capability in the Ghanaian electricity supply industry including imports from neighbouring La Côte d'Ivoire exists and is well above the system maximum demand of 1,200 MW by about 57 percent. However, the total amount of energy that can be delivered is constrained by several factors including the low level of water in the country's hydro system (Akosombo reservoir), technical problems with the 330-MW state-owned combined cycle thermal plant and transmission bottlenecks on the Western Corridor.

As with the country's generation system, Ghana's electricity distribution sector has been bedevilled with several problems including: (i) inadequate and outdated infrastructure; (ii) underfunding and under-investment; (iii) managerial problems; and (iv) low tariffs coupled with under recovery and inability to collect bills etc, all of which have led to unreliable supply and long outages, high system losses, unsustainable debt levels and severe liquidity problems. These factors have contributed not only to the lack of competitiveness of Ghana's electricity industry, but have also created significant social issues.[8] It has been argued that for Ghana to achieve its GDP growth target of eight percent, it is absolutely essential that the minimum power supply growth rate be at a

[6] Edjekumhene, Amadu, and Brew Hammond (2003) "Power Sector Reform in Ghana in the 1990's: The Untold Story of A Divided Country Versus A Divided Bank."

[7] Energy Commission (2005), Strategic National Energy Plan 2005-2025.

[8] *State of the Ghanaian Economy 2002*, ISSER, University of Ghana, Legon.

factor of 1.5 of the GDP growth.[9] It is observed that limitations on electricity services delivery to consumers are both technical and infrastructural in nature[10] and cut across all aspects of the electricity generation and supply business. Ghana's distribution network is bedevilled with bottlenecks resulting from poor maintenance of equipment installed over 30 years ago and overloads in the low voltage systems.

According to Center for Policy Analysis (CEPA),[11] the long-term energy problem of Ghana was compounded by the public sector dominance of the power sector. These constraints have led to serious deterioration in the performance of the industry over the last several years resulting in customer dissatisfaction and general discontent by Government. While inadequate investment in generation and distribution infrastructure,[12] have played a significant role in the unsatisfactory performance of the industry, to a larger extent the difficulties faced by the state-owned electric utilities as the key players in the electricity industry may be attributed to poor management and staff dissatisfaction. According to a 2001 Management Audit of the operations of the Electricity Company of Ghana, though the company has established a sound record of system planning as well as in projects implementation, ECG is an electric utility in crisis.[13] The report reveals the inefficiency of ECG operations and the shortcomings of its commercial performance.

Under-performance on the part of management and staff has led to several negative impacts; for instance, the continued government interventionist role in the industry, which goes beyond the policy and ownership role of the state. The current level of liabilities of the distribution utility for instance, which is estimated at about US$300 million, it is argued is too high to be sustainable considering the current annual revenue base and collection rates of the company. The absence of effective control systems of critical expenditure, particularly fuels and capital expenditure in respect of distribution system extensions for which the company has no funding, has also compounded the difficulties of the company.

The operations of ECG and NED are also characterised by high system losses (unaccounted for electricity in the system) of about 26 percent and 30 percent per annum respectively. Of these, 16 percent is non-technical loss resulting in an annual revenue loss of about US$40.3 million, whilst low collection rates of electricity bills averaging 87 percent per annum has resulted in a further loss of about US$27.7 million per annum. It is estimated that revenue losses resulting from the company's operations will grow significantly as the demand for and supply of electricity grows if

[9]Address delivered by the Minister for Private Sector Development at an International Investments Forum for Electricity Sector Investors in Accra on January 26, 2005.

[10] *Study on Electricity Services Delivery to the Private Sector*, Private Enterprise Foundation, 2003.

[11] *Ghana Mid-Year Micro-economic Review*. Jan-June, Centre for Policy Analysis, Accra, 1998.

[12] Sources within the ECG intimated that no significant investments have been made in the company's distribution network over the past 10 years resulting in unreliable supply and periodic extended outages.

[13] ECG Management Support Services Contract, 2004.

nothing is done about the huge system losses and poor collection rates. In general, the technical and financial performance of ECG continues to deteriorate as the company does not generate enough financial resources to address the issues of technical and non-technical losses that impede the increase in access to electricity and improvements in the quality of service such that ECG is no longer servicing its current debt obligations.

6. Future Trends

6.1 Introduction

If the recent past is the prologue, then we can be assured that the electricity industry will continue to become more competitive and that some changes will take place. Electricity will remain an important component of our daily lives, perhaps increasingly so as we move forward into the Information Age. There is sure to be conflict about how to best provide electricity to all users, how best to facilitate consumers' desire for choice and how to manage all of this while protecting the environmental and social values that are important to us.

We can strive to consider what the future will hold in today's decision making, but that is often not possible. Looking back at the historic changes in telecommunications, airlines, trucking, banking and natural gas around the world, there are many things that could have been done differently. Perhaps the best we can do is to watch the key trends and try to anticipate the actions of today with the needs of tomorrow. Here are four key trends to watch in the electric power industry.

