Project proposal for funding under the
USAID co-operative agreement on Equity And
Growth through Economic Research/Trade
Regimes and Growth (EAGER/TRADE)

MODELING ELECTRICITY TRADE

IN SOUTHERN AFRICA - 1998

Purdue University
June 1997

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Contents

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SUMMARY

In the short to medium-term it has been estimated that US$1.6 billion could be saved by the Southern African electricity network through integrated planning and operation. The potential savings from a well structured Southern African Power Pool, SAPP, providing optimal trading, are clearly very great. The collaborative modeling in 1997, that is taking place between SAPP and Purdue University, is for the short-term scenario and the proposal for 1998 is now for the long-term scenario.

The SAPP, agreed with Purdue staff at the February 1997 meeting in Namibia, that modeling in 1997 should concentrate on the gains from trade in the short-term by planning electricity trade through a more centralized power pool arrangement which could give greater economic efficiency as well as greater reliability in electricity supplies. A tighter electricity power pool has more economic and operational benefits with a centralized dispatch and unit commitment policy compared to loose pool arrangements. The first year of the research project involves the collection of data from each of the twelve countries in SAPP (the countries of the Southern African Development Community, SADC, as well as Zaire). The data collection is needed from three main areas, each of which can have significant effects on the costs and revenues involved with electricity trading; from thermal generators (mainly coal), hydropower generating stations and regional transmission lines. The objective functions of each national utility, establishing weightings between independence and regional interdependence, and refining quantitative trade models will be important parts of the modeling and analysis of results. A SAPP/Purdue Modeling Workshop, is to take place, in West Lafayette, in August 1997.

A 1998 long-term study would focus on coordinated capacity expansion in SAPP by means of modeling capital investments in new regional links and capacity expansion (coordinated construction compared with independent construction). Benefits from coordinated construction include cost reductions in expansion, the sharing of risk, and a greater availability of finance. Long-term quantitative models will demonstrate the magnitude of the regional and national economic gains that could be made. A regional modeling workshop, in Africa, is proposed to take place in 1998. This would be on a larger scale than the August 1997 workshop, at Purdue, and would aim to include many more energy planners and decision makers from the region, so as to promote a more significant regional awareness of the benefits that can be gained from alternative electricity trading policies for both long and short-term scenarios.

Excellent cooperation, between planners in the Southern African Development Community (SADC) and analysts at Purdue University, has developed through meetings and frequent communications over recent months. The effective combination of experience from the region and the modeling skills at Purdue's State Utility Forecasting Group (SUFG) provides a unique modeling opportunity for assessing the benefits from alternative electricity trading scenarios in this region of Africa.

1. Background to SAPP

The EAGER funded activities in 1997, for electricity trade modeling between SAPP and Purdue University, were provided at a propitious time for furthering an appreciation of the benefits to be gained from regional integration. There are nine SAPP national utilities

connected to the grid, seven of whom are actual operating member utilities. The five non-operating member utilities are looking towards becoming operating members, (twelve utilities in all). With the strategic establishment of a regionally centralized control center, the significant average regional electricity demand growth rates of 4 to 5%, and several major generating and transmission constructions being proposed, the contribution of the research project is proving very timely [2].

The Southern Africa region has for many years essentially consisted of two loose power pools. The pool to the north consisted of connections between Zaire, Zambia, Zimbabwe and Botswana. The most significant link in this northern pool had been at Kariba (connecting Zambia with Zimbabwe). The Kariba Hydropower station was officially opened in 1960. All of the Southern Pool members had links with South Africa. These countries included Namibia, Botswana, Mozambique, South Africa, Lesotho and Swaziland. The high voltage, 400kV, link opened between South Africa and Zimbabwe in 1995 marked the latest and most powerful link within the SAPP grid for providing further integration of the two earlier pools (Figure 1).

In December 1995 the Inter Utility Memorandum of Understanding was signed between the twelve Southern African utilities. This agreement at inter government level officially formed the SAPP with its own operating guidelines. The model used for shaping the operating rules for SAPP was that of the North American Reliability Council (NERC).

