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 1999 ~ 2000

June 1999

Purdue University

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Summary

In its work to date, Purdue University's work on electricity trade in Southern Africa has shown operating-cost savings of $80 million per year from implementing electricity exchange instead of existing bilateral contracts, and capacity-expansion savings of $700 million over the next twenty years from coordinated construction with competitive exchange rather than national plans. The savings would be spread among the national utilities and their governments as well as residential and commercial users of electricity, representing a net addition to the region's real income. The computation of these savings is based on linking computer models for each country's national electricity system, constructed through the collaboration among utility staff working through the Southern African Power Pool (SAPP).

In this document Purdue proposes a third year of collaboration with SAPP, building on SAPP's official recognition of the Purdue models as their analytical tool of choice for projecting the costs and benefits of alternative policies, issued in February 1999. The present proposal, which was developed in close collaboration with utility staff and SAPP officers, calls for:

(1) implementation of the model with an improved windows interface,
(2) strengthening the individual national models of long-term investment options and,
(3) preparation of country specific analysis papers on options in electricity generation and transmission expansion with alternative trade policies.

Some of the key issues identified as having priority, by the collaborating utilities in Southern Africa, are capital borrowing strategies for major capacity and transmission expansions, costs of fuel and reserve power, tariff setting, wheeling rates, and maximum integration of the new coordination center. The existing SAPP models already contain most of the data needed to address these issues and the results from this proposed third and final year of modeling will assist the SAPP with detailed analysis of its long-term planning options. The third year results on long-term planning options will consider the benefits to be gained from regional long-term planning compared with independent national plans.

A key feature of the Purdue project and of SAPP's work in general is its focus on regional meetings of engineers and policymakers to implement cross-country collaboration. This proposal calls for three different major meetings:

(a) in August 1999, a demonstration of the windows interface version of the long-term model at the SAPP management meeting to be held in Tanzania. Recommendations will be made for the final refinements of the interface.
(b) in November 1999 a one week consultation and training workshop for the SAPP representatives (one from each of the twelve utilities and from the coordinating center) will be held at Purdue, and
(c) around May 2000 a set of dissemination seminars within the region to meet with utilities to present and discuss the specific country papers and further demonstrate the use of the final windows version of the model.

Accomplishments to Date and Summary of Proposed Third Year Work

1.) Accomplishments during the Second Year of the Study

Major milestones of the second year's work, fully described in the year 2 final report [1], include:

- Construction of an initial "Mark I" version of a long term model of optimal capacity expansion and capacity utilization for the SAPP region, whose eventual objective is to answer more exactly the question of the least cost mix of new thermal, hydro, and transmission capacity to meet the region's growing demands, which led to…

- Presentation of this initial model to 40 workshop attendees in Cape Town in July to elicit their suggestions as to improvements in the model;

- Modification of the model in response to the groups' suggestions, as outlined in Table 1; and…

- Improvement of the data base supporting the model, which allowed…

- Preparation, analysis, and presentation of the initial runs of the "Mark II" version of the model to SAPP Management and Planning Committee members at their February 1999 meeting in Swaziland. As expected, the results indicated that major SAPP system wide savings were possible if the expansion of the system was carried out with the objective of minimizing collective SAPP construction and operating costs, rather than having each country build and operate its own units to meet its own domestic demand, which led to…

- The initial presentation of a theme that will undoubtedly remain as the major policy conclusion of this model created for SAPP use – that the "least cost" supply strategy for SAPP nations will feature a combination of the use of cheap northern hydro capacity and southern demand side management to postpone or eliminate the need for the construction of more expensive and polluting southern thermal capacity.

The runs that were accomplished in the second year of modeling proved the working value of the SAPP long-term planning model. When the SAPP countries relax their autonomy constraint (and there is an average electricity demand growth) then the regional costs amount to 11.47 billion USD over the twenty years 2000-2020. Figure 1 shows how the bulk of these costs arise from the construction of expansion of thermal power stations. The majority of the thermal power is built in the second half of the 20-year horizon as shown in Figure 2.

When the autonomy constraint is enforced then the total regional cost increases to 12.17 billion USD, an increase of just over 6%. The extra costs occur from increased thermal construction in the earlier years.

Figure 1 Total Expansion Costs for Each Period for Thermal and Hydropower Generation and Transmission. Expansions - with Relaxed Autonomy Constraint in the 20 Year Horizon (Millions of USD per Period)
(Total 20-year cost is 11.4 billion USD with average growth)

