Electricity Trade and Capacity Expansion Options in West Africa

A proposal for collaborative research to
change policy and promote economic growth

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Summary and Introduction

The reliable provision of low-cost electricity is critical for industrial development, employment and poverty alleviation. In West Africa, economic growth is currently being stifled by insufficient supply of electricity to meet burgeoning demand. Ironically, as a whole, the region is an energy-surplus region. This irony is explained by the fact that the policy environment and institutions that could induce new investments to increase generation and transmission capacity to produce and trade electric energy have been absent. Each national utility now works independently of its neighbors, evaluating its operation and expansion options on a project-by-project basis. Moreover, no framework exists within which electricity utilities can coordinate their investment plans and develop reliable trading relationships as is the case in Southern Africa.

The activity outlined in this document, proposes a phased approach to assist West Africa in the development of electricity expansion planning tools and in identifying expansion project priorities necessary to improve reliability and indicate how to more efficiently produce and trade electricity. This activity will build on the proposer group's previous collaboration with the Southern African Power Pool (SAPP). The first phase of the proposed activity involves a detailed identification of the issues, actors and institutions that might be built on to develop a strengthened regional electricity infrastructure and market. This phase will produce a preliminary model and a report around which comprehensive electricity trade protocols might be discussed and constructed. It will also be a beginning of the consensus building process among the actors which is a pre-condition for any cross-national project such as this. Based on this analysis, it will provide a more detailed design for the second phase of this activity and clarify the collaboration between these efforts and parallel efforts that may be funded by other donors.[1]

The second phase will involve research to develop and equip each utility in the region with a common analytical model of the region's electricity grid. This tool will serve several purposes. First, it will fill a highly valuable informational need. Within this second phase, the model will provide initial estimates of the savings to countries in the region that might be had from greater integration of their power grids. These savings are likely to come, first, from reductions in the costs of maintaining the reliability of each country's own utilities, and secondly in sourcing less costly electricity through trade to meet growing demand. This information will serve both to make the case for further cooperation, and to provide data to planners in respective countries, as well as to donor and private investors as to how to immediately improve the efficiency of investments in the electricity sector in the region. A model training workshop will take place at Purdue in this second phase.

Second, the activity of undertaking the modeling research will serve a capacity building role. It will involve intensive collaboration with technical and management personnel from participating utilities to construct the model. This process will entail training these personnel to manipulate, modify and interpret the model. In so doing they will also gain a detailed appreciation for the

[1] Specifically, the World Bank is also seeking to support institutional development in order to most economically improve electricity supplies in West Africa.

operational constraints involved in the growth of electricity markets as well as the potential benefits to be had from cooperative investments in electricity generation and from spot trade of electricity. Participants in the activity will also become exposed to the regulatory policy issues that must accompany increased and flexible electricity trading transactions.

Third, the activity will compliment the first steps being taken by regional governments towards building the institution of a power pool. This will occur, first, in so far as it will bring together technicians and managers of participating utilities to work collaboratively on common issues. These actors must provide the impetus and leadership for the actual operation of a power pool for it to become a success. Moreover, the analysis will result in a common set of data and initial grid configurations that can serve as the basis for identification and ironing our of issues that the power pool must address. Finally, part of the design of the second phase will involve dovetailing the proposed analytical research with other initiatives to develop the institutional framework for trade and investment in the region's energy sector. Notably, these include, first, a USAID sponsored effort to the development of a framework for regional trade in natural gas. Secondly, the regional governments and their energy ministers as well as the World Bank are planning to sponsor the institutional development of a West African Power Pool (WAPP), including direct support to developing the legal and regulatory basis for the power pool.

Successfully executed, these proposed activities may be expected to result in a broad range of economic benefits to the region, including higher levels of electricity trade and investment, lower costs and greater reliability of electricity supply, and higher levels of employment and output in electricity-using sectors. These claims are made based upon past experience of the Purdue team. The present proposal builds on a similar activity conducted over the past two years with the 12 national utilities in the SAPP. In Southern Africa, Purdue and African researchers have worked extensively with utility staff and policy-makers to construct models of each country's electricity generation and transmission system, linking them together in a regional model to simulate the costs and benefits of alternative trading arrangements and capacity expansion plans. These SAPP-Purdue models have shown how greater trade can generate operating-cost savings of $80 million per year, with coordinated capacity expansion saving billions of dollars over the next twenty years. The Southern African utilities have clearly recognized the value of the analytical tools developed with Purdue. In February 1999, the SAPP officially established the model constructed in collaboration with Purdue as their principal instrument for evaluating policy changes and infrastructure investment.

West Africa currently has substantially less electricity trade and inter-utility collaboration than Southern Africa. But with less existing trade and collaboration there are likely to be even greater gains to these activities than those found in the SAPP region.

Background

Shortages of electricity are a severe constraint on economic growth and poverty alleviation in West Africa. The lack of electricity is often exacerbated by shortages of imported fuel, wood/charcoal and other forms of energy. The high cost and unreliability of energy supplies is a handicap for industrial development and employment generation, and also for poverty alleviation and public health.

To make energy more available, the region's hydropower and thermal power stations as well as international transmission lines are in great need of refurbishment. West African electricity suppliers are currently negotiating for a wide range of funding and trading arrangements to support these investments.

The analytical agenda of this proposal consists of using new computer simulation techniques to bring together a variety of energy analysts and policymakers, assemble their knowledge of each country's electricity grid, and return detailed simulations of new trading arrangements and infrastructure investments. The result is a powerful new approach to coordination among utilities, facilitating policy change by providing a basis for realistic dialogue about the consequences of each option.

New computer software developed by the State Utility Forecasting Group (SUFG) at Purdue University provides the level of technical and economic detail needed to capture the unique features of electricity generation and trading systems. The software builds on work to guide deregulation and new investment by electricity utilities in the Midwest region of the United States. Since 1997, SUFG has also worked with the managers and engineers of the Southern African Power Pool (SAPP) to facilitate increased trade and coordinated investment in that region, with funding from USAID's project on Equity and Growth through Economic Research (EAGER).

Southern Africa is the first region outside of Europe and North America to arrange a power pool for coordinated trading and investment in utility expansion. West African states have similar needs and interests. Coordination requires development of the capacity for forecasting and simulation, and SUFG's work in the United States and in Southern Africa has led to powerful new analytical tools that can function on a high-speed personal computer platform. They are designed so as to allow detailed modeling to take place in any one of the African states, as well as in regional institutions such as the Economic Community of West African States (ECOWAS).

Each of West Africa's sixteen nations -- Mauritania, Mali, Niger, Chad, Senegal, Gambia, Guinea Bissau, Guinea, Sierra Leone, Liberia, Ivory Coast, Ghana, Togo, Benin, Nigeria and Burkina Faso -- has its own national electricity corporation, with very limited trade between them. The expansion of generation and international transmission is being planned on a case-by-case basis, with no possibility of analyzing the interactions between new projects being considered in various locations.

Some of the key similarities and differences between the two regions, West and Southern Africa, are summarized in the table below.

TABLE 1. THE ENERGY SECTOR IN WEST AND SOUTHERN AFRICA, 1992

	Area (1000 km^2)	Population (Million)	Installed Capacity (GW)	Energy Consumed (TWh)	Oil/Gas Reserves (Million TOE)
West Africa	6,132	200	8.2	23.1	1,920
Southern Africa	5,898	100	33.6	183.8	738

Source: [1]

The Southern region, defined as the Southern African Development Community (SADC) has a similar land area to ECOWAS. SADC's population is half as large as ECOWAS,'s but its installed generating capacity in 1992 was four times as large, and energy consumption was eight times larger. While there are significant economic and infrastructural differences between the two regions, the similarities suggest that West Africa could learn a lot from the progress that have been made in Southern Africa in regional cooperation in electricity planning and integration of regional electricity trade.

There are two major differences between the Southern and Western African electricity regions. These are:

- Southern African governments legally instituted the Southern African Power Pool (SAPP) in 1995. It was for the purpose of increased system reliability through sharing reserves and mutual support during emergencies. Its second major objective was to maximize the economic synergies that arise out of the diverse nature of the SAPP utilities.
- The level of interconnection of regional international transmission lines. The SAPP has greater capacity transmission lines within its region with extensive plans to further increase them. Nine of the countries were interconnected by 1995. The remaining three member countries will be connected by the year 2000. With more interconnections, there are increased possibilities for improved alternative electricity trading, so the potential exists for an improved and more sustainable regional electricity market.

It is possible that the West African experience will follow a similar path to that taken in Southern Africa. It was because of the need for detailed quantitative modeling in Southern Africa that financial support was approved for the collaborative work that is taking place between the SAPP and Purdue University. The SADC Secretariat and the twelve government energy departments involved have all welcomed the collaborative modeling work with SAPP and SUFG, and, as mentioned above, SUFG's modeling activities are now institutionalized through the Planning Committee of the SAPP. This example of close institutional cooperation and coordination could be transferable to the West African region, which has structures such as ECOWAS and UEMOA in place that could accommodate the need for governments to work together effectively amongst

themselves and in interaction with public utilities, individual private producers and transmitters of electricity.

The West African Generation and Transmission Network

The West African electricity network is characterized by many small national utilities with one large national utility in Nigeria. Most of the small utilities depend on thermal power, with hydropower available primarily in Ghana. Some countries, such as Benin, depend heavily on diesel generators, which are not connected to its national grid. The projected demand for the region in the year 2000 is shown in Table 2.