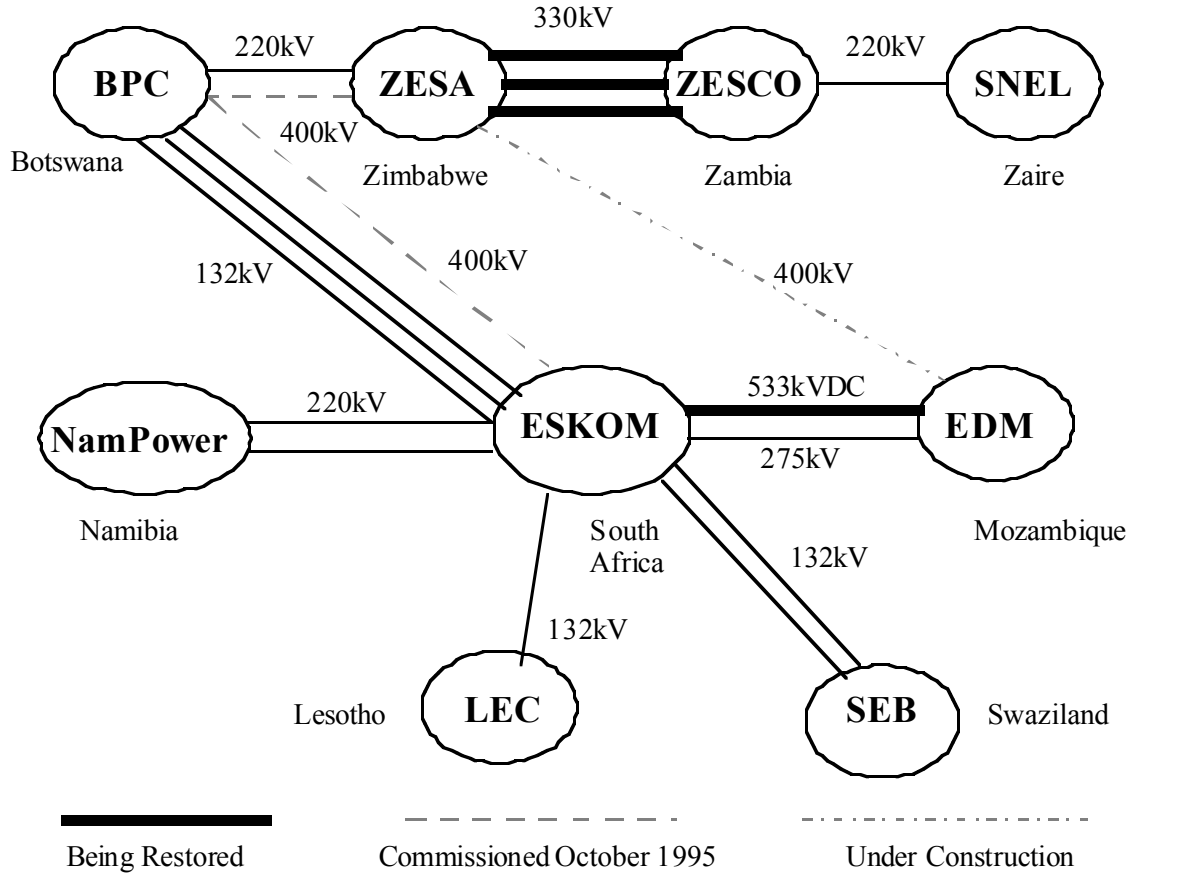
The objective of SAPP is:-

> "*to provide reliable and economical electric supply to the consumers of each of the SAPP members consistent with reasonable utilization of natural resources and effect on the environment. The purpose is to establish the basic principles under which SAPP will operate, inter alia:*
> *(a) the operation of and the co-operation in the planning and operation of the various systems to minimize costs while maintaining reliability and,*
> *(b) the full recovery of costs and the equitable sharing of the resulting benefits."*
>
> *- SAPP Article 1* [3]

In late 1996 the SAPP Management Committee accepted the Purdue proposal and agreed that collaboration with Purdue University for this research project would be a valuable exercise [4]. At the February 1997 Regional SAPP Meeting, in Windhoek Namibia, the work outline for 1997 was confirmed with Purdue staff:-
Professor F.T. Sparrow,
(Email:fts@ecn.purdue.edu, Fax: 765-494-2351, Phone: 765-494-7043)
and Mr. Brian Bowen,
(Email: bhbowen@ecn.purdue.edu, Fax: 765-494-2351, Phone: 765-494-1873).
The primary contact for Purdue staff with the SAPP has been through the SAPP Planning Sub Committee Chairman:-

Mr. Arnot Hepburn, an Eskom corporate advisor,
(Email: hepbura@mp3nis01.eskom.co.za, Fax: 27-11-8---2455, Phone:27-11-800-2022).

Figure 1. The SAPP Interconnect System



Source: Reference [14]

2. 1997 Objectives and Workplan

The Windhoek meeting confirmed the research objectives for 1997. Using the existing infrastructure of the SAPP the trade model would evaluate alternative electricity trade policies. The 1997 model would be a short-term model with a time horizon of less than five years.

SAPP delegates at the Windhoek meeting expressed a wide range of views on what the priorities for improving trade should be (Table 1). There was however a unanimity regarding the chief objective for the modeling in 1997. It should concentrate on the short term gains from electricity trade within the existing infrastructure and generating capacity. Within this short-term framework priorities 3 and 4 would be included as variables within the models together with the first SAPP objective, already listed on page 4.