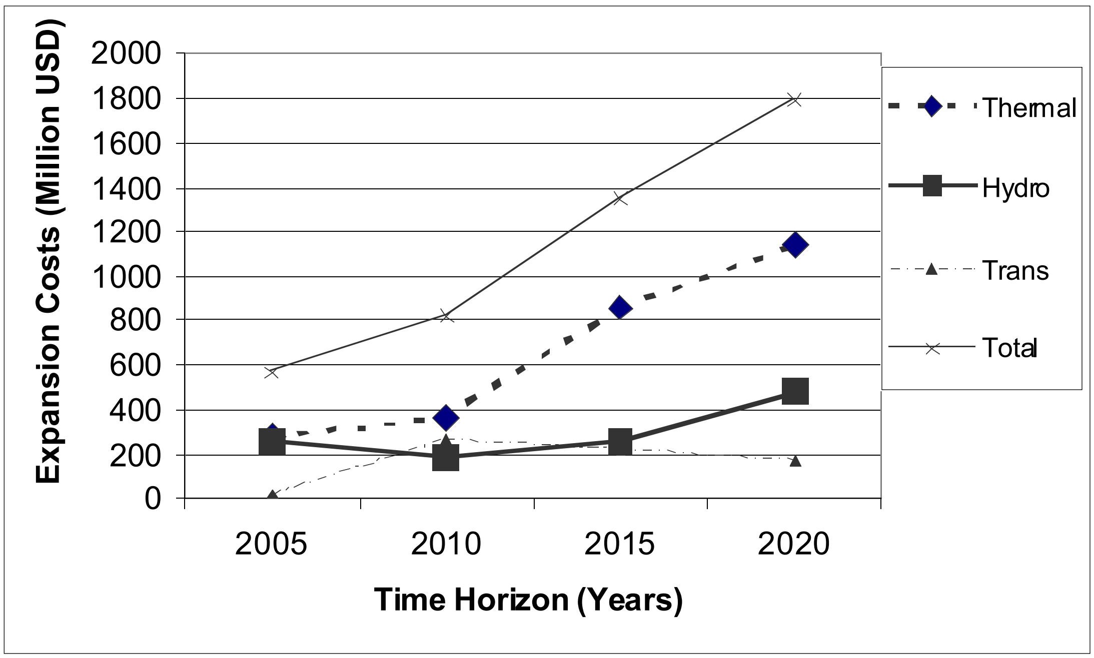
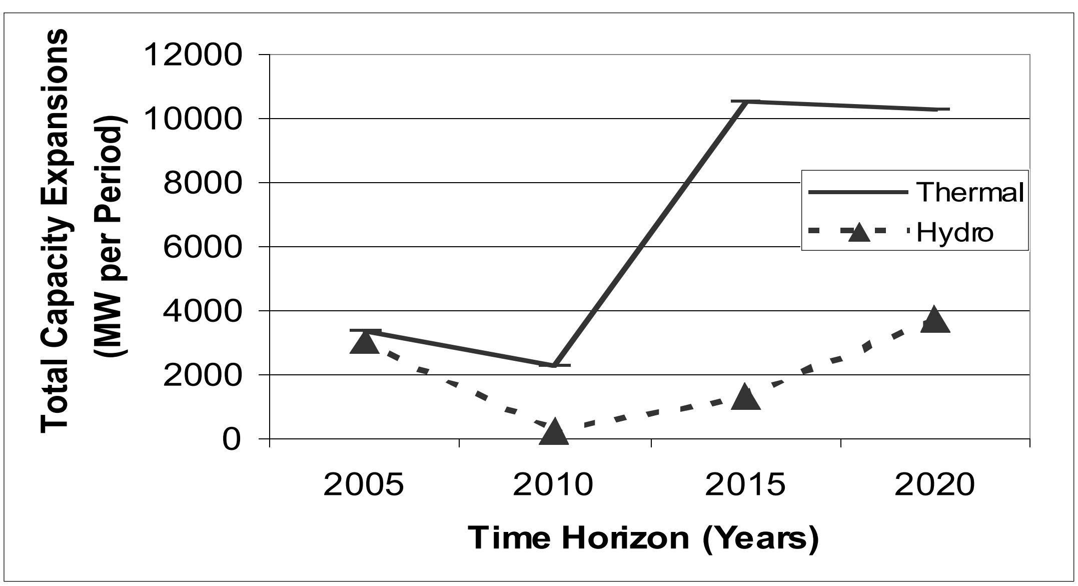


Figure 2 Thermal and Hydropower Expansions for Each Period with Relaxed Autonomy Constraint in the 20 Year Horizon (MW per Period.)
(Total 20-year cost is 11.4 billion USD with average growth)



Various model runs were made which quantified capacity expansions for a number of scenarios. Figure 3 summarizes the 20-year horizon scenario with the autonomy constraint relaxed and with an average demand growth in electricity of 3.8% for the region. The new transmission expansions are the numbers in the "boxes" and the generation capacity expansions are the numbers in the "ellipses".

Figure 3 shows the summation of all the expansions over the 20-year horizon. This run of the model has included all the SAPP specified new projects (in Table 3) as well as the generic projects, which have current USA costing. Strengthening of the spine of the transmission grid in SAPP (DRC to Zam to Zim to RSA) is shown as well as a new major line down the west side of the region. Large thermal stations are built in the South and combined cycle plants are substantially employed. The biggest new hydro plant is in DRC at Inga3. No new hydro plant was built at Inga on an earlier 8-year model run which had excluded all the new generic sites.

The planning horizon was over 20 years, allowing choice to be made in 2005, 2010, 2015, and 2020; SAPP demand growth was again the average scenario specified by Dr. Robinson. The set of capacity expansion options was expanded to include the construction of generic plants, whose cost and performance data were taken from a recent U.S. study. The country autonomy constraint remained relaxed, only requiring that SAPP countries satisfy their reserve requirements by a mixture of thermal and hydro capacity and firm imports.

Expansion costs are a substantial (40%) portion of total system costs. This is to be expected, as system demand catches up, and then surpasses system supply, over the longer planning horizon. Fuel costs again dominate operating costs. Thermal and hydro costs are a much larger fraction (85%) of total expansion costs; transmission costs represent only 15% of total expansion costs.

The vast majority of additional MW is devoted to new generation construction, rather than transmission. This is not because transmission expansion substantially decreased as the horizon lengthened, but rather because of the substantial increase (5 fold!) in the need for new generation, as the planning horizon extended into the years where substantial generation deficits exist.

The general pattern of transmission capacity expansion found in the short-term model persists in the longer-term model – initially invest in the DRC/Zambia/Zimbabwe/RSA "spine", then build the western route from DRC through Angola and Namibia to RSA.