TABLE 2. ELECTRICITY-DEMAND FORECASTS FOR WEST AFRICA IN THE YEAR 2000

	Peak power demand	
Country	*High forecast (MW)*	*Low forecast (MW)*
Benin	190	50
Burkina Faso	130	65
Gambia	40	20
Ghana	1700	1300
Guinea Bissau	40	20
Ivory coast	1500	1100
Liberia	500	290
Mali	130	80
Mauritania	60	40
Niger	290	130
Nigeria	5200	3400
Senegal	550	360
Sierra Leone	130	95
Togo	340	190

Many generators in the West Africa region are old and have high operating costs. Investment in new power generation is a top priority for most nations in this region of Africa. The crisis resulting from electricity shortages in Nigeria is causing major damage to the manufacturing and commercial sectors and the prospects for the regional economy in general. In 1998 it was estimated that $5.3 billion dollars were required to rehabilitate Nigeria's four thermal stations [2]. In an area of the world where positive foreign trade balances are small or non-existent there is a critical need for economizing on investments which use foreign currency.

TABLE 3. GENERATION AND TRADE IN SELECTED AFRICAN COUNTRIES

Country	*Electricity Production (1982-TWh)*	*Electricity Production (1994-TWh)*	*Electricity Imports (1994 GWh)*	*Electricity Exports (1994 GWh)*	*Hydropower Generation (1994 GWh)*
West Africa					
Benin	0.01	0.01	242		
Ghana	5.01	6.12	4	263	6077
Ivory Coast	1.95	2.31	34		971
Nigeria	8.57	15.53		138	5561
Senegal	0.63	1.0			
Southern Africa					
RSA	120.53	189.32	58	1583	1074
Zambia	10.86	7.79	20	1500	7745
Zimbabwe	4.06	7.33	1716		2370

Source [3]

West Africa is similar also to Southern Africa in that it has one major utility in the region. Nigeria's NEPA (4,548 MW installed capacity in 1995) is much larger than any other electricity authority in the West Africa region, much like the Republic of South Africa's (RSA) Eskom (38,000 MW installed capacity) is the largest in the Southern African region. The electrical energy consumed in Nigeria is smaller though than South Africa although it has more than double the population of South Africa. 1994 statistics show Nigeria generating 15.53 TWh compared with South Africa's 189.32 TWh (Table 3). Ghana is the second largest utility in the region with Ivory Coast being the third (Table 4).

TABLE 4. GENERATING CAPACITY AND DEMAND IN FIVE WEST AFRICAN STATES, 1995

Country	*Maximum Capacity (MW)*	*Operating Capacity(MW)*	*Peak Demand (MW)*
Nigeria	4548		
Ghana	1102	1102	923
Ivory Coast	886	703	450
Togo & Benin	193	61	148

Source: [5]

A comparison of the region's existing thermal and hydropower consumption and hydro potential is shown in Table 5.

TABLE 5. ELECTRICITY GENERATION AND HYDRO POTENTIAL IN WEST AFRICA

Country	*Thermal GWh (1980)*	*Hydro GWh (1980)*	*Hydro as % of total supply (1980)*	*Max. annual hydro potential*		*Installed hydro 1985 (MW)*	*Potential warranting investigation MW*
				MW	*GWh*		
Benin	15	94	86%	700	2500	-	300
Burkina Faso	107	-	0	200	800	-	100
Gambia	40	-	0	-	-	-	-
Ghana	55	4910	99%	2000	10000	952	1000
Guinea	260	140	35%	5000	30000	40	2200
Ivory Coast	185	1659	90%	3000	14000	614	1800
Liberia	600	400	40%	2000	11000	64	1100
Mali	54	37	40%	2000	10000	54	900
Mauritania	100	-	0	-	-	-	-
Niger	124	106	46%	235	1330	-	235
Nigeria	5249	2225	30%	12400	38000	1320	6000
Senegal	635	-	0	500	2500	-	250
Sierra Leone	220	10	4%	1300	6800	2	400
Togo	18	257	93%	450	1700	-	230
Total	7736	9838	56%	29845	128930	3046	14545

The West Africa region has great unexploited hydropower potential. Hydroelectric development was implemented in the 1960's with Akosombo in Ghana and Kainji in Nigeria. Akosombo remains the largest hydro station in West Africa with 792 MW. It was developed in conjunction with an aluminum smelter. The existing hydroelectric stations in the region are listed in Table 6. Four of these stations exceed 500 MW in capacity. Three of these are in Nigeria and the fourth in Ghana.

TABLE 6. EXISTING HYDROELECTRIC PROJECTS AND MAJOR RIVERS IN WEST AFRICA

Country	*Project*	*Installed capacity (MW)*	*Date of commissioning*	*Major Rivers*	*Average flows (m^3/s)*
Benin	-	-	-	Queme	140
Burkina Faso	Kompienga	15	1988	-	-
Gambia	-	-	-	Gambia	110
Ghana	Akosombo	792	1965	Volta	500
	Kpong	160	1982		
Guinea Bissau	-	-	-	-	-
Ivory Coast	Ayame I & II	50	1959, 1965	Sassandra	575
	Kassou	174	1972	Bandama	340
	Taabo	210	1979	Cavally	600
	Buyo	180	1980	Comoe	250
Liberia	Mt. Koffee	64	-	St. Paul	600
Mali	Felou	0.5	1928	Niger	2000
	Sotuba	5.4	1966	Senegal	530
	Selingue	48	1981	-	-
Mauritania	-	-	-	-	-
Niger	-	-	-	Niger	1000
Nigeria	Kainji	760	1966	Niger	7000
	Jebba	560	1984		
	Shiroro	600	1986		
Senegal	-	-	-	Senegal	650
Sierra leone	-	2	-	-	-
Togo	Nangbeto	63	1937	Mono	120
	Kpime	1.5	-		
		3725			

Ghana's existing hydropower from the Akossombo Dam (Volta River Authority – VRA) has had significant strategic importance for the region. Its1072MW capacity has also supplied neighboring countries Togo and Benin. Smaller hydro schemes such as at the 65MW Nangbeto Dam (Mono River) have also provided strategic supplies to both Togo and Benin. Ivory Coast has two thirds of its power coming from hydropower (895MW) [3].

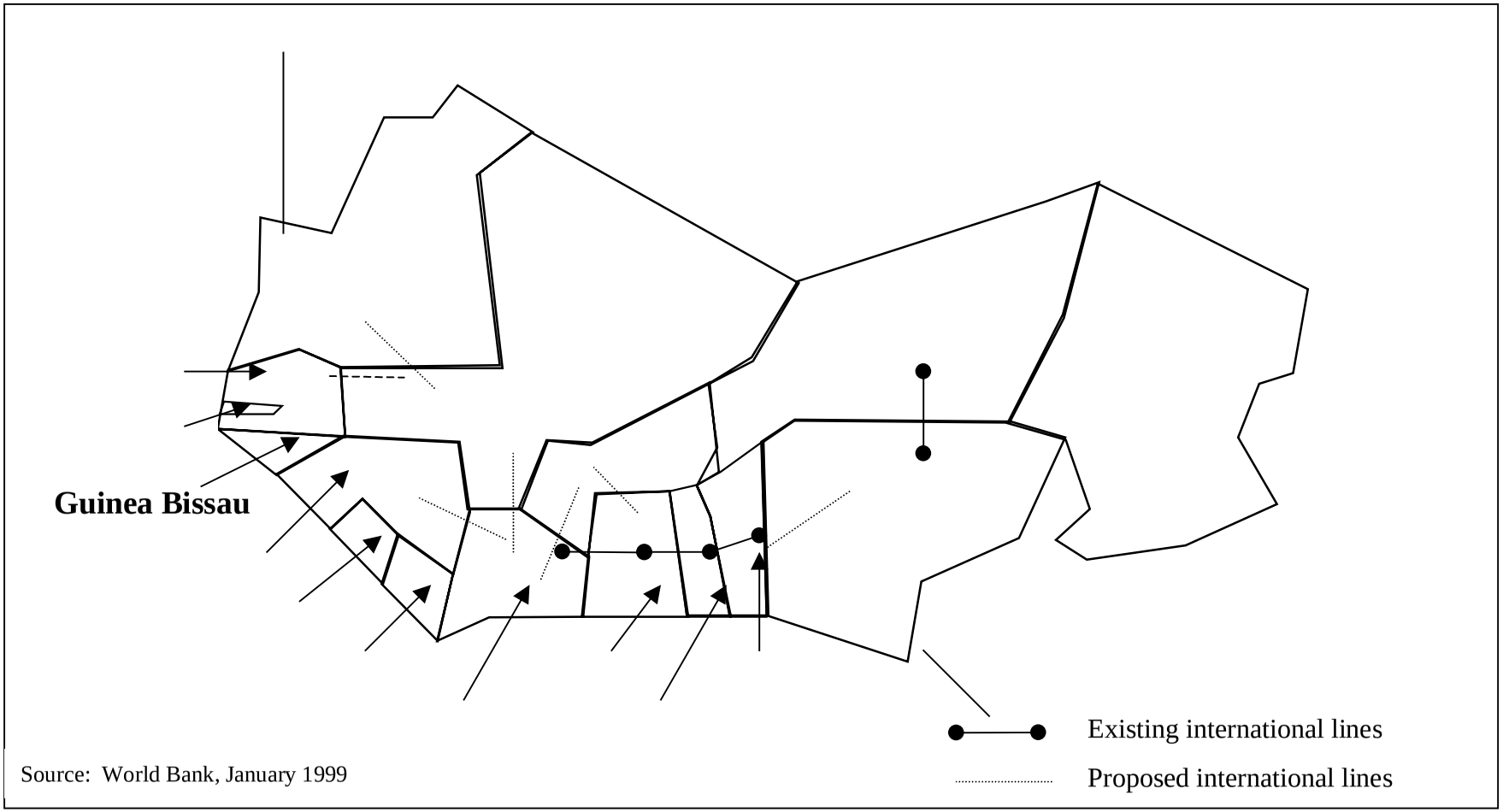
The main hydropower station at central Nigeria's Kainji has an installed capacity of 760MW but in 1998 its eight turbines failed to generate. The Afam hydropower station (427MW installed capacity) in Nigeria's River Niger Delta also now has very limited output owing to serious maintenance problems.