Table 1. Summary of Results from the SAPP Questionnaire Electricity Trade Priorities

Order	*Subject*	*Total points*
1st	Develop interconnectors	40
2nd	Improve tariff structures	37
3rd	Establish & develop the SAPP coordinating center	24
4th	Decide upon an equitable wheeling policy	20
5th	Improved communication and transparency of information	17
6th	Increased generating capacity	16
7th	Political stability & cooperation	15

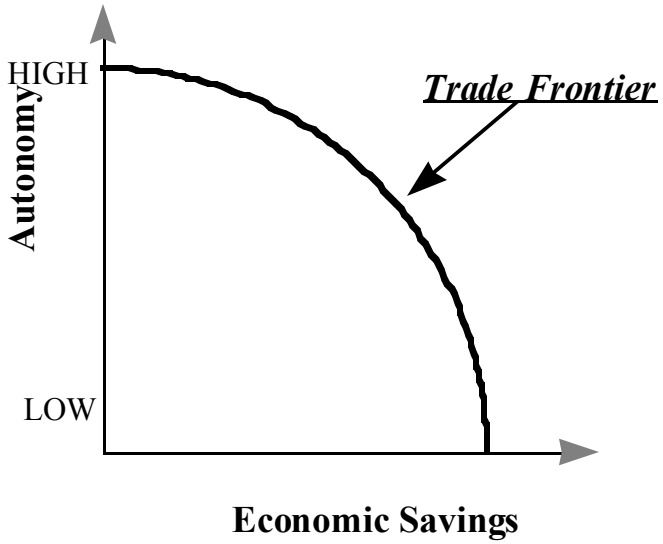
These top seven priorities obtained 80% of the total number of points given to the SAPP members and were specified by them (Windhoek, Feb12, 1997. Purdue University Survey)

Source: Reference [6]

In 1997 the research study has been focusing on developing a trade model which will be based on coordinated dispatch (the economic planning of power station usage including efficient costing of fuel) and coordinated unit commitment (what is the most economic time period for switching on a specific generating unit).

National and regional multi-area modeling will simulate and optimize alternative trading arrangements with appropriate constraints that reflect the operation and efficiency of the SAPP national utilities. For each country, the maximum economic savings achievable for any specified maximum level of import dependence will be calculated. The plot of this "trade frontier" would resemble Figure 2 below:

Figure 2. Individual Country Trade Frontier



Such figures have proven a useful tool for economic policy makers, to assess the trade-offs involved in changing electricity trade arrangements.

With the imminent establishment of a SAPP regional control center (equivalent to an Independent System Operator or ISO in North America) the SAPP Planning Sub Committee (PSC) fully agreed on the timeliness of the Purdue study.

The 1997 workplan can be summarized as:

- ***February 1997***- Presentations and model discussion at the Windhoek SAPP regional meeting.
- ***May 1997*** - Presentation of the wheeling and loose pool paper at the Harare SAPP regional meeting. A questionnaire presented to all SAPP delegates related to determining the appropriate objective function for operation of the pool.
- ***January to July 1997*** - Development of models and collection of data from the regional utilities.
- ***August/September 1997*** - SAPP/Purdue Modeling Workshop at West Lafayette with modeling reports from each participating country.
- ***September to January 1997*** - Refinement of models, simulation and analysis of results with an interim report prepared for the November 1997 regional SAPP meeting.
- ***February 1998*** - Presentation of final report on short-term trade model results at SAPP regional meeting.

At the Windhoek meeting Purdue's Professor Tom Sparrow gave presentations on electricity trade policy, electricity trade modeling and participated in discussions on current plans and concerns within SAPP [5,6,7].

The SAPP requested help from Purdue concerning the trade options available to the existing loose pool (having no centralized control and trading electricity through binational agreements only). Particular emphasis was asked to be given to the question of wheeling rates (the charges for transporting electricity along the lines from one area or country to another). A short comparative study between Southern Africa and the practices in North America was planned. The collaboration between Professor Tom Sparrow and Purdue's regional consultant produced a paper for presentation at the May regional SAPP meeting in Harare [8]. The Purdue regional consultant is:-
Dr Peter Robinson,
(Email: probinson@mango.zw, Fax: 263-4-302496, Phone: 263-4-335869).

Purdue's State Utility Forecasting Group (SUFG) staff are preparing three main models for the August Modeling Workshop. The results from each model will be compared for consistency.

- The first of these models is a unit commitment and dispatch "point" model which assumes the demand and generating capacity for the country to be at one location with transmission loss a fixed fraction of demand. It is a dynamic model incorporating optimal dispatch and unit commitment with no explicit modeling of the transmission grid. The reason is that technical complexities considerably increase when integer mathematical programming (used for the unit commitment), linear programming (used for dispatch), and non-linear programming (needed for the transmission and hydro models) are combined.

- The second model is the country dispatch and transmission model which incorporates the unique regional features of long transmission lines in the network. It assumes commitment based on the results from the point model, line loss, and inclusion of the load flow equations in the model. This is a non-linear programming problem.

- The third model is a collective multi-country model which will permit the analysis of electricity trade between SAPP members. It will incorporate aspects of models one and two. Taking data from single, several or all of the country sets will involve careful data management.

Special modeling attention is also being given to the Southern Africa hydrothermal mix of coal powered generating stations and the existing hydropower stations. Two papers have been prepared on these models so far [9,10].