6.2 Technological changes

In the past, the main source of power generation in Ghana has been hydro with some amount of generation from diesel plants. It is anticipated that thermal power generation mainly from natural gas will become a significant source of electricity generation. Natural gas supply is expected to come mainly from Nigeria, possibly from La Côte d'Ivoire and possibly from domestic sources if natural gas finds in Ghana are in commercially significant quantities.

The electric power industry has often been criticized as a "low technology" industry, but nothing could be farther from the truth. In this document we have discussed a number of technologies that are vastly changing the way electricity is produced, delivered and priced. Future expectations for electric power should be no different, but the outcomes may take a different form. Around the world, utility spending on R&D may be affected by increased competition, but new R&D arrangements are likely to emerge from smaller technology companies such as Ballard (manufacturer of fuel cells), major corporations such as General Electric, Siemens and Westinghouse as well as state-owned entities in China, India and South Africa.

New Generation Technologies

In addition to the advances in natural gas turbine design, new ways to achieve clean combustion of coal and fuel oil and improvements in alternative energy technologies, there are technologies on the horizon that may completely change the industry. Often discussed are fuel cells, which use electrochemical reactions - like automotive batteries - to produce electricity. Most promising are fuel cells that can use natural gas as feedstock for producing hydrogen. Fuel cells are smaller and modular and could be used to power individual buildings or neighborhoods with none of the noise and unsightliness of traditional generating stations. Fuel cells, improved solar technologies and other developments may lead to a "decentralizing" of electric power systems, allowing small scale applications and resolving many of the potential reliability problems that customers fear.

Further into the future, economic nuclear fusion technologies may finally be achieved. Unlike nuclear fission, fusion is the combination of atoms to produce heat. Fusion is a long sought technology that holds the tremendous promise of clean, renewable energy, if it can be achieved.

Given the abundance of coal resources around the world and the recent concerns about natural gas resource base and prices, there is an increasing interest in technologies that may help lower the emissions from coal-fired generation. Older coal plants with higher emissions will need to be replaced in many countries. Neither renewable nor gas-fired generation may be sufficient to substitute for all of the coal-fired capacity. One of the most promising and definitely most talked about technologies is the integrated gasification combined cycle (IGCC) approach where coal is gasified.

Microturbines, solar power (either as large collector farms or photovoltaic cells on buildings), and ocean power (using either the tidal currents of waves) are other technologies that are being watched closely by the investor community. On the other hand, wind energy, which has established itself as the most rapidly growing renewable technology, started to face problems as public opposition to wind farms became more vocal and government subsidies were challenged in some countries. Nevertheless, improvements in technology lowered costs and offshore offers a less objectionable frontier for wind farms.

Transmission, Distribution and Storage Technologies

As electricity travels over the transmission grid, much of it is lost (sometimes upwards of 10 percent). This is because the materials typically used in transmission wires can only withstand a certain amount of heat. New superconducting materials may change that. At research centers around the world, scientists are developing new materials that can withstand levels of heat and stress beyond anything achievable with traditional metals. These materials, if they can be economically developed for applications like electricity transmission, will dramatically reduce the amount of electricity that must be generated and allow electricity to be efficiently transported over long distances. Experiments with short-distance high voltage lines that use superconducting materials have produced encouraging results.

For electricity to be more easily managed, new ways of handling electricity are needed that take advantage of superconducting materials and devices. One such technology is the use of superconducting devices for instantaneous management of electric power. Such devices would enable various power management services such as stability enhancement, increased transmission capacity, voltage and frequency control and other quality enhancements for a transmission company or utility.

Storage technologies are the biggest hope and at the same time challenge for the electricity industry. Flywheel technology seems to be the most advanced. A Texas company, Active Power developed the first commercially viable flywheel energy storage system and has distribution deals with companies such as Caterpillar, GE and Invensys.

Information Technologies

The sophistication of electronic information systems is one of the most important factors in the drive to restructure industries like natural gas pipelines and utilities and electricity transmission and utilities. These information systems have removed many of the barriers to common carriage by allowing real-time management of energy flows and exchanges.

Electronic bulletin boards and software systems required by regulators for pipeline transportation and electricity transmission include information on capacities, prices, transactions and other variables. This information is necessary to facilitate a properly functioning marketplace. It also facilitates the development of "secondary" markets so that holders of excess capacity on pipelines or transmission grids can release or resell that capacity. This prevents many of the kinds of disruptions and shortages that have posed serious problems in the past.

Finally, the advent of information systems for natural gas and electricity has supported the growth and effectiveness of new businesses, independent third party marketers of gas and power in advanced markets. These companies - they may be entirely unaffiliated or they may be "nonjurisdictional" or unregulated affiliates of gas pipelines or gas or electric utilities - act as intermediaries in a complex marketplace. Using electronic information, they are able to package services and build flexible arrangements and contractual terms between suppliers of gas and electricity and end users.