On the demand side, there are also strong arguments for a regional grid. The West Africa region extends from 10 degrees east of Greenwich to 20 degrees west. This results in a two-hour time difference across the region and so gives a reasonable diversity of the daily

maximum demand. Substantial temperature variations, north to south during parts of the year also provide a basis for demand differentials seasonally.

The international lines that currently exist in West Africa, together with the excess generating capacity in the region put major restrictions on the current capacity to trade electricity between the nations. The existing lines and proposed lines in the region are listed in Table 7 and shown in Figure 2.

FIGURE 2. INTERNATIONAL TRANSMISSION LINES IN WEST AFRICA



Source: World Bank, January 1999

Many transmission projects are being planned and these could radically improve the quality of supply in the region and also reduce total costs. With the construction of a trade model for West Africa, an optimal construction plan can be produced to show the most cost effective construction plans for the region. The value of further international lines can also be easily assessed. For example, when Nigeria is connected to the Ivory Coast-Ghana-Togo-Benin Grid, then the backbone of a regional grid will be substantial. With future international lines also extending to Chad, Liberia, Sierra Leone, Guinea Bissau, and the Gambia, then a comprehensive regional grid would be fully established.

TABLE 7. EXISTING AND PROPOSED INTERNATIONAL LINES IN WEST AFRICA

Existing Lines, 1999	*Ivory Coast*	*Togo*	*Benin*	*Niger*
Ghana	320kV 100MW	161kV 100MW		
Togo			161kV 100MW	
Nigeria				132kV 70MW

Lines under Construction & Built by 2002	*Ivory Coast*	*Mauritania & Senegal*
Burkina Faso	225kV 200-100MW	
Mali		225kV 200-100MW

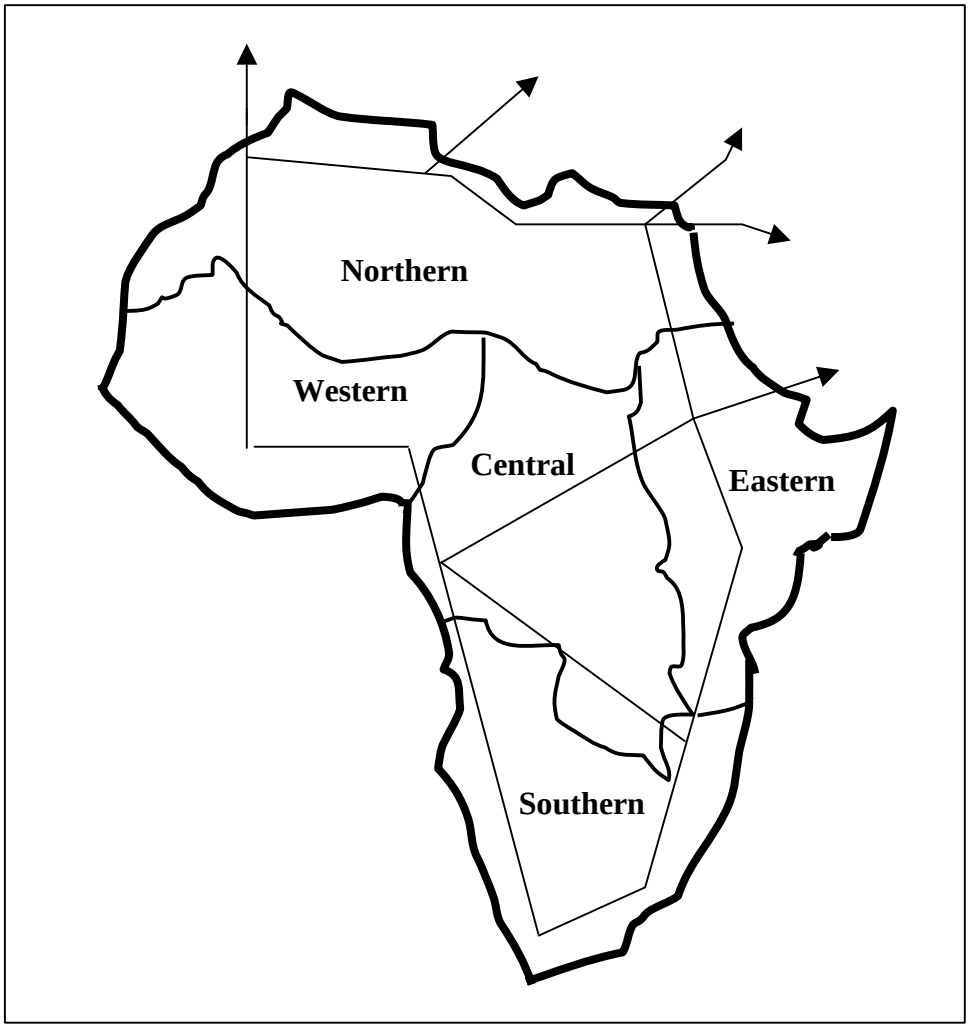
Lines to be built after 2002	*Mali*	*Guinea*	*Burkina Faso*	*Benin*
Ivory Coast	220kV 200-100 MW	220kV 200-100W		
Ghana			225kV 200-100MW	
Nigeria				330kV 600-300MW

Source: [5]

Although the immediate demand for connections in West Africa are to serve electricity suppliers and users within the region, in the long run one of the greatest payoffs will be to the coordination of trade and investment across the African continent. A major source of gains from trading electricity lies in distributing hydroelectric power, and for Africa as a whole the huge hydro-electric potential of the Congo River – notably the 100,000 MW site at Inga -- will be the major source of cheap, clean power for the 21st century.

Figure 1 shows the future likely routes for inter-continental trade. Egypt has already conducted a feasibility study for a transmission line from the Democratic Republic of Congo (DRC) to Cairo. South Africa has conducted similar studies for flows from the DRC, through Angola and Namibia, to Cape Town. For the West Africa region there will also be very substantial benefits for a line to connect DRC to Nigeria and go into the Western Africa region.

FIGURE 1. PROPOSED AFRICAN INTER-REGIONAL ELECTRICITY TRANSMISSION LINES
(only Central to Southern via eastern route exists in 1999)



Institutional Basis for a Power Pool in West Africa

Currently, the regional Economic Community of West African States (ECOWAS) may provide the most appropriate inter-governmental superstructure for the creation of a regional West African electricity utility power pool. ECOWAS was formed in1975 to promote trade, co-operation and self-reliance in West Africa. One of its mandates is to promote rational regional investment and trade in energy. To promote this, an Energy Resources Development Fund was established in 1982 to promote increasing energy efficiency [26].

Other initiatives to support regional energy trade include plans for a West African gas pipeline to be constructed from the off-shore gas fields of Nigeria in the Gulf of Benin to Western Ghana. This project has already begun to establish the framework for regional

gas trade between Ghana, Benin, Togo and Nigeria. Cote d'Ivoire is also likely to join in the project.

The existence of these initiatives suggests that they should be built upon to develop a regional electricity power pool. Given that most international electricity trade in the West Africa region already occurs between the countries of Cote d'Ivoire, Ghana, Benin, Togo and Nigeria, these are likely to form the core of a loose power pool. In light of transmission projects to be completed by the year 2002, another likely participant in an initial power pool is Burkina Faso. In the longer run, linkage through Mali with the proposed Manantali grid will also allow expansion to include Mali, Mauritania and Senegal.

Methodological Approach: Analyzing Electricity Generation and Trade Options

A simple three-panel trade diagram illustrates how trade between low cost and high cost countries can be modeled. The three panel trade diagram, illustrated below in Figure 3, shows supply and demand schedules for a low-cost utility on the left-hand panel, and shows supply and demand schedules for a higher-cost utility on the right-hand panel. Note supply and demand schedules are shown as straight lines on the diagrams, but would be nonlinear in any empirical model. The third panel, in the middle, shows the schedules of excess demand of the importer and excess supply for the exporter, which can be derived from the other two panels.

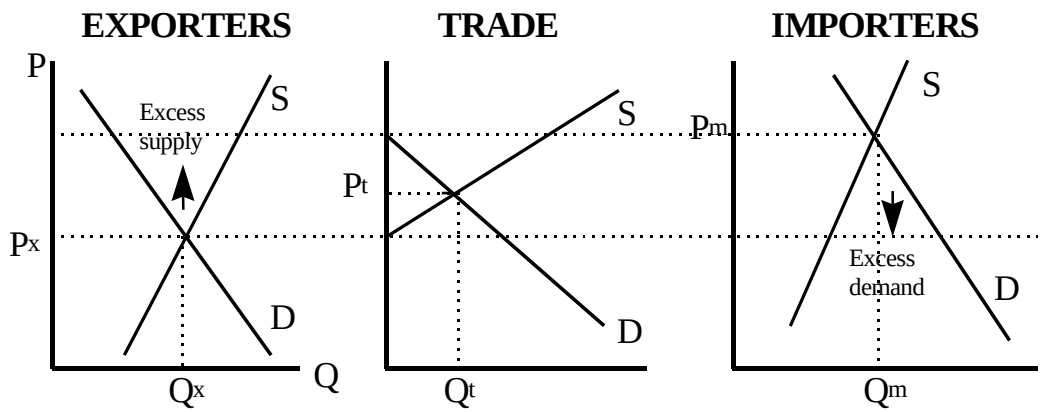
Each panel reveals the prices and quantities, which would arise under alternative trading arrangements. P_x and P_m would be the prices in the exporting and importing regions without trade: at these prices, the supply and demand schedules meet and demanders want to purchase exactly the amount producers want to sell in each country(Q_x). If higher prices were to prevail in the export country, then suppliers would offer additional production, demanders would offer to purchase less, and there would be excess supply, in the amount of the horizontal difference between the demand curve and the supply curve at that price. In the importing region, there would be excess demand if prices were lower than P_m.

