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Assistance to Zambia's Office for Promoting Private Power Investment

Final Report

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Section 1 Introduction

1.1 *Background*

The United States Agency for International Development has selected Bechtel/Nexant to assist Zambia's Office For Promoting Private Power Investment (OPPPI) in conducting Phase 1 of a three phase project leading to preparation of solicitation documents for private development of new hydropower plants and transmission lines. Phases 2 and 3 of the project will be funded from other sources and performed by other consultants.

Four projects in particular were proposed as likely candidates: the Kafue Gorge Lower hydro power plant, the Itezhi-tezhi hydro power plant, the Zambia - Tanzania transmission interconnection, and extension of the grid into the Mkushi farming area. Phase 1 lays the foundation for the work of Phases 2 and 3 by:

- Evaluating the power market in Zambia and the Southern African region as a whole.
- Identifying and evaluating the interactions among the projects and working out a strategy and schedule for their joint development.
- Reviewing and summarizing the key documents which affect the prospects for private power investment.
- Reviewing the four projects and recommending whether OPPPI should proceed with preparing solicitation documents for them.
- Studying the Mkushi project and recommending the best way to proceed with grid extension into the area.
- Determining a target schedule for the activities from preparation of documentation through project implementation of the various projects.
- Estimating the OPPPI resources needed to carry out the studies and preparatory work for the later phases.
- Contributing to the development of the OPPPI staff through on-the-job and other training activities.

The Phase 1 Project's eight Tasks require a total of eight deliverables, which we provide in six separate reports . This report is the deliverable for Task 7: Project Summary Report. It is the summary report for the entire project, whereas the reports for the other Tasks are more limited in scope.

1.2 *Objectives*

The general objective of the project is to support the process of bringing private investment into the power sector by addressing the issues noted above. More specific objectives applied to each of the supporting tasks. Our objective for this report is to provide a concise summary of the work of the entire project.

1.3 *Approach*

We took the necessary steps to complete each of the supporting tasks, producing draft reports which we distributed for comment to USAID and OPPPI. We revised the drafts based on their comments, our own review, and in some cases results from the other reports. Final reports for each of the supporting tasks were the product.

From those reports we distilled the most important results and identified the critical issues which must be addressed for private investment in the projects to materialize. In this report we focus on those key items.

1.4 *Organization Of This Report*

The remainder of this report is organized as follows:

- Section 2 presents our conclusions and recommendations.
- Appendices A through E provide complete copies of each of the other five reports.
  - Appendix A. Southern African Power Market Study.
    This report provides the deliverable for Task 1.
  - Appendix B. Evaluation Of Projects
    This report provides the deliverables for Task 2, Analyze Project Interactions, and Task 4b, Project Recommendations.
  - Appendix C. Document Review.
    This report provides the deliverable for Task 3.
  - Appendix D. Evaluation Of Grid Extension Into The Mkushi Farming Area
    This report provides the deliverable for Task 4a.
  - Appendix E. Schedule And Resources Needed
    This report provides the deliverables for Task 5, Schedule, and Task 6, Resources Needed.

Section 2 Conclusions And Recommendations

2.1 *Projects*

2.1.1 Economics

Using Base Case assumptions for hydrology, demand growth, costs, and other parameters, we conclude that Kafue Gorge Lower, Itezhi-tezhi, and the Zambia - Tanzania interconnection are economically attractive projects. The economic attractiveness extends from their earliest reasonable commercial operation dates and their benefits would not be significantly affected for later starting dates.

In the Base Case, new resources are needed in about 2007 in the Southern African region as a whole. In Zambia, demand exceeds effective supply under average hydrological conditions slightly earlier.

We considered other scenarios in addition to the Base Case, producing a range of results, some with higher and some with lower benefits. In particular, low demand growth reduces benefits by over 50% for the hydro projects, which would render them unattractive based on the earliest reasonable commercial operation dates. The interconnection has unfavorable economics if much more natural gas becomes available for power generation than was assumed in the Base Case.

The values calculated correspond to estimates of the prices that could be obtained from other resources. Only by obtaining prices lower than these values, for example through a power purchase agreement with the developer of one of the projects, would the buyer obtain a net benefit.

2.1.2 Solicitation Documents

Kafue Gorge Lower, Itezhi-tezhi, and the Zambia - Tanzania interconnection all appear to have sufficiently attractive economics to justify development. However, there is some uncertainty regarding the hydro projects' output. There is also a possibility that the hydro projects reduce each others' value, and the impact may be more serious for Itezhi-tezhi. Therefore we recommend the following approach to the solicitation process.

- OPPPI should initiate the process of developing solicitation documents for the Zambia - Tanzania interconnection.
- OPPPI should initiate the process of developing solicitation documents for the Kafue Gorge Lower hydro power plant.
- OPPPI should initiate the process of developing solicitation documents for the Itezhi-tezhi hydro power plant, but be prepared to review that decision upon the completion of the hydro operations modeling studies referred to below.
- OPPPI should develop a hydro operations modeling capability and refine the estimates of expected generation at Kafue Gorge Lower, Itezhi-tezhi, and existing plants.

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- OPPPI should use this capability to support the following activities, which are discussed in more detail in Section 2.2 below:
  - Developing a preferred operating regime based on the policy/risk preferences of the GRZ.
  - Establishing the expected output of the existing and potential new hydro plants.
  - Confirming the decision to proceed with Itezhi-tezhi.
  - Developing joint operating agreements to govern the operation of the Kafue river system as a whole.
  - Developing contractual arrangements for the projects.

We note that other issues must also be resolved before a Request For Proposals for any of the projects is issued, among them certain decisions or actions by the Government of the Republic of Zambia which will require agreement among officials that may be difficult or time-consuming to achieve. Work on these should go forward concurrently with the studies noted above.

In particular, we emphasize the need to define a buyer for the services to be provided by the developer

2.1.3 Mkushi Electrification

The Mkushi project has significantly different characteristics than the other three projects, as recognized by the Terms of Reference for this study. Accordingly we discuss it in this separate section.

At this time, several factors limit the prospects for development of grid extension into the Mkushi area as a stand-alone private project based on a competitive tendering process: the basic technical and economic information is badly outdated and could not be relied on to prepare a RFP or the proposals themselves, the project appears to be too costly to be attractive, and others.

Therefore we recommend that OPPPI not prepare model solicitation procedures for private development of grid extension into the Mkushi farming area at this time.

If the Government of the Republic of Zambia chooses to pursue extension of the grid into the Mkushi farming area, perhaps as part of an overall program of rural electrification, the Evaluation Of Grid Extension Into The Mkushi Farming Area report provides a discussion of the subject and recommendations regarding how to proceed.

2.2 *Project Development Issues*

2.2.1 Plant Output Studies

Reducing the uncertainty in plant output will make a new plant more valuable to both Zambia and potential developers. We are aware of no comprehensive study involving the

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operation of all three Kafue river plants. Accordingly we recommend that OPPPI undertake a comprehensive study of plant output, which would involve at least the following steps:

- Develop a model for the Kafue river system that calculates the output of each plant based on technical factors, hydrological inputs, and assumptions for rules governing river management procedures. This is the same modeling capability referred to in the discussion of solicitation documents in Section 2.1.2 and the work below would support the process of making the decisions needed. .
- Establish river management practices designed to maximize joint output (i.e., of all plants being studied for a particular case) at different levels of risk (e.g., average, worst year, etc.).
- Use the model to estimate annual output for each plant over a full range of hydrological conditions and to evaluate the impact of the plants on each other.

2.2.2 Approach To River Management

From Zambia's point of view a reasonable objective would be to maximize the generation from its set of hydro plants within the framework of the hydrologic risks it believes appropriate to take. This is likely to result in each plant generating less than if it tried to maximize its own generation. It would be difficult to achieve this overall maximization if each plant were able to control releases without consideration of the impact on the other plants.

We recommend that OPPPI develop an approach for the joint operation of the dams and power plants on the Kafue river, which would be consistent with the goal of maximizing joint output. The approach would involve some form of central direction, and would include some or all of the following:

- Description of how the direction of operation would be achieved.
- Specification of the approach describing how the system will be operated.
- The legal, administrative, procedural, and other arrangements to create such an organization.
- A Joint Operations Group consisting of the interested parties, including the power purchasers, to exchange information and as a forum for discussion.
- Mechanisms for the sharing of costs and benefits.

2.2.3 Contractual Provisions

Developing a Power Purchase Agreement is part of the scope of the Phase 2/3 Consultants. However, we believe that their role with respect to the issues below should be to advise the Government of the Republic of Zambia and implement its informed decisions.

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The draft Standard Power Purchase Agreement developed by International Resources Group in 1997 provides for all of the payment to depend on the amount of energy generated, or offered to be generated, at prices to be determined at contract signing. This puts the risks associated with hydrology and the management of the river system on the developer, and the risks associated with demand growth and other market factors on the buyer.

There are many other approaches. For example, another approach would be to have all of the payment be fixed each month and not dependent on the amount of energy generated, with prices determined at contract signing. Requirements for high plant availability and efficiency would encourage the developer to maximize the energy it generated with the available water. Such an approach would greatly simplify dealing with the issues of electric dispatch and joint operation of several plants on the same river, and would remove the risk of hydrology from the developer, presumably enabling it to offer better prices. However, that risk would then fall on the buyer, in addition to the market factor risks.

Almost any mix of capacity and energy payments is possible, and also any mix of prices fixed at contract signing and prices that depend on market conditions. Which would be preferable depends on what the parties want to achieve with the provisions related to the payment scheme.

We recommend that OPPPI develop an approach for the structure of the payment scheme (energy and capacity components, how to encourage availability and efficiency, the allocation of risks, etc.). This would involve at least the following activities:

- Develop several alternatives such as nearly all capacity payment, nearly all energy payment, etc..
- Assure that the terms recognize the joint operation of the river system and the electrical dispatch procedures.
- Analyze the alternatives in the context of the risks such as hydrology and demand growth.
- Discuss with Government of the Republic of Zambia officials and other interested parties, and select a preferred approach with their concurrence.
- Coordinate with the Phase 2/3 Consultants, who should participate in the work within the framework of their Terms of Reference, throughout the course of the work..

2.2.4 Power Purchasers

This is the most critical of the decisions or actions by the Government of the Republic of Zambia referred to in the discussion of solicitation documents in Section 2.1.2.

We conclude that it is unlikely that a private investor would develop these projects on a "merchant" basis, in other words without a buyer and payment terms identified and agreed to. Thus a critical issue is to identify who the buyer will be.

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For Itezhi-tezhi and Kafue Gorge Lower the buyer would be the one or more organizations purchasing the power generated by the plants. Potential buyers include ZESCO, the Copperbelt Energy Corporation, the Government of the Republic of Zambia, ESKOM, and others.

For Zambia - Tanzania interconnection the buyer would be the one or more organizations purchasing the transmission services provided by the interconnection. This could be ZESCO and/or TANESCO, or others. However, the buyer of transmission services is also likely to want assurances that the services purchased will be needed, in other words that there will be sufficient transactions to justify the cost. This implies that a power purchase agreement covering sales from Zambia to Tanzania between the utilities or the governments may be required.

2.3 *Schedule And Resources Needed For OPPPI Activities*

The Evaluation of Projects report recommends that OPPPI initiate the process of developing solicitation documents for the Zambia - Tanzania interconnection, Kafue Gorge Lower, and Itezhi-tezhi, but notes that for Itezhi-tezhi the decision should be reviewed upon the completion of certain hydro operations modeling studies. Since there is more uncertainty regarding Itezhi-tezhi we present a schedule that assumes that just the interconnection and Kafue Gorge Lower will be pursued. If the modeling results confirm that Itezhi-tezhi is economically beneficial, it can be added. Its schedule would look much like that for Kafue Gorge Lower.

2.3.1 Schedule

The schedules presented in Figure 2-1 and Figure 2-2 are based on the times needed for the different activities and their dependencies. However, we emphasize that it will be necessary for the Government of the Republic of Zambia to make certain decisions and take certain actions for the process to proceed according to schedule. We have indicted when such decisions or actions are needed. Any delays in these matters will lead to delays in project implementation.

2.3.2 Resources Needed

We conclude that OPPPI presently lacks many of the logistical and basic office resources which would help it operate more effectively, especially when the process of preparing solicitation documents get underway in earnest. OPPPI would need additional staff if all three projects were to go forward at the same time, and we discuss its training needs in ten areas such as finance, contracts, project management, and others. We understand that most of the logistical and basic office resources, and some of the training, will be provided as part of the Phase 2/3 Consultants Terms of Reference. For those items not covered by those Terms of Reference, we recommend that they should be sought from other sources.

OPPPI will require assistance and cooperation in undertaking the studies and other activities involved in addressing the project development issues discussed above.

2.3.2.1 Plant Output Studies

Therefore we recommend that this work be performed by international consultants expert in this area under the direction of OPPPI. It will be important that OPPPI and eventually the organization responsible for Kafue river management become fully familiar with the concepts, procedures, and programs used in the analysis.

Funding for these consultants would have to be obtained from other sources, because OPPPI does not have the funds available to hire them.

The Phase 2/3 Consultants should coordinate with this effort as much as possible, so that they will understand the implications of plant output in the context of the Power Purchase Agreement.

2.3.2.2 Approach To River Management

OPPPI's role here would be as leader of the effort to institute a joint management approach. In order to perform effectively the OPPPI staff person assigned to this area would need to be extremely knowledgeable regarding the results of the plant output studies and other technical matters. Other key inputs would be provided by the representatives from the Government of the Republic of Zambia, ZESCO, and the Zambezi River Authority regarding their views in this area.

This would require the commitment of those organizations to provide such support through active participation in the process.

In addition legal documents creating an organization perhaps akin to the Zambezi River Authority would probably have to be created. This could be done by the Government of the Republic of Zambia or outside local legal assistance, but not by OPPPI.

The Phase 2/3 Consultants should coordinate with this effort as much as possible, so that they will understand the implications of river management on the provisions of the Power Purchase Agreement.

2.3.2.3 Contractual Provisions

Once again the role of OPPPI would be as provider of technical inputs and project leadership. The Government of the Republic of Zambia would provide key inputs regarding its preferences. The Phase 2/3 Consultants will have special expertise in developing contractual provisions, but the focus of this activity will be on assuring that such provisions properly reflect the objectives of the GRZ and its willingness and ability to deal will different kinds of risk. The Phase 2/3 Consultant's role will be to create the provisions that implement preferences in those areas.

It will be important for OPPPI to have the commitment of the Government of the Republic of Zambia either to participate actively in this process, or to defer to the judgement of OPPPI in establishing the preferences.

Figure 2-1. Schedule For Kafue Gorge Lower

ID	Task Name	Duration
1	**Assemble Necessary Documents**	**42d**
2	Catalog Current Library	1w
3	Collect Missing Documents	4w
4	**Preparatory Activities**	**120d**
5	Hydrologic Studies	24w
6	River Management Approach	24w
7	Structure For Payments	24w
8	**Government Decisions/Actions**	**180d**
9	Determine Buyer	24w
10	Define ZESCO Role	24w
11	Legislation For FPI	24w
12	Define Acceptable Risks	12w
13	**Phase 2/3 Activities**	**215d**
14	Complete Detailed Wrok Plan	2w
15	Develop Solicitation Strategy	2w
16	Assess Alternative Structures	3w
17	Detailed Financial Analysis	4w
18	Legal/Regulatory Changes	3w
19	Prepare Phase 2 Report	3w
20	Prepare Solicitation Documents	13w
21	Draft Legal Documents	8w
22	Prepare Phase 3 Report	5w
23	**Project Implementation**	**727d**
24	Establish Short List	1w
25	Review And Approve RFP	4w
26	Issue RFP	1w
27	Prepare Proposals	12w
28	Evaluate Proposals	4w
29	Select Concessionaire	2w
30	Negotiate Agreement	12w
31	Financial Closure	24w
32	Final Design	78w
33	Licensing, Preconstruction	78w
34	Start Construction	1w