Table 2. SAPP Collaborators to attend the August 1997 Workshop at Purdue

SAPP Utility	Collaborator's name / Fax & Email
BPC (Botswana)	Mr Bruce RF Moore / 267-373563, bmoore@info.bw
BPC	Mr Modiri Badirwang / 267-214516
EDM (Mozambique)	Mr Mario Houane / 258-1-431029
Eskom (South Africa)	Mr Ferdie Kruger/27-11-8004054,krugerf@mp3nis01.eskom.co.za
Eskom	One Other
NamPower (Namibia)	Mr WO Kleyenstuber / 264-61-2052334, uhek@nampower.com.na
SEB (Swaziland)	Mr Bongoni Mashwama / 268-48274/42335
SNEL (Zaire)	Prof Senghi Kitoko / 243-88-43513
ZESA (Zimbabwe)	Mr Alison Chikova / 263-4-774542
ZESCO (Zambia)	Mr Roland Lwiindi / 260-1-237601
ZIMCONSULT (consultancy)	Dr Peter Robinson / 263-4-335947, probinson@mango.zw

The SAPP/Purdue Modeling Workshop (August 19 to September 3) will bring eleven collaborators from Southern Africa (eight different countries) to Purdue to work together on the electricity trade modeling of the region. Regional planners who are coming to the workshop have limited experience in modeling techniques (Table 2 and Agenda in Appendix I). The Purdue program will assist the region in developing its awareness of the value of models for quantifying the possible gains from electricity trade. The workshop will also include visits to loose and tight power pools on the East Coast of the USA.

At the workshop initial modeling reports will be prepared from each of the eight participating countries. These will be prepared by SAPP and Purdue colleagues working together.

During the last part of 1997 the models will be further refined and the results analyzed in more depth. An interim report is to be prepared for the November 1997 SAPP regional meeting and a report and presentation prepared for the February 1998 SAPP regional meeting.

3. Objectives of the 1998 Research

The SAPP, as a young and rapidly developing power pool (the first formal international power pool outside of North America and Europe) has major trading policy issues being addressed from a short-term perspective in the first year of research. It is addressing the issues of national independence with regional interdependence and equity with efficiency for a more closely integrated regional power pool.

In contrast to the first year of research, the objective of the second year of research is for concentrating on long-term electricity trade modeling. This will address the gains to be made from specific major proposed projects in the region and also consider especially the gains that could be made from having a coordinated construction policy. Priorities 1,5 and

6 from Table 2, will be embedded in the long-term model together with the SAPP cost minimization objective.

A wider definition of the objectives for a second year of research would be:

(a) To collaborate with each SAPP utility to demonstrate the capital cost reductions from regional cooperation as compared with independent national system development plans. One study has estimated that SADC could save about US$1.6 billion in the short to medium term through integrated operation and planning [1]. It further showed savings of US$785 million (1992 prices) over 1995-2010 from integrated regional development compared with independent development. Another medium-term estimate has stated potential savings in the range of US$600 million per annum [11]. For the potential savings to be fully realized it is essential that each SAPP utility has worked out these savings for themselves. The Purdue collaborative research will assist by enabling SAPP colleagues to further appreciate the trade modeling techniques.

Long-term construction projects include new interconnectors as well as generation capacity expansion. Several projects would be included into the model such as:

- The single new link for connecting SNEL (Zaire) directly to NamPower (Namibia). This would be a new link going from the northern border to the southern border of Angola and would also therefore incorporate Angola into the grid. Such a new link in the SAPP grid could make very significant changes to future electricity trade in the region.

- The next major hydropower scheme on the River Zambezi, at Mepanda Uncua (2000MW), down stream of Cahora Bassa (Mozambique). There is a vast hydro potential in the region (Appendix II). To demonstrate the gains to be made from alternative trade policies (from both national and regional perspectives) with expanded hydro capacity will be a major policy forming aid to each SAPP utility [12-16].

(b) In order to assist a much bigger number of decision/policy makers and planners within the SAPP, in evaluating trade options, a regional electricity trade modeling workshop in Africa is being proposed for 1998. The SAPP/Purdue Modeling Workshop at Purdue University, in August 1997, expects eleven collaborators to come from Southern Africa and this number should be tripled if the venue of the workshop was in Africa.

Proven collaboration and mutual working confidence between the Purdue staff and the SAPP management committee makes this proposed activity achievable and a valuable contribution in assisting the SAPP planners.

As with the first year of collaborative research the Purdue staff will continue to share with SAPP counterparts their experience and knowledge of related electricity trade policies, reliability improvement, power pools and regulatory controls from North America, throughout the proposed second year.

4. 1998 Workplan and Dissemination of the Results

The workplan for 1998 is summarized below:

- ***February 1998*** - Presentation of short-term trade model results from the first year of research and agreement to be made between SAPP and Purdue on the long-term construction projects to be considered in the 1998 study, at the February regional SAPP meeting (end of 1997 budget).
- ***February to July 1998*** - Building and testing of long-term model.
- ***Mid-year 1998*** - Presentation of short-term and long-term results at SADC Energy Ministers Meeting (F.T. Sparrow).
- ***Mid-year 1998*** - Africa Regional Modeling Workshop with Purdue team and 30 to 40 African delegates (venue in Africa to be confirmed).The topic of the workshop will be short-term and long-term electricity trade modeling for the region and individual countries. Country papers to be prepared jointly by members from each country.
- ***August-December 1998 -*** Refinement of long-term models.
- ***Late 1998*** - Presentation of long-term results to November 1998 SAPP regional meeting (or February 1999).