The curves in the middle panel are constructed by tracing out the excess supply schedule from the exporter and excess demand schedule from the importer. With no transaction costs (losses or other costs of transmission), the equilibrium price with trade would be equal to P_t, and quantity Q_t would be traded (i.e., produced by the exporter and sold to consumers in the importing region).

The model can take account of transmission costs as a wedge between the price received by the importer and the price paid by the importer. Thus, in Figure 3, if the transmission

charge/kWh were C, importers would pay $P_t^{im} = P_t^{ex} + C$, and trade would be reduced to Q_t^* rather than Q_t.

FIGURE 3. THE THREE PANEL TRADE MODEL



In the Southern Africa case, a long-term simulation model capturing changes over time and space was tailored to the computing facilities specified by the SAPP management, by linking short-term models of trade to the various options for generation and transmission expansion. The chronological and spatial nature of this model makes it very large, in the order of tens of thousands of constraints, and near 1000 integer variables in addition to an even larger number of continuous variables.

Multi-regional spatial optimization takes place with generation units and transmission lines whose limited capacity can be expanded at a cost. The cost function (capacity and line expansion costs plus operational costs over 20 years) will minimize the sum of present value for the whole of West Africa. Generation and transmission data (technical, capital investment, and operational costs) will need to be collected from each country.

The long-term model will be driven by the "typical hour/day/season/year" chronological demand approach taken by many of the latest commercial models, rather than the load duration curve methodology used in earlier approaches. The model will be set up to model demand in five representative periods in the future, starting in year 2000 to allow completion of all West African projects now underway.

The demand in a given region can be met from a variety of energy sources: (a) existing thermal sites, (b) new thermal sites, (c) existing hydro sites, (d) new hydro sites, (e) net imports (imports less exports), (f) paying an unserved energy cost, (g) pumped storage. Within each region, generating sites are identified which contain generating plants. For purposes of dispatch, all plants at a site are collectively dispatched.

Power flows on existing lines, measured in MW, are denoted PF in any year "ty", season "ts", day "td", hour "th", from country "z" to country "zp", and given by the variable "PF(ty,ts,td,th,z,zp)" Power flow on new lines are given by the variables "PFnew(ty,ts,td,th,z,zp)". Using this notation, and accounting for line losses reducing the amount of power arriving at country "z", net imports for country "z" in a given hour would be;

$$\sum_{zp}\left[\overbrace{\mathrm{PF(ty,ts,td,th,zp,z)(1-PFOloss(zp,z)}}^{\text{imports arriving on old lines}}-\overbrace{\mathrm{PF(ty,ts,td,th,z,zp)}}^{\text{exports sent on old lines}}\right]$$
$$+\sum_{zp}\left[\overbrace{\mathrm{PFnew(ty,ts,td,th,zp,z)(1-PFNloss(zp,z)}}^{\text{imports arriving on new lines}}-\overbrace{\mathrm{PFnew(ty,ts,td,th,z,zp)}}^{\text{exports sent on new lines}}\right]$$

The long-term model is capable of being run on a PC platform and therefore will be suitable for implementation in all of the countries of the region.
The specification for the PC is:

PentiumII BX 100 MHz motherboard and 350 MHz processor,
512 Mb 100 MHz RAM,
9.61Gb UW SCSI hard drive

Detailed reports and papers are available on the modeling work that has been completed for the Southern African utilities [6-18]. These provide detailed reports and information on the modeling completed so far. A User Manual for the long-term model is also soon to become available. This will be obtained from: callen@ecn.purdue.edu.

Project Workplan

The present proposal calls for an initial period of work, based around two phases:

PHASE I: Identification and Design of Analysis to Support Regional Electricity Developments in West Africa (July 1999 – March 2000)

The first phase of the activity will undertake the following seven tasks:

- Preliminary regional electricity data collection.
- Identification of specific issues and projects for analysis in building a framework for a comprehensive regional electricity infrastructure.
- Coordination of activities with other regional energy sector initiatives.
- Fall 1999 - Construction of a preliminary six country West Africa model.
- January 2000 - Visit region's utilities, energy departments, and agencies and participate in three-day regional workshop (World Bank to confirm dates).
- Detailed design of Phase II analytical research.
- March 2000 – PhaseI Report.

Identification of specific issues for analysis and for building a comprehensive regional electricity framework.

An initial West Africa regional electricity model, involving the core pool countries of Ghana, Ivory Coast, Togo, Benin, and Burkina Faso, will be made in fall 1999 incorporating data supplied from collaboration with World Bank colleagues. It is likely that Nigeria will be included even though its international connection to Benin is not yet in place. In January 2000 (or late 1999), three members of the Purdue SUFG team will visit the region to hold discussions with potential participants and stakeholders concerning regional investments and issues related to developing a regional electricity trade. An initial model will be used to demonstrate the benefits for long-term investments and operational costs from greater regional electricity trade and a flexible market. Discussions should focus on:

a. Initial and long-term objectives of regional electricity generation and transmission.
    - Contracts for trade and reliability.
    - Investment coordination and harmonization.
    - Joint investments.
    - Bulk contract trading.
    - Spot trading.
b. The likely participants and configuration of a West African core electricity grid.
c. Policies and electricity regulatory frameworks to be developed.
    - Wheeling electricity.
    - Investing jointly.
    - Redress of grievances.
d. The institutional options for growth in regional electricity infrastructures.
    - The affiliation to governmental and intergovernmental structures.
    - Formulae for supporting and criteria of membership for a regional electricity power pool.

Contact will be made with potential participants and stakeholders in the West African electricity sector in the core countries identified. Likely participants will include the electricity utilities, and energy supply companies in these countries. Other national stakeholders whose perspective will be sought will include ministries of energy, electricity regulatory boards and other actors in the energy sector. At an intergovernmental level the energy commissions of ECOWAS and UEMOA will be contacted, as well as any ad hoc organizations that seek regional trade or investment in energy sectors. University scholars (Prof. Iwayemi, University of Ibadan) and private consultants with expertise in these issues will also be identified.

All contacts will be conducted in close coordination with bilateral USAID missions in these countries. These missions will also be approached to obtain their perspective on the issues raised by the activity and on proposed activities under the second phase.

Coordination of activities with other regional energy sector initiatives.

PhaseI will be based agreed criteria needs of the region, USAID, and World Bank being supported by the field visits in West Africa. The Purdue team will develop an initial model and prepare for a short three day regional workshop in January 2000 and will also confirm the proposal for phase two activities. It will visit Washington to bring together officials from USAID's Global Bureau (Energy Office) and Africa Bureau (Sustainable Development Office) together with interested parties in the World Bank to determine if and how to collaborate in further activities to support development of an effective West African electricity grid. Conclusions of these meetings will also be incorporated into the analysis for Phase II.

A March 2000 outline model report will conclude Phase I. The Phase I initial modeling of West Africa will be replaced by a broader regional electricity trade and investment analysis in the Phase II. An appendix of the March report will provide a revised design of the second phase of the activity.

Detailed design of Phase II analytical research.

Contacts made during the first phase will also be used to explain the nature and value of the proposed second phase. These discussions will provide an opportunity to identify potential collaborators in a second phase of analysis and to coordinate a workplan for the second phase to assure full participation of important participants. During this trip, recruitment of research collaborators in the region will also be initiated. A first approximation of Phase II is provided below. Upon approval Phase II should run from April 2000 to December 2000.

Phase II. Building Analytical Tools for A West African Electricity Trade and Expansion Plan (April 2000 – December 2000)

The principal objective of the second phase activities is to develop a broad analytical model that will serve to illustrate the value of a strong and efficient West African electricity market. The model building exercise will also serve to build capacity among probable participants in an expanded regional electricity grid and provide a basis for regional governments and agencies for beginning the institutional development for loose power pooling as well as providing analysis for major investment proposals.

The first requirement for creating this model of the West African electricity sector will be the construction of a comprehensive set of data on current electricity generating capacity (thermal and hydropower) together with the transmission line capabilities. This database-assembly activity will require close collaboration with the engineering leadership of the national utilities, and is a critical first step in establishing the credibility and policy

relevance of any subsequent work. The level of complexity of this model will be defined in the PhaseI March 2000 report.

A second step is to work with national policymakers and energy analysts to characterize proposed and potential generation and transmission expansion projects, in terms of both technical and financial characteristics.

The collaborative links required here are key to generating local ownership of the analytical agenda, so that the simulations of the modeling exercise addresses questions of immediate concern to decision-makers in the region. Once the database characterizing the existing grid and potential changes is assembled, the resulting simulation model can be constructed. Representatives from the region will join in a workshop in PhaseII to discuss and assess the results from the model. This workshop can be located at Purdue in the fall of 2000.

A first application of the model is to assess the technical and economic benefits of establishing an extensive regional West African electricity trading structure. The maximum savings in capital expenditure saved via regional generation construction quantified benefits from increased regional transmission lines could all be determined, along with the levels of trade within the West Africa region and the degree of interdependence between the states and future formal electricity regional structures.