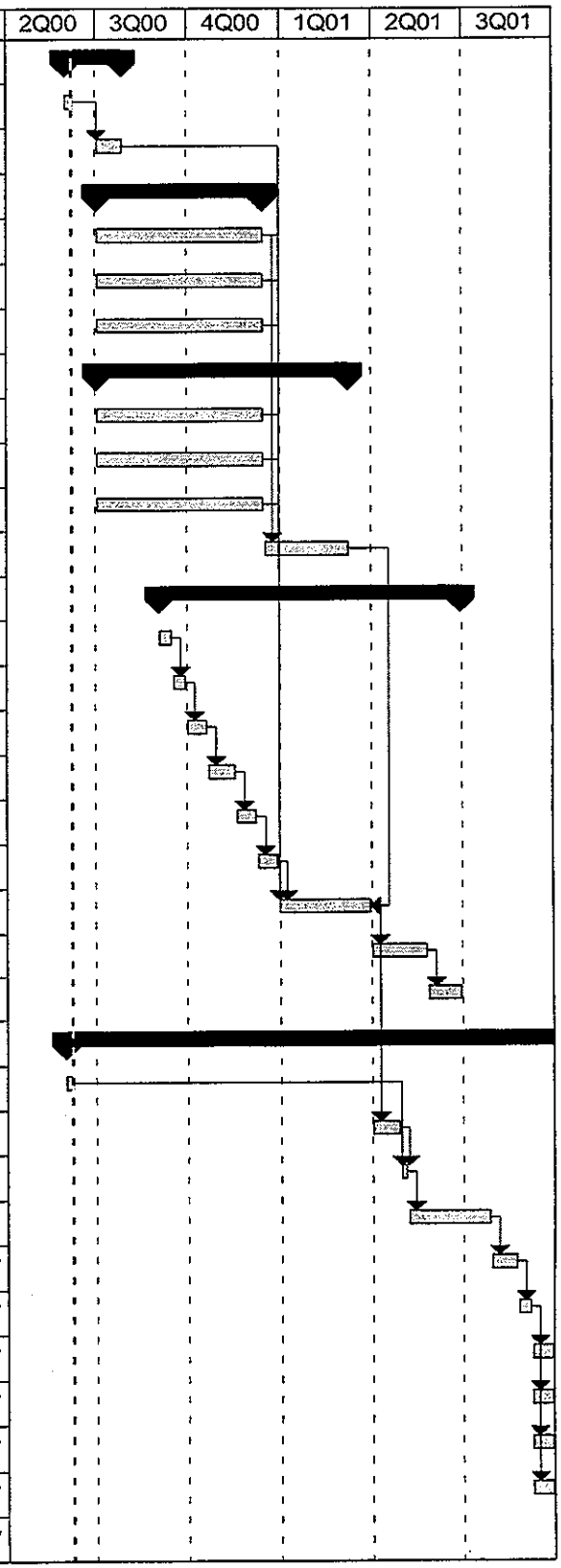

Figure 2-1 (continued). Schedule For Kafue Gorge Lower

ID	Task Name	Duration
1	**Assemble Necessary Documents**	**42d**
2	Catalog Current Library	1w
3	Collect Missing Documents	4w
4	**Preparatory Activities**	**120d**
5	Hydrologic Studies	24w
6	River Management Approach	24w
7	Structure For Payments	24w
8	**Government Decisions/Actions**	**180d**
9	Determine Buyer	24w
10	Define ZESCO Role	24w
11	Legislation For FPI	24w
12	Define Acceptable Risks	12w
13	**Phase 2/3 Activities**	**215d**
14	Complete Detailed Wrok Plan	2w
15	Develop Solicitation Strategy	2w
16	Assess Alternative Structures	3w
17	Detailed Financial Analysis	4w
18	Legal/Regulatory Changes	3w
19	Prepare Phase 2 Report	3w
20	Prepare Solicitation Documents	13w
21	Draft Legal Documents	8w
22	Prepare Phase 3 Report	5w
23	**Project Implementation**	**727d**
24	Establish Short List	1w
25	Review And Approve RFP	4w
26	Issue RFP	1w
27	Prepare Proposals	12w
28	Evaluate Proposals	4w
29	Select Concessionaire	2w
30	Negotiate Agreement	12w
31	Financial Closure	24w
32	Final Design	78w
33	Licensing, Preconstruction	78w
34	Start Construction	1w

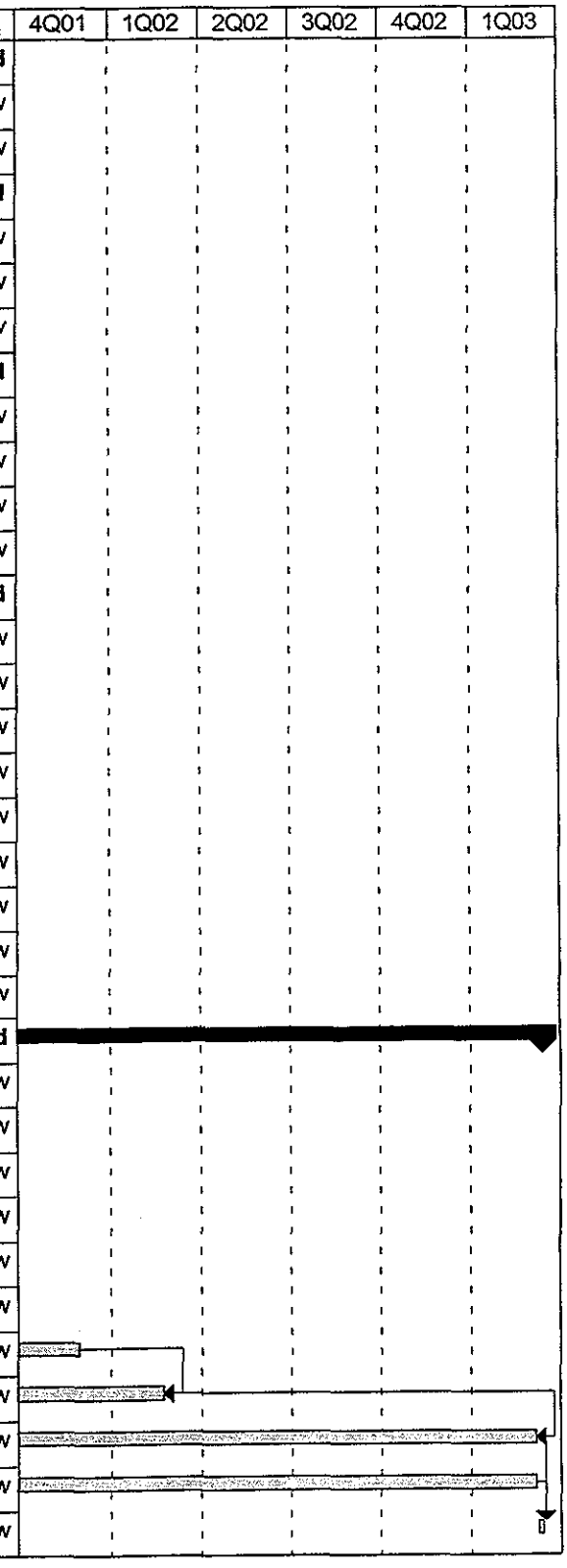

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Figure 2-2. Schedule For Zambia - Tanzania Interconnection

ID	Task Name	Duration
1	**Assemble Necessary Documents**	**42d**
2	Catalog Current Library	1w
3	Collect Missing Documents	4w
4	**Government Decisions/Actions**	**260d**
5	Negotiate PPA With Tanzania	52w
6	Determine Transmission Seivices Buyer	24w
7	Define ZESCO Role	24w
8	Legislation For FPI	24w
9	**Phase 2/3 Activities**	**215d**
10	Complete Detailed Work Plan	2w
11	Adaptations Of BOM Model	5w
12	Financial Analysis	4w
13	Legal/Regulatory Changes	3w
14	Prepare Phase 2 Report	3w
15	Prepare Solicitation Documents	13w
16	Draft Legal Documents	8w
17	Prepare Phase 3 Report	5w
18	**Project Implementation**	**435d**
19	Revise Solicitation Documents	8w
20	Expressions Of Interest Process	14w
21	Establish Short List	1w
22	Review And Approve RFP	4w
23	Issue RFP	1w
24	Prepare Proposals	12w
25	Evaluate Proposals	4w
26	Select Concessionaire	2w
27	Negotiate Agreement	12w
28	Financial Closure	24w
29	Final Design	52w
30	Licensing, Preconstruction	52w
31	Start Construction	1w

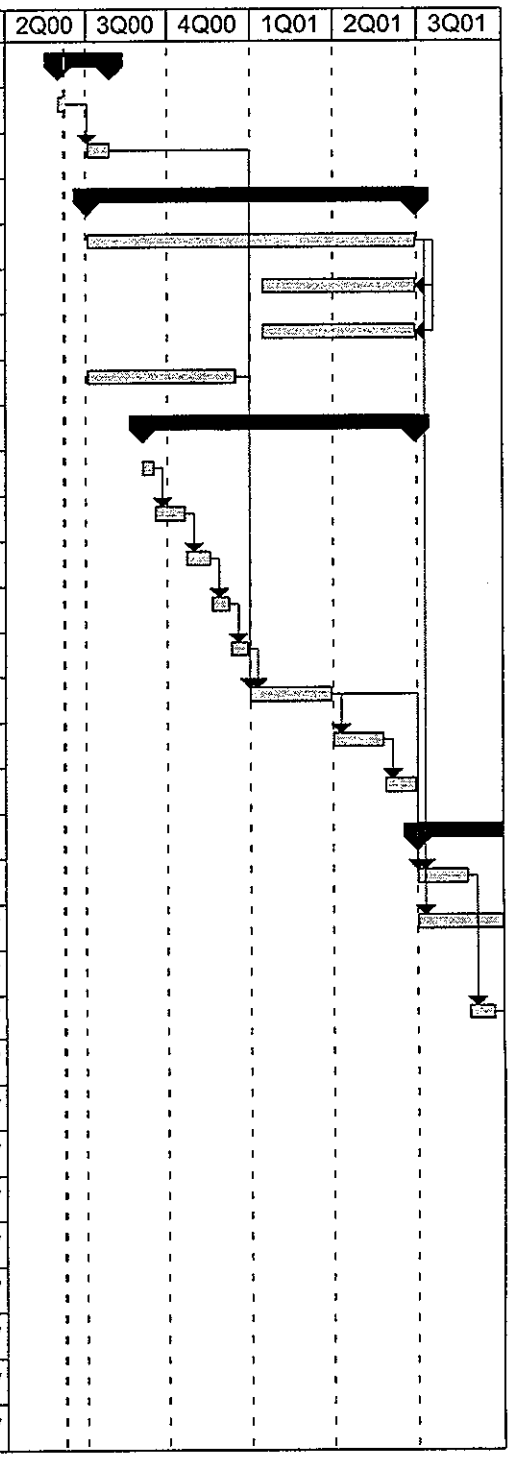

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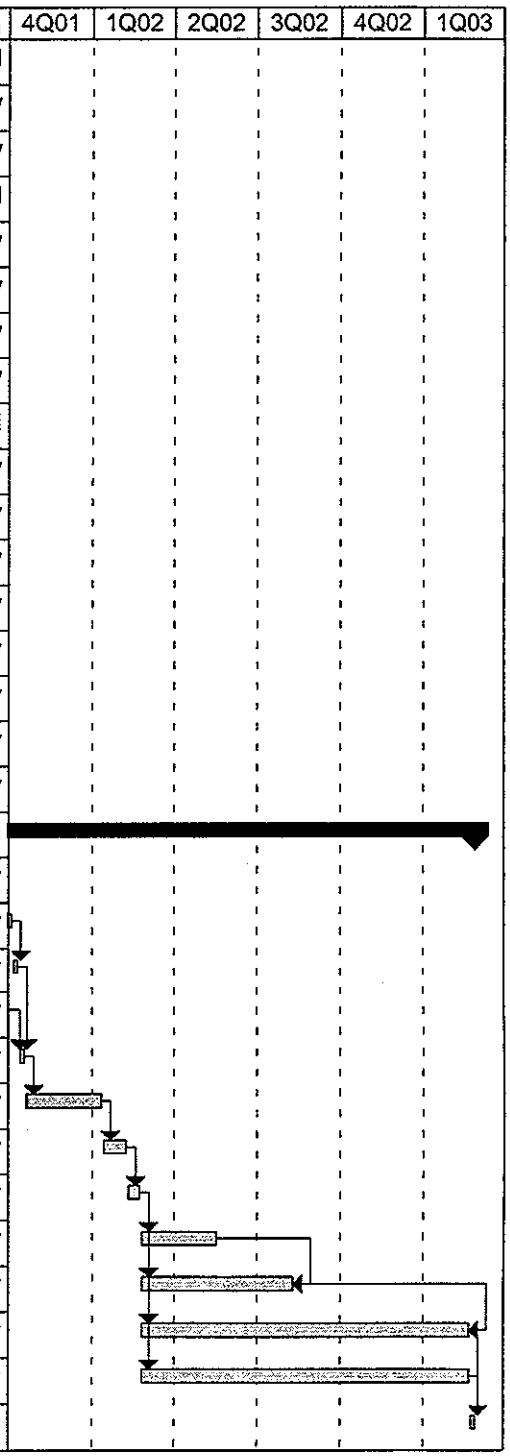
Figure 2-2 (continued). Schedule For Zambia - Tanzania Interconnection

ID	Task Name	Duration
1	**Assemble Necessary Documents**	**42d**
2	Catalog Current Library	1w
3	Collect Missing Documents	4w
4	**Government Decisions/Actions**	**260d**
5	Negotiate PPA With Tanzania	52w
6	Determine Transmission Seivices Buyer	24w
7	Define ZESCO Role	24w
8	Legislation For FPI	24w
9	**Phase 2/3 Activities**	**215d**
10	Complete Detailed Work Plan	2w
11	Adaptations Of BOM Model	5w
12	Financial Analysis	4w
13	Legal/Regulatory Changes	3w
14	Prepare Phase 2 Report	3w
15	Prepare Solicitation Documents	13w
16	Draft Legal Documents	8w
17	Prepare Phase 3 Report	5w
18	**Project Implementation**	**435d**
19	Revise Solicitation Documents	8w
20	Expressions Of Interest Process	14w
21	Establish Short List	1w
22	Review And Approve RFP	4w
23	Issue RFP	1w
24	Prepare Proposals	12w
25	Evaluate Proposals	4w
26	Select Concessionaire	2w
27	Negotiate Agreement	12w
28	Financial Closure	24w
29	Final Design	52w
30	Licensing, Preconstruction	52w
31	Start Construction	1w



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Southern Africa Power Market Study

The value of additional Zambian hydroelectric projects and an interconnection with Tanzania

Final Report

Assistance To Zambia's Office For Promoting Private Power Investment
Task 1: Southern African Power Market Study

Prepared under Contract for:
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Acronyms And Abbreviations

AC	Alternating current
BPC	Botswana Power Corporation
CEC	Copperbelt Energy Corporation
CO2	Carbon dioxide
DC	Direct current
DRC	Democratic Republic of the Congo
EDM	Electricite de Mozambique
ESKOM	South Africa's national electric utility
g	Gram
GJ	Gigajoule
GRZ	Government of the Republic of Zambia
GW	Gigawatt
GWh	Gigawatt-hour
IDC	Interest during construction
IPP	Independent power producer
IPTL	Malaysian firm developing IPPs
KNBC	Kariba North Bank Company
km	Kilometer
kW	Kilowatt
kWh	Kilowatt-hour
kV	Kilovolt
m	Meter
MOU	Memorandum Of Understanding
MVA	Megavolt-ampere
MVAR	Megavolt-ampere reactive
MW	Megawatt
MWh	Megawatt-hour
m^3/sec	Cubic meters per second
NOx	Nitrogen oxides
OPPPI	Office for Promoting Private Power Investment

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O&M	Operation and maintenance
rpm	Revolutions per minute
SAPP	Southern African Power Pool
SNEL	Societe Nationale d'Electricite, the DRC's nat'l electric utility
SOx	Sulfur oxides
TANESCO	Tanzania Electric Supply Company
TCF	Trillion standard cubic feet
US	United States
USAID	United States Agency for International Development
ZESA	Zimbabwe Electricity Supply Authority
ZESCO	Zambia Electricity Supply Corporation
ZCCM	Zambia Consolidated Copper Mines

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Executive Summary

The Government of the Republic of Zambia has tentatively selected a first round of four projects for which model solicitation procedures for private development may be prepared. These projects are the Kafue Gorge Lower hydro project, the Itezhi-tezhi hydro project, the 330 kV transmission interconnection from Zambia to Tanzania, and grid expansion into the Mkushi farming area in Central Province. One of the areas to be addressed in Task 4 of this project is to review the four projects and recommend whether the Office for Promoting Private Power Investment should proceed with preparing solicitation documents for them.

Evaluation of the costs and benefits of a project is crucial to our making sound recommendations regarding the project, and crucial also to Zambian officials' ability to make informed decisions. Most of the costs associated with the projects have been estimated in existing feasibility studies. However, the question of their value (benefits) has not been evaluated in a comprehensive manner.

This Southern African Power Market Study provides that evaluation of benefits for three of the projects (all but the Mkushi project, which requires a different analytical approach). Current data on the power market will be valuable to Zambian decision makers in deciding whether and how to proceed, and with which projects. It also may be valuable to interested private developers in evaluating the attractiveness of the projects from their point of view.

The objective of this study is to estimate the market for and value of the Kafue Gorge Lower hydro project, the Itezhi-tezhi hydro project, and the Zambia - Tanzania interconnection.

The general approach for the calculation of value is to estimate the costs that would be avoided if the projects were built. For example, the energy from Kafue Gorge Lower or Itezhi-tezhi displaces energy from plants that burn coal and liquid fuels, reducing the need for those fuels and the costs associated with them. The hydro projects also reduce the need for new investment in power plants elsewhere in the region, and their associated costs. Likewise, transmission interconnections provide opportunities to displace higher cost with lower cost generation. With adequate reliability, interconnections can also defer the need for new generation investment, although in our analysis of the Zambia - Tanzania interconnection we take no credit for this potential impact.

In the power market study we estimate the costs that would be avoided if the projects were built by simulating the operation of the interconnected system in Southern Africa. Thus a key premise is that the market for the Zambian projects is the regional system, with due regard for transmission constraints. The Southern African Power Pool currently provides a mechanism for such trade, and substantial trade has taken place before and since its creation.