Discussion and demonstration of all models (from the first and second year of modeling), together with dissemination of the results, would be achieved through presentations at a **regional modeling workshop** in Africa. The venue and date for this has yet to be worked out. It would be hoped to have up to 40 African delegates participate in this regional modeling workshop. The venue of the workshop being in Africa will ensure the maximizing of its value by allowing a high number of delegates to attend.

It is anticipated that a high level presentation of results will be given at the **Southern African Development Community (SADC) energy ministers meeting**. A presentation at this meeting would provide the most influential audience for maximizing the results from the project. Providing facts from the quantitative analysis to the ministers could have far reaching benefits for the long-term planning of electricity trade in the region. The Southern African colleagues consulted for arranging this are:
Mr Willem Goeiemann, SADC Senior Economist, Gaborone, Botswana,
(Email: willemg@sadc.wn.apc.org, Fax: 267-372848, Phone: 267-351863).
Dr Tony Surridge, Director Electrical Energy, DMEA. Pretoria, S.Africa,
(Email: tonys@mepta.pwv.gov.za, Fax: 27-12-322-0810, Phone: 27-12-317-9106).

The US Department of Energy (DOE) has shown particular interest in Purdue's modeling with the SAPP [17]. They are supportive of the work being done and are recommending that additional financial support might be available through the **USA-South Africa Binational Commission**. The next meeting of the Commission, at which a proposal could be presented, will be in July 1997. DOE staff interested in supporting the research are:
Mr Art Baldwin, (DOE Energy Technology),
(Email: baldwin@petc.doe.gov, Fax: 412-892-4775, Phone: 412-892-6011).
Mr Paul Carrier, (DOE Energy Policy),
(Email: paul.carrier@hq.doe.gov, Phone: 202-586-2699).

The World Bank continues to maintain interest in the modeling project and requests up-dates on developments and results from the work. It is particularly impressed with the list of SAPP delegates who will be attending the August 1997 workshop at Purdue (Re: Email message of 20 May 1997 from Kurt Schenk). The two World Bank staff involved are:
Mr Kurt Schenk,
(Email: kschenk@worldbank.org, Fax: 202-477-0542, Phone: 202-473-3228)
Mr Donal O'Leary,
(Email: doleary@worldbank.org, Fax:202-473-8301, Phone: 202-458-0408)

5. Expected Results

The optimization of electricity generation will be undertaken in both 1997 and 1998. The short-term scenario of 1997 considers the value of trade from a loose pool to tight pool structure. A tighter structure can be implemented once the Southern African Control Center becomes established. The results from the first year of modeling will help SAPP planners and SADC government energy departments formulate the most beneficial trade policies under which the new regional control center should operate. The short-term model results will show the sensitivities and consequences of variations in generating costs (thermal), effectiveness of hydropower coordination, and wheeling charges for various bilateral and multilateral trading contracts as well as for centralized pool sales.

The long-term 1998 modeling results, from a coordinated construction, as compared to the independent national construction, will come from focusing on coordinated capacity expansion in SAPP by means of modeling capital investments in new regional links and capacity expansion (coordinated construction compared with independent construction). Modeling the benefits from a coordinated construction will include:

- predictions of cost reductions from coordinated expansion,
- demonstration of the advantage of sharing of risks,
- analysis of increased levels of trade that is made possible through new and greater line capacity links in the grid,

- estimates of the magnitude of the regional and national economic gains that could be made when capital investment projects are constructed jointly through an easier availability of finance.
- the regional workshop will have helped planners and decision makers within SAPP to better understand the application of electricity trade modeling techniques. The SAPP staff will gain insights into how to quantify and analyze reliability enhancement programs as well as short-run and long-run optimal operation.

6. Personnel and Budget

Six staff members from Purdue (Sparrow, Masters, Morin, Yu, Nderitu, Bowen) together with the regional consultant (Robinson) will be working on the project in 1998. Several other staff members at Purdue (full-time researchers and graduate staff), who are not supported from this research project, made important contributions to the 1997 modeling and are expected to make similar contributions in the research proposed for 1998. Supported staff and contact numbers are listed below (resume for each in Appendix III):

- Professor F.T. Sparrow is the Director of the State Utility Forecasting Group, Professor of Industrial Engineering, Professor of Economics, and Director of the Institute for Interdisciplinary Engineering Studies (IIES). He is the major designer behind the SUFG Modeling System.
- Professor William A. Masters is Associate Professor of Agricultural Economics with extensive experience in trade and policy reform in Southern Africa, having worked in Zimbabwe for several years.
- Professor T.L. Morin is Professor of Industrial Engineering. His research interests are in Dynamic, Integer, Linear and Multiple-Objective Optimization; Energy and Water Resources Systems.
- Dr. Zuwei Yu is a senior analyst with the SUFG. He has long experience in modeling electricity policy reform, with regard to deregulation and non-discriminatory access to transmission systems.
- Mr David G. Nderitu is a research assistant with the SUFG. He has several years of experience in plant maintenance and supervisory responsibilities in Kenya. Interests in mathematical programming and engineering economics.
- Mr. Brian H. Bowen is a research assistant with the SUFG. He has wide experience in industrial organization in Africa and a background in operations research.
- Dr. Peter Robinson, of Zimconsult, Zimbabwe, has a long and extensive experience of electricity policy issues in the Southern Africa region.