The development of electronic information systems has been one of the most important factors in the reconceptualization of what monopoly in a gas or electricity service is. These tools have enabled the separation of the commodities gas and power from the physical systems used to deliver them to customers. The result is that the scope of regulation can be narrowed to the physical systems, where before it applied to both the systems and the commodities (which were not commodities since there were not separate markets for the exchange of gas and electricity). This has been a critical step in the evolution of both the natural gas and electricity industries.

6.3 Financing

According to the International Energy Agency's *World Energy Investment Outlook 2003*, an investment of roughly $10 trillion worldwide will be needed between 2001 and 2030: $4.4 trillion for new generation capacity; $1.6 trillion for transmission lines; and $3.6 trillion for distribution grids. Although more than half of this investment will be in developing countries, there would be about 1.4 billion people without access to electricity in 2030. Only about $2 trillion will be invested in building new generation in the developing world. The IEA estimates that an additional $665 billion will be necessary for 100 percent electrification.

Similarly, the World Bank estimates that developing countries will need $120 billion a year between 2004 and 2010 in infrastructure investments in the electricity sector.[14]

Since the 1980's, numerous states and nations have attempted significant electricity reform. In those nations where electricity assets have been publicly owned, privatization and/or corporatization have been a major element of reform. Many nations have also opened their doors to foreign investment in the electric power industry for the first time. As a result, about $200 billion dollars were invested by the private sector in developing countries, mostly in East Asia and Latin America, between 1990 and 2001.[15] In East Asia, almost 70 percent of roughly $95 billion invested has been in greenfield projects while in Latin America, almost 75 percent of approximately $80 billion has been invested in privatized state assets.

Note that this amount of investment is significantly less than the investment levels estimated by the IEA as needed in the next three decades. Governments, state companies or multilateral agencies cannot be expected to supply the difference. More private investment needs to flow into the electric sector in developing countries.

Unfortunately, after 1997, private investment in developing country power sectors fell significantly from $45-50 billion in 1997 to less than $6 billion in 2002. Over the same period, the number of transactions also declined from about 125 to about 30. The financial crises in Asia, Argentina, and Turkey that led to currency devaluations and macroeconomic instability rendered these investments riskier. Exposure of some investors to these riskier countries as well as problems experienced by some companies in their home markets (e.g., some U.S. companies suffered significantly following the California crisis and the collapse of the energy trading business) restricted the ability to raise financing in international capital markets. Moreover, many companies overpaid based on optimistic estimates of potential return or changes in markets.

In order to meet investment needs of the electric sectors in the emerging markets governments need to create frameworks attractive to private investors as public funds, money-losing state companies, and development assistance cannot provide the investment needed. These frameworks need to be transparent, fair, stable, and credible. The independence, stability and competence of regulatory agencies from political interference are vital. Governments, multilateral agencies, and investors need to be honest with the public and not raise expectations with unrealistic promises about lower prices and increased access to electricity. At the same time, safety nets and subsidy structures must be put in place to protect the most vulnerable. These measures must be independent of electricity prices. The segments of the society which truly cannot afford to pay market prices for their electricity need to be identified carefully and

[14] *Global Development Finance 2004*, the World Bank. April 2004.

[15] See *What International Investors Look for When Investing in Developing Countries: Results from a Survey of International Investors in the Power Sector.* Energy and Mining Sector Board Discussion Paper No. 6, The World Bank Group, May 2003.

financial support provided to them from general government funds and not via the electricity system.

Finally, governments need to lay the foundation for competition by improving commercial practices at vertically integrated state companies *before* they face competition. This commercialization will require the freeing of the government budget from financing losses and reorganizing the companies along functional lines with separate cost accounting. Most importantly, governments must allow electricity prices to adjust until they are high enough to recover costs so that these companies can become profitable. Improved productivity and cost reductions can be achieved through management contracts, capacity-building programs, and other human resource actions. These changes, supported by government reforms, will help to improve corporate governance and transparency in the sector. With these reforms, it will be much easier to attract private investment to the electricity sector or restructure the market.

The power sector of Ghana has, in the past, been financed through bilateral loans contracted with Government guarantees on behalf of the sector organisations and Government direct financial support. In recent times, Government's policy has been to attract the private sector to finance the development of the sector. The first mainly private sector owned power generation plant, the Takoradi International Power Company (TICO), with a 220MW capacity was constructed in 2000. With the arrival of natural gas through the West Africa Gas Pipeline (WAGP) and the existence of a well-regulated market structure, Ghana should expect to see more private generation to come online.

6.4 Industry Re-organisation

The re-organisation of the electric power industry in Ghana was initiated in 1995 under a Power Sector Reform Programme (PSRP). The reforms were intended to create the environment to attract private sector investments in the power sector owing to the fact that Government of Ghana and its traditional financiers (the World Bank and other bilateral donors) were not able to provide the significant funding required for future expansion of the power system. Following from the initiation of the programme in 1996, the Energy Commission (EC) and the Public Utilities Regulatory Commission (PURC) were established as part of the reforms in 1997.