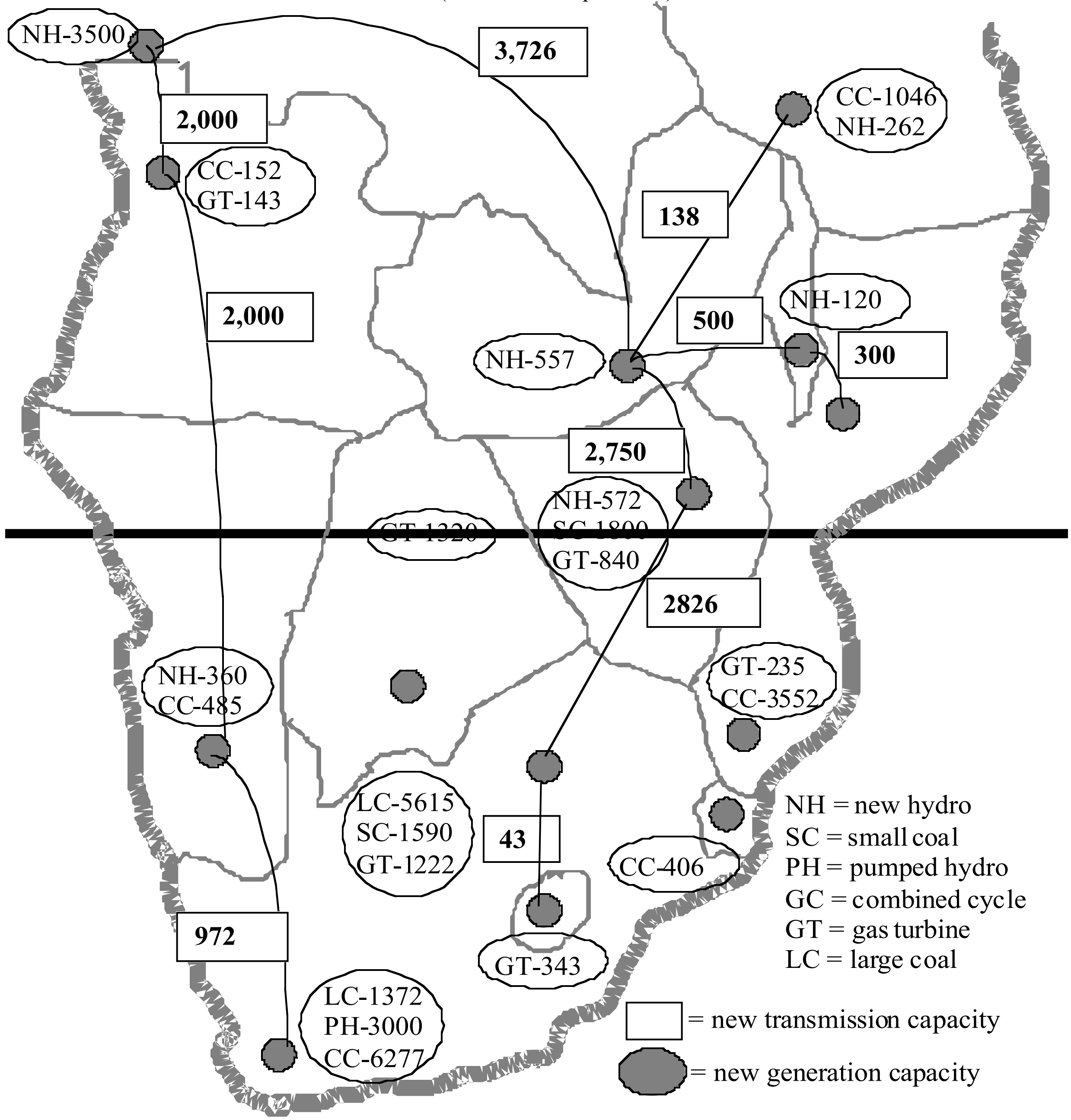
In contrast to the short-term model, thermal construction becomes a major (50%) part of the total construction dollar budget, and an even larger (over 70%) part of the MW total. Thermal construction is dominated by construction of over 6000 MW of large coal generation plants in the South, and a surprising amount of construction of generic combined cycle plants in those countries where a source of natural gas supply was identified. In addition, relatively small investments were made in small coal plants, and generic gas turbines for peaking purposes, again restricted to those countries where gas was assumed available at competitive prices.

New Hydro construction was dominated by drawing on the resources of DRC's Inga site towards the end of the horizon; early hydro expansion was, as in the short-term model, concentrated in hydro investments along the DRC/Zambia/Zimbabwe/RSA "spine", and in pumped storage investment in the South.

These results should be viewed with caution. They assume SAPP has access to thermal technologies at the going world average cost. This may be a wildly optimistic assumption, given the nature of generation plant construction in the SAPP region. In particular, it assumes that the SAPP region can invest in the substantial infrastructure necessary to allow the bulk (all countries except Zambia, Malawi, Mozambique, Swaziland, and DRC) of SAPP members to have access to natural gas as a fuel source, either from domestic production, or imports. Such access would allow SAPP members to benefit from the substantial advantages of gas fired combined cycle generation plants, which now dominate new construction in North America. (The assumption is easy to change by simply eliminating generic combined cycle plants from consideration.)

Figure 3 Expansion Results of 20-Year Planning Horizon, Country Autonomy Constraint Relaxed

(all units on map in MW)



Values are in Billions of Dollars

Total Variable Costs for the Horizon	
Fuel	5.604
O&M	0.923
Water	0.419
Total	6.947

Total Expansion Costs for the Horizon	
Thermal	2.651
Hydro	1.187
Transmission	0.690
Unserved En.	0.000
Total	4.527

Total: $11.474 Billion ****DEMONSTRATION RUN ONLY** – Not to be used for project evaluation*

TABLE 1: List of Major Model Changes Suggested at July 98 Workshop now in Model

- A complete users guide documenting the model, its assumptions, and the data now supporting it.
- Revision of the reliability constraints to bring them into line with SAPP conventions
- Allow users to choose how capacity expansion is to be modeled – continuous, or fixed multiples of a given size.
- Allow users to select the length of the planning horizon – near (5 years) to long term (20 years).
- Allow users to invest in pumped storage and other DSM options that can vary by hour and country as an alternative to traditional supply options.
- Allow for decommissioning and decay of older generating units.
- Redo of assumptions governing derating of generating units to allow preventive maintenance to take place during off-peak periods.
- Introduced scale economies into new plant construction.
- Allowed the capital recovery factor to vary by country and equipment type.
- Allowed users to specify differing hourly demand patterns for differing day types.