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Peter Robinson	*263-4-335869*	*263-4-302496*	*probinson@mango.zw*

There has been excellent response from the SAPP utilities in 1997 in providing additional financial support, as well as the EAGER funding, to enable ten members from the SAPP utilities to attend the August Workshop at Purdue. Seven SAPP delegates are being provided with $3000 each from the EAGER funds.

The extra $1500 or more that is needed for the two and a half weeks in the USA is to be provided to each by the national utility. The three other delegates are to be totally supported by the respective utility. Only Purdue's regional consultant (P. Robinson) will be provided for fully from the EAGER funds.

Discussions have taken place between Purdue and the DOE over the plans and expenses for the trips to the power pools and utilities on the East coast. A request has been submitted to the DOE to provide the finances to undertake these trips to the various East coast facilities. The budget to undertake these off-campus trips for the four days of the workshop (August 27-30, Appendix I) amounts to $16000. These trips were not originally budgeted for in the 1997 budget but result from discussions with SAPP members at the February meeting in Namibia.

It is anticipated that SAPP delegates to the 1998 Africa Regional mid-year workshop will be totally supported by the respective utilities. The DOE has recommended that Purdue request funding for this workshop from the USA - South Africa Binational Commission. All the details for the 1998 workplan can be noted in Appendix IV.

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Appendix I

Agenda of August 1997 Modeling Workshop at Purdue

Institute for Interdisciplinary Engineering Studies
PURDUE UNIVERSITY
SAPP/PURDUE Modeling Workshop, August 19 to September 3, 1997

Sun **AUG 17**	Mon **AUG 18**	Tues **AUG 19**	Weds **AUG 20**	Thurs **AUG 21**	Fri **AUG 22**	Sat **AUG 23**
		9am-12 Intro. #1	***National models*** ←			→
SAPP ***Delegates arrive*** in West Lafayette →		1pm-4 Intro.#2 6pm-8pm **Welcome dinner**	9am-12 MS#1 1pm-4 MS#2 6pm-8 MS#3	9am-12 MS#4 1pm-4 MS#5 6pm-8 MS#6	9am-12 MS#7 1pm-4 MS#8 6pm-8 MS#9	9am-12 MS#10 pm **Social**
Sun AUG 24	**Mon AUG 25**	**Tues AUG 26**	**Weds AUG 27**	**Thurs AUG 28**	**Fri AUG 29**	**Sat AUG 30**
	Manipulate models ← →		***Off campus visits*** - loose power pools, tight power pools & new technologies ←			→
	9am-12 MS#11 1pm-4 MS#12 6pm-8 MS#13	9am-12 MS#14 1pm- 4 DOE & Binational .Commission.				
Sun AUG 31	**Mon SEPT 1**	**Tues SEPT 2**	**Weds SEPT 3**	**Thurs SEPT 4**		
	Collective models ← →					
	9am-12 MS#15 1pm-4 MS#16 6pm-8 MS#17	9am-12 MS#18 1pm-4 MS#19 6pm-8 MS#20	9am-12 Final #1 1pm-4 Final #2	SAPP ***Delegates depart*** West Lafayette →		

Key: MS=Modeling Session

Appendix II

Southern Africa's Potential and Actual Hydro-power (1995/95)

	Hydro -Potential capacity (MW)	*Actual hydropower capacity (MW)*	*Ratio - Actual Hydro / Thermal & other*
Angola	16,000	301	54% / 46%
Botswana	0	0	0 / 100
Lesotho	350	2	67 / 33
Malawi	515	219	89 / 11
Mozambique	9,250	2,181	91 / 9
Namibia	900	240	62 / 38
S.Africa	3,500	1,940	5 / 95
Swaziland	75	41	81 / 19
Tanzania	5,040	326	66 / 34
Zaire	100,000	1,775	98 / 2
Zambia	3,970	1,753	91 / 9
Zimbabwe	2,515	666	34 / 66
TOTAL	**142,115**	**9444**	

Source : [3,4,9]

Appendix III

Resume of Staff

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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.

WILLIAM A. MASTERS

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West Lafayette, IN 47907-1145
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E-Mail:

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.

THOMAS L.MORIN

Education: B.S., Rutgers, 1965; M.S., Case Western Reserve University, 1969; Ph.D. (Operations Research), Case Western Reserve University, 1971.

Recent Professional Experience: Purdue University: Professor of Industrial Engineering (1981-present); Chair, Program in Computational Combinatorics (1986-1994).

Research Interests:
Dynamic, Integer, Linear and Multiple-Objective Optimization; Energy and Water Resources Systems

Professional Achievements:
Fullbright Scholar, Greece (1984); Associate Editor, *ORSA Journal on Computing* (1987-1992); Associate Editor, *Annals of Operations Research*, Special Issue on Interfaces with Artificial Intelligence (1987-1990); Founding Editor, *Journal of Water Resources Planning and Management, ASCE* (1976-1978); Associate Editor, *Management Science* (1976-1985); Associate Editor, *Transactions on Operational Research* (1993-); Program Co-Chair, XXXI International TIMS Meeting, Rio de Janeiro (1991).