PHASE II: Developing A Model of the West African Power Grid

The Phase II activities identified below are:

(1) During the spring of 2000, recruited participants from each of the utilities would be given initial data collection and analysis tasks. By the end of April 2000, draft reports based on these instructions would be forwarded to Purdue by each participant. Participants would be trained in coordination techniques, such as information sharing across the region, in order to ensure that the relevant institutions can smoothly begin what must inevitably be a long and close relationship.

(2) During the summer of 2000, data from these reports, as well as from research conducted by the SUFG and regional modeling team would be used to prepare a preliminary model of the regional electricity grid to prepare for the two-week modeling workshop.

(3) In the fall of 2000, the two-week modeling workshop would be held to bring study participants together. This workshop would train all participants in the modeling methods, and the structure of the model, and permit them to examine the preliminary model results. The workshop would be aimed at reconciling differences in the data provided by each utility and merging these

data into a single model of the regional grid, establishing confidence in the resulting model, and defining the main scenarios to be explored in initial simulations of policy change and new investment. Based upon this workshop, participants would be given additional assignments to refine and improve assumptions of the model. Each would be provided a version of the model to allow them to use it to finalize their own national reports. Further, participants would discuss the institutional development needed for an appropriate governance and regulatory framework to foster a competitive environment. By the end of the fall of 2000, a draft final report will be completed and distributed to participants and interested collaborators. A proposed agenda for further research work will also be prepared as part of this report

(4) In December of 2000, the Purdue team would return to the region and disseminate the finalized report on Phase II work. As part of this trip they would hold seminars in the region to present the results of the research, to evaluate proposed ideas for continuing the effort and to solicit collaboration from national and regional utility authorities for these proposals.

Proposed Resources

The activities of this proposal will be carried out by the State Utility Forecasting Group (SUFG) at Purdue University with subcontracted assistance of Associates for International Resources and Development (AIRD). The experiences of each of these institutions are briefly reviewed below followed by a brief description of the principal individuals proposed for the project.

Purdue University's State Utilities Forecasting Group (SUFG)

SUFG's integrated electricity modeling system projects electricity demand, supply, and price for each electric utility in the state of Indiana, USA. The modeling system captures the dynamic interactions between customer demand, the utility's operating and investment decisions, and customer rates by cycling through the various bus-models until an equilibrium is attained. The SUFG modeling system is unique among utility forecasting and planning models because of its comprehensive and integrated characteristics. Both generation and transmission constraints are included in the models something that is not available in the commercial software. For over two years the SUFG has been specifically working with the Southern African utilities in developing the models through workshops and correspondence.

SUFG has developed and acquired both econometric and end-use models to project energy use for each major customer group. These models use fuel prices and economic drivers to simulate growth in energy use. The end-use models provide detailed projections of end-use saturation, building shell choices, and equipment choices (fuel type, efficiency, and rate of utilization). The econometric models capture the same

effects but in a more aggregate way. These models use statistical relationships estimated from historical data on fuel prices and economic activity variables. The energy impacts and hourly load profiles of existing and planned DSM programs are estimated from information provided by Indiana's electric utilities. Publications and information from SUFG can be obtained from sandersp@ecn.purdue.edu (Email) or 317- 494 - 2351 (Fax). Some titles are listed in the bibliography [20-25].

Associates for International Resources and Development (AIRD)

Established in 1980 with the goal of applying rigorous economic analysis to the issues of international development, the firm has extensive experience in developing countries worldwide. AIRD's ongoing and completed research and consulting projects encompass those aspects of international development related to pricing policy, marketing, international trade, exchange rate management, monetary and fiscal policy, financial management, agricultural and livestock economics, industrial economics, labor economics, natural resource use, legal and regulatory environments, and investment policies. AIRD has significant experience in assisting multilateral and bilateral donors in the preparation, implementation, and evaluation of their programs. The firm is increasingly serving as a catalyst to private entrepreneurs wishing to invest in developing country economies assisting private sector partners in engaging public policy makers to improve the policy environment for their investments and raising awareness in public circles of the constraints confronted by the private sector.

Proposed Personnel

Responsibility for the project at Purdue University is held by Prof. F.T. Sparrow, Director of the State Utility Forecasting Group and Prof. William A. Masters, an economist with extensive experience in both West and Southern Africa. The core team implementing the project will include Dr. Zuwei Yu and Dr. Brian H. Bowen, engineers experienced in modeling policy change and new investment in Asia, North America and Southern Africa.

In addition, Dr. Jeffrey C. Metzel, a consultant economist from Associates for International Resources and Development (AIRD) with extensive experience managing regional projects in Francophone West Africa, will participate in the project to assist in study coordination, data collection and analysis, with a focus on the Francophone countries of the region. A West African regional consultant, Prof. Akin P. Iwayemi, an economist at the University of Ibadan, Nigeria, will participate in both the Phase I and Phase II of the project.

Secretarial help is planned for producing the new Model User Manual, for assistance in liaison with the regional personnel and for organizing the proposed workshop. Student help is needed for methodical and systematic testing of the updated versions of the trade model.

The AIRD will also develop, through consultation and advice from regional governments, national utilities and possible donor agencies, capacity building exercises for institutional

development in electricity markets governance and regulation. Detailed CVs for project personnel are presented in Appendix II to this document.

Bibliography

[1] T.J. Hammons et al, “African Electricity Infrastructure, Interconnections, and Exchanges”, IEEE POWER ENGINEERING REVIEW, January 1997,(pp.6-16).

[2] James Barker, Jr., Bernard Tenenbaum, and Fiona Woolf, GOVERNANCE AND REGULATION OF POWER POOLS AND SYSTEM OPERATORS: An International Comparison, World Bank Technical Paper No.382, work in progress for public discussion, Washington, D.C., 1997.

[2] MAIL AND GUARDIAN, Johannesburg, April 24, 1998.

[3] ELECTRICITY INFORMATION 1995, International Energy Agency, July 1996, (p.16).

[4] “Opportunities in African Power Generation: A Business Briefing for Industry and Investment Executive”, US Trade and Development Agency, Baltimore, MD, June 21-22, 1995.

[5] Telephone conversation and subsequent fax - from Mr Kwawu M. Gaba, Energy Group, World Bank, January 13, 1999.

[6] J.B.C Lazenby, P.M.S. jones, “Hydroelectricity in West Africa: It’s Future Role”, ENERGY POLICY, pp.441-455, October 1987.

[7] F.T. Sparrow, William A. Masters, Zuwei Yu, Brian H. Bowen, & Peter B. Robinson. “Modeling Electricity Trade in Southern Africa. Year 2 Interim Report”, Purdue University, USA, August 1998.

[8] F.T. Sparrow, “The SAPP Long-Term Model–Lecture Notes”, Cape Technikon Workshop, June/July 1998.

[9] B.H. Bowen, “The Benefits from Central Unit Commitment and Dispatch: An Application to the Southern African Power Pool”, PhD dissertation, Purdue University, August 1998.

[10] F.T. Sparrow, W.A. Masters, Zuwei Yu, B.H. Bowen, G. Nderitu et al, “Modeling Electricity Trade in Southern Africa, Second Year Final Report to the Southern African Power Pool”, forthcoming early 1999.

[11] F.T. Sparrow et al, “Modeling Electricity Trade in Southern Africa, User Manual for the Long-Term Model”, forthcoming early 1999.

[12] F.T. Sparrow, Brian H. Bowen, William A.Masters, Z.Yu, “Electricity Trade Policies and the Southern African Power Pool”, SAPP Regional Meeting, Windhoek, Namibia, February 1997.

[13] F.T. Sparrow, Brian H. Bowen, William A Masters, Zuwei Yu, D.G.Nderitu, “Electricity Trade Modeling; A SAPP Seminar”, SAPP Regional Meeting, Windhoek, Namibia, February 1997.

[14] F.T. Sparrow, Brian H. Bowen, “Report to USAID/EAGER Trade on the SAPP (Southern African Power Pool) Meeting held at Windhoek, Namibia”, 12,13 February 1997.

[15] P. Robinson, F.T. Sparrow, “Wheeling Charges and Loose Power Pools: North American Experience and its Relevance for the Southern African Power Pool”, Sixth Joint Plenary Session of SAPP Sub-Committee Meetings, Harare, Zimbabwe, May13 1997.

[16] Zuwei Yu, F.T. Sparrow, Brian H. Bowen, “A New Long-Term Hydro Production Scheduling Method for Maximizing the Profit of Hydroelectric Systems”, IEEE Transactions on Power Systems - accepted for publication in 1998, IEEE PES 1997 summer meeting, Paper #97sm-868.

[17] Zuwei Yu, “Hydrothermal Unit Commitment Model”, Departmental paper, Institute for Interdisciplinary Engineering Studies, Purdue University, April 1997.

[18] P. Robinson, ECONOMIC INTEGRATION IN SOUTHERN AFRICA, Volume 2, Chapter 5, ENERGY, 1994.

[19] F.T. Sparrow, W.A. Masters, Z. Yu, B.H. Bowen, P.B. Robinson et al, “Modeling Electricity Trade in Southern Africa. First Year Report to the Southern African Power Pool, Purdue University, USA, September 1997. Lusaka, Zambia, March 3-4, 1998

[20] SUFG 93-1, "Review of EIA's industrial energy demand model", Proceedings of the National Energy Modeling System Conference, Arlington, Virginia, February 1-2, 1993 (DOE/EIA-0566, May 1993), pp.538-550.

[21] SUFG 92-2 "The proper design of DSM incentives", Presented at the Least Cost Planning Conference, Washington, April 7-8, 1992.