Other aspects of the reforms, particularly the re-structuring of the Volta River Authority (VRA) and the divestiture of the Electricity Company of Ghana (ECG), were not effected. The re-structuring of the sector involved:

i) Reconstitution of VRA into two companies – a Hydro Company (including non-core activities) to be responsible for hydro generation, and another company to own the Aboadze Thermal Power Complex;

ii) Establishment of a separate Transmission Company, wholly-owned by Government to provided non-discriminatory, open access transmissions service in order to offer a level playing field for all participants in the power market;

iii) Reconstitution of ECG and NED, the existing distribution utilities, into a single Distribution Company.

iv) Establishment of a Wholesale Power Supply Market (WPSM) to create an environment for the competitive procurement of power. It is envisaged that and Independent System Operator will manage the operations of the electric power market in Ghana.

Key Drivers

Like in many other countries, the fundamental drivers for restructuring the Ghanaian electricity sector are primarily three-fold:

- Investment shortages
- High electricity prices
- Technological developments, particularly those related to the growing efficiency of natural gas turbines.

Investment Shortages: In the developing world, a lack of access to capital has hindered investment in infrastructure projects, including power generation, transmission, and distribution facilities. State utilities in many countries are not profitable and hence are unable to finance their own projects. The utilities are not able to generate sufficient revenues because of low electricity prices (usually subsidized by governments), payment and collection shortfalls, and system losses. If they are also required to purchase fuel, especially oil products, for their power plants at world prices their financial situation becomes even more precarious. The IEA expects fuel purchases by developing country generators to cost almost $5 trillion by 2030 – roughly equivalent to total electricity sector investment required in those countries. State utilities also suffer from high production costs which primarily result from operational and maintenance problems that lower efficiency and from a high level of system losses (both technical and non-technical). Poor fuel quality, high cost of equipment due to non-competitive and/or non-transparent procurement practices, and poorly designed electrification policies necessitating high levels of investment in transmission and distribution networks also contribute to higher costs.

Governments cannot, and should not, be expected to continue to support inefficient state utilities or finance new projects while their budget deficits and sovereign debt increase. Their revenues are usually low and unpredictable due to inability to collect taxes and volatile economic performance. Governments have other priorities such as health and education and are better placed to focus on providing services in these areas. Traditional funding for infrastructure investments from development assistance, and especially bilateral aid, has declined significantly as donor countries have meticulously examined past results. Development agencies such as the World Bank started to require economic reforms, including energy sector restructuring, as a precondition to further assistance.

As a result of these developments, many countries have opened their electricity sectors to foreign investment, primarily in generation. This has been particularly true for countries that suffered most during the debt crisis of the 1980s, especially in Latin America. Moreover, during the 1980's, financial institutions, in particular commercial banks, incurred severe losses from loan defaults among developing nations which may have had a limiting impact on the developing world's access to some world capital markets and may have driven developing countries to allow greater direct investment from abroad.

High Electricity Costs: Electricity costs vary considerably across regions and countries, mostly depending on fuel diversity and reflecting poorly financed (or regulated) large investments, technical and non-technical system losses, and operational inefficiencies. Sometimes prices reflect these costs but at other times they are shielded by government policies such as subsidies. Electricity prices also vary considerably with the ownership structure of the industry and the degree of regulation. The resulting price differentials can have a significant effect on a region's degree of competitiveness. They can also affect real standards of living. Therefore, it is not surprising that many high-cost electricity regions were among the earliest reformers. For instance, both California, where 1995 electricity prices were 43 percent higher than the U.S. average and Germany, where industrial electricity prices were 15 percent higher than in the Organization of Economic Cooperation and Development (OECD), were early reformers. The consumers (in particular, large industrial and commercial consumers) in these regions were avid proponents of competition. The price of electricity continues to be a key cost factor for most industries, perhaps even more so now than before due to increased automation of many processes. As such, industries will continue to push for restructuring that can lower their electricity prices. Clearly, low-cost electricity is important for developing countries as well because it helps to increase access to electricity and allows local industries to develop cost competitiveness.

Technological Developments: Electricity generation has always been thought to exhibit economies of scale requiring construction of larger plants and expansive transmission and distribution networks. Technological developments (in particular, in natural gas turbine technology) however, have changed this. It is now possible to build smaller, more efficient units. For example, a state-of-the-art combined-cycle gas turbine (CCGT) generating unit is more efficient than coal or nuclear units (roughly 50 percent versus 35 percent on average – 6,800 versus 9,800 heat rate).[16] Gas-fired plants also have shorter construction times. The time needed to build a natural-gas-fired generation unit averages two to three years, compared with three to five years for coal plants, and five to seven years for nuclear plants. Construction time is only one of the factors that increases the capital cost of coal and nuclear facilities, which are on average 2-3 times more costly on a kW basis than a modern CCGT plant. Natural gas plants are also more flexible. The maximum efficiency of a gas-fired power plant is achieved at a much smaller level of capacity than a coal-fired unit. As a result, the size of a new natural gas plant can be adapted readily to various

[16] GE's new H-series turbines promise heat rates as low as 5,700, raising efficiency to about 60 percent.

changes in demand and the plant can be built closer to the load.