Selected Publications:
T.L. Morin, N. Prabhu and Z. Zhang, "Complexity of the Gravitational Method for Linear Programming," to appear in the *Journal of Optimization Theory and Applications.*

S. Ikeler, T.L. Morin and N. Prabhu, "Solution of an Open Problem Posed by Gale: The Jeep Problem with Fuel on Both Sides," *Congressus Numeratium*, Vol 111, pp. 49-64, 1995.

M.I. Kaiser and T.L. Morin, "Characterizing Centers of Convex Bodies via Optimization," *Journal of Mathematical Analysis and Applications*, Vol 184, pp. 533-559, 1994.

J.R. Araque, G. Kudua, T.L. Morin, and J.F. Pekny, "A Branch-and-Cut Algorithm for Vehicle Routing Problems," *Annals of Operations Research*, Vol 50, pp. 37-59, 1994.

S.S. Abhyankar, T.L. Morin and T.B. Trafalis, "Efficient Faces of Polytopes: Interior Point Algorithms, Parameterization of Algebraic Varieties and Multiple Objective Optimization," *Contemporary Mathematics*, Vol 114, pp. 319-341, 1990.

R.E. Marsten, T.L. Morin and J.A. Singhal, "Fixed Order Branch-and-Bound Methods for Mixed-Integer Programming: The ZOOM System," *ORSA Journal of Computing*, Vol 1, pp. 44-51, 1989.

R.L. Carraway, T.L. Morin and H. Moskowitz, "Generalized Dynamic Programming for Stochastic Combinatorial Optimization," *Operations Research*, Vol. 37, pp. 819-829, 1989.

G.W. Evans and T.L. Morin, "Hybrid Dynamic Programming/Branch-and-Bound Strategies for Electric Power Generation Planning," *IIE Transactions*, Vol 18, pp. 138-147, 1986.

G.W. Evans, T. L. Morin, and H. Moskowitz, "Multi-Objective Energy Generation Expansion Planning Under Uncertainty," *IIE Transactions*, Vol 14, pp. 183-192, 1982.

R.T. Jenkins and T.L. Morin, "OPTIMIZER: An Enhanced Dynamic Program for Generation Planning," *Electrical Generating System Expansion Analysis*, Nakamure, S., Kanter, M.A. and Jenkins R.T. (Eds.), Ohio State University, Columbus, OH, 1981. pp. 238-252.

Selected Grants:

Principal Investigator, "Computational Combinatorics," Office of Naval Research, University Research Initiative, Contract No. N00014-88-K-0689, 1986-1992, $4,246,350.

Principal Investigator, "Dynamic Multicriteria Decision Making," NSF Grant No. SES-8312256, 1983-1986, $246,351.

Principal Investigator, "Improvement of the TVA WASP/TARANTULA Generation Planning Program," Electric Power Research Institute, Technical Agreement No. TPS80-729, 1980-1984, $33,000.

Principal Investigator, "Optimal Expansion of Electrical Power Generation Systems," NSF Grant No. ENG-7614396, 1976-1978, $121,370.

Selected Consulting:

Electric Power Research Institute, Inc., Palo Alto, CA.
Ministry of Research and Technology, Athens, Greece.
Standard Oil of Indiana, Chicago, IL.
TAHAL Water Planning for Isreal, Ltd., Tel-Aviv.
Tennessee Valley Authority, Chattanooga, TN.

ZUWEI YU

State Utility Forecasting Group, 1293 Potter Center Room 334,
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.

DAVID GACHIRI NDERITU

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EDUCATION

Purdue University GPA: 4.00/4.0
Industrial Engineering, Doctor of Philosophy
Graduation Date: May 98 (expected)

Purdue University GPA: 4.00/4.0
Industrial Engineering, Master of Science
Attended: Aug. 91 to July 93

University of Nairobi, Kenya 1st class honors
Mechanical Engineering, Bachelor of Science
Attended Nov. 81 to Jun. 84

Significant course work includes Mathematical Programming, Engineering Economics, Probability Models, Production Control, Simulation. Computer literacy includes C, GAMS, CPLEX, PROLOG,

EMPLOYMENT INFORMATION

Institute for Interdisciplinary Engineering Studies, Purdue West Lafayette, IN
Research Assistant 1995,1996
Research Topic: Incorporating transmission into the electric utility capacity expansion model

East African Fine Spinners Nairobi, Kenya
Plant Engineer 1989-1994
Responsibilities included managing the maintenance workshop and coordinate all Engineering activities in the spinning mill.

Central Glass Industries Nairobi, Kenya
Shift Engineer 1987,1988
Responsible for supervising one of the four shifts in a glass container

Kenya Railways Corporation Nairobi, Kenya
Assistant Mechanical Engineer, Central Maintenance Workshops, Nairobi 1985-1986
Part of the technical team maintaining locomotives and rolling stock

ACTIVITIES AND HONORS

Host/Leader African Christian Fellowship at Purdue, member institute of Industrial Engineers, INFORMS, Institute of Engineers of Kenya.