[22] SUFG 91-5, Sparrow, F.T. and McKinzie, Lance, "Predicting electricity use by the iron and steel industry using mathematical programming", Presented at the Joint International Meeting of TIMS and SOBRAPO, in Rio de Janeiro, July 15-17, 1991. (Presentation only.)

[23] SUFG 90-2, Sparrow, F. T., Schmidt, P., McCallister, R., and Lenagh, W. "Targeting electric utility DSM energy conservation programs in the industrial sector", Presented at the Innovations in Pricing and Planning Conference, May, 1990.

[24] SUFG 89-4 Sparrow, F.T., Reed Cearley, Otto Doering, Forrest Holland, Lance McKinzie and Paul Preckel, "Strategic load growth and demand-side management" May, 1989. Presented at EPRI's Fourth National Conference on Utility DSM Programs, Cincinnati, Ohio, May 2-4, 1989.

[25] SUFG 92-1, Amy Mathews and J.C. Randolph, "Global climate change, electric utilities and energy policy", School of Environmental Affairs and State Utility Forecasting Group. SUFG Technical Report No. 103, January 1992.

[26] AFRICALAND – WIDNET, http://focusintl.com/whos0004.htm, January 18, 1999

Appendix I: Utilities in West Africa

CEB	-	Communauté Électrique du Bénin (Benin and Togo)
CEET	-	Compagnie Énergie Électrique du Togo (Togo)
CIE	-	Compagnie Ivoirienne d?Électricité (Côte d?Ivoire)
ECG	-	Electricity Corporation of Ghana (Ghana)
EDM	-	Électricité Du Mali (Mali)
NED	-	Northern Electrification Department (Ghana)
NEPA	-	National Electric Power Authority (Nigeria)
NIGELEC	-	Société Nigérienne d'Electricité (Niger)
SBEE	-	Société Béninoise d'Électricité et d'Eau (Benin)
SOGEL	-	Société Guinéene d'Electricité (Guinée)
SONELEC	-	Société Nationale d'Electricité (Mauritanie)
SENELEC	-	Société Nationale d'Electricité (Sénégal)
SONABEL	-	Société Nationale Burkinabé d'Électricité (Burkina Faso)
VRA	-	Volta River Authority (Ghana)
LEC	-	Liberia Electricity Cooperation (Liberia)

Appendix II: Core Personnel

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email: fts@ecn.purdue.edu
http://www.ecn.purdue.edu/IIES

Education:

B.S., Geology, University of Michigan, 1953
M.B.A., Managerial Economics, with distinction, Cornell University, 1956
Ph.D., Economics and Operations Research, University of Michigan, 1962

Work Experience:

1979-Present:
Purdue University -
Professor of Industrial Engineering, School of Industrial Engineering
Professor of Economics, Department of Economics
Director, Institute for Interdisciplinary Engineering Studies
Director, State Utility Forecasting Group
Director, Coating Applications Research Laboratory

1976-1978:
University of Houston -
Professor, Department of Economics, and Chairman, Department of Industrial Engineering

1973-1976:
National Science Foundation -
Deputy Assistant Director for Analysis and Planning, Research Applications Directorate

1962-1973:
The Johns Hopkins University -
Assistant and Associate Professor of Economics and Operations Research

1956-1958:
U.S. Atomic Energy Commission -
Operations Analyst, Office of Operations Analysis, Washington, D.C. (GS-9)

Current Research Interests:

Energy, with emphasis on Electricity
Energy Conservation
Industrial Use of Electricity
Natural Resource Economics

Memberships:

Association of Demand-Side Management Professionals
American Institute of Industrial Engineers
Demand-Side Management Society of AEE
American Society for Engineering Education
The Association of Energy Engineers

Consulting & Appointments:

Argonne National Laboratory
Battelle National Laboratory
Bonneville Power Administration
Electric Power Research Institute
Hydro Quebec
Niagara Mohawk Power Company
Ontario Hydro
Barakat and Chamberlin, Inc.
BENTEK Energy Research Inc.
Brookhaven National Laboratories
Gas Research Institute
Illinois Power
Southern California Edison

Industrial/Technical/Professional Committees:

1988-1994, Advisory Panel Member, National Science Foundation
1990, Member, Environmental Advisory Panel, PSI Energy
1990, Member, Indiana Coal Forum
1991-Present, Member, Indiana Energy and Recycling Development Board
1992-1994, Member, National Research Council Committee on Integrated Resource Planning
1994-1995, American Council for an Energy-Efficient Economy, Industrial Energy Conservation Workshop Committee and Summer Study Program Committee

Publications list available.

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Education:

Stanford University, Food Research Institute
M.A. (1986), Ph.D. (1991) in Agricultural Economics
Thesis title: "Comparative Advantage and Government Policy in Zimbabwean Agriculture."
Yale University
BA (1984) in Economics and Political Science
Deep Springs College
(1979-1982)

Fields of Expertise:
Trade and development policy analysis, indicator methods, impact of agricultural research. Regional experience in Zimbabwe, Mali, Colombia, Haiti.

Languages: Fluent French, some Spanish.

Employment:

Purdue University
Associate Professor (1996-present), Assistant Professor (1991-1996)
Major research projects have included:
- Assessment of alternative policy analysis and comparative advantage indicators, e.g. effective protection, domestic resource costs (DRC) and other measures;
- Impact of agricultural research in West Africa, using farm-household models and market-level economic surplus measures;
- Impact of grain market reform in Zimbabwe, including a variety of consulting activities for USAID and the World Bank;
- Impact of grain market reform in Zambia, based on new types of spatial-equilibrium modeling.

Principal teaching activities include:
- “Economics of World Agricultural Development”, an upper-level undergraduate course taught annually since 1992.
- “Agriculture and Trade Policy in Developing Countries”, and “Agricultural Development in Africa”, graduate seminars taught in 1993-1995.
- “Agricultural Policy”, a graduate course beginning Fall 1996.
- “Impact of Agricultural Research”, a short course taught at the Institut du Sahel (Bamako, Mali) annually since 1994.

Major professor for three MS theses and six PhD dissertations.

Stanford University (1987 - 1991)
Teaching Assistant for courses in trade policy, microeconomic theory, and the world food economy;
Research Assistant for Prof. Bruce Johnston to help write teaching materials for use in World Bank/EDI courses, and Research Assistant for Prof. Scott Pearson to help write a book on Indonesian food policy.

University of Zimbabwe, Harare, Zimbabwe (1988-1990)
Research Associate and part-time lecturer. Stationed primarily at the Ministry of Lands, Agriculture, and Rural Resettlement, to collaborate on the first nation-wide small holder farm survey and other assist with other policy analysis activities.
Funded by a Fulbright Dissertation Research Grant (1988-89) and a Rockefeller Foundation research grant (1990).

International Food Policy Research Institute, Washington (1987)
Research Assistant for Dr. John W. Mellor
Mavhudzi Government Secondary School, Nyazura, Zimbabwe (1985)
Teacher -- Form IV English Language
COLANTA Dairy Cooperative, Medellin, Colombia (1983)
Intern in Technical Assistance Department
Haitian Development Foundation, Port-au-Prince, Haiti (1981)
Intern in Head Office Staff

Consultancies and Grants:
Total research and technical assistance funding totals over one million dollars, from:

- US Dept. of Education - Building Agribusiness Capacity (1996-98)
- USAID - Equity and Growth through Economic Research (EAGER/Trade) (1995-99)
- USAID - Economic Impact of Agricultural Technology in West and Central Africa (Joint with Prof. John H. Sanders) (1993-97)
- USAID - Zimbabwe Grain Market Reform Research Project (1994-96)
- USAID - Agricultural Policy Analysis Project (APAP III) (1994)
- Purdue University - Global Initiative Faculty Grant for Teaching (1993)
- Purdue University - Global Initiative Faculty Grant for Teaching (1992)
- USAID/Zimbabwe - Consultancy on Grain Market Reform (1992)
- World Bank - Consultancy on Agricultural Pricing in Zimbabwe (1991)
- Rockefeller Foundation - Research Fellowship (1990)
- ICRISAT - Consultancy on Sorghum and Millets in Zimbabwe (1989)
- USIA Fulbright Program - Dissertation Research Grant (1988-89)

Publications list available.

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Purdue University, West Lafayette, IN 47907, USA
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Education:

Ph.D. of EE (Fall, 1995), with a *minor in industrial engineering/operation research*, School of Electrical Engineering, University of Oklahoma, Norman, OK 73019, USA.
MS and BS of EE, Dept. of EE, Beijing University of Aero & Astro, Beijing, China.
Trainee (1985), economics, cost & pricing, econometrics, and contract management, GD, USA.

Expertise:

- Extensive and in depth knowledge in power system engineering, especially in the following areas:

power system economics	load forecasting & DSM	multi-area production simulation	least-cost planning
competitive pricing/risk	power economics & regulation	wheeling & transaction	power system reliability
optimal power flow, etc.			

- Very knowledgeable in:

econometrics	probability, stochastic processes, and applications	
linear programming	nonlinear programming	dynamic programming
network flow models	interior point method	engineering management, etc.

- Very strong analytical and quantitative skills.
- Strong organizational and communication skills.
- Self-motivated and very responsible for what is done.

Experience (Partial):

5/96 - present: Senior Analyst, State Utility Forecast Group, Purdue University.

- Unit commitment/generation scheduling, multi-area production simulation and power flow analysis.

2/92 - 4/96: IEEE technical paper reviewer, IEEE Transmission Open Access Subcommittee.

- Evaluated IEEE PES technical papers on transmission open access, deregulation, and electrical power industry restructuring issues.

6/90 - 8/95: Research assistant, Power Lab., School of EE, Univ. of Oklahoma.