In addition, a series of minor changes were made to allow more user choice in the structure of the model.

Finally, after exchanging over 200 e-mails with SAPP members, the data base supporting the model has been dramatically improved thanks primarily to the SAPP Generation Planning Group, under the leadership of Dr. J.L. Pabot.

2.) Background for the 1999 Study

The Cape Town Regional Modeling workshop, in July 1998, confirmed the importance that the SAPP is placing on the LT model [2]. Over 40 delegates attended the workshop, representing nine of the twelve Southern African Development Community (SADC) countries with a tenth country being the Democratic Republic of Congo (DRC is not a SADC member).

SAPP utilities await eagerly to see the results of the long-term model in order to evaluate and improve planning and to assist in obtaining financing for major capacity expansion projects. Considerable interest and debate is expected from the LT model sensitivity analysis. Details of the LT model formulation were first made available in Cape Town [3].

The electricity demand growth statistics within SADC that are employed in the LT model were compiled by regional consultant Dr. P.B. Robinson. These are shown below in Table 2. The medium growth scenario is used in the year 2 sensitivity analysis. The values of these growth rates, as well as dozens of other significant variables in the model (discount rates, fuel costs, building costs, maintenance costs, time horizons, etc.) can all be changed very easily. At the request of the delegates in Cape Town, a 200 page user manual has just been completed, which thoroughly describes the model and provides operating instructions for new users of the model; a near final draft of the User's Manual will be provided under separate cover.

TABLE 2: SADC & Southern Africa Power Pool Capacity Growth Rates - 1996-2020

1996-2020	Maximum Demand (internal - 2020)			Maximum Demand growth rates 1996-2020		
	LOW MW	MEDIUM MW	HIGH MW	LOW % p.a.	MEDIUM % p.a.	HIGH % p.a.
Angola	765	1111	2004	6.2%	7.9%	10.5%
Botswana	529	606	903	3.7%	4.3%	6.0%
Lesotho	171	312	501	3.4%	6.1%	8.2%
Malawi	268	346	693	2.1%	3.2%	6.2%
Mozambique	1481	2299	3662	8.9%	10.9%	13.1%
Namibia	1210	1704	2265	5.7%	7.2%	8.5%
South Africa	40244	62199	95108	1.8%	3.6%	5.5%
Swaziland	251	315	400	2.5%	3.4%	4.5%
Tanzania	1068	1672	2452	4.0%	6.0%	7.7%
Zambia	1928	2866	4511	2.7%	4.4%	6.4%
Zimbabwe	3490	4626	6982	2.9%	4.1%	5.9%
SADC tot/weighted av	51406	78055	119483	2.0%	3.8%	5.7%
South Africa	40244	62199	95108	1.8%	3.6%	5.5%
Rest of SADC	11162	15856	24374	3.6%	5.0%	6.9%

Compiled by: Peter B. Robinson, July 1998

Table 3: Optional New SAPP Generating Capacity

(A Revision of Year 2 Interim Report Appendix V, February 12, 1999)

Country	Powerstation H = Hydro T-SC = Small coal T-LC = Large coal	Number of Units	Unit Size (MW)	Total Added MW)	Cost $ million	Type T/H/PS	Cost $/kW	Heat Rate Btu/KWh	Fuel Cost $/MWh	O & M Cost $/MWh
	Optional Projects									
Angola	Cambambe (Ext.)	2	45	90		H				
Angola	Capanda II	2	130	260		H				
Botswana	Moropule	2	120	240		T-SC				
DRC	Inga3			3500		H				
DRC	Grand Inga ST1	8	750	4750		H				
DRC	Grand Inga ST2	9	750	4750		H				
DRC	Grand Inga ST3	9	750	4750		H				
DRC	Grand Inga ST4	7	750	4750		H				
Malawi	Kaphichira Phase1 *	2	32	64		H				
Malawi	Kaphichira Phase 2	2	32	64		H				
Malawi	Lower Fufu	2	45	90		H				
Malawi	Mpatamanga	5(?)	63(?)	315		H				
Malawi	Kholombidzo	2	35	70		H				
Mozambique	Mepanda Uncua	5	400	2000		H				
Mozambique	Cah. Bassa N. (Ext.)			1240		H				
Namibia	Kudu (Gas)	1	750	750		T				
Namibia	Epupa	1(?)	360	360		H				
South Africa	Komati A (Recomm).	5	5x90	450		T-SC				
South Africa	Grootvlei (Recomm).	6	5x190+ 1x180	1130		T-SC				
South Africa	Komati B (Recomm).	4	4x110	440		T-SC				
South Africa	Camden (Recomm).	8	190	1520		T-SC				
South Africa	PB Reactor	10	100	1000		T-SC				
South Africa	Lekwe	6	659	3950		T-LC				
South Africa	Pumped Storage A	3	333	999		PS				
South Africa	Pumped Storage B	3	333	999		PS				
South Africa	Pumped Storage C	3	333	999		PS				
South Africa	High head UGPS	2	500	1000		PS				
South Africa	Gas Turbine	4	250	1000		T				
Tanzania	Ubungo (Gas)	1	40	40		T				
Tanzania	Tegeta (Gas)	10	10	100		T				
Tanzania	Kihansi	3	60	180		H				
Tanzania	Rumakali	3	74	222		H				
Tanzania	Ruhudji	4	89.5	358		H				
Zambia	Itezhi-Tezhi	2	40	80		H				
Zambia	Kafue Lower	4	150	600		H				
Zambia	Batoka North	4	200	800		H				
Zambia	Kariba North (Ext.)	2	150	300		H				
Zimbabwe	Hwange Upgrade	1	84	84		T-SC				
Zimbabwe	Hwange 7 & 8	2	300	600		T-SC				
Zimbabwe	Gokwe North	4	300	1200		T-SC				
Zimbabwe	Batoka South	4	200	800		H				
Zimbabwe	Kariba South (Ext.)	2	150	300		H				
	Commited Projects									
South Africa	Majuba*	6	3x612, 3x667	3837		T				
South Africa	Arnot 3-6 Recomm.*	4	4x330	1320	—	T				

* Commissioned by 2000, **Estimated, *** Estimated by given 664 and assumed without dam.