All of these advantages make the financing of gas-fired plants easier for smaller, independent players and hence lower the need for integrated utilities. Accordingly, in recent years, almost all new generation capacity added around the world has been natural gas-fired. In resource-rich countries, gas-fired power plants provide an opportunity to monetize stranded gas resources by creating local demand. In most places, low cost of construction, higher efficiency, and lower emissions of gas plants increase their popularity. The liquefied natural gas (LNG) industry, which has been cutting costs across the LNG value chain from liquefaction to regasification, now makes natural gas available to an increasing number of consumers around the world. The IEA expects more than 40 percent of new capacity to be gas-fired. Almost half of this increase will happen in OECD countries; there are significant uncertainties in most other countries regarding the ability to attract capital needed for infrastructure investments such as upstream development, pipelines, LNG terminals and ships, and power facilities.

Developments in other generation technologies from renewable technologies such as wind and solar to clean coal will continue to provide alternatives. As consumers' exposure to market prices expands, their interest in energy efficiency and conservation technologies will also increase. Storage technologies and small scale distributed generation technologies may also play an important role in the electricity industry of the future. These and other technologies at different stages of development will play a dual role. Their commercialization is stimulated by increased competition and market price signals. At the same time their continuous improvement impels and supports restructuring efforts because they provide options to market participants and offer increased efficiency in energy production and consumption.

Key Characteristics

Electricity restructuring has usually involved a separation of the industry along the lines of its different functions as well as a rewriting of rules to allow for competition in generation and marketing. New regulatory agencies were created to supervise the activities of private players in this new marketplace, to protect consumers against market manipulation, to develop service quality standards, and to ensure the successful implementation of the competitive model. There are differences among the approaches used by different countries, but they all involved a combination of the following actions:

- Unbundling of generation, transmission, distribution, and marketing functions
- Open access to the transmission and distribution grid
- Creation of electricity trading arrangements (e.g., pools)
- Creation of independent system operators (ISO's)
- Creation of an independent regulatory agency (if one does not already exist)

- Privatization of electricity assets through sale or public auction, or the corporatization of the governance of the assets
- Deregulation of electricity prices
- Retail competition.

In many places, these are politically challenging reforms. Caught between investment needs of the power sector and the difficulty of implementing restructuring of the sector, many governments sought ways of inviting private capital to build new generation capacity via models such as build-operate-transfer and build-operate. Investors responded but required power purchase agreements (PPA's), which, in many instances, reflected significant risk premiums in their price structures. Not only have some of these PPA's become political issues, they also present serious obstacles to opening the market to competition. Some of these agreements ended up in arbitration while others were renegotiated.

On the other hand, some countries pushed forward with significant reforms although the market was not large or diverse enough for a competitive model. If the market is not large and diverse enough, it probably is not appropriate to pursue a full-scale restructuring with unbundling, open access and all its associated changes. Even if the market is large, the state entities will not attract investors because of their inefficiencies and cumbersome bureaucratic practices. Of course, it is not a simple matter to decide what is too small and what is large enough.

The World Bank itself recognizes the shortcomings of the reform strategy it promoted in many countries: "the Bank's project-level outcomes were disappointing, mostly because the Bank underestimated the complexity and time required for reforms to achieve lasting and equitable outcomes. At the sector level, outcomes have been poor or, at best, mixed, except in countries fully committed to reforms. Private sector development of the electric power sector is a work in progress because the power sector reform process is complex, takes time, is resource-intensive, and requires phasing and careful sequencing to create the conditions for sector transformation."[17]

It is now clear that there is no single model that applies to all countries. As such, instead of following a rote checklist of market characteristics, each country needs to develop its own commercial framework that reflect its own socioeconomic and electric sector circumstances and priorities while following certain fundamental guidelines.