- Power system economic, competitive pricing, risk evaluation, optimal pricing, rate making issues.
- Engaged in load forecasting projects for utilities in Oklahoma using Multi-regression, Neural Networks, State Space, Categorical Regression models, etc.
- Developed a Compensated Box-Jenkins Transfer Function Model and a Temperature Match Based Optimization Model for load prediction.
- Developed security constrained Economic Dispatch algorithm for energy exchange/wheeling pricing.
- Screened DSM methodologies and applications.
- Completed an integrated resource planning project jointly sponsored by EPRI & OG&E.
- Introduced a Level-crossing Based Analytical Method in the DSM control of electrical appliances.

- Engaged in production costing considering capacity reserve & risk, and least cost planning.
- Developed a Unit Commitment Model by using a modified DPSTC method.
- Introduced a Line Flow Magnitude Method and a Multi-level Optimization Method in electrical power wheeling study.

1/83 - 8/89: Engineer, deputy director and executive director, Electrical & Power Systems Dept., Technology and Economics Consulting Center (TECC), CARITE, Beijing, China.

- Long term and short term forecasting, econometrics models, and engineering economics.
- Analysis of electrical and power systems, including software development and simulation.
- Integrated analysis of engineering problems, including risk and uncertainty analysis, by using technology, engineering economics and operations research models.
- Planned the research activities of that department.
- Job allocation, research supervision, and engineering management, etc.

Publications list available.

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Experience:

- Electricity regulatory policy. Energy economics.
- Quantitative analysis of electricity markets and trade. Modeling and analysis of power pools (linear and mixed integer programming, GAMS, CPLEX). Operations research.
- Proposal preparation leading to funding, from USAID, for the SAPP project.
- Hydro-thermal coordination policy.
- Collaboration with the national utilities in the Southern African Power Pool.
- Electrification and development.
- Design and manufacture. Solar energy systems. .

Substantial regional experience in Mauritius, Sierra Leone, Zimbabwe, Southern Africa region, U.S.A., Great Britain. Engineering background in design and manufacturing. University teacher and projects administrator.

Education:

Purdue University, School of Industrial Engineering,
Ph.D. (1998). "Short-Term Benefits from Central Unit Commitment and Dispatch:
Applications to the Southern African Power Pool."
University College, Cardiff, Department of Mechanical Engineering & Energy Studies,
MSc in Energy Studies (1985)."Assessment of Solar Heating Systems for a Developing Country".
Liverpool John Moore University, CAD/CAM masters courses (1986-87),
Oxford University, Department of Education, PGCertEd., (1973),
Coventry University, Department of Mechanical Engineering, BS (1971).

Employment:

- Purdue University, Institute for Interdisciplinary Engineering Studies (July 1996-present), Assistant Research Director, SAPP Project. Project management and liaison between national electricity utilities in SAPP (Southern African Power Pool) and Purdue University researchers. Organization of data collection, construction of models (optimization methods using GAMS). Workshop management that culminated in the successful visit of colleagues from several nations to an event I had large responsibility for organizing. Liaison with related agencies (USAID, DOE, WORLD BANK). Presentations in South Africa, Mozambique, Zimbabwe, Botswana and at 1997 U.S.-South Africa Binational Commission Sustainable Energy Sub-Committee Meeting, Washington DC; 1998 World Bank Energy Week, Washington DC.
- Purdue University, School of Technology, Visiting Assistant Professor,(1998 - present).
- Purdue University (1994-July 1996), Research Associate - USAID/EAGER
- Manchester University and Manchester Metropolitan University (1993-1994), Lecturer,(part-time). Principle teaching activity: Engineering production management and design for manufacture.
- University of Zimbabwe (1990-1993), Lecturer in Drawing and Design (British Government sponsorship). Supervision of industrial and university research projects in production management.
- John Moore University at Liverpool (1987-1990), Senior Teaching Associate (Otis Elevators Corporation.
- University of Sierra Leone (1974-1986), Lecturer in Mechanical Engineering (British Government sponsorship).

- University of Mauritius (1971-1973), International Voluntary Service Lecturer in Mechanical Engineering.
- British Insulated Callenders Cables Ltd, Helsby, England (1964-1971), Technical Officer & Junior Engineer for electric cable manufacturing.

Selected Publications:

"A Multi-Regional Electricity Trade Study for the Southern African Power Pool", F.T.Sparrow, Z.Yu, B.H.Bowen, G,Nderitu, J.Wang, F.Smardo, K.Stamber, American Power Conference. Accepted for publication in 1998.

"A New Long Term Hydro Production Scheduling Method for Maximizing the Profit of Hydroelectric Systems", Zuwei Yu, F.T.Sparrow, Brian H. Bowen, IEEE TRANSACTIONS on Power Systems, February 1998.

"A Low Cost Short-Term Hydrothermal Scheduling Algorithm", Zuwei Yu, Frank J.Smardo, Brian H.Bowen, Douglas Gotham, IEEE TRANSACTIONS on Power Systems, Forthcoming.

"Manufacture of solar water heating systems in Zimbabwe," Brian H. Bowen, H.Mukore, MINING AND ENGINEERING, November 1991, Vol. 56, No.11, pp. 21-25.

"Solar water systems heat up in Zimbabwe," Brian H. Bowen, H. Mukore, I.S.E.S. SUNWORLD, July/August 1991, Vol. 15, No. 3, pp. 19-21.

"Energy and Sierra Leone," Brian H. Bowen, HELIOS, November 1983, Vol.19, University CollegeCardiff, pp.6-7.

"Performance of solar water heaters manufactured in Sierra Leone, West Africa," Brian H. Bowen, INTERNATIONAL JOURNAL OF AMBIENT ENERGY, May 1983, Vol.4, No.2, pp. 69-78.

"Solar water heater for West Africa," Brian H. Bowen, I.S.E.S. SUNWORLD, November1977, No.6.

"Solar collectors; reducing the cost," I.S.E.S. SUNWORLD, September 1981, Vol.5, No.5, 137-138.

Conference Papers:

"Southern African Power Pool Modeling Results", F.T.Sparrow & Brian H.Bowen, World Bank Energy Week, Washington DC, April 6-8, 1998.

"Modeling Electicity Trade in Southern Africa: First Year Report to the SAPP", F.T.Sparrow, Brian H. Bowen, Zuwei Yu, et al; Presented to utilities and government energy departments in South Africa, Zimbabwe, Botswana, Zambia, Mozambique, February 24 – March 6, 1998.

"The Southern African Power Pool and Purdue University Modeling Workshop", Brian H. Bowen, Presentation at the U.S. - South Africa Binational Commission Sustainable Energy Sub-Committee Meeting, Washington DC, July 28, 1997.

"Regional Electricity Trade in Southern Africa", Brian H. Bowen, USAID/EAGER Trade Semi Annual Workshop, Accra, Ghana, February 3-8, 1997.

"Electricity Trade Policies and the Southern African Power Pool", F.T.Sparrow, Brian H. Bowen et al, SAPP Regional Meeting, February 12-13, Windhoek, Namibia.

"Performance of solar water heaters manufactured in Sierra Leone," Brian H. Bowen, M.Bassey, Final Report-Overseas Development Administration (U.K.), Project No. R3039 B, July 1982, pp. 1-63.

"The manufacture and evaluation of domestic solar water heaters in Sierra Leone," Brian H. Bowen, presented at International Conference on Appropriate Technology in Rural Societies, Freetown, July 1978.

Professional Association:

Chartered/professional engineer – C.Eng., M.I.Mech.E., 1978, Institution of Mechanical Engineers, Gt.Britain.

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EDUCATION

Ph.D.	Tufts University, Fletcher School, 1984. (Development Economics with specializations in International Trade, Agricultural Policy, Rural Development, and Law and Development)
M.A.L.D.	Tufts University, Fletcher School, 1981.
A.B.	Davidson College, 1978 (International Development; magna cum laude).

PROFESSIONAL EXPERIENCE

Senior Economist, Associates for International Resources and Development, Cambridge, Massachusetts. Principal areas of work include trade and price policy, and sectoral and production level modeling, primarily in agriculture, livestock, irrigation and natural resource areas. See **RECENT CONSULTING EXPERIENCE** below for details. (February 1988 - present)

Research Associate, The Fletcher School of Law and Diplomacy, Tufts University, Medford, Massachusetts. Responsibilities include advisor and dissertation reader for doctoral candidates, and invited lectures. (March 1984 - present)

Macroeconomist, Ministry of Planning, Government of Niger. Advisor with the Agricultural Sector Development Grant Technical Assistance Team, a USAID-funded project administered by the University of Michigan's Center for Research in Economic Development. Responsible for appraisal of the macroeconomic impact of Niger's public investments in the agricultural sector. Participation in formulation of the national investment budget, and in the annual evaluation exercise of the previous year's investment performance for the agricultural sector. (1986 - 1988)

Livestock Economist, Niger Integrated Livestock Production Project, Tufts University/Ministry of Rural Development, Tahoua, Niger. Administrative duties as Chief of the Division of Studies and Programming. Established a livestock market information collection system in 24 livestock markets in collaboration with the national livestock service. Responsible for implementation and analysis of a baseline census of 2500 pastoral families. Responsible for elaboration and implementation of a pastoral zone drought monitoring survey. (1984 - 1985)

Economic Consultant, U.S. Agency for International Development, Design Economist for the OMVS Integrated Development Project, Dakar, Senegal and for the Nigner Integrated Livestock Production Project, Tahoua, Niger. Also performed economic evaluations of a public health project, and the credit and private sector components of an irrigation development project in Senegal. (1981-83)

Ph.D. dissertation field research, Senegal River Valley. Conducted survey research on farm systems in the upper Senegal River Valley in Senegal, Mali, and Mauritania. Developed linear programming models of irrigated and rainfed farm households to determine resource allocation with and without introduction of animal traction. Shell International Studies research fellow. (1981-83)

Research Assistant, Tufts University, Fletcher School. Assisted in preparation of lectures and performed research related to course in Development Economics. (1980 - 1981)
Assistant Editor, The African Business and Economic Review, Washington, DC. Responsible for newsletter articles on public investments in sub-Saharan Africa. (1980)

Research Fellow, Thomas J. Watson Fellowship. Performed a study of international surface transport integration

in Africa. Examined benefits and costs of the Lagos-Mombasa Trans-African Highway and the Trans-Sahara Highway. (1978 - 79)

REPORTS AND PUBLICATIONS

List available on request.