The results of the simulation show when new resources are needed on an economic basis and what a potential new plant's value is to the interconnected system (and to its local area) every year of the simulation. Key inputs to the simulation include demand forecasts in the different areas that make up the interconnected system, data on the cost and

performance of existing resources, similar data for new resources, and data on transmission constraints.

The key results include the following. Note that the present worth of benefits in $/kW presented below cannot be directly compared to the projects' installed cost in $/kW because of the impact of taxes and other investment-related yearly costs. The proper comparison would be with the present worth of annual costs. The energy values are levelized and could be compared to the levelized costs of generation from the projects..

- Considering each project alone, that is as the only one of the three to be built, produces the following values, expressed in year 2000 US$. The $/kW values are the present worth as of the commercial operating date; the $/MWh values are levelized over the project's lifetime.
  - Based on the direct benefits of the generation it displaces, the value of the Kafue Gorge Lower project is 3,223 $/kW. The levelized value of its energy is 38.3 $/MWh.
  - Based on the direct benefits of the generation it displaces, the value of the Itezhi-tezhi project is 2,981 $/kW. The levelized value of its energy is 51.6 $/MWh.
  - Based on the net benefits of the generation displaced as a result of its presence, the value of the Zambia - Tanzania interconnection project is 3,289 $/kW. Because it doesn't generate any energy, the energy values are less meaningful. However, the levelized value of its net energy benefits is 40.8 $/MWh. That represents the difference between the cost of energy displaced in Tanzania and the lower cost of energy generated to replace it.
- The results of a preliminary analysis of river operations indicates that both Kafue Gorge Lower and Itezhi-tezhi projects have substantial added value in that their operation increases the net output of Kafue Gorge Upper and Kariba projects. However, for various reasons one must take these results cautiously. We view these preliminary results more as indicating a critical need for more modeling of river operations and estimating of plant generation than as values to be relied upon for making decisions.
- The results above are for Base Case conditions. We also evaluated a range of sensitivity cases. Results for the cases with the most adverse effect on value are:
  - If regional demand growth is 1.1% per year rather than the 2.7% assumed for the Base Case, the direct benefits of the Kafue Gorge Lower project are 1,369 $/kW. The levelized value of its energy is 16.2 $/MWh.
  - If regional demand growth is 1.1% per year rather than the 2.7% assumed for the Base Case, the direct benefits of the Itezhi-tezhi project are 778 $/kW. The levelized value of its energy is 11.9 $/MWh..
  - If much more natural gas becomes available for power generation than was assumed in the Base Case, the net benefits of displaced energy in Tanzania fall due to natural gas's lower cost compared to liquid fuels. As a result the value of

the Zambia - Tanzania interconnection project falls to 892 $/kW. The levelized value of its net energy benefits becomes 14.4 $/MWh.

- In the Base Case the values of the hydro projects approach their long-term maximum by 2010. The value of the Zambia - Tanzania interconnection approaches its long-term maximum by 2008.
- The preliminary analysis of river operations also indicates that the Kafue Gorge Lower and Itezhi-tezhi projects have a significant impact on each other's value, in general reducing it. These results also must be viewed cautiously, and confirmed through further analysis. The Zambia - Tanzania interconnection has no significant effect on the value of either hydro project, nor do they have a significant effect on its value.

1.1 *Background*

The United States Agency for International Development (USAID) has selected Bechtel/Nexant to assist Zambia's Office For Promoting Private Power Investment (OPPPI) in conducting Phase 1 of a three phase project leading to preparation of solicitation documents for private development of new hydropower plants and transmission lines. Phases 2 and 3 of the project will be funded from other sources and performed by other consultants (the Phase 2/3 Consultants, for convenience of reference). Phase 1 lays the foundation for the work of Phases 2 and 3 through market and economic analysis, project selection, and establishing schedules and resource needs for OPPPI.

The Phase 1 Project has eight Tasks requiring a total of eight deliverables. This report is the deliverable covering Task 1: Southern African Power Market Study.

The Government of the Republic of Zambia (GRZ) has tentatively selected a first round of four projects for which model solicitation procedures for private development may be prepared. These projects are the Kafue Gorge Lower hydro project, the Itezhi-tezhi hydro project, the transmission interconnection from Zambia to Tanzania, and grid expansion into the Mkushi farming area in Central Province. One of the areas to be addressed in Task 4 of this project is to review the four projects and recommend whether OPPPI should proceed with preparing solicitation documents for them.

Evaluation of the costs and benefits of a project is crucial to our making sound recommendations regarding the project, and crucial also to GRZ officials' ability to make informed decisions. Most of the costs associated with the projects have been estimated in existing feasibility studies. However, the question of their value (benefits) has not been evaluated in a comprehensive manner.

This Southern African Power Market Study provides that evaluation of benefits for three of the projects (all but the Mkushi project, which requires a different analytical approach). Current data on the power market will be valuable to Zambian decision makers in deciding whether and how to proceed, and with which projects. It also may be valuable to interested private developers in evaluating the attractiveness of the projects from their point of view.

1.2 *Objectives*

The objective of this study is to estimate the market for and value of the Kafue Gorge Lower hydro project, the Itezhi-tezhi hydro project, and the transmission interconnection from Zambia to Tanzania. Secondary objectives are to evaluate their impact on each other and to tabulate other information which may be relevant to decision-making, such as their impact on environmental emissions.

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1.3 *Approach*

The general approach for the calculation of value is to estimate the costs that would be avoided if the projects were built. For example, the energy from Kafue Gorge Lower displaces energy from plants that burn coal and liquid fuels, reducing the need for those fuels and the costs associated with them. Kafue Gorge Lower also reduces the need for new investment in power plants elsewhere in the region, and their associated costs. Likewise, transmission interconnections provide opportunities to displace higher cost with lower cost generation. With adequate reliability, interconnections can also defer the need for new generation investment.

In the power market study we estimate the costs that would be avoided if the projects were built by simulating the operation of the interconnected system in Southern Africa. Thus a key premise is that the market for the Zambian projects is the interconnected system, with due regard for transmission constraints. The Southern African Power Pool currently provides a mechanism for such trade, and substantial trade has taken place before and since its creation.

The results of the simulation show when new resources are needed on an economic basis and what a potential new plant's value is to the interconnected system (and to its local area) every year of the simulation. Key inputs to the simulation include demand forecasts in the different areas that make up the interconnected system, data on the cost and performance of existing resources, similar data for new resources, and data on transmission constraints.

Results for different areas within the interconnected system vary depending on transmission constraints and losses between the areas, and the resources and loads with each area. The simulation treats Zambia, Zimbabwe, South Africa, Mozambique, Botswana, and Namibia as separate areas. In the analysis of the Zambia - Tanzania 330 kV interconnection, Tanzania is also treated as a separate area, because if the line is built Tanzania will be within the interconnected system.

The hydro projects and the Tanzania interconnection have potentially strong interactions with one another and their value depends on the nature of the market. Figure 1-1 summarizes the approach taken to reflect these factors in determining the market value of the projects. A joint modeling approach was used to capture both the interaction of hydroelectric plants on the Kafue and Zambezi Rivers (hydro operations analysis performed by OPPPI staff) and the operation of the Southern African regional power market (market analysis performed by Nexant).[1] For hydro projects, the value was estimated based on the benefit of displacing thermal generation and deferring capital investment in generating capacity in the rest of the regional system. For the

[1] OPPPI staff used the Valoragua hydro simulation model to represent the interaction of hydro plants on the Kafue and Zambezi Rivers. Nexant performed the market analysis using the ELFIN Generation Planning and Market Simulation Model. The ELFIN model was developed by the Environmental Defense Fund and licensed to Nexant was used to represent the operation of the regional market.

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interconnection, the value was calculated based on the operating savings that could be achieved through connecting Tanzania to the regional system.[1]

We considered the full range of hydrologic conditions over the past 70 years in the hydro operations modeling. In the market analysis we only considered average hydrologic conditions.[2]

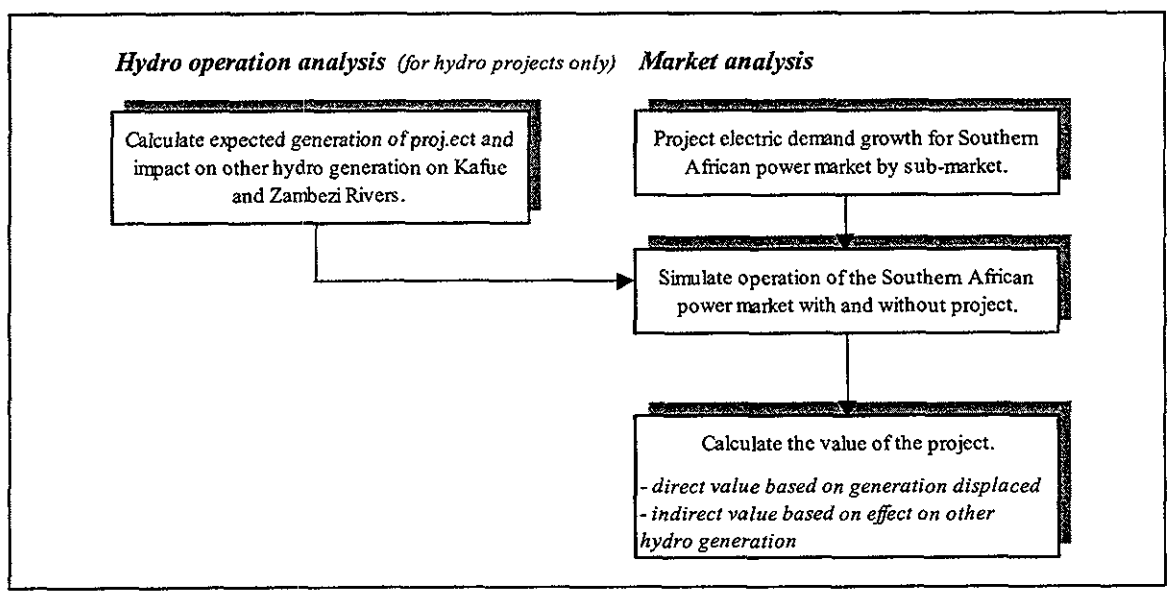

Figure 1-1 Power Market Analysis Approach

1.4 *Relationship of Study Results to Commercial Arrangements*

The results of the power market study are based on an idealized situation in which a regional power market, or a tight power pool, were in operation and mechanisms were in place to reward entities for cooperative operation of the Kafue and Zambezi Rivers. Neither of these conditions is in place today. SAPP is a loose pool, with significant price differences within the interconnected system. The Zambezi River Authority is an example of one type of institution that has been created to achieve cooperative operation; however, it is a questionable model to be used in conjunction with private power development on the Kafue River. Therefore, the results of the study require interpretation as the structure of the regional power market and the approach to river management becomes better defined over time.

[1] End effects corrections were made to adjust the results of market simulation analysis to the full life of projects.

[2] The consideration of the full range of hydrologic conditions was not possible in the time allotted for this analysis. The potential effect on the results is difficult to predict because of consideration would have both positive and negative effects on project value.

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Based on the hydro operations analysis, we found that the proposed new hydro projects have a significant effect on the operation of existing hydroelectric stations, sometimes allowing them to increase their generation. While this is a benefit of the project, the IPP developer of the project would find it difficult to realize a commercial gain out of the benefit unless there was some sort of coordinated operating agreement among the operators of different projects. For this reason, we have divided the estimates of value into direct commercial benefits that could be achieved through direct sale from the project and indirect benefits that could only be realized by the developer if there were a coordinated operating agreement.

Transmission projects also have indirect benefits in increasing system reliability and allowing greater economies of scale in the development of new projects. Our analysis is conservative in that it does not credit these benefits.

The size of the direct commercial benefits estimated are an indication of the maximum price that could be negotiated in an open market. If the developer were to negotiate such a price, other parties should be economically indifferent. However, they would not receive any net benefit from purchases at this price and so would not have a strong motivation to buy. Therefore, the estimated value to a developer, as reflected in the price, would be somewhat less that the values estimated.

1.5 *Organization Of This Report*

The remainder of this report is organized as follows:

- Section 2 discusses the Southern African power market in general and four sub-markets in particular: Zambia, Zimbabwe, South Africa, and Tanzania
- Section 3 discusses the characteristics of the potential Zambian power projects under consideration: Kafue Gorge Lower, Itezhi-tezhi, and the interconnection with Tanzania.
- Section 4 presents the results of the power market analysis, including a discussion the key factors affecting the value of these projects.

The following appendices are with the report:

- Appendix A provides the data used in the regional load (demand) forecasts.
- Appendix B summarizes data on existing and future power resources.
- Appendix C provides the detailed results from which the summary information presented in Section 4 was derived.

2.1 *Supply and Demand*

The countries that are members of the Southern Africa Power Pool (SAPP) are shown in Figure 2-1. Together, they had electricity sales exceeding 200,000 GWh in 1999, 85% of which was in South Africa. Angola, Malawi and Tanzania, representing less that 3 percent of the market, are currently not connected to other SAPP countries. The remaining countries engage in significant cross-border electricity trade and, while transmission constraints often limit trade, it is reasonable to consider the whole region in estimating the market potential for Zambian hydroelectric projects.

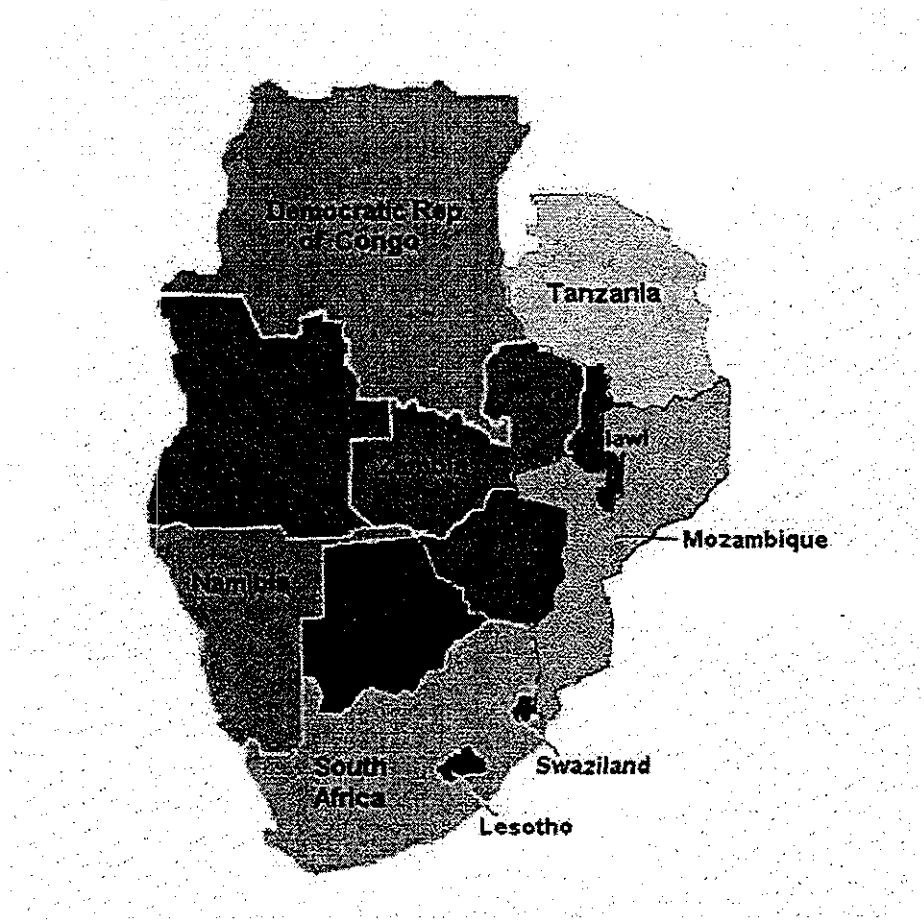

Figure 2-1. The Southern African Power Pool

The SAPP interconnected system is currently characterized by oversupply (i.e., greater generating capacity than required to meet existing demand. There are several reasons for this situation. All of the southern African economies concerned have a high percentage of their demand from mining and mineral processing industries. Low growth and, in

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some cases, retrenchment, in the mining sector has held growth in the 1990s lower than the projections of the previous decade. The economic embargo of South Africa prior to the abolishment of apartheid, wars in several countries and low world commodity prices have all had a negative impact on grow in the region. An ambitious construction program by ESKOM has left the region with 3,600 MW of mothballed capacity at the same time that construction is continuing on 1,200 MW at the Majuba plant.

Nevertheless, political reform and the beginnings of economic diversification throughout the countries interconnected to the SAPP has set the stage for sustained economic growth. The quantity of electricity delivered by the interconnected SAPP countries, grew by 4.1% between 1998 and 1999.

Figure 2-2 shows a projection of the capacity requirements of the interconnected countries of SAPP. For purposes of illustration, the capacity requirements are calculated based on a 15% reserve margin above projected peak load. The medium growth case corresponds approximately to SAPP projections of 2.8% per year. The low and high case correspond to 1.2% and 4.4% growth, respectively. The existing and committed capacity consists of capacity levels in 1999 plus the projected addition of the Majuba units in 2001, 2002, and 2003. Mothballed ESKOM capacity in not included in this figure. Appendix A provides a detailed presentation of the peak and electric energy forecasts.