The SAPP defined generation projects are now included in the model listed in Table 3 and the regions that have the extra options to build generic generating stations (based on costs from the USA) are shown in Table 4.

TABLE 4: Countries which have the Option of Generic New Generating Stations

Country	NSC	NLC	CC	GT
1 Ang	●		●	●
2 Bots	●			●
3 DRC				●
4 Les	●			●
5 Mal	●			●
6 Nam			●	●
7 NMoz	●			●
8 SMoz			●	●
9 NSA	●	●		●
10 SSA	●		●	●
11 Swaz	●			●
12 Tan	●		●	●
13 Zam				●
14 Zim	●			●
NSC = New Small Coal NLC = New Large Coal CC = Combined Cycle GT = Gas Turbine				

*3.) **Summary of Proposed Work During Year 3***

Based on the accomplishments of years one and two of the project and following the adoption by SAPP of the resolution shown in Appendix I, third year work is proposed in three areas:

I). Modeling Refinement: Create windows interface, incorporate model changes, further testing of model, update data sets.
II). Model Dissemination: SAPP training, install model at SAPP coordinating center.

III). Analysis of the Model's Results: Service runs of the model for each utility with special attention to projects having specific national interest.

I.) Area One: Modeling Refinement

This involves four sub-tasks;

(a) Create a "Windows" interface version of the model. The SAPP management expressed strong support for the project to surround the model with a windows based input/output module. While the current GAMS files are quite understandable to those well versed in optimization codes, they cause unnecessary confusion for those SAPP managers who plan to use the model as a decision support system.
Consequently, it is proposed to develop such an interface with the help of Purdue University's Computer Science Department, and have it available for demonstration in the early Fall of 1999. The primary design of the interface will be done by soliciting the SAPP committee members themselves as to their desires for specific input and output windows. A trial version would be demonstrated at the August SAPP meetings in Dar-es Salaam, Tanzania, in order to allow revisions suggested by SAPP members.

(b) Incorporate the changes in the model structure suggested at the February 1999 Swaziland SAPP Management Meeting. During the meeting, SAPP members suggested several additions to the model, which they thought would make it more responsive to their needs. Some of these are minor embellishments, others will take a significant amount of time. Major changes include a reformulation of both the reserve requirement and country autonomy constraints. All will require the user's manual be updated to include the revisions.

(c) Further testing of the model to insure all modules are functioning properly. The second year of the research created a "Mark II" version of the long run model, and initially exercised the model to demonstrate its usefulness. By the end of the second year, the model will still need additional exercising to insure that all the representations of SAPP behavior are functioning correctly. This process involves altering each parameter individually and then in concert with other parameters, and observing if the optimal solution changes in the expected way.

(d) Update the data sets that drive the model. The model is now populated with data whose quality precludes drawing any dependable detailed policy conclusions vis a vis the specifics of optimal trade patterns. Only the general patterns of trade – immediate expansion of the hydro capacity in the north and the transmission capacity to carry it to the South, thus forestalling the construction of expansive and polluting new thermal capacity in the South – can be relied upon at this stage of the analysis, along with the staggering (billions!) magnitude of the SAPP wide cost reductions possible for all SAPP utilities if free trade is allowed.

It remains in year 3 to convert these initial optimal trade patterns into more dependable indicators of country by country optimal "make or buy" decisions, and to then test the robustness of these conclusions under varying assumptions regarding construction financing costs, the differing country by country needs for reliable electricity service, the varying need for country autonomy vis a vis its electricity supply, and other crucial policy parameters. Without this step, SAPP policy makers will use the tentative model results generated in year two at their own risk.

II.) Area Two: Model Dissemination

This will involve two subtasks:

(a) Training SAPP members in the use of the Windows version of the model. Upon completion of the Windows input/output interface, a workshop for SAPP users will be held at Purdue University in November of 1999. Completion of the workshop will enable any SAPP member who has the necessary software to run the model with data sets of their won choosing, enabling them to see how changes in the attributes of the competing generation and transmission options alter the SAPP wide least cost solution. Consideration will also be given to training a few select SAPP modeling experts in the modification of the source code, enabling SAPP to alter the internal structure of the model to meet SAPP's changing requirements.

(b) As specifically requested by SAPP, install the model at the SAPP coordinating center in Harare, and train staff members in the use of the model. The planned staffing of the SAPP coordination center at Harare offers a unique opportunity for enhancing the analytic capabilities of the center to carry out its mission by training them in the use of the model. While the budget allows separate training for the staff, it is possible that the SAPP coordination center training could take place at the same time SAPP utility staff is being trained at Purdue.

III.) Area Three: Analysis of the Model Results

Following final data and model checking, presentation of policy oriented seminars, prepared for, and presented to, each of the SAPP country delegates are planned. These would present the trade and construction implications of the optimal solutions, for each country, along with a sensitivity analysis tailored for each country, as well as the economic consequences of depending only on domestic generation facilities, rather than trade, to meet domestic demand. As was the case with the short run model, the analysis will apply several methods of allocating the gains from trade to each country's situation, as well as consideration of the broader economic issues discussed below. These would be planned in February 2000.