AWARDS AND HONORS

Shell International Studies Research Fellow (1981-82).
Thomas Watson Fellow (1978-79).
Honorary fraternities: Phi Beta Kappa, Omicro Delta Kappa.(1978).

LANGUAGE SKILLS

Fluent French and Tshiluba (a language of Zaire).

PERSONAL DATA

Date of Birth: 1956 Place of Birth: Lubondai, Republic of Zaire
Married in 1986 to Joann Lindenmayer, DVM, MPH; two children.

RECENT CONSULTING EXPERIENCE with AIRD

Design Economist – Electricity sector, *Southern Africa,* EAGER/Trade Regimes and Growth. Prepared studies of the electricity sector for USAID/Washington EAGER and ATRIP initiatives based on visits to the Southern African Development Community and to utilities of the Southern African Power Pool (SAPP). Identified issues where follow-on activities to the Purdue University /SAPP collaborative study of potential for regional trade in electricity. (1998-99)

Macro and sectoral reform, *Mali.* A study sponsored by the Africa Trade and Investment Initiative to prepare and oversee sector analyses in oilseeds, leather products, and textiles in Mali. (1998- present)

Global Food Security Strategy, *USAID Washington* Co-authored a global strategy to achieve the 1996 World Food Summit to cut world hunger by half by the year 2015. The strategy included a modeling analysis of the cost effectiveness of alternative interventions to address chronic undernutrition. In addition to the global strategy, the study also included the design of a presidential initiative to launch the US commitment to the strategy. (1998)

Livestock export promotion, *Mali.* EAGER/Trade Regimes and Growth study. Principal Investigator on a study of livestock trade prospects for Mali and the potential for specialization and value added through, fattening, slaughter and hides and skins industries. (1995- 1998)

Political economy of trade liberalization, *Madagascar.* Principal Investigator of a EAGER/Trade Regimes and Growth study to assess the impact on the vanilla market of measures to liberalize exports of vanilla. The study includes analysis of changes in structure and performance of the market since liberalization, and models the impact of economic and political interests on the process of liberalization. (1997- present)

Rice sector liberalization, *Senegal.* USAID sponsored exercise to monitor production level impacts of rice sector liberalization measures being undertaken between 1994 and 1997. Oversaw teams within the Policy Analysis Unit of the Ministry of Agriculture charged with assessing impacts on input markets, farmer resource allocation, productivity levels, and marketing decisions as a result of liberalization measures. (1996-1998)

Effective protection in livestock sector, *Romania.* World Bank/Romania Agricultural Sector Adjustment Loan. Team leader, and responsible for production budgeting and nominal and effective protection analysis of key livestock sectors (milk, pork and poultry), including examination of emerging private farms in contrast with state farms. (1996)

Trade policy reform, *Sub-Saharan Africa.* EAGER/Trade Regimes and Growth project. Review of literature on trade policy reform experience in Sub-Saharan Africa. Presented at the First EAGER Conference in Washington DC. July 1996. To be published.

IWAYEMI, Akinbolaji Philip

ADDRESS: Dept. of Economics,
University of Ibadan,
Ibadan, NIGERIA.

PROFESSION: Environmental and Energy Economist

UNIVERSITY EDUCATION:

1. University of Ibadan 1966-69
2. John Hopkins University, Baltimore, U.S.A. 1970-75

ACADEMIC QUALIFICATIONS: B.Sc. (Econ) First Class Honours,
Ibadan, 1969.
Ph.D (Econ) John Hopkins University,
Baltimore, 1975.

Scholarship, Fellowship and Prizes:

1. University Scholar, Ibadan. 1967
2. Post Graduate Scholarship, University of Ibadan, 1969-70
3. Rockefeller Foundation Fellowship to study at The John Hopkins University, 1970-75
4. Department Prize: (Best Economics Graduate) 1969.
5. Faculty of Social Sciences Prize: (Best Graduate) 1969.
6. U.A.C. Prize: (Best Economics Graduate) 1969.

HONOURS, DISTINCTIONS AND MEMBERSHIP OF LEARNED SOCIETIES:

1. Member, International Association for Energy Economics
2. Member, Nigerian Economic Society
3. Member, West African Economic Association
4. Member, The African Academy of Sciences
5. Past Associate Editor, West African Journal of Economics (1980-83)

LANGUAGES

Excellent proficiency in speaking, reading and writing English. Fair proficiency in reading French.

WORK EXPERIENCE:

(a) Teaching and Research Experience:

1975-1978	Lecturer II, Department of Economics, University of Ibadan, Ibadan.
1978-1982	Lecturer I " "
1982-to 1993	Senior Lecturer, (Leave of Absence 1983-88 working in OPEC Vienna)
1993-Present , Professor	

(b) Other Work Experience: (While on Leave of Absence in OPEC Vienna)

1983-88	Energy Economist in OPEC.
1989-96	Senior Research Fellow, Centre for Econometric and Allied Research (CEAR) University of Ibadan, Ibadan.
1992-98	Deputy Director, Centre for Econometric and Allied Research, (CEAR) Ibadan.
1998- Present	Director, Centre for Econometric and Allied Research, (CEAR) Ibadan.

CONSULTANCY WORK:

I have been involved in environment, energy and economic studies and consultancies in Africa. In addition, I have participated in the application of quantitative and models to policy design and perspective planning. The following selected consultancy studies demonstrate the experience I have in the area of environment, energy and economic studies

- Performance of African Economies in 1998, Part 1 of African Development Report 1999 Principal Consultant to the Research Division of the African Development Bank. October 1998 to January 1999
- Performance of African Economies in 1997, Part 1 of African Development Report 1998 Principal Consultant to the Research Division of the African Development Bank. October 1997 to January 1998
- Ecologically Sustainable Industrial Development in Namibia: Policy Instruments and Measures, **UNIDO**, Vienna. September-November 1995.
- North-South Sustainability: Energy Policy and Carbon Dioxide Emission in Nigeria, **Nigerian Environmental Study Group/Friends of the Earth Europe**, June- September 1995.
- Economic Development Scenarios in East and Southern Africa **African Development Bank (ADB)/African Energy Programme**. 1994.
- Global Environmental Facility (World Bank/UNDP/UNEP) **Information Technology, Capacity Building and the Environment; Case study of Nigeria.** 1994.
- US Environmental Protection Agency funded project **Climate Change and the Economy; The Macroeconomic Impact of Green House Gas Emission Reduction on the Nigerian Economy.** 1993 to 1996.
- NPC/UNDTCD/CEAR/SOW-VU **Development of Applied General Equilibrium Model for Perspective Planning in Nigeria**. 1990 to 1997
- Ford Foundation **Policy Modelling in ECOWAS; a Preliminary Assessment,** funded by Ford Foundation. New York. 1991.
- UNDP/NIDB/World Bank CEAR **Infrastructural Constraints to Industrialization in Developing Countries with Nigeria as case study.** 1989-91.
- Economic Community of West African States (ECOWAS) **Energy Sector in West Africa.** 1982.

SELECTED PUBLICATIONS:

Iwayemi, A. (1978), "An Investment Planning Model for the Electricity Sector in Nigeria"; Socio-Economic Planning Sciences, Vol. 12, pp. 285-292.

- (1978), "An Econometric Analysis of the Demand for Electricity in Nigeria"; Research and Development, Vol.I, No.1.
- and Ayodele, O. (1980) "The Energy Sector in ECOWAS - Consultant Report to the Economic Community of West African States"; ECOWAS Project, NISER, Ibadan.
- (1983) "Planning in the Electric Power Sector in Nigeria", Chapter 12 in (ed.) Iz. Osayimwese Development Economics and Planning, pp.176-191 University of Ibadan Press
- (1983), "Energy in West Africa: Issues and Policy Approaches", Energy Policy, Sept., pp. 235-249.
- (1983), "Investment Planning with Multiple Objectives in ECOWAS - A Methodology", Chapter 23 in Ubogu, R.E., G.M., Adamu and T.A.C Gogue (ed.) Development Planning in the Economic Community of West AFrican States (ECOWAS). Heinemann Educational Books (Nig.) Ltd. pp. 443-456.
- (1984), "Nigeria's Internal Petroleum Problems: Perspectives and Choices", The Energy Journal, Vol.5, No.4, pp. 45-54.
- (1985), "Natural Gas in Nigeria: Issues and Policy in Resource Development" in Ayodele (ed), Energy Development and Utilization in Nigeria.
- (1991), Energy Statistics: A perspective from Nigeria" presented at the Training Workshop for the Staff of the National Data Bank, Lagos, June-July 1991.
- (1992) "Energy: Long Term Perspectives and Issues", background paper for the Perspective Plan. National Planning Commission, Lagos. Centre for Econometric and Allied Research (CEAR) project, University of Ibadan.

DATE OF BIRTH:	July 8, 1946
MARITAL STATUS:	Married with 4 children