This rough analysis indicates a need for new regional capacity sometime between 2004 in the case of high growth to after 2015 in the case of low growth. Supply and demand are projected to come into balance in 2007 under the medium projection with the current levels of supply plus the completion of the Majuba plant. Requirements at that time would be about 1400-1500 MW of new generating capacity per year.

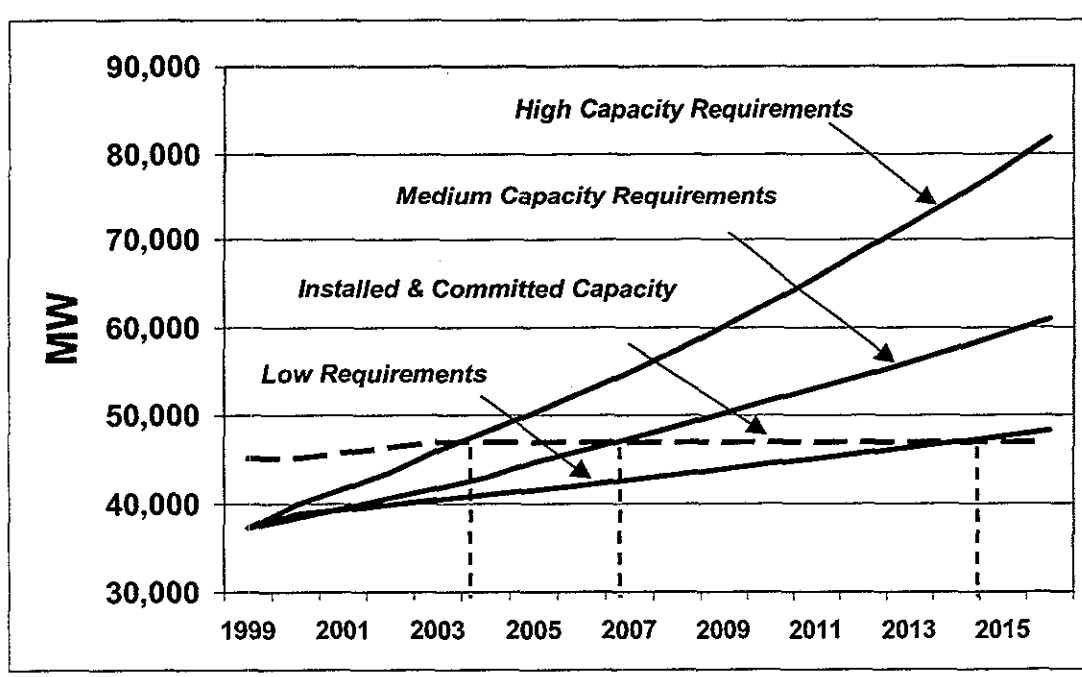

Figure 2-2. Capacity Requirements Versus Existing and Committed Capacity

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The previous analysis shows the situation for the overall region. Regional statistics tend to be dominated by South Africa which represents approximately 85% of the regional demand for electricity. Figure 2-3 shows the supply/demand balance for the other interconnected countries plus Tanzania. Appendix B provides details regarding the individual plants in each country, including South Africa, which does not fit on the scale of Figure 2-3.

The Zambia, Zimbabwe, South Africa and Tanzania sub-markets are discussed in more detail below in terms of power demand, internal electricity supply and other import possibilities.

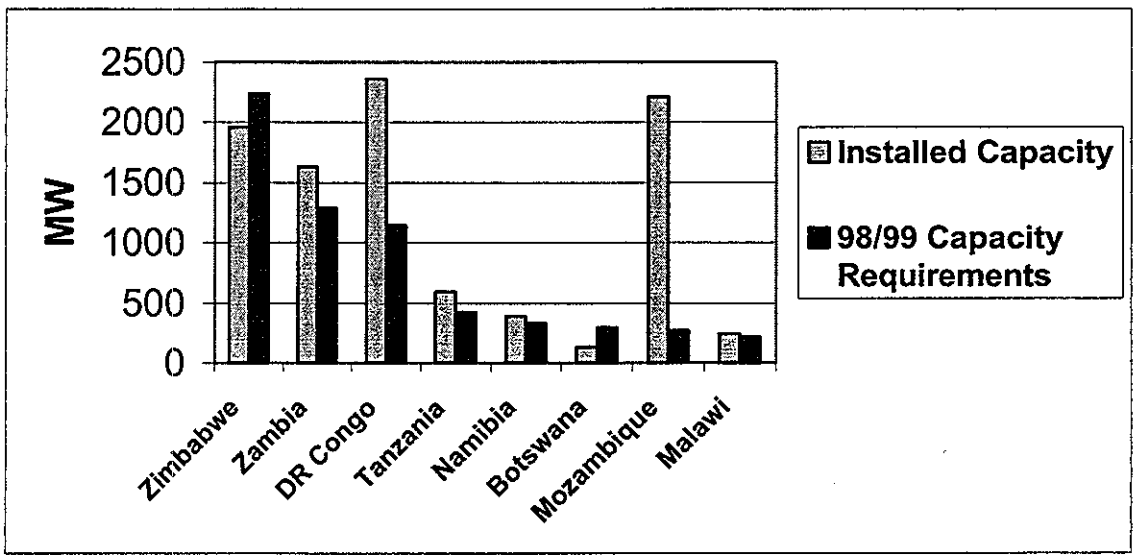

Figure 2-3. Sub-Market Supply/Demand Balance

2.2 *Sub-market Characteristics*

The market for power within individual countries can differ from that for the Southern African area as a whole for several reasons.

- Physical transmission constraints may limit or eliminate the possibility of cross-border trade.
- The cost of transmission service and power losses associated with transmitting power over long distances may reduce or eliminate the economic advantages of trade.
- National policy may favor self-sufficiency in power production.
- Individual utilities may lack the financial strength or other prerequisites to engage in and to pay for imported power.

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In this sub-section we evaluate the market for power in four countries important for the market for power from new generators in Zambia. Zambia itself, of course, is a natural market for power produced within its borders. There are strong transmission interconnections to Zimbabwe, which has the second largest national demand in the region, is short of domestic resources, and has over the years been a substantial trading partner of Zambia. South Africa dominates the Southern African market in terms of both demand and generation. Tanzania at present lacks a high-voltage transmission interconnection with Zambia, but it may have relatively high-cost alternatives to power from elsewhere and is short of resources.

2.2.1 Zambia

Starting in 1992 the government initiated a series of market-oriented economic reforms aimed at reducing state participation in and control of economic activity, such as decontrolling prices, ending some parastatal monopolies, and many others. Despite the impressive scope of reforms, their impact has been limited due to a combination of problems: continued poor performance of the copper mines, falling copper prices, and a series of droughts.

The recent apparent sale of the bulk of the mining operations gives cause for optimism regarding economic development in the coming years, but the actual impact of the change in ownership remains to be seen.

Hundreds of mostly smaller organizations have been privatized. The Zambia Electricity Supply Corporation (ZESCO) is not among them, but the GRZ has placed a high priority on addressing its situation in the near future. Although the likely restructuring, unbundling, commercialization, and at least partial privatization would be positive steps, the current uncertainty limits the willingness and ability of others and ZESCO itself to make various kinds of decisions and commitments.

Zambia has no known petroleum or natural gas resources. Coal from the Maamba mine supplies about 17% of Zambia's consumption of commercial fuels, but production has been declining due to supply problems at the mine. Given this resource situation, an adequate electricity supply is critical to overall economic development. At present Zambia has excess capacity and energy available for export.

Zambia has significant hydro potential. The policy of the GRZ is to give priority to the construction of the Kafue Gorge Lower power station, as well as to restructure the electricity industry, provide for private participation in the power sector, take advantage of the strategic location of the country in the sub-region, and promote interconnection with neighboring countries in order to increase security of supply and secure markets for power export.

Electricity Demand - Historical

Historically, mining has dominated the demand for electricity in Zambia. However, mining energy demand in 1999 was below what it was in 1980, while demand from industry, services, agriculture, and residential consumers almost doubled during that same period. Nevertheless mining demand was still about 60% of total demand in 1999.

Overall, demand has grown at only about 0.9% per year since 1980. In 1999 it was below 1996 and only slightly above 1988. Figure 2-4 shows the energy demand since 1980. This includes ZESCO retail sales plus wholesale deliveries to Zambia Consolidated Copper Mines (ZCCM) and the successor to its power division, Copperbelt Energy Corporation (CEC).

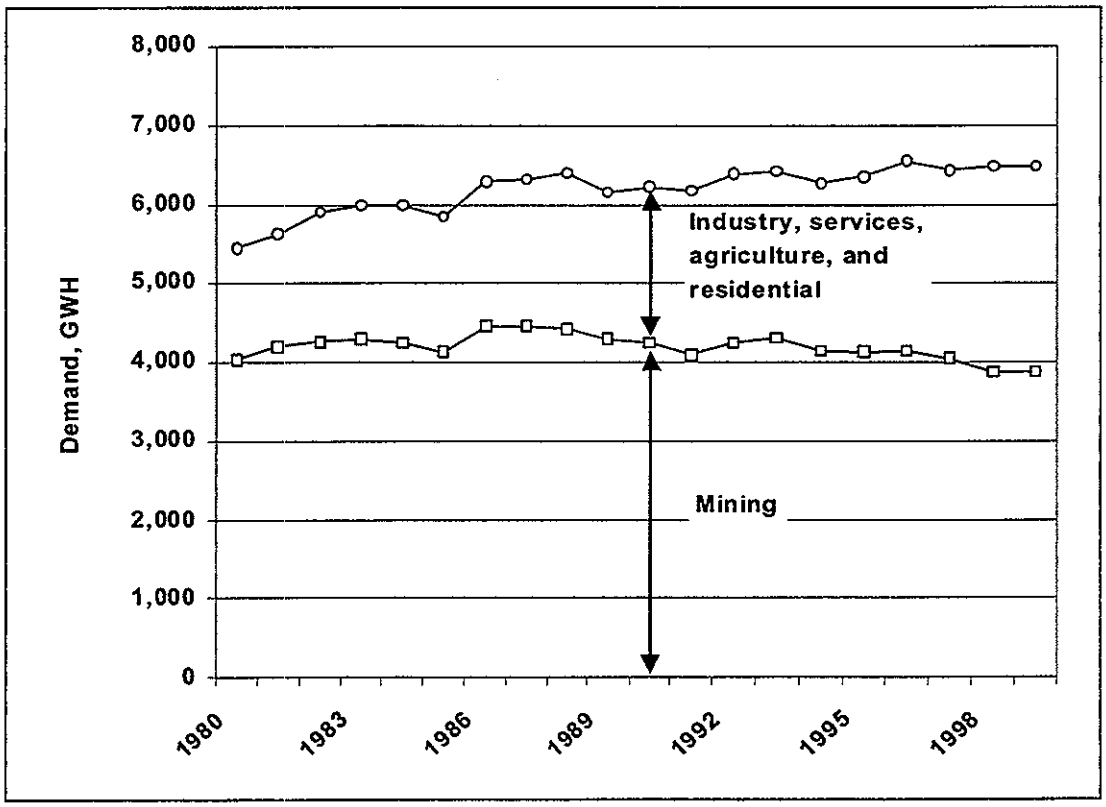

Figure 2-4. Historical Energy Demand

Mining loads have a relatively high load factor. As their share of overall demand has dropped and the share of categories with lower load factors has increased, overall load factor declined from 0.84 to 0.70 between 1980 and 1998 and peak demand increased at 2.1% per year, about twice as fast as energy demand. Figure 2-5 shows peak demand, measured at the transmission substation delivery points, and load factor .

Power is delivered to the mines typically at high voltage. This minimizes losses, which are included in the wholesale deliveries to ZCCM/CEC but not broken out. The transmission losses have been relatively low, at about 3% of high voltage deliveries in 1998, reflecting the strong system and high voltages. The transmission losses include losses associated with wheeling and export transactions. Distribution losses associated with ZESCO retail sales were about 18% of retail sales in 1998. As retail sales increase relative to mining load, overall losses will increase accordingly.

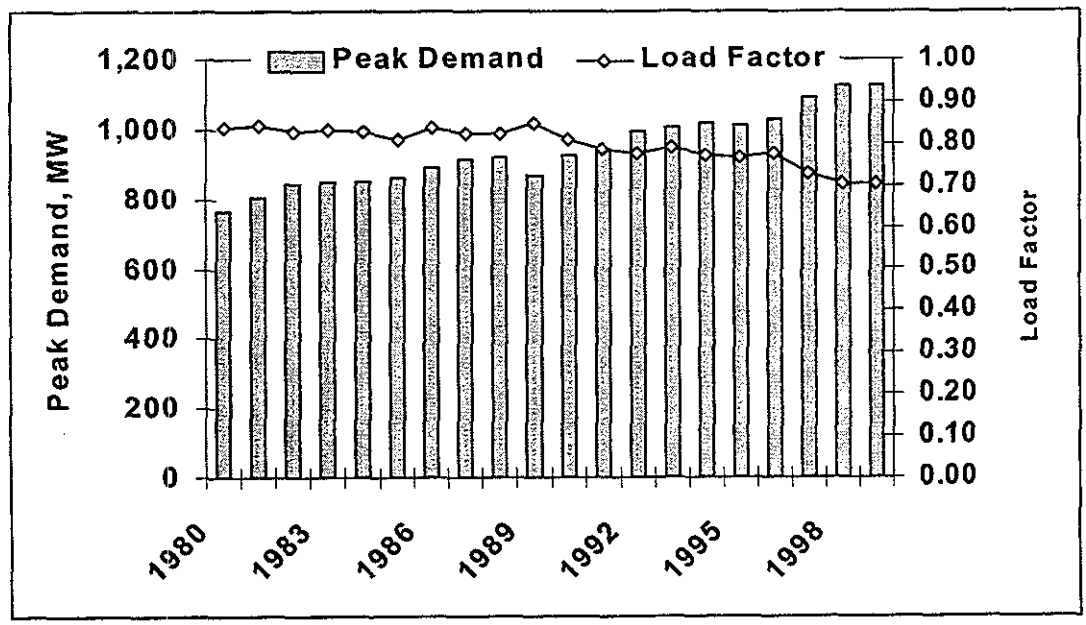

Figure 2-5. Historical Peak Loads And Load Factors

Electricity Demand - Forecast

There is a relatively high degree of uncertainty in forecasting Zambian electricity demand. Previous forecasts have tended to overestimate actual demand, in the sense that only the "Low" scenarios are close to the actual demand that has occurred. Figure 2-6 compares historical end use energy loads and four forecasts. The three lines labeled Forecast Low, Forecast Base, and Forecast High are derived from a draft Feasibility Study of the Development of Hydroelectric Power in the Luapula and Northern Areas of Zambia, conducted for ZESCO by Harza and Ekono Energy (References 18 and 23). That study's forecasts went through the year 2020.

Those forecasts assumed no new smelters would be built. In fact, two new smelters are under construction at Chambeshi, due on line in late 2000 and 2001. They will provide a demand of 45 MW each, at 80% load factor. We added that amount of additional demand to the three forecasts.

The line labeled Trended Historical was calculated by applying the actual average annual demand growth rate of 0.9% from 1980 - 1999 to the prior year demand, starting with estimated actual 1999 demand. In comparison, the average annual growth from 1999 through 2030 is also about 0.9% for the Forecast Low, 2.1% for the Forecast Base, and 3.0% for the Forecast High cases. The Low, Base, and High Forecasts represent different degrees of optimism regarding the growth of the economy in general and the copper mining industry in particular.

The Harza/Ekono Energy study builds up overall load from forecasts for each category of load based on assumptions such as growth in population, gross domestic product by

category, changes in specific consumption by category, and so on. The study made forecasts of copper production for each mining division and considered factors such the amount of water pumping and others to determine the specific consumption of electricity (GWh per ton of copper) year by year for the three scenarios. There is a dramatic increase in assumed copper production from 1999 to 2000 for the Base and High scenarios. In all three scenarios there are substantial year-to-year changes in assumed copper production, which is the key factor in the yearly variation in load shown in Figure 2-6. Overall losses increase from 10% of high voltage deliveries in 1998 to as much as 16% in the three Forecast cases.

Figure 2-7 provides the corresponding peak load forecasts. We estimated the peak loads based on the forecast energy loads and our own assumptions regarding load factors and losses. The load factors are forecast to continue to decline, to about 0.60 for the Forecast cases and 0.67 for the Trended Historical case. Reflecting this, the peak loads grow faster than the energy loads.

The decreasing load factors will tend to increase the effectiveness of the capacity of the energy-limited hydro resources.