6.5 Electric power and Ghana's neighbours – West African Power Pool

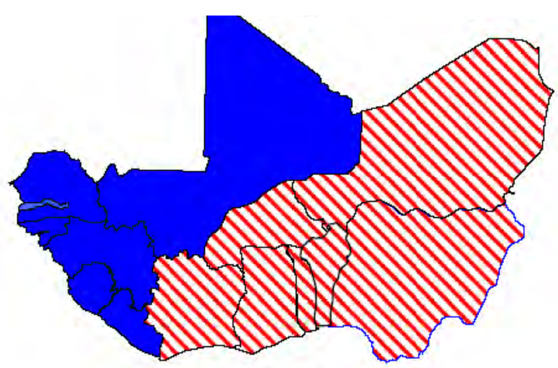
Ghana's electric power transmission system is connected to La Côte d'Ivoire's on the west and to Togo and Benin's on the east. Ghana also supplies electric power to Burkina Faso in the north through a low voltage distribution network. The high voltage transmission system between Ghana and Burkina Faso is being developed. There are other interconnections

[17] *Power for Development: A Review of the World Bank Group's Experience with Private Participation in the Electricity Sector* by Fernando Manibog, published by the World Bank, January 2004.

between countries in the region, including links between Burkina Faso and La Côte d'Ivoire, Niger and Nigeria, and Benin and Togo (Table 6.1).

The existing interconnections are being extended to link all the countries in West Africa with the view of creating a power pool that would consolidate the power generating resources of all the countries in West Africa. In October 2000, 14 ECOWAS (Economic Community of West African States) members signed the West African Power Pool (WAPP) agreement which calls for developing energy production facilities and interconnecting their respective electricity grids to boost power supply in the region. According to the agreement, the WAPP will be accomplished in two phases. The first phase involves countries that are already interconnected, including Nigeria, Benin, Togo, Ghana, La Côte d'Ivoire, Niger and Burkina Faso (known as Zone A).

The second phase involves countries which are yet to have interconnection facilities, which in-



clude Guinea, Guinea-Bissau, Liberia, Mali, Senegal, Gambia and Cape Verde (known as Zone B).

***Table 6.1*: WAPP international transmission lines**

Line	Load capacity (MW)	Voltage (kV)	Length (km)	Capital Cost ($ million)
Benin-Togo	150	161	183	existing
Burkina Faso-La Côte D'Ivoire	200	225	150	existing
Ghana-Togo	256	161	129	existing
Ghana-La Côte D'Ivoire	327	225	220	existing
Niger-Nigeria	70	132	264	existing
Benin-Nigeria	560	330	16	20.00
Gambia-Senegal	20	225	110	27.83
Guinea-Senegal	150			19.27
Guinea-La Côte D'Ivoire	150	225	450	65.22
Guinea-Sierra Leone	80	110	93	13.48
Guinea-Guinea Bissau	150	225	123	17.82
Guinea-Mali	90	225	368	53.33
Liberia-Guinea	80			13.48
Liberia-Sierra Leone	80			13.48
Mali-Senegal	150	225	821	111.34
Mali-La Côte D'Ivoire	100	225	616	88.18
Burkina Faso-Ghana	30	225	116	7.5

Source: *The West African Power Pool & Optimal Long-Term Planning of International Transmission with a Free-Trade Electricity Policy,* Interim Report, 2001, F.T. Sparrow and Brian H. Bowen, Purdue University.

In December 2003, member states signed the ECOWAS Energy Protocol, which calls for the elimination of cross-border barriers to trade in energy, and encourages investment in the energy sector by providing for international arbitration for dispute resolution, repatriation of profits, protection against expropriation of assets, and other terms considered attractive by potential investors. The Protocol provides open and non-discriminatory access to transmission facilities. A regional regulatory body and common standards for maintaining grid reliability are also being developed.

The ECOWAS Energy Information Observatory (EIO), one of the first permanent bodies of WAPP, was established in February 2003. The WAPP EIO is based at the headquarters of the Communauté Electrique du Bénin (CEB) in Cotonou, Benin. The EIO is set to benefit from substantial local contributions by CEB, Togo Electricité, and the National Electric Power Authority (NEPA) of Nigeria. USAID and the French Cooperation currently support the Observatory; but the EIO is expected to become self-supporting by means of a small fee assessed on all cross-border electricity trading within the region.

The WAPP EIO will collect monthly energy supply and demand balances, provide forecasts of potential energy surpluses available for trading, coordinate maintenance schedules, and engage in long-term generation and transmission capacity expansion planning. The EIO is designed to have access to the electricity companies' data and information in each of the member countries. Eventually, access should be allowed in real time.

Key multi-lateral partners in the development of the WAPP are ECOWAS, the World Bank, and the African Development Bank. Other important bilateral donors are Agence Française de Développement (AFD), the French Ministry of Foreign Affairs, and the Japanese International Cooperation Agency (JICA). USAID-funded implementing partners working with ECOWAS and national utility corporations include PA Consulting, Nexant, Associates for International Resources and Development, Purdue University, and the U.S. Energy Association.

Although slightly behind schedule, some of the interconnection projects are under construction or near completion. Nigeria and the AfDB signed a $15.6 million loan agreement in December 2002 for the interconnection of NEPA (Nigerian Electric Power Authority) and Compagnie Electrique du Benin (CEB) networks in Benin and Togo.