Results and analysis of the short-term (ST) model [4,5] and the long-term (LT) model [6] can be found in other reports to the SAPP. Nine SAPP countries are included in the first year ST model and all twelve countries form a part of the LT model (see Figure 1). The third year will provide an analysis to assist in the determination of long-term planning strategies in each country to choose the optimal minimal cost of capacity expansion. It is anticipated that it will take a while before each utility has the hardware in place to run the LT model. Year three is therefore expected to provide service runs for each utility in which the values associated with projects of specific interest to a country can be changed and the costs and benefits analyzed.

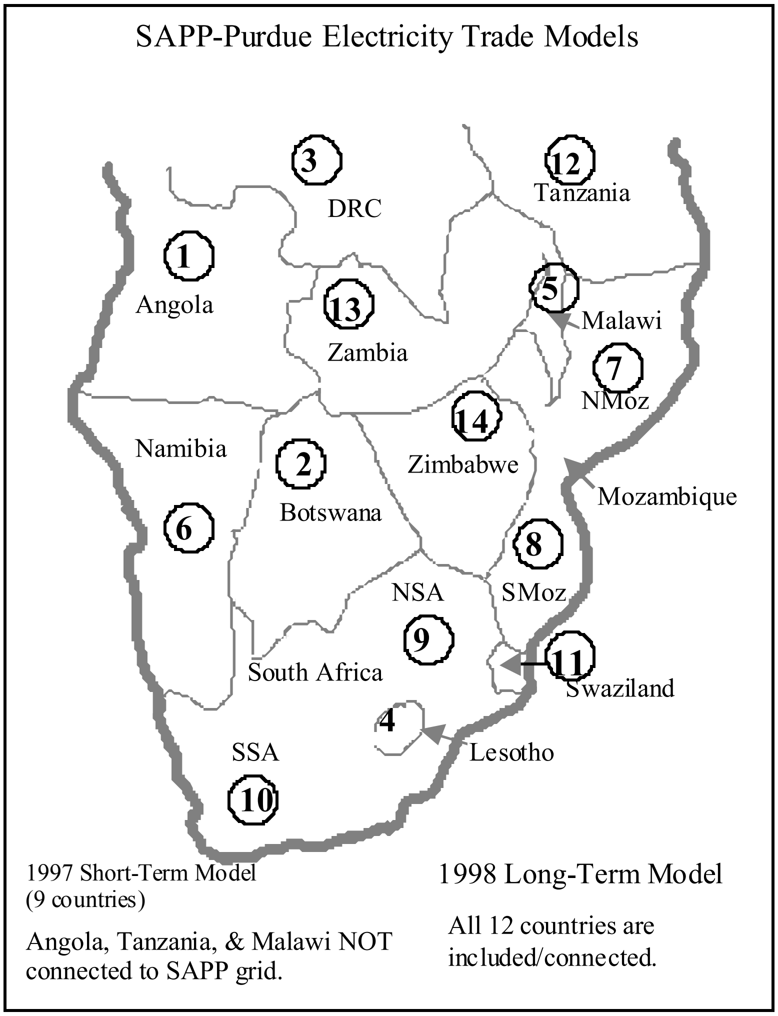


Figure 4: The 12 Countries in the Long-Term Model

The node numbering in Figure 1 (nodes 1 to 14) continues to be used in year two together with mixed integer linear programming techniques. The notation and formulation will remain much the same in year three as in year two except for the gradual improvements and likely evolving nature of the model that will take place. The objective function of the current version of the

long-term model is to minimize the present value of the levelized cost of construction and operation of the SAPP grid while maintaining sufficient reserves in each country to meet demand as well as unanticipated shortages. Inclusion of various financing options (long term bonds, leasing, borrowing) could be added, if the users of the model thought it desirable.
All of the details of the formulation together with notation definitions, coding and model operating instructions are available in the 1998 SAPP Model User Manual. Copies of this are available from Ms. Chandra Allen (E-mail: clallen@ecn.purdue.edu, Phone USA: (765) 494-7036, Fax: (765) 494-2351).

The third year analysis will continue from the year two work. In year two a 20-year time horizon was chosen planned and the two contrasting expansion scenarios that are considered are:

(a) SAPP chooses a central construction policy for the generation expansion plan in order to minimize total regional expansion costs.
(b) Each country chooses an independent construction policy to meet domestic demand only from domestic power sources.

The long-term model gives a substantial insight for investment strategies. The benefits of central construction planning for capacity expansion can be compared with the "go it alone philosophy" of capacity building from a national perspective only. Optimal minimal total costs for the years 2000 to 2020 are shown to be about $10 billion for the harmonized expansion case. Total regional costs can be as high as $12 billion for the "go it alone" case. The total costs of generation expansion are reduced by planning regionally.

The twelve SAPP utilities each have their own national responsibilities while maintaining a mutual integrity of purpose as a formal power pool. Three groupings however, can be made from among the 12 utilities for purposes of the year three work. These three groups, who will form the basis of organizing the seminars, are;

1.) South Africa's Eskom. Eskom generates 80% (38,000 MW generating capacity in 1997) of all the power in the pool and has vast resources compared to all of the other partner utilities. The bulk of its generation is from coal fired stations. South Africa has much to gain from increased imports of cheaper hydro generated power.

2.) The large hydro power utilities of the SAPP form a second grouping. The Democratic Republic of Congo, Mozambique and Zambia are almost totally hydropower. SNEL (DRC) has an existing (1997) generating capacity of 2241 MW, EDM & HCB (Moz) 2156 MW, and ZESCO (Zam) 1600 MW. Zimbabwe's ZESA has a generating capacity of 1892 MW of which 666 MW is hydropower. This hydro dominated group will make large gains from increased exports of their low running cost hydro stations. To this group the water rate will be a contentious issue but will help in trade bargaining, once resolved, for coming to an agreement on trade tariffs.