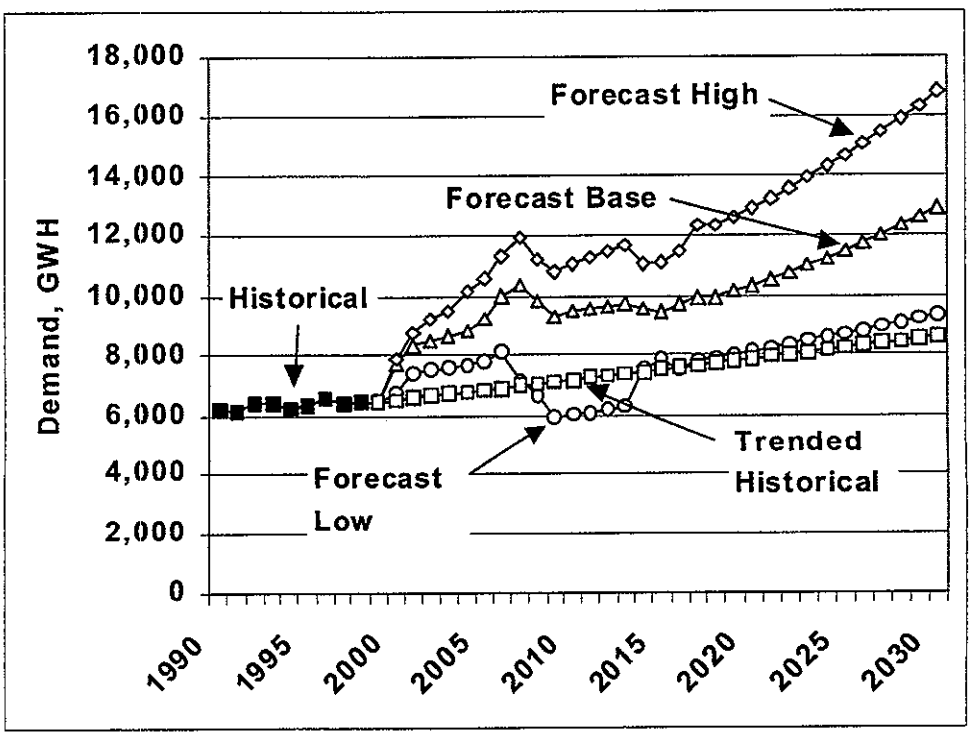

Figure 2-6. Forecast Energy Demand

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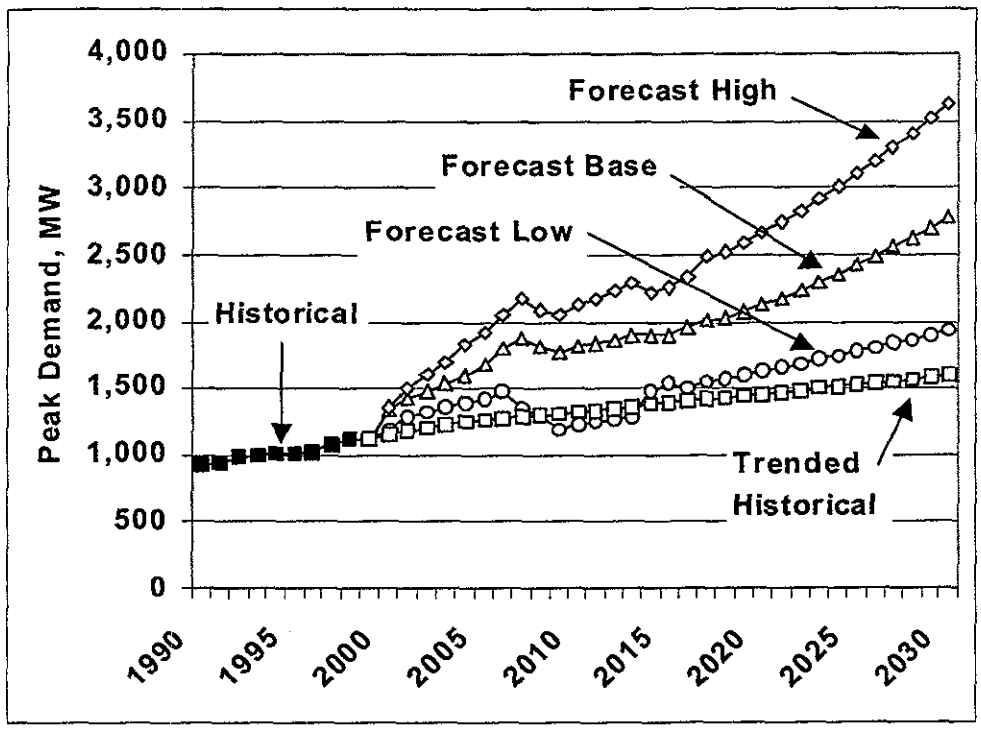

Figure 2-7. Forecast Peak Demand

Internal Electricity Supply

Table 2-1 presents data on the existing power plants in Zambia. The ZESCO thermal and small hydro, not connected to the main grid, are used to serve isolated communities. The ZCCM thermal plants are on cold standby and are used for emergencies. Plans to privatize the ZCCM hydro units are inactive.

Kariba North is actually owned by the Kariba North Bank Company (KNBC), but ZESCO and KNBC have operated as a single administrative unit with a common chief executive since 1986. Efforts are underway to separate the operations of the two companies.

The table illustrates Zambia's high degree of dependence on hydro power, which provides 99% of the energy and 94% of the capacity. All the important potential new projects are also hydro. Two key issues are associated with this dependence on hydro- variation in energy production and difficulty in matching resources with domestic demand.

Energy Production Variability

The energy figures shown are averages. In a dry year, or especially in the second of two dry years in a row, the energy can be much less. All the plants on the Kafue River share the same watershed, so they all will be adversely affected by the same dry conditions. The Zambezi River watershed is close to the Kafue River watershed and has similar

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precipitation patterns. The live storage in the reservoir for Kariba North is large enough to hold two years of an average hydrologic year's inflows, so that plant is better able to withstand dry conditions. Nevertheless, for the three large plants combined, the 1992 generation was 6,399 GWh compared to an average of 8,681 GWh.

Table 2-1. Existing Zambia Generating Plants

Owner/Type/ Plant Name	Capacity (MW)	Annual Energy Production (GWh)			Capacity Factor		Initial Year of Operation
		Average	*Minimum*	*Year of Minimum*	*Average*	*Minimum*	
ZESCO							
Large Hydro							
Kariba North	600	3,153	1,635	1997	60%	31%	1976
Kafue Gorge	900	4,877	3,210	1992	62%	41%	1972
Victoria Falls	108	640	495	1991	68%	52%	1938
Total	1,608	8,669	6,399	1992	62%	45%	
Small Hydro	24	82	82		39%	39%	
Diesel	6	11	11		21%		
Total	1,638	8,762	6,492		61%	45%	
ZCCM							
Hydro	38	216	216		65%	65%	
Thermal	100	44	44		5%	5%	
Total	138	260	260		21%	21%	
Total Hydro	1,670	8,967	6,697		61%	46%	
Total Thermal	106	55	55		6%	6%	
Zambia Total	1,776	9,022	6,752		58%	43%	

Matching Resources with Domestic Demand

The plants' capacity and energy mix needs to match the pattern demand in Zambia. Ideally, installed capacity just adequate to meet the peak demand would also be adequate to supply the yearly energy needs. However, if the match is perfect based on average hydro conditions, there will be surplus energy in wet years and a shortage in dry years. This points up the benefit of interconnections, especially to areas with thermal systems that can provide energy in dry years and accept energy in wet years.

To give a rough idea of when new resources would be needed considering only Zambia's demand and resources, Figure 2-8 compares existing average and minimum energy supply to forecast energy demand. Figure 2-9 compares existing capacity to forecast capacity requirements, which are roughly estimated as simply the peak load forecasts in MW, plus 4% to account for transmission losses from the plants to the substations, plus another 10% as a reserve margin to account for outages.

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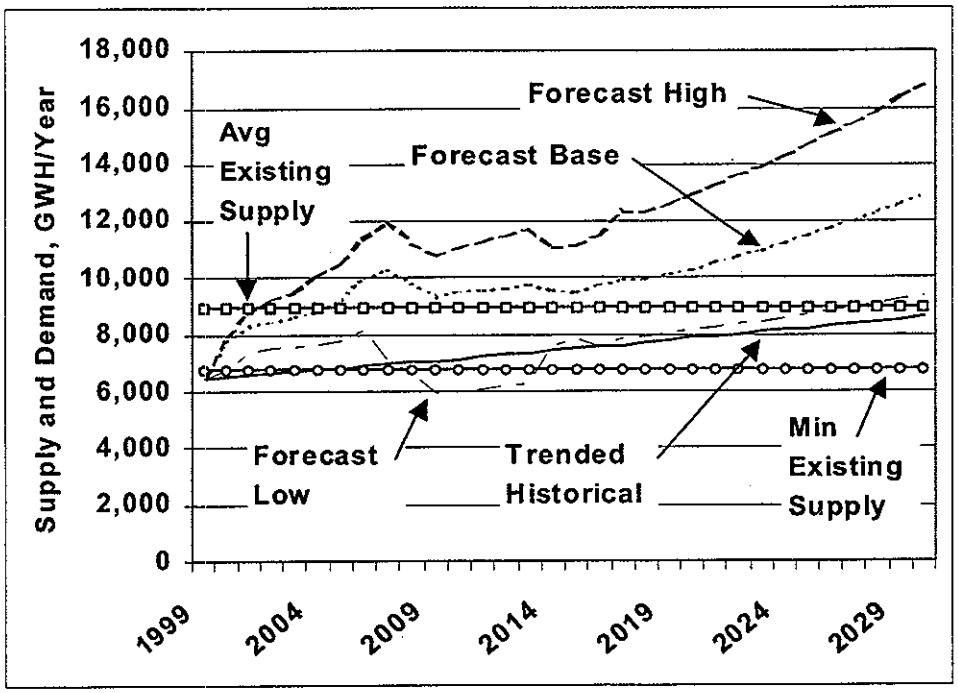

Figure 2-8. Existing Energy Supply And Forecast Demand

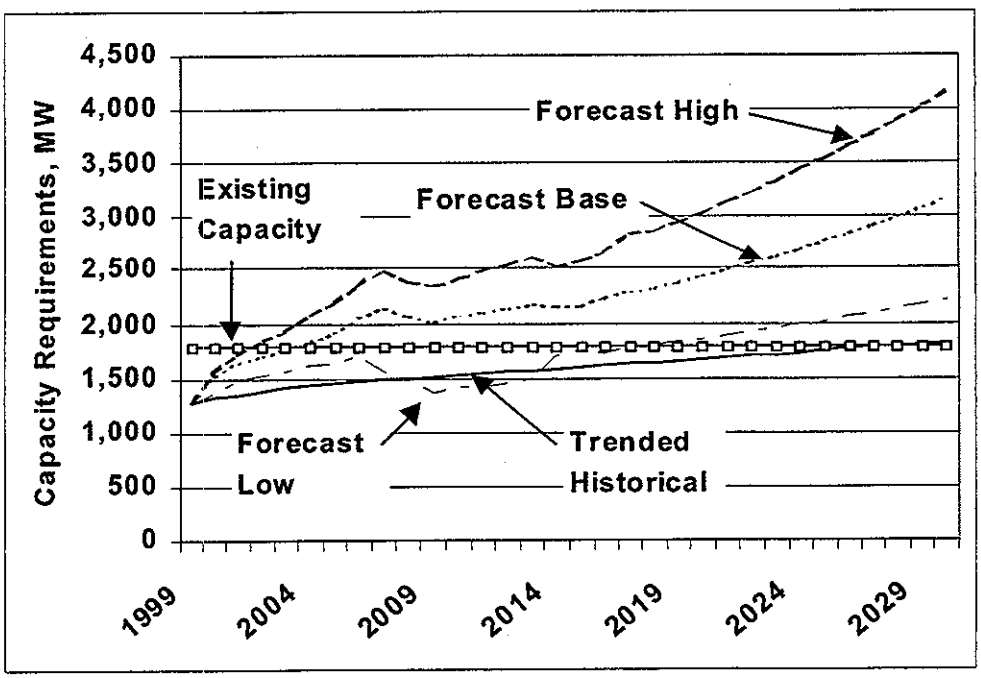

Figure 2-9. Existing Capacity And Forecast Capacity Requirements

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Table 2-2 summarizes the information presented in the two figures. The table shows the years in which new resources (new plants or imports) would first be needed to supply either additional capacity or energy. New resources would be needed at the earlier of the time they are needed for energy purposes or capacity purposes. Bearing in mind that these are only rough estimates, the table shows that:

- If planning is conservatively based on assuming hydro energy equal to the minimum energy achieved historically, then new resources are needed almost immediately for all demand growth scenarios.
- If planning is based on the High demand growth forecast, then new resources are needed almost immediately regardless of hydro energy supply assumptions.
- If planning is based on assuming hydro energy equal to the average energy achieved historically, then new resources are needed before 2005 for the High and Base demand growth forecasts, but not until after 2017 for the Low and Trended Historical demand growth scenarios.
- If planning is based on assuming minimum hydro energy, then energy needs determine the year in which new resources are needed. If planning is based on assuming average hydro energy, then capacity needs determine the year in which new resources are needed.

Table 2-2. Year In Which New Resources Are First Needed

Demand Growth Forecast	Based On Need For New Energy In Addition To: Minimum Existing Supply	Average Existing Supply	Based On Need For New Capacity
Forecast Low	2000 - 2014[1]	2027	2018
Forecast Base	2000	2005	2004
Forecast High	2000	2002	2002
Trended Historical	2004	After 2030	2027

1. Demand first exceeds average existing supply in 2001 falls below it again in 2008, and finally exceeds it for good in 2014

Generation Projects

The potential for hydro power generation in Zambia has long been recognized. Feasibility studies exist for many hydro sites in Zambia, some going back to 1929. Hydro projects are the only new plants under consideration in Zambia today. The two most favored projects are Kafue Gorge Lower and Itezhi-tezhi, both on the Kafue river. Compared to the other projects, these projects have attractive economics, minimal environmental impacts, and no need for coordination with neighboring countries.

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There are also four major sites on the Zambezi river, an 850 - 1118 MW development scheme for the Luapula river, a 114 MW development scheme for the Kalungwishi river, a 40 MW extension of the existing small development of the Lusiwasi river, and various small hydro possibilities. The small hydro projects in general are relatively high in cost and an economic choice only in isolated areas not served by the main grid. They will not be considered further here.

Table 2-3 summarizes the basic project parameters for the major Zambian plants. Section 3 discusses Kafue Gorge Lower and Itezhi-tezhi in more detail, in addition to the information summarized below for them.

Table 2-3. Zambia Hydro Project Basic Parameters[1]

Project	Capacity (MW)	Average Energy Production (GWh/year)	Average Capacity Factor	Capital Cost (1995 US$ millions)	Capital Cost per unit of capacity ($/kW)
Itezhi-tezhi	120	642	61%	82	683
Kariba North Extension	300	130	5%	225	750
Kafue Gorge Lower	600	3,033	58%	563	938
Batoka Gorge	800	4,300	61%	920	1150
Kalangwishi River	224	400	20%	376	1679
Devil's Gorge	800	4,250	61%	1,655	2069
Lusiwasi Extension	40	150	43%	92	2300
Mpata Gorge	320	1,600	57%	839	2622
Luapula River	850	4,800	64%	2,501	2942
Total	4,054	19,305	54%	7,253	

Kafue Gorge Lower

Kafue Gorge Lower would develop the remaining 200 meters of head in the Kafue Gorge. The existing plant, which we will refer to as Kafue Gorge Upper, is Zambia's largest power plant at 900 MW. Its reservoir, and the larger reservoir at Itezhi-tezhi, would provide the long term storage for Kafue Gorge Lower, whose reservoir would store enough water for only a few hours full power operation. Using this small reservoir and associated 62 meter dam keeps both costs and environmental impacts relatively low.

[1] Physical data on projects comes from the Twenty Year Power System Development Plan For Zambia Report, prepared by Ekono Energy in 1996. The costs presented come from different sources and do not necessarily represent a consistent approach. Where feasible we have revised the source values to increase the degree of consistency. We removed the duties from the data extracted from the Ekono Energy Development Plan, added the interest during construction, and de-escalated the values for Itezhi-tezhi from 1998 US$ to 1995 US$. The values presented are construction costs and do not include the costs (if any) of land, taxes or duties, major environmental mitigation measures, development costs of IPP sponsor, and major transmission improvements.

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Most of the head is developed through use of an eight kilometer rock tunnel tailrace to the corresponding elevation further down the Gorge.

Kafue Gorge Lower would incorporate four 150 MW units for a total capacity of 600 MW. With optimal reservoir management of the entire Kafue river system, Kafue Gorge Lower would provide 3,033 GWh per year on average, with a maximum of 4,379 GWh and a minimum of 1,024 GWh, before allowances for outages and station use.

Itezhi-tezhi

The existing dam at Itezhi-tezhi reservoir has no power generation facilities. This project would add a power plant to the existing dam and reservoir complex. Adding power generation to an existing dam and reservoir minimizes the costs and environmental impacts of the project.

Itezhi-tezhi would incorporate two 60 MW units for a total capacity of 120 MW at maximum reservoir elevation. At minimum reservoir elevation the output would be about 80 MW. With optimal reservoir management of the entire Kafue river system, Itezhi-tezhi would provide 642 GWh per year on average, with a minimum of 292 GWh, before allowances for outages and station use.