Growing demands for power have prompted Burkina Faso to seek import electricity from neighboring La Côte d'Ivoire. A 225-kV power line, connecting the city of Ferkessedougou in northern La Côte d'Ivoire with the Burkina Faso's capital, Ouagadougou, is expected to begin operations in 2005. Burkina Faso employs diesel generators to produce electricity, but high production costs attributed to fluctuating oil prices prompted the government to begin interconnecting Burkina Faso's grid with that of neighboring countries like Ghana and la Côte d'Ivoire to import additional electricity requirements.

Work began in early 2003 on a project to connect portions of Niger to Nigeria's electricity grid. The project involves the construction of three separate networks at an estimated cost of $16 million. The imported power will be much cheaper than the domestically oil-generated electricity currently consumed, and the project will help eliminate several diesel-powered generators.

Overall, WAPP is an ambitious project initiated by ECOWAS Energy Ministers and championed by the ECOWAS Department of Infrastructure. Many international entities and bilateral aid institutions have become involved in this undertaking mainly because they realized its potential benefits for the region.

If the WAPP initiative succeeds in building the interconnections, establishing a transparent and efficient regional regulatory framework, and attracting private investment in power generation, regional economic development will receive a significant boost while saving the regional economies several billion dollars over the next couple of decades.

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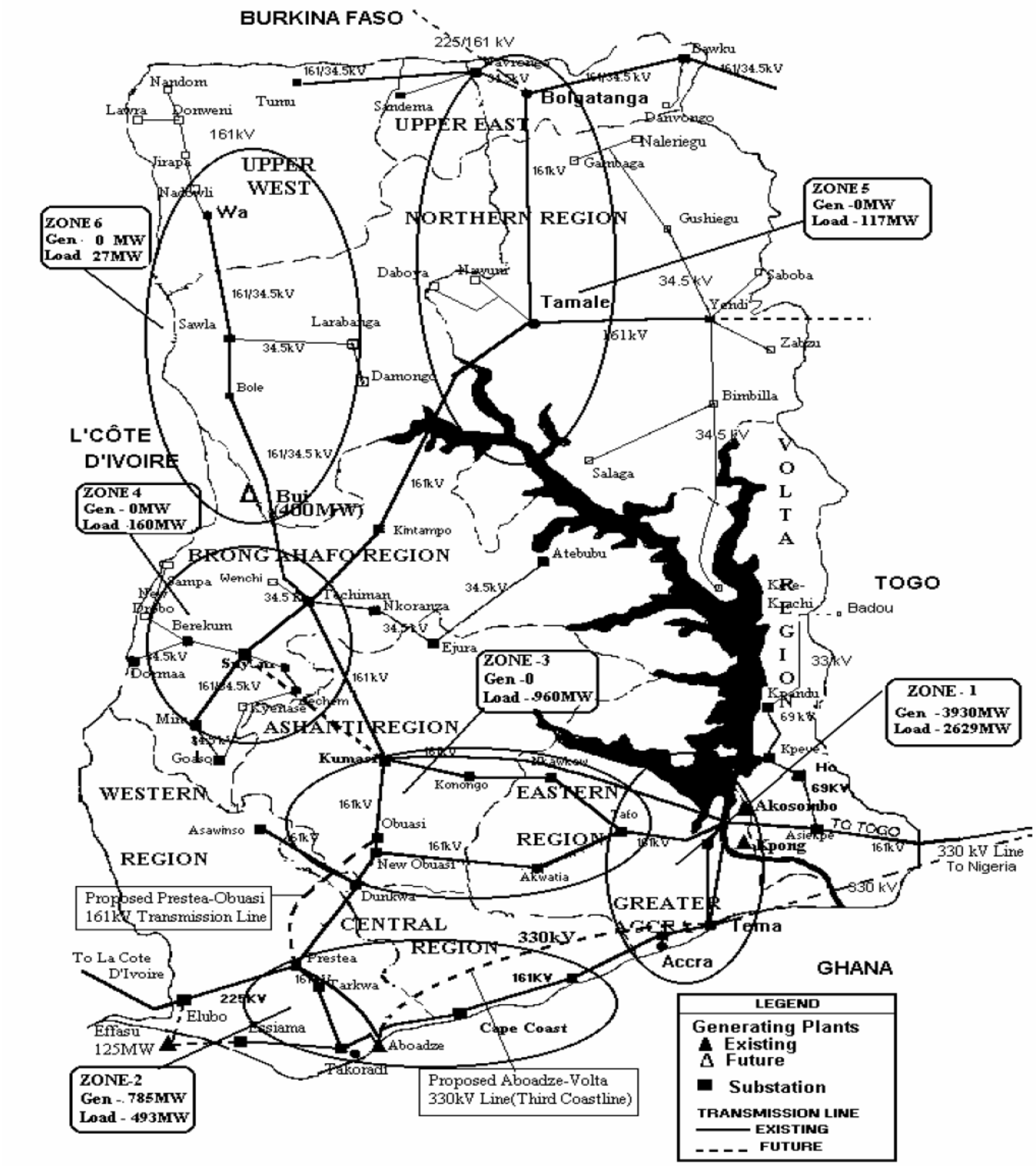
Appendix 1: Ghanaian Electricity Infrastructure



Source: Energy Commission, March 2005.