BRIAN H. BOWEN

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765/463-1297 (Home)
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Email: bhbowen@ecn.purdue.edu

Education:

- Purdue University, School of Industrial Engineering,
  Ph.D. in Industrial Engineering (Expected 1998),
- John Moore University at Liverpool, School of Mechanical, Production & Marine Engineering. Post graduate Diploma in CAD/CAM, (MSc courses) (1987).
- University College, Cardiff, Department of Mechanical Engineering & Energy Studies, MSc in Energy Studies (1985).
  Thesis title: "Assessment of Solar Heating Systems for a Developing Country".
- Oxford University, Department of Education, Post graduate Diploma in Education (1973).
- Coventry University, Department of Mechanical Engineering,
  BSc in Mechanical Engineering (1971).
- Chester College of Further Education (1964-1967)

Experience:

Modeling and analysis of energy systems (electricity). Energy economics. Solar heating system design. Design for manufacture and production using conceptual, traditional and computer assisted processes.
Experience in proposal development for multinational consortium.
Extensive regional experience in Zimbabwe, Sierra Leone, Mauritius

Employment:

- Purdue University Research Assistant (1996-present), - USAID/EAGER (Equity And
  GrowthThrough Economic Resarch)Trade project: "Modeling Electricity Trade in Southern Africa".
- Purdue University, Teaching Assistant in Manufacturing Laboratory(1994-1996).
- 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.

Grants:

Research funding received from:

- USAID - Equity and Growth through Economic Research (EAGER/Trade) (1996-98).
- UK - Overseas Development Administration (1980-82).

Professional Association:

MIMechE, CEng, Member of the Institution of Mechanical Engineers (United Kingdom). Professional engineer status (chartered engineer) (1978).

Publications:

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

F.T. Sparrow, B.H.Bowen, William A.Masters and Zuwei Yu, "Electricity Trade policies and the Southern African Power Pool", SAPP Regional Meeting, Windhoek, Namibia, February 12-13, 1997.

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

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

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

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

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

PETER BRODIE ROBINSON

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P O Box A228,Avondale,Harare
Zimbabwe

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Profession Economist / Mathematical Modeller
Languages English, Portuguese

EDUCATION AND AWARDS

1973	University of the Witwatersrand BSc (Electrical Engineering) Chamber of Mines Gold Medal & Research Scholarship for the best engineering graduate, 1973
1974-1977	Rhodes Scholarship
1976	Balliol College, Oxford University MA (Politics, Philosophy & Economics) First Class Honours George Webb Medley Prize for the best performance in Economics in the final University examinations
1981	Stanford University, California USA PhD (Engineering-Economic Systems)

EXPERIENCE

1982-present Zimconsult

Main areas of expertise in ZIMCONSULT have been as follows:

1 Industrialisation and Trade
2 Macro-Economic Planning and Modelling
3 Water Supplies & Water Resources Development
4 Energy Economics and Optimisation
5 Transport Economics
6 Evaluation and Strategic Planning for Donors
7 Environmental and Resource Economics
8 Market Studies (water, steel, cement, beef, dairy products, wood, energy)
9 Development Projects in Rural and Small-Scale Urban Settings (including Co-operatives & Health Economics)
10 Project Feasibility Studies
11 Training

RECENT WORK ON ENERGY & ENVIRONMENT IN ZIMBABWE & SADC

Energy Planning

Projects:

Prospects for Economic Integration in Southern Africa in the Post-Apartheid Era
Tariffs & Charges for the Zambezi River Authority
Modelling Electricity Trade for the Southern African Power Pool

Agencies : Oxford International Associates
Zimconsult & Powerplan
Purdue University Institute for Interdisciplinary Engineering Studies/USAID

Clients : African Development Bank
Zambezi River Authority
Southern African Power Pool

Projects: Zimbabwe Energy Accounting Project
Integrated Energy Supply Strategy for Zimbabwe
Electrification Masterplan (Report II)
South African Energy Policy Research and Training Project
National Electricity Rationing Study
Energy Policy and Training
Liquid Fuels Price Review
Electricity Tariffs for Sable Chemicals
Zimbabwe Energy Efficiency Project

Agencies: Beijer Institute of the Royal Swedish Academy of Sciences
Energy Sector Management Assistance Programme
Bicon (Zimbabwe)
Plan Inc
John Hollaway & Associates
RAJ Consultants
Stewart Scott Kennedy
GTZ (Harare)
Powerplan (Zimbabwe)
SADC Energy Conservation Office
LanXang International
LaRocco Associates

Clients: Ministry of Energy & Water Resources & Development
UNDP/World Bank
Department of Energy Resources and Development -
Zimbabwe Electricity Supply Authority (ZESA)
Energy for Development Research Centre, University of Cape Town
Zimbabwe Association of Business Organisations
Swedish International Development Authority
Ministry of Transport and Energy

Responsibilities: In Beijer study, participation in drawing up and implementing a survey of energy use, conservation and substitution by manufacturing industry, mining and the commercial sectors; development of economic growth scenarios using the input-output model and use of this data as an input to the detailed energy accounting model.

Further details and publications list available.