3.) The third group consists of the seven smaller SAPP utilities which have generating capacities less than 300 MW. Three of these seven countries (Ang, Mal, Tan) are yet to become connected to the grid (but are assumed all connected by 2000). The other four countries (Bots, Nam, Les, Swaz) are currently highly dependent upon trade with South Africa.

Construction at Inga, on the River Congo, together with major new regional international transmission lines from this site makes this particular site of special interest. Very high capital costs are associated with it (Table 2). Current instability in the country will hopefully be reduced in the near future and the role of SNEL's Inga will eventually come to provide enormous electricity trading supplies for the SAPP region and to North Africa. Early runs of the LT model indicate the long-term benefits to progressing with construction at Inga.

Mozambique's expansion plans for increased hydropower on the River Zambia, at Cahorra Bessa North and Mepandua Uncua, will make great contributions to regional trade. The timing and costs of these projects will have significant impact on regional trade over the next ten years.

Zambia and Zimbabwe are at the center of SAPP's trade grid. As an exporter and a vital wheeling agent in the pool, Zambia's expansion plan to increase its hydropower, primarily at Kafue, will be a further study in itself. Zimbabwe's current needs for imports, together with its unique mix of hydropower and thermal capacity expansion will be another special case study. This grouping will be affected very significantly by tariff levels and wheeling costs within the pool.

It is in the interest of each national utility to maintain sufficient generating capacity for local demand in order to maintain a strong negotiation position. This position is argued for the case of the smaller utilities in particular. In year three modeling each of the smaller utilities will require a careful analysis appropriate for their individual country. The role of new hydropower in Angola and major transmission lines across the country, extra thermal power in Botswana, new hydropower for Namibia, and significant hydropower increases in Tanzania will make great economic contributions as well as heavy financial burdens to each of these countries.

The second grouping of hydro dominated countries has the excess power for providing a reduction in the region's electricity costs. DRC and Mozambique have vast supplies of hydropower and only a small percentage (less than 10%) is consumed by domestic demand. The initial high costs for these two hydro countries provides a unique case study within the SAPP's long-term planning horizon. Each country has potential for vast export revenues from electricity sales.

IV.) Computing Requirements

At the start of the year 2 modeling, it was requested by the SAPP that both short-term and long-term models should be able to operate on a personal computer. This has been achieved with good accuracy using a high speed Pentium II PC. The specification for the PC is:

PentiumII BX 100 MHz motherboard,
PentiumII 350 MHz processor,
512 Mb 100 MHz RAM,
961Gb UW SCSI hard drive

All future work in the region is therefore expected to run on this platform in order to achieve reasonable running times for the complex and lengthier long-term model.

At Purdue, the models will continue to be tested on the purpose built Pentium II as well as on the UNIX machines. Institutions in the region are well equipped with PC's, but in most instances the upgraded PentiumII will need to be purchased, but these are not budgeted in this proposal. About $4000 would cover the costs for the new Pentium. Utilities, regulatory boards, government departments and regional consultants will need one of these high speed data processing machines. The successful initial runs on a 300MHz laptop are also proving to be an attractive computing facility that can be used readily in any location. It's specification is as follows:

IBM ThinkPad 770
PentiumII 300 MHz
8.1 GB hard drives, 320MB RAM, Win NT

The electricity trade models require GAMS and CPLEX software to be installed on the PC's in order to run the models. The actual trade models that are developed under this research project are of course freely distributed. Detailed costs for the GAMS and CPLEX can be obtained from P. Steacey at the GAMS CORPORATION (Email: pete@ike.gams.com, Phone: 202-342-0180, Fax: 202-342-0181).

A most helpful facility in making the LT planning model more accessible to a wide range of users will be the windows interface. A lot of coding time will be required to provide this facility. It is planned to appoint computer programmers to write up the lengthy coding to achieve this within the year three of modeling. Time and money was not available to do this in year two. Resources and manpower have been stretched in year two so as to provide the 200 page User Manual to explain the LT model. This user manual was specially requested by the SAPP members at the end of using the early LT model at the Cape Town Workshop. A windows interface will make the LT model more user friendly. The user manual will continue to be indispensable to regional modelers who wish to understand the formulation and constraints that are in the model.

Operating instructions for running the model are supplied in detail in the "User Manual for the Long-Term Model" [6]. Copies of this can be obtained from C. Allen (E-mail: clallen@ecn.purdue.edu, Phone USA: (765) 494-7036, Fax: (765) 494-2351). This manual provides a detailed formulation of the model as well as operating instructions for changing the values of data and financial. The in depth explanation of the LT model, in the user manual, is supplemented with full notation and a simpler introductory model of the region.

V.) Timeline for Deliverables

The long-term model will provide the basis of all the work for the third year of the research, May 1999 to May 2000. The SAPP PSC Chairman provided an outline recommendation, at the February 1999 Swaziland SAPP Management meeting, on behalf of the SAPP management for modeling work in a third year (Appendix I). This outline complies with the work dates that are shown below:

End of Year 2 Modeling:

- February 23-25 1999 [Swaziland] — Year Two Final Report and presentation of results to Swaziland SAPP Management Meeting.

Start of Year 3 Modeling:

- May-October 1999 [Purdue] —
  a) Final exercising and validation of the model, with suggestions from February 1999 meeting included.
  b) Creation and development of windows interface.

- August 1999 [Tanzania] — Early demonstration of the windows user interface at Dar-Es-Salaam, Tanzania, SAPP Management Meeting.

- 14-19 November 1999 [Purdue] — Purdue - Consultation and Training Workshop with SAPP colleagues (one representative from each SAPP utility to attend at Purdue – accommodation and workshop expenses paid by Purdue, utility to provide air ticket).