Appendix 2: Energy Sources for Generating Electricity

Fossil Fuels

Fossil fuels are derived from decaying vegetation over many thousands or millions of years. Coal, lignite, oil (petroleum) and natural gas are all fossil fuels. Fossil fuels are non-renewable, meaning that we extract and use them faster than they can possibly be replaced. Fossil fuels are combusted in boilers in order to convert water to steam that is used to power the turbines in an electric generator.

Coal

A black or brownish black solid combustible fossil fuel typically obtained from surface or underground mines. Coal is shipped by rail to power plants and may be imported from other countries. In Texas, as in other coal producing states, electric generating stations are often "mine-mouth," meaning that they are built at the mine and extracted coal is taken directly to the generator.

Coal is classified according to carbon content, volatile matter and heating value. Lignite coal generally contains 9 to 17 million Btus (British thermal units, a measure of heat content) per ton. Sub-bituminous coals range from 16 to 24 million Btu per ton; bituminous coals from 19 to 30 million Btu/ton; and anthracite, the hardest type of coal, from 22 to 28 million Btu per ton.

Natural Gas

Natural gas is a mixture of hydrocarbons (principally methane, a molecule of one carbon and four hydrogen atoms) and small quantities of various non-hydrocarbons in a gaseous phase or in solution with crude oil in underground reservoirs.

Ghana has some gas production associated with oil in the Central and Western Regions of Ghana. More gas can be found if more exploration takes place either offshore or onshore.

Fuel Oil

Fuel oils are the heavier oils in a barrel of crude oil, comprised of complex hydrocarbon molecules, which remain after the lighter oils have been distilled off during the refining process. Fuel oils are classed according to specific gravity and the amount of sulfur and other substances that might occur. Virtually all petroleum used in steam electric plants is heavy oil. Currently, roughly 30 percent of electricity in Ghana are generated using light crude oil, which is somewhat unusual.

Renewables

Renewable fuels are those that are not depleted as they are consumed. The wind, sun, moving waters (hydroelectric), water heated in the earth (geothermal) and vegetable matter (biomass) are typical renewable energy sources for electricity.

Hydroelectricity

Electricity can be created as turbine generators are driven by moving water. Ghana depends heavily on hydroelectricity, most of which comes from two facilities, Akosombo and Kpong stations.

Wind Electricity

Electricity can be created when the kinetic energy of wind is converted into mechanical energy by wind turbines (blades rotating from a hub), that drive generators. Currently, there are no wind facilities in Ghana.

Solar Electricity

Radiant energy from the sun can be converted to electricity by using thermal collecting equipment to concentrate heat, which is then used to convert water to steam to drive an electric generator. Solar electricity is about a decade behind wind electricity in development for commercial applications. Solar electricity can represent an important future energy source, especially for niche markets like off-grid power. Solar energy depends on available sunlight and is reliant on storage or supplementary power sources. There are some rural applications of solar energy in Ghana in the form of photovoltaic cells used to charge batteries and to generate direct use electricity.

Biomass and Geothermal

Electricity can be created when various materials (like wood products and agricultural waste, or even crops grown for use in electricity production) are combusted. Heat from combustion is used to convert water to steam for power generation. Electricity can also be created when steam produced deep in the earth is used to run turbines in a generator. Ghana has some agricultural waste but there are no biomass generation facilities, mainly because the technology is relatively expensive and waste quantities are limited.

Nuclear

Nuclear energy is a non-renewable, non-fossil fuel form of energy derived from atomic fission.

Nuclear Electricity

The heat from splitting atoms in fissionable material, such as uranium or plutonium, is used to generate steam to drive turbines connected to an electric generator. Uranium is a heavy, naturally radioactive metallic element which has two principle isotopes, uranium-235 or uranium-238. Uranium-235 is the only isotope existing in nature in appreciable quantities and is thus indispensable to the nuclear industry (which includes applications other than electric power for civilian use). Uranium-238 absorbs neutrons to produce a radioactive isotope that decays to plutonium-239, which is also fissionable. Nuclear plants have been by far the most expensive to construct, although uranium is the least expensive fuel to use (apart from questions about disposal costs). Disposal of waste fuel, which remains radioactive for a long time, has been a major concern. For these reasons, no nuclear plant has been ordered in the U.S. since 1978. The costs and hazards associated with decommissioning nuclear facilities are likely to be substantial and the disposal of radioactive wastes from these facilities remains an unresolved issue in the U.S. On the other hand, countries such as France, Japan, South Korea and Finland continue to depend on nuclear power at significant rates (for example, more than 70 percent in France) and to build new facilities.