Zambezi River

All of the potential developments on the Zambezi are on stretches of river where it forms the border between Zambia and Zimbabwe. The Kariba North Extension would add 300 MW to the capacity of the existing Zambian plant and would not be a joint development with Zimbabwe. The other three sites would be joint developments.

Kariba North would provide 130 GWh of energy on average, corresponding to a capacity factor of only 5%. All of that would come in wet years, and none would be firm energy. It would provide relatively inexpensive capacity, and backup for the existing generators when they have technical or other problems.

Mpata Gorge (Zambia's share 320 MW) is the next site below Kariba Dam. Devil's Gorge (Zambia's share 800 MW) is the site immediately upriver from Lake Kariba, and Batoka Gorge (Zambia's share 800 MW) is the next site upriver from there, about 50 km downstream from Victoria Falls.

Luapula River

The main catchment areas for the Luapula river are several hundred kilometers from the catchment areas of the Zambezi and Kafue rivers. Therefore the inflow to the Luapula is not as strongly correlated with the inflows of the Kafue and the Zambezi as they are with each other. This adds to the value of hydro development on the Luapula.

The most suitable sites on the Luapula would support development of 1,188 MW, and other sites would add to that amount. However, where the river forms a boundary with the Democratic Republic of the Congo (DRC) development is less likely because the DRC does not need additional capacity, has less costly sites even if it did, and might be unwilling to allow areas within the DRC to be inundated by hydro development. By

developing the potential with all of the storage within Zambia the capacity would be reduced but problems would be avoided. 850 MW can be developed in this manner.

Kalungwishi River

Lumangwe Falls and Kabwelume Falls provide a total head of 140 meters on the Kalungwishi river. The river could be developed with a storage dam/reservoir and two power plants (60 MW and 54 MW), one at each falls, with daily storage reservoirs.

Lusiwasi Extension

The existing 12 MW Lusiwasi power plant is 60 kilometers downstream of Lake Lusiwasi . A new dam 20 kilometers upstream from the existing power station would increase firm flow from 3.0 cubic meters per second (m3/sec) to 6.5 m^3/sec and permit the installation of two 20 MW units at the existing power plant.

Summary

Itezhi-tezhi has the lowest total capital cost, lowest per unit capacity cost in $/kW. Kafue Gorge Lower has the third lowest capital cost behind Kariba North Extension; however, the capacity factor of Kariba North Extension is a less than a tenth that of Kafue Gorge Lower. Batoka Gorge has a 20% higher per unit capital cost requirement than Kafue Gorge Lower with little increase in average capacity factor. The per unit investment requirements are considerably higher for remaining projects. The table clearly illustrates the economic advantages of Kafue Gorge Lower and Itezhi-tezhi.

Other Import Possibilities

Although Zambia has traditionally viewed itself as a power exporting country, its ability to call on its neighbors for support was important in 1989, after the fire at the Kafue Gorge Upper Power Plant. The same transmission interconnections that permit exports also permit imports. In the future as well, imports will be needed in several circumstances:

- If Zambia elects to build low capacity cost but low energy output plants such as Kariba North Extension, and fills in the energy with (for example) off-peak energy imports.
- If domestic resources are not built in time. This is especially important if demand grows at rates comparable to the Base or High Forecasts.
- In less than average hydro years, if Zambia elects to plan based on average hydro conditions.
- In dry years, especially the second of two dry years in a row.
- In case of emergencies.

Exchange or banking type arrangements can be valuable even if there are no net imports. They differ in the time frame of the transaction, and therefore in some cases the motivation.

- Importing off-peak energy in or in anticipation of a dry year, to be returned on- or off-peak peak in a normal or wet year, to serve the trading partners energy needs.
- Importing off-peak energy to be returned the next day or other time frame, to enable the trading partner to operate fewer thermal units, but at higher average capacity factor and more efficiently. ZESCO's current banking arrangement with ESKOM is representative of this kind of transaction.

The payment for the transaction may be in energy or other services as well as with money. ESKOM, with more than 20,000 MW of coal-fired thermal units and excess capacity, is the natural trading partner for such transactions. Even when its capacity surplus declines there will be benefits to ESKOM to bank energy off-peak and withdraw it on-peak.

With its existing resources and current demand, Zambia would be energy deficient today during very dry conditions (i.e., less hydro output than has occurred since all plants have been operational). Thus even today a need for energy imports could develop, even though installed capacity exceeds peak demand by hundreds of MW. Addressing this potential problem through some kind of pre-arranged banking transaction could provide a degree of protection.

With its excess capacity and energy and direct interconnection with Zambia, SNEL also is a natural trading partner, and in fact has been Zambia's main source of imports. Not having thermal capacity, SNEL's more likely role is as a source of energy than as a significant partner in banking transactions.

Figure 2-10 shows that Zambia has been a net exporter in every recent year except 1989, when the fire at Kafue Gorge Upper shut it down, and the very dry year 1992. Net export levels were between 2,500 and 4,000 GWh per year until 1987. They have generally been around or under 1,000 GWh per year since then, except in dry 1991. Net exports to the Zimbabwe Electricity Supply Authority (ZESA) were over 2,100 GWh that year, probably representing reservoir draw-down to assist ZESA in a time of shortage, and also setting the stage for being a net importer the next year. (Zambia's transmission capabilities to import and export are discussed in Section 2.3 below.)

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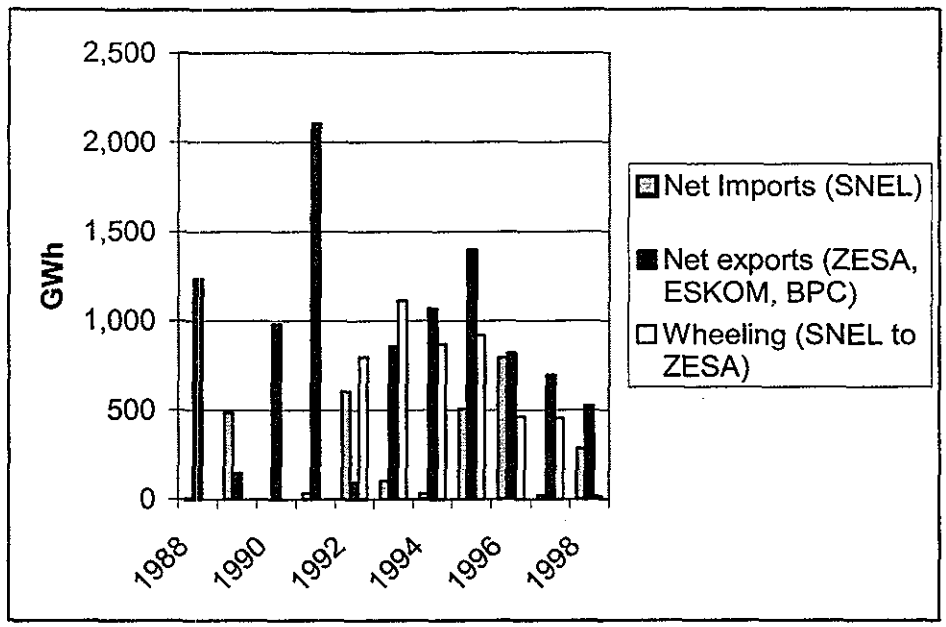

Figure 2-10. Zambia Imports And Exports

2.2.2 Zimbabwe

Under the existing Electricity Act of 1985, generation, transmission and distribution are done by the Zimbabwe Electricity Supply Authority (ZESA), which is 100 percent government-owned. ZESA has formed a subsidiary, Zimbabwe Power Company, for developing new power projects as of the beginning of 1999. This structure is in response to expected requirements of modifications to the revised Electricity Act, which is still in process.

ZESA is an established trading partner with ZESCO. Imports from ZESCO have decreased after ZESA's interconnection with Mozambique and increased imports from the Cahora Bassa project.

2.2.2.1 Electricity Demand

Zimbabwe has the highest demand of any country in the region other than South Africa and along with Botswana depends heavily on imports. It is already an important export market for Zambian power.

Electricity demand by sector in shown in Figure 2-11 based on 1995/96 data. Approximately 20% of Zimbabweans have access to electricity, so the potential for growth in the domestic sector is large. The mining sector is experiencing the same uncertainties as in the rest of the region. The industrial sector, contributing over 40% of total sales, is a sign of economic diversification. However, a large percentage industrial demand is from is from a single customer, the Zimbabwe Fertililizer Corporation. It uses an electricity intensive electrolysis process in its manufacturing process drawing a 400 MW load. There is currently consideration of replacing this process with one that uses

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coal-bed methane. Such a substitution would have a significant impact on Zimbabwe electricity usage.

Peak load was 2,034 MW in 1999 and has been experiencing 5-7% growth over the last four years, despite a decline in sales in 1998.

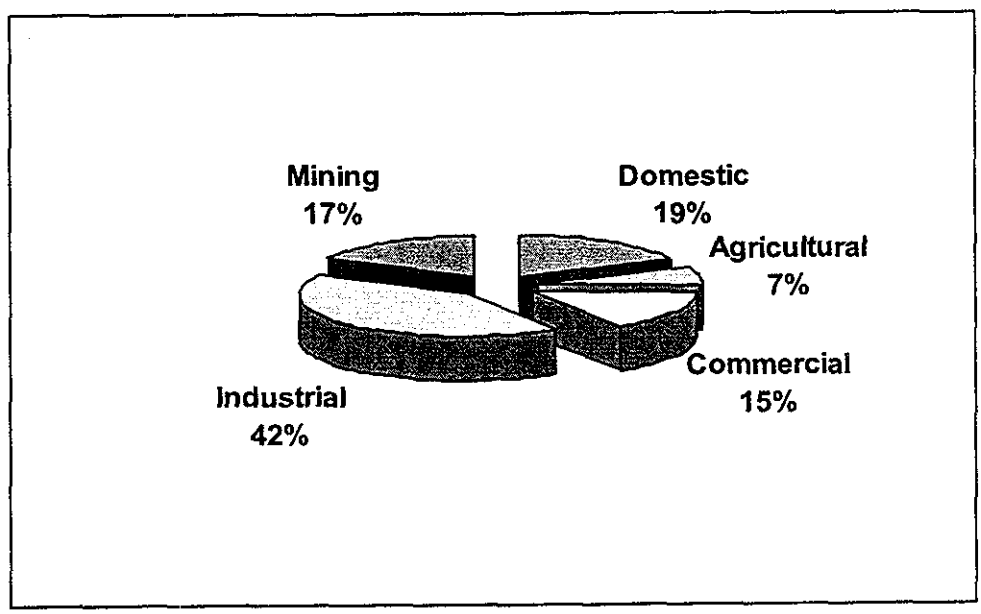

Figure 2-11. Sectoral Electricity Demand in Zimbabwe

2.2.2.2 *Internal Electricity Supply*

High quality coal deposits occur in Hwange, other parts of North Matabeleland, the Zambezi valley and in the South east, adjacent to the Gona-re-Zhou National Park. Zimbabwe has estimated recoverable reserves of 740 million metric tonnes of coal. Its annual production of 2.2 million metric tonnes is all in the Hwange area. The Wankie Colliery, the only operating mine, produces coal for both the Hwange power plant and the for industrial use from both surface and underground works.

Zimbabwe generating capacity is made up of four coal-fired thermal plants and Kariba South, Zimbabwe share of the Kariba project on the Zambezi (666 MW). Rehabilitation of Kariba South would bring its generating capacity to 750 MW. The largest coal-fired plant is Hwange (856 MW effective capacity), Munyati (60 MW), Harare (80 MW), and Bulawayo (60 MW). The thermal plants at Munyati and Harare were refurbished in 1995. None of the plant are operated at full capacity.

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2.2.2.3 Generation Projects

There are a number of potential generation project developments in Zimbabwe that could affect the market for power from Zambia.

Batoka Gorge Hydro

This is a 1,600 MW project that would require joint development with Zambia. A recent hydro master plan ranks this project behind the Itezhi-Tezhi and Kafue Gorge Lower projects

Hwange Extension

This project consists of two new units at the existing Hwange coal fired station (Units 7&8, 660 MW) based on a joint venture agreement was formed between ZESA and the Malaysian company, YTL Corporation. The Zimbabwe government has abandoned the sale of Hwange power station to Malaysia's YTL and is currently renegotiating the deal to attract the support of international financiers. A successful deal would likely also involve rehabilitation and upgrade to existing units, adding another 84 MW to generating capacity.

Gokwe North

A National Power consortium with Zimbabwe Power Company, ZESA's investment subsidiary, and Rio Tinto Zimbabwe has been awarded exclusive negotiating rights by the Government of Zimbabwe to develop a new 1,400 MW coal-fired power station in Gokwe North, situated in north west Zimbabwe. The project is likely to cost around US$ 1.5 billion. National Power is to invest up to US$ 400 million in a majority equity stake of between 60% and 80% in the project and will operate the plant, together with ZESA. The power station will consist of four 350 MW generating units. The first of these could be operational by the end of 2004.

If self-sufficiency were a goal in Zimbabwe, expected demand growth in the country could absorb both the Hwange Extension and the Gokwe North projects. This is illustrated in Figure 2-12. Zimbabwe would require few imports until after 2015 under such a development scenario. However, this scenario would be costly for Zimbabwe consumers or for the developers. The market price of power already pushed down by regional over-capacity would continue to be depressed for under medium load growth by the addition of 2060 MW of generating capacity. From 2001 through 2007, Zimbabwe consumers would either pay substantially more for domestically-produced electricity than they would for imports, or developers would have to accept a price that would, at least initially, be lower than would justify their investment.

Both Hwange Extension and Gokwe North should be considered serious projects. Development of either or both would seriously diminish the market for exports to Zimbabwe. Under the growth projected by SAPP, it is highly likely that these projects will be delayed until the Kafue Gorge Lower and Itezhi-tezhi projects could be constructed at would compete for the Zimbabwe and regional market

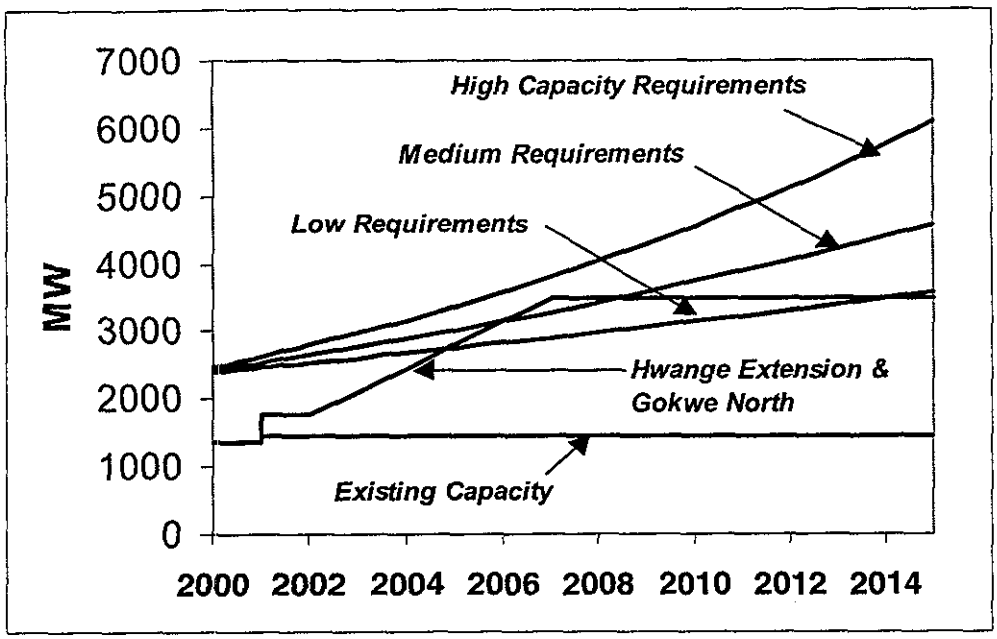

Figure 2-12. Zimbabwe Thermal Projects and Capacity Requirements

2.2.2.4 Other Import Possibilities

Zimbabwe is interconnected with Zambia (330 kV), Mozambique (400 kV, energized at 330 kV), Botswana (220 kV and 400 kV), South Africa through Botswana, and the Democratic Republic of the Congo through Zambia. The transfer capabilities between Zambia and Zimbabwe is 1000 MW. The transfer capability to South Africa is 250 MW, but with an upgrade to the substation in Botswana can be increased to 700 MW. The transfer capability to Mozambique is 500 MW with the 400 kV line energized at 330 kV.

Zimbabwe is the largest electricity importer in SADC. It is particularly well situated at the center of SAPP to benefit from electricity power transactions. ZESA has bilateral contracts with ESKOM, Hydroelectrica Cahora Bassa (HCB), ZESCO and with SNEL. Until 1998, ZESCO and SNEL were exporters to Zimbabwe. The ZESCO and SNEL contracts are now used primarily for emergency purposes. ZESA imports for the past two years are illustrated in Figure 2-13.

The contract for Cahora Bassa power (500 MW) is based on ESKOM laying off 500 MW of its 2000 MW contract until 2003. Should the Mpanda Uncua hydroelectric project be developed in Mozambique, Zimbabwe would be a prime export market. Increase in the DRC/Zambia transfer capability could increase import from the DRC.