- Dec. 1999 to April 2000 [Purdue]
  a) Finalize windows interface.
  b) Detailed analysis and discussion of individual utility investment plans, responding to the long-term planning objectives and demand growth of each SAPP member.
  c) Preparation of individual country reports for each SAPP utility long-term investment plan.

- May 2000 [Region]
  (a) Year Three Final Report presentation to SAPP Management.
  (b) Presentation of seminars for national utilities. These are proposed primarily to take place in South Africa, Mozambique, Zimbabwe, Zambia, and the DRC. - Major trading utilities of the region. Venues to be confirmed.

VI.) Methodology and Personnel

Year 2 of modeling provides an accurate and comprehensive long-term model for the SAPP. Total costs (present value) are determined for centralized construction and compared with independent national expansion plans. The interests of each country are considered and are individually analyzed in detail in year 3. This will be achieved via the continuation of collaboration between SAPP personnel and Purdue's SUFG. The staff at Purdue will consist of:

F.T. Sparrow, SUFG Director
W.A. Masters
Z. Yu
B.H. Bowen
T.L. Morin
F. Smardo
G. Nderitu

The regional consultant will continue to be P.B. Robinson of ZIMCONSULT, Zimbabwe.

May to August 1999 extra computer science staff are to be employed at Purdue for the creation and development of the windows version of the long-term model. A questionaire is to be sent out to the SAPP utilities to gain more information on the requirements of the interface. By August 1999 a substantial interface version of the model will be ready for presentation to the Tanzania SAPP management meeting.

The November 14-19, 1999, Workshop at Purdue will introduce each utility to the completed full windows version of the long-term model. The 1998 Cape Town Workshop employed the simplified initial long-term one hour version of the model. The November 1999 workshop will involve each delegate using the full model. At this workshop the investment and planning policy of each utility will be compared with the results from the model.

The last months of the third year will involve analysis of the results for each SAPP country. This will be in preparation for the end of year three national seminars which will take place before the presentation of the Year Three Final Report to SAPP around May 2000.

Dates are to also to be set for the installation of the computer hardware and software at the SAPP coordinating center in Harare, Zimbabwe.

The resumes of all personnel are attached in Appendix II.

Bibliography

[1] F.T. Sparrow, et al, "Modeling Electricity Trade in Southern Africa" Year 2 Final Report, Purdue University, USA and presented at Swaziland SAPP Management Meeting, February 23-25, 1999

[2] 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.

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

[4] 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

[5] 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.

[6] 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.

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

[8] R. Glazier, B. Pauley, C.H. Haanyika, M. Mondoloka, F. Holland, B.H. Bowen, Meeting between the Zambian Energy Regulation Board and the Indiana Utility Regulatory Council, Indianapolis, USA, November 10, 1998.

[9] 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.

[10] 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.

[11] 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.

[12] 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.

[13] 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.

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

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

[16] S.E. Mangwengwende, ZESA Chief Executive, "National Blackout: The Facts", Zimbabwe national newspaper "Herald", May 15, 1998.

[17] A. Eberhard, C. Van Horen, POVERTY AND POWER, ENERGY AND THE SOUTH AFRICAN STATE, Pluto Press, 1995.

[18] I.H. Rowlands, Ed., CLIMATE CHANGE COOPERATION IN SOUTHERN AFRICA, UNEP, Earthscan Publications, 1998

[19] F.T. Sparrow, Reed W. Cearley, Lance D. Mckinzie, and Forrest D. Holland, "Equity, Efficiency, and Effectiveness in DSM Rate Design", *The Electricity Journal*, vol 5 (4), May 1992, pg. 25-33.

Appendix I

SWAZILAND SAPP MANAGEMENT MEETING

FEBRUARY 24, 1999

"MODELING ELECTRICITY TRADE IN SOUTHERN AFRICA"

Upon the recommendation of the SAPP planning sub-committee, the SAPP Management adopts the following resolution;

"SAPP welcomes the participation of Purdue University in the third and final year of their USAID funded project to aid SAPP in the development of fast, user friendly P.C. based investment decision support models. SAPP intends to use these models as an aid in the determination of system wide least cost capacity expansion and operation strategies which make best use of the limited SAPP resources";

More specifically, SAPP endorses the following activities: -

- Final validation of the model and users guide, modified to include features suggested by SAPP members at the February 1999 meeting;
- Development of a windows interface version of the model for SAPP users;
- Installation of the model software and hardware at the SAPP coordination center in Harare;
- Preparation and presentation of papers discussing the implications of model trial results at SAPP utility sites, including applications of the model to consider equitable and efficient tariffs, wheeling rates, water charges, environmental aspects, DSM, and consideration of uncertain demand growth in the development of least cost investment plans;
- Training of SAPP personnel in use of the final windows version of the long-term model.

DAVID MADZIKANDA
CHAIRMAN – SAPP PLANNING SUB COMMITTEE

APPENDIX II

RESUME OF STAFF

FREDERICK TOMLINSON SPARROW

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Fax: 765/494-2351
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.

WILLIAM A. MASTERS

Department of Agricultural Economics
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Purdue University
West Lafayette, IN 47907-1145

Phone: 765/494-4235 (office)
765/743-0032 (home)
Fax: 765/494-9176 (office)
E-Mail: masters@agecon.purdue.edu

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

Professor of Industrial Engineering, Purdue University, 1287 Grissom Hall, West Lafayette IN 47907-1287
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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 Israel, Ltd., Tel-Aviv.
Tennessee Valley Authority, Chattanooga, TN.

ZUWEI YU

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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 1989-1994
Plant Engineer
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 1985-1986
Assistant Mechanical Engineer, Central Maintenance Workshops, Nairobi
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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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 of 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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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.