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ZESA is arrears in paying for ESKOM imports. As of March 15 2000, the amount of arrears was reported by ESKOM as 135 million Rand and rapidly mounting. ESKOM has qualified ZESA as an "interruptible customer", meaning that in case of a power shortage it could be cut off first. ESKOM has indicated that they would be within their rights to discontinue exports to ZESA, but have agreed to continue unless ZESA's financial situation deteriorates significantly. ZESA's payment status for other imports is not known.

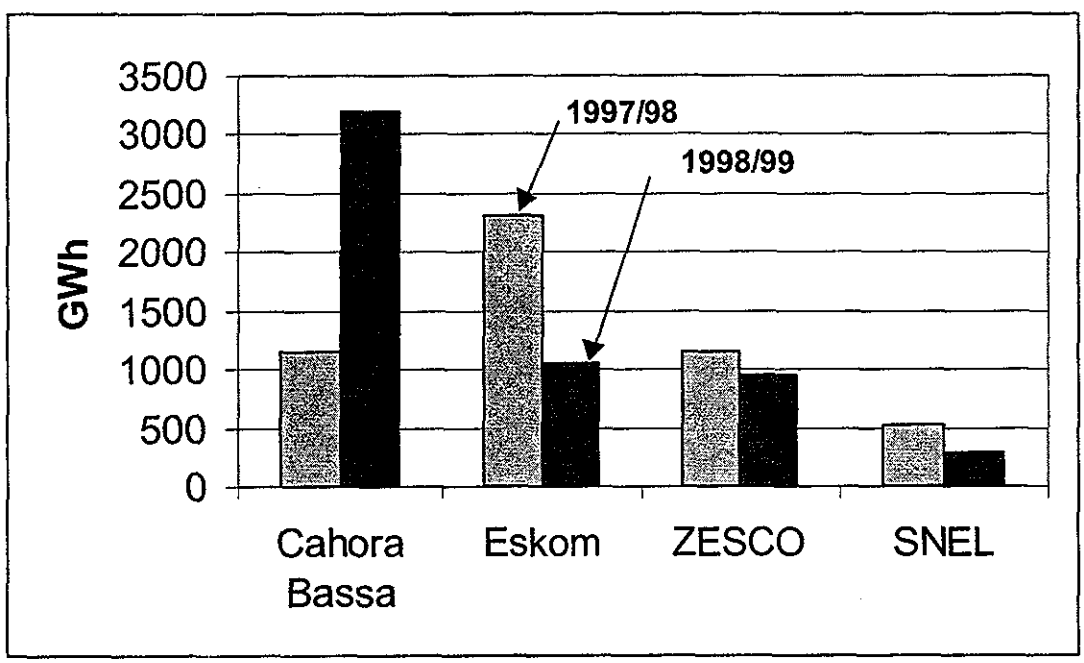

Figure 2-13. ZESA Imports

2.2.3 South Africa

About 95% of South Africa'a generation supply is provided by ESKOM along with the operation of its transmission system. Municipal and private parties provide the balance of generation. Distribution has been given the highest priority for restructuring of the electricity sector. The industry's new structure will require ESKOM's distribution division to be unbundled and merged with municipalities to form a separate company called EDI Holdings. The National Electricity Regulator licenses operators of generation, transmission and distribution and oversees pricing. The Ministry of Mines and Energy is responsible for the power sector and is currently developing a restructuring plan.

2.2.3.1 Electricity Demand

South Africa accounts for 85% of SAPP electricity demand. Along with Zimbabwe, South Africa is currently the major export market for Zambian power. Figure 2-14 shows the breakdown of South African electricity demand by consumer type based on 1996 data. ESKOM submissions to SAPP project an annual growth rate in energy sent out of 2.4% through 2010.

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The South African sub-market can be further divided into two distinct areas - East and West. In general the west is much smaller and has been growing at a higher rate. The capacity balance is significantly different in the two areas, with the West needing capacity earlier. ESKOM's current plan is to increase east-west transmission capacity and utilize excess generating capacity in the East to continue to supply the West.

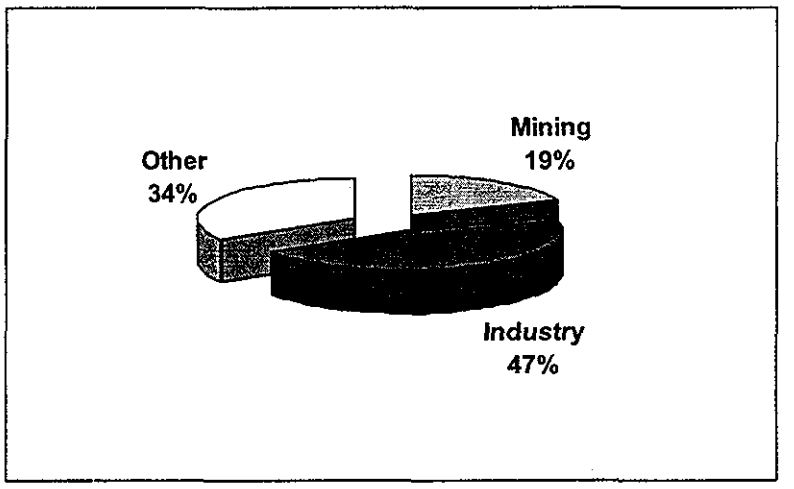

Figure 2-14. Sectoral Electricity Demand in South Africa

2.2.3.2 *Internal Electricity Supply*

Existing and Committed Generation Capacity

Generation in South Africa is operated by ESKOM, municipalities and by private enterprises. Figure 2-15 shows a breakdown of capacity by type and ownership.

Appendix B provides a detailed description of the performance characteristics of existing generating capacity by plant. Key characteristics that have the most influence on the need for new capacity and the value of new projects are discussed below.

ESKOM has made contractual commitments to complete another 1836 MW (3 x 612 MW) at the Majuba site and to demothball 990 MW at the Arnot site. Substantial progress has been made at both sites. ESKOM has a license from National Electricity Regulator to complete and operate this capacity. Additionally, ESKOM is planning for imports from the Cahora Bassa project in Mozambique. The DC line from the project to Pretoria has been restored and price negotiations for the power sale are currently underway. Initial imports are to amount to 75% of project output or 1480 MW. In 2004, ESKOM is entitled to the full 1850 MW.

All these projects are "committed" in the sense that they are under construction or otherwise virtually certain to be completed, and thus for the purposes of this study are not subject to an evaluation and decision whether or not to proceed. They are not subject to deferral by the Zambian hydro projects. They are included in the resource mix during the year when they are expected to be complete or contractually available.

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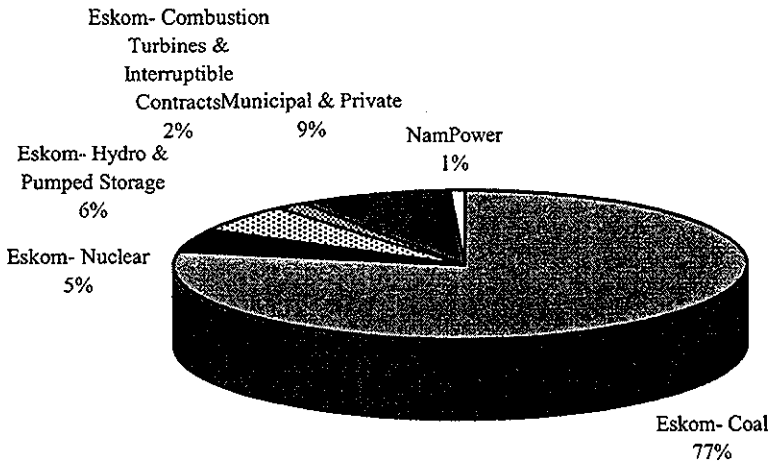

Figure 2-15. Existing Capacity to Serve South African and Namibian Demand[1]

We did not have access to any existing coal contracts for purposes of this study. Based on published overall cost data, we developed estimated coal costs for each operating plant. For Arnot, Kendal, Kriel, Lethabo, Matla and Tutuka, the fixed cost represents the sunk cost in mine development. These plants have dedicated mines. Mine development was shared by ESKOM and the coal house and the coal house receives an agreed-upon return for their share of the mine development.. The fixed portion amounts to about 20% of the total cost.

The mines serving Duvha and Hendrina are more integrated with export coal operations. The contracts associated with these mines are based on a fixed price with escalation clauses, primarily because the separation of costs of export and domestic operations is impractical. The net effect of this type of contract is that fixed costs under the contracts are a much higher proportion of total costs. We have assumed 80%. The coal contract associated with the Matimba plant is similar to the those for Duvha and Hendrina. The mine serving Matimba is integrated with Iscor's coking coal operations rather than export coal.

The ESKOM 1997 Annual Report indicates that greater flexibility in coal supplies will be sought during the next five years, suggesting that greater proportions of coal cost will be variable in the future.

Majuba does not have a nearby mine. Coal is currently sourced from Matla and transported to Majuba by rail.

[1] Namibian supply is also included in Figure 2-13.

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Air Emissions and Water Usage

Table 2-4 summarizes the air emission and water usage rates for existing plants. Data is based on ESKOM's 1996 Environmental Report.

Table 2-4. Air Emission and Water Usage Rates for Existing Plants

Plant	Particulates (g/GJ)	SOx (g/GJ)	NOx (g/GJ)	CO_2 (g/kWh)	Water Usage (liter/kWh)
Eskom Coal Plants					
Arnot	265	770	375	950	2.0
Duvha	30	846	375	950	1.8
Hendrina	321	700	375	950	2.0
Kendal	20	706	375	950	0.1
Kriel	51	515	375	950	1.6
Lethabo	31	700	375	950	1.6
Majuba	10	700	375	950	1.1
Matimba	29	700	375	950	0.2
Matla	28	649	375	950	1.5
Tutuka	21	694	375	950	1.8
Non-Eskom Coal (average)	119	700	375	950	2.0
Non-Eskom Bagasse	0	0	44	1000	2.0
Existing Combustion Turbines	0	30	400	450	0.1
NamPower					
Van Eck	265	846	375	950	0.1
Walvis Bay	0	700	375	950	0.1

2.2.3.3 Generation Projects

There are numerous projects under consideration in South Africa.

Re-commissioning of Mothballed Capacity

In 1989 and 1990, 5260 MW of ESKOM generating capacity was placed in reserve storage, or "mothballed" at the Camden, Grootvlei, Highveld, Ingagane, Komati, and Taaibos plants. In 1992 three units at the Arnot plant (990 MW) were added to reserve storage. Highveld, Ingagane and Taaibos were never returned to service and have since been retired. The three units at Arnot are currently being re-commissioned. This is summarized in Table 2-5.

Current ESKOM plans are to re-commission (demothball) units at Camden, Grootvlei, and Komati, a total of 3550 MW, when additional capacity is required. Therefore, the technical and economic feasibility of this re-commissioning has a direct impact on the perceived value of the Zambian hydroelectric projects.

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There are numerous examples of power plants being put in reserve storage for four or five years, like Arnot Units 4-6. However, there is no experience mothballing plants for what will be approximately 15 years by the time the capacity is needed. At that time the average age will be approximately 45 years.

Existing coal plants in South Africa, or elsewhere in southern Africa, do not have flue-gas desulfurization equipment. This has been justified on the basis of cost and the relatively low sulfur content of coal used for power generation (generally in the range of 0.8%-1.3%). We expect that any new coal-fired plant additions will require such equipment. It is a distinct possibility that such equipment will also be required five years from now if plants in extended reserve storage were to be re-commissioned. If such equipment were required, re-commissioning would become, if not clearly uneconomic, then only marginally so.

We feel that the age of the units in reserve storage, the length of time they will be required to be mothballed, and uncertain environmental requirements provide substantial doubt as to whether these units will ever be re-commissioned. In our Base Case Development Plan, we have assumed that they would not.

Table 2-5. Status of Plant Placed in Reserve Storage

Station Name	Net Maximum Capacity (MW)	Average Age at Time of Mothballing	Last Year in Commercial Service	Status
Arnot Units 4-6	990	21	1993	3 units in reserve storage returned to service by 2000
Camden	1520	28	1990	Reserve storage
Grootvlei	1130	24	1990	Reserve storage
Highveld	412	36	1990	Reserve storage, retired in 1995
Ingagane	465	27	1990	Reserve storage, then retired
Komati	900	32	1990	Reserve storage
Taaibos	440	41	1990	Reserve storage, retired in 1995

Conventional Pulverized Coal Plants

Conventional pulverized coal plants have been the mainstay of South Africa's power generation development. Our best information is that there are economic reserves of coal adequate to support another 24 x 635 MW units within relatively easy transmission distance to the existing transmission system.

The cost and performance characteristics of a conventional pulverized coal units in Table 2-6 is based on dry cooling, inclusion of flue-gas desulfurization (FGD) for 90%

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removal, low-NOx burners, installation of baghouse filters, and construction in six-unit plants similar to current practice in South Africa.

As shown in Table 2-6, 100 US$/kW is for FGD equipment. South Africa currently has no regulatory requirement for the use of FGD equipment on new plants.

Table 2-6. New Coal Plant Capital Cost Estimate

	US$/net kW
Installed cost without flue-gas desulfurization (1994)	1010
Adjustments	
escalation to 1998	*58*
flue-gas desulfurization	*100*
low NOx burners	*5*
rate for interest during construction from 6% to 7%	*27*
Total adjustments	*190*
Total adjusted cost	1200

The basis for the medium capital cost estimate of 1200 US$/kW is the cost contained in the SAPP Agreement for a coal-fired plant in southern Africa without flue gas desulfurization. Table 2-6 shows the adjustments that have been made to this cost. The escalation and interest rate adjustments make the reference estimate consistent with the economic and costing assumptions of this study. The other adjustments bring the plant to Western European or US environmental standards.

Our assumption that they will be included on future plants is based on a judgement that South Africa will adopt regulations closer to those of developed countries by 2011, the first year that new baseload generating capacity will be required under the Base Case demand scenario.

Wet scrubber technology is the most proven and commercially established SO2 removal process in most developed countries (Europe, Japan, and the United States). At the end of 1993, there were more than 132 GW of installed capacity operating worldwide. Approximately 40 GW (installed in the late 1980s) are in Germany and more than 62 GW in the United States. Of the 9,200 MW of coal-fired capacity in Japan, approximately 93 percent use scrubbers (mostly wet type). Wet scrubbers are the technology of choice for retrofit applications requiring more than 80 to 90 percent SO2 removal.

ESKOM has installed baghouse filters at its large power plants to control particulate emissions. Bagfilters or baghouses are based on the following operating principle: particles and flue gas are separated in tube-shaped filter bags arranged in parallel flow paths. The particulates are collected either on the outside (dirty gas flow from outside-to-inside) or the inside (dirty gas flow from inside-to-outside) of the bag.

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A significant percentage of future investment requirements for new generation capacity is based on the cost of new coal plant. At this level of detail, estimation errors of plus or minus 15% can be expected. For this reason, variations in cost of plus or minus 180 US$/kW have been considered in sensitivity analysis.

Coal is assumed to supplied 50% from an adjacent mine and 50% from other sources requiring transportation. The cost of the coal from the adjacent mine is estimated as the same as current mid-cost collieries, such as Khutala, Kriel and New Vaal, plus a 10% real cost increase, plus another 15% increase to reflect the effect of 100% private mine development. The cost of coal delivered from other mines is again estimated as the same as current mid-cost collieries plus a 10% real cost increase plus 0.28 US$/GJ for transportation. Sensitivity of the results to coal costs to new plants was conducted at plus and minus 15%.

Simple Cycle Combustion Turbines

Combustion turbines operating in a simple cycle mode are a common solution for systems requiring peaking generation. We have considered simple cycle combustion turbines using distillate fuel oil for fuel. The cost and performance characteristics are consistent with the US Electric Power Research Institute Technical Assessment Guide.

Rainbow Millennium Power Plant

Xolani Mkwanazi, the chief executive of the National Electricity Regulator, indicated in early March 2000 that the first license for an independent power project would be granted to a local consortium for a 210 MW plant to be located in the Richard's Bay areas. It is expected to come on stream between 2005 and 2007 according to news reports. The cost reported to be R 1 billion.

ESKOM Power Station

In last year's tariff application, ESKOM including funding for a new power station in its revenue requirements analysis. This aspect of the tariff application was rejected by NER. Specifics of ESKOM's plans are not available; however, we are aware of siting studies for a natural gas-fired combined cycle power plant to be located on the west coast carried out by ESKOM While the nature of restructuring of ESKOM is yet to be decided, the NER decision suggests the new generation is likely to be an IPP rather than an ESKOM-financed project.

Cape Town Combined Cycle Plant

The City of Cape Town and Shell are currently having a feasibility study completed for a nominal 1000 MW of combined cycle capacity to be fueled by gas from the Kudu field in Nambia.

Pumped Storage Projects

ESKOM operates two pumped storage plants, Drakensburg (4x250 MW) and Palmiet (2x200 MW). In addition, the City of Cape Town operates the 180 MW Steenbras pumped storage plant. These projects allow pumping with lower cost off-peak power and

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generation during higher cost peak periods. Their round-trip efficiency is between 72% and 75% so that a cost differential of approximately 40% between peak and off-peak power is required for economic operation. We understand that all of these projects have secondary water transport benefits.

ESKOM is currently proposing a number of addition pumped storage projects for installation beyond 2010. We have evaluated pumped storage in screening analysis and included in a variation of the Base Case plan. We have excluded pumped storage from our Base Case development plan because of the site-specific nature of the projects. A variation on the Base Case development plan has been considered in order to investigate the potential impact of pumped storage on future system costs.

2.2.3.4 Other Import Possibilities

South Africa is interconnected with Namibia (400 kV and 220 kV), Botswana (400 kV) and Mozambique (500 kV DC to the Cahora Bassa project and 220 kV to Maputo), and through Botswana with Zimbabwe, Zambia and the DRC.

2.2.4 Tanzania

The state-owned Tanzania Electric Supply Company (TANESCO) operates generation, transmission and distribution in Tanzania. Prepartory work for the privatization of TANESCO was begun in February 2000. While there are a number of projects in the works, the country is facing a capacity shortage without any high voltage interconnections and is using load shedding during peak loads.

2.2.4.1 Electricity Demand

SAPP projects the fiscal 1999 peak load and sales to grow at an annual rate of about 8%.

2.2.4.2 Internal Electricity Supply

The interconnected Tanzania system is primarily supplied by hydroelectric power with two cascading systems. The Pangani Rive system contains the Hale plant (20 MW), Old and New Pangani plants (89 MW) and Nyuma ya Mungu (8 MW) with the main reservoir at the Nyuma ya Mungu dam. The Great Ruaha system contains Kidatu (4x50 MW) and Mtera plants(2x40 MW), with the main reservoir at the Mtera Dam.

TANESCO reports a total installed capacity of 591 MW; however much of this either requires rehabilitation or is unavailable to the interconnected grid. Our understanding that only the only thermal plant available to the grid is the Ubungo thermal plant in Dar-es-Salaam (69 MW). By 2000, Tanzania expects to have the Kihansi power project with electric generating capacity of 60 MW with 120 MW to follow. There are over 100 MW of diesel capacity, much of it in poor repair.

Even when the Kihansi plant is added to the system, our information indicates that the interconnected system will be in a capacity deficit. There are a number of projects in various stages of development. These are discussed below.

2.2.4.3 Generation Projects

Mtwara Gas Project

In late January 1998, the Tanzanian government signed an agreement with Tornado Resources for the development of a $32.5 million natural gas-fired, electric power project in southern Tanzania. The project will use gas from the 500-Bcf Mnazi Bay gas field in the town of Mtwara, transported through a 16-mile gas pipeline, to a 15-20 MW power plant.

Songo Songo Gas Project

A project to exploit natural gas on Songo Songo Island, in the country's largest known field. Songo Songo Island is located in the Indian Ocean southeast of Dar-es-Salaam. The project stalled two years ago, but has been revived. The project is a joint venture between TransCanada Pipeline and Ocelot Energy. It involves a 140-mile pipeline from Songo Songo to a 37 MW gas-fired plant in Dar-es-Salaam. TANESCO is reviewing terms under which it would buy power from the generator. Songo-Songo's reserves are estimated at 1 trillion cubic feet (TCF).

IPTL Project

As of late 1999, Malaysia-based IPTL remained in a long-standing dispute with TANESCO over IPTL's power project. The dispute has centered on the cost of a 100-MW thermal power plant in Dar es Salaam. IPTL intends to sell electricity from the plant for 21 cents per kWh, while the government wants the price to be set at nine cents. The IMF and the World Bank had been against the project, saying that a 21-cent tariff would be too high a burden on Tanzania's economy. The Tanzanian government had awarded the contract to IPTL in 1994 as an emergency measure to solve a power crisis. Malaysian investors have a 70% stake, while Tanzania has a 30% stake. Construction of the power plant was completed in September 1998 but no electricity has been produced due to the dispute. The World Bank had threatened to withhold funding for additional development projects in Tanzania if the IPTL contract is not re-negotiated.

Aggreko Project

This is a 100 MW power project. We little additional information on it at this time.

Hydroelectric Projects

Only 5% of the estimated potential for 4700 MW of installed hydroelectric generating capacity has by developed. Previously planned TANESCO have included the 200 MW Rumakali plant in 2004 and the 160 MW Mpanga plant in 2006. The likelihood of developing these projects in this timeframe is very low given that developers has yet to be identified.

Reasonable development scenarios were postulated for high, medium and low load growth for purposes of evaluating the potential high voltage interconnection between Zambia and Tanzania. The details of these alternative plans are presented in Appendix B.

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2.2.4.4 *Other Import Possibilities*

Tanzania is without any major high voltage interconnections with limited import opportunities. Tanzania imports power from Zambia to supply isolated networks of Tunduma and Mbozi. In March 1999, the Norwegian government provided a grant for the construction of a 66-kV power line from Zambia's northern city of Mbala to Sumbawanga in southwestern Tanzania. TANESCO has indicated that it is less expensive to import power from Zambia than from the Kalambo hydroelectric dam in southern Tanzania.

Aside from the 330 kV Zambia/Tanzania transmission interconnection under study, there is a 330 kV Tanzania-Kenya-Uganda interconnector under study.

2.2.5 Mozambique

Mozambique and Nambia are both sub-markets that do not have a direct impact on the market for Zambian power export. The primary characteristics of the Namibian sub-market have been discussed in the section on South Africa.

Ministerial responsibility for the power sector lies with the National Directorate of Energy in the Ministry of Mineral Resources and Energy. EDM is currently responsible for transmission and distribution in commercially viable areas. EDM became a public corporation in 1995. Further restructuring will be done as a result of implementation of the Electricity Law.

The Electricity Department of the National Directorate of Energy is responsible for rural electrification. The largest domestic generator is Hidroelectrica Cahora Bassa, which produces power for export to South Africa and Zimbabwe.

2.2.5.1 *Electricity Demand*

EDM domestic sales were 779 GWh in 1997 of which 64% was in the Southern System, 24% in the Central System and 12% in the Northern System. Peak demand was 198 MW. The number of customers was 177,793 for an average annual consumption of 4400 kWh per customer per year. Growth has been at 8 percent per year in the last two years. Approximately 5 percent of Mozambicans has access to electricity. SAD-ELEC in South Africa has estimated electricity demand growth in Mozambique to be between 6 and 6.5 percent per year after the year 2000. This estimated growth does not include the planned Mozal smelter will which, at 450 MW, will more that triple electricity demand in the country. A description of the Mozal project follows.

The 233 thousand tonne-per-year (TPY) Mozal aluminum smelter is to be owned by a consortium of Billiton (47%), Mitsubishi Corporation (25%), the Industrial Development Corporation (24%) and the Mozambique Government (4%) and is expect to require a total investment of US$ 1.36 billion. The Mozal project will make Billiton, the western world's third largest aluminum producer. The consortium believes Mozal will be cost competitive and remain profitable even with seriously low aluminum prices in the future. Mozal's initial break even point will be at an aluminum price of US$ 750/tonne. After this Mozal is forecast to have a cash operating cost of $980/tonne at a London Metal Exchange (LME) aluminum price of $1,650 per tonne.

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The smelter will have the capacity to double production and consume about 450 MW of electricity and 500,000 tons of alumina a year, some of which will be supplied from the Worsley alumina mine in Australia and from Malawi. The consortium has agreed a particularly low price for its electricity for the first six years with ESKOM and EDM. Thereafter, the smelter will be locked into a competitive electricity contract for six years and an agreement comparable to that of Billiton's Hillside smelter for a further twelve years. During the second 12 year phase of project, electricity prices will be linked to LME aluminum prices.

2.2.5.2 *Internal Supply*

Transmission and transmission interconnections

The Mozambican power system is divided into three separate systems. The Southern and Central systems are at 100 kV. The Northern System has a maximum voltage of 220 kV. The Southern System supplies Maputo and is interconnected with South Africa by means of 110 kV and 275 kV lines. The Central System supplies Beira. The Northern System contains the Cahora Bassa power project and is interconnected with South Africa and Zimbabwe. The interconnection with South Africa is by means of a 533 kV DC line. The 400 kV Songo/ Bindura/Dema interconnection with Zimbabwe began operation at the end of 1997. This line is currently energized at 330 kV.

Generation

The Southern System is supplied by imports from South Africa and by 70 MW of liquid-fuel-fired simple-cycle combustion turbines located in Maputo for peaking purposes and the small Corumana plant. The Central System is supplied by the Chicamba and Mavuzi hydro plants and the Northern System is supplied by the Cahora Bassa plant. Numerous diesel generators supply isolated system. A gas-fired combustion turbine supplies an isolated system in Vilankulos.

2.2.5.3 *New Generation Projects*

Extension of Cahora Bassa

During the construction of Cahora Bassa, provision was made for a future north bank development (up to 1,100 MW). Several studies have established that the present spillway arrangements are insufficient and that both present operations and future downstream developments would benefit from additional spillway capacity. The inclusion of 550 MW of the above mentioned capacity may be economically justified. The likelihood of this project being implemented is relatively low due to a number of complicated political issues to be resolved between HCB, EDM and ESKOM as well as between the Governments of Portugal, Mozambique and South Africa.

Mpanda Uncua

A number of pre-feasibility studies have been carried out on various hydropower developments in the country, mainly for export. The most likely option for future hydropower supply from Mozambique seems to be development of the Mpanda Uncua or

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alternative Cambewe Foz sites, both downstream of the existing Cahora Bassa plant. Currently a full feasibility study on the Mpanda Uncua site has been awarded (also including consideration of the Cahora Bassa North bank project) with expected completion by the end of 1999.

The study will be an update of a 1996 study. From the 1996 study two main options can be derived: base load operation with an installed capacity of 1,600 MW or mid-merit operation with 2,400 MW of installed capacity. The choice of the final design option will depend on the relative merit of the extra peaking capacity compared to other alternatives for meeting mainly South African system requirements.

The Mpanda Uncua site is basically a "flow of the river" location where the dam is used for regulation of flow and short-term storage. The reservoir will be kept as near full as possible, implying that operations will depend on discharges from the Cahora Bassa reservoir.

Mpanda Uncua, being a large hydro power project, will require the construction of associated high voltage transmission facilities (either AC or DC) to bring the power to markets in Mozambique and South Africa. This increases the financing requirements of this project. In general, the Mpanda Uncua project will have a size and financing requirement that might cause problems for timely implementation of the project, particularly taking into account the relatively high risk profile of Mozambique in terms of foreign investments and in light of a number of other large scale developments in the country.

Moatize Coal-fired Plant

Based on the Moatize coal deposit JCI, the South African Mining house, is exploring the possibility of restarting mining operations with the main purpose of exporting coking coal. However, production of coking coal will result in large volumes of low grade steam coal being produced as well. The only viable alternative for use of this steam coal is found to be possible use in a coal fired power station. JCI is therefore investigating the construction of a 1,000 MW coal station, targeted for commissioning by 2004. The Moatize coal project would be linked to an iron processing plant in Beira (importing iron ore while exporting coking coal on the same ships). Other necessary components of the project are a new deep water harbor north of Beira and rehabilitation of the Tete - Beira railway line.

The coal fired power station would only be required to pay the true transfer cost for coal as fuel. Furthermore, the developers are aiming at bringing in potential users of the power as owners in the power station, offering a low cost supply of electricity in return for a very modest return on the power station investment. The power station will primarily be aimed at markets/customers in central and northern Mozambique and in Zimbabwe. Although the provisional numbers coming out of the project study are attractive, the power station is reliant on many other components to materialize as outlined above. This could easily imply that a decision to proceed may be delayed.

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Pande Gas Combined Cycle

Mozambique also has a potential for gas-fired power generation from resources such as the Pande and other fields. A study was carried out on the overall concept of gas for power generation in Mozambique. Indications showed that development of a combined cycle gas turbine (CCGT) either in Beira or Maputo was at the time (1995/96) not a competitive option. Since then the kW cost of combined cycle and simple cycle combustion turbine power stations have almost halved. A power generation project of 500 - 1,000 MW in combination with a large scale industrial development such as the proposed Maputo iron and steel project where the marginal cost of additional gas production/transport would be low therefore looks more promising. Indicative figures from the proposed Pande developments indicate that considerable additional capacity would be available in the transport system from Pande to Maputo to also serve other gas use options. Gas fired power generation as an anchor customer to start gas developments in Mozambique looks unlikely at this point.

2.3 *Transmission Constraints*

2.3.1 Zambia

2.3.1.1 Existing Transmission System

Zambia's transmission system is based on the fundamental fact that large hydro plants in the south must provide power to major loads in the north and in the large cities along the way.

A strong 330 kV backbone extends almost due north from Kariba North and Kafue Gorge Upper in the south to Luano in the north. Four lines go from the power plants directly to Lusaka; a fifth passes through Kafue Town on its way to Lusaka. Three lines extend from Kabwe to Kitwe and Luano. A 330 kV spur extends northeast about 250 kilometers from Kabwe to Pensulo.

In the south, a 220 kV line connects the Victoria Falls plant to the 330 kV substation in Kafue Town. In the north, the CEC, formerly the ZCCM Power Division, now privatized, owns and operates the 220 kV system and most of the 66 kV sub-transmission system that the serves the mining loads.

132 kV has been adopted as the new sub-transmission voltage, and it is replacing some of the non-standard 88 kV lines, especially around Lusaka.

Outside the backbone corridor, 66 kV serves as the transmission voltage. For small distant rural centers, 33 kV is used as the transmission voltage. Much of the rural population is not served at all. Several rural communities are served by isolated networks at 33 kV and lower voltages.

The existing grid is basically adequate to serve the existing loads for many years. The level of transmission losses has been between 2.5 - 4% in the 1990s, supporting this conclusion. As loads grow, reinforcements will be necessary. Most of the planned major

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improvements address the connection of new power plants to the grid or new interconnections, rather than extension or strengthening of the existing network.

2.3.1.2 Existing Interconnections

Centrally situated in Southern Africa, Zambia is well-positioned to benefit from transmission interconnections with neighboring countries. Its existing interconnections have been adequate to permit active electricity trading for decades. Upgrades to these interconnections will provide the capability for expanded two-way trade and additional wheeling.

Zambia's primary interconnections are with SNEL (220 kV) and ZESA (330 kV). The interconnection with ZESA also provides access to ESKOM and Botswana Power Corporation (BPC).

ZESCO also provides relatively small low voltage exports to isolated areas in Botswana, Zimbabwe, Tanzania, the DRC, and Namibia. The existing 66 kV line to Katima Mulilo in Namibia is in the process of being upgraded to 132 kV, with support provided by the African Development and the Development Bank of Southern Africa. The areas served are "fringe" areas where it is less costly to deliver bulk energy from the ZESCO system than from the local utility. These interconnections will not be discussed further.

The connection to SNEL is a single circuit 220 kV line that extends from Luano through Michelo, then several substations in DRC to Karavia. The Zambian section is owned and operated by CEC, the DRC section by SNEL. The current transfer capability is 250 MW north to south and south to north, although there is little call for south to north transactions. The line is typically close to fully loaded with north to south flows, mostly for wheeling to ZESA or ESKOM. Once into Luano, power from SNEL can move without constraint north to south through Zambia to Zimbabwe, because the prevailing flows are south to north.

The thermal rating of the line is 375 MW, but transfers are limited to 250 MW due to conditions on current-voltage transformers and line traps at Luano. Voltage issues would limit transfers to 310 MW if the current-voltage transformers and traps were replaced.

The connection to ZESA is a twin circuit 330 kV line at Kariba. Stability would limit transfer capability to perhaps 1,000 MW, but as a practical matter the lines can handle more power than SNEL plus ZESCO would want to export or import.

To trade with ESKOM requires wheeling through the ZESA system, which is not the limiting factor currently. The predominant power flow is on the 400 kV line from Insukamini in Zimbabwe to Matimba in South Africa. The BPC system, through Phokoje - Segoditshane, and into the ESKOM system at Spitskop forms a parallel path to the Phokoje - Matimba 400 kV line. It therefore follows that part of the power flow into the ESKOM system from the ZESA system will inevitably flow through this BPC parallel loop. Above about the 250 MW level of power flow, this parallel loop flow causes overloading of BPC's 220/132 kV transformers at Segoditshane. Accordingly the limit on power transfers is 250 MW.

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In a sense ZESCO competes for the use of this path with energy-surplus SNEL for north to south exports to ESKOM, and with energy-deficient ZESA for south to north imports from ESKOM.

Potential Improvements To Existing Interconnections

Replacing the current-voltage transformers and traps at Luano would increase transfer capability by 60 MW, from 250 MW to 310 MW. The cost would be US$105,000.

The next increment of improved transfer capability would be obtained by building a second 144km 220 kV transmission line between Karavia (DRC) and Luano (Zambia), and installation of 2 x 72 MVA shunt capacitors at Karavia. This would increase transfer capability to 500 MW, at a cost of US$ 17,417,000.

The hydro plant at Inga in the DRC is the source of the power that is exported to Zambia and points south. The capacity of the direct current transmission lines from Inga to Kolwezi substation is 1120 MW, but the present terminal equipment limits the transfer capacity to 560 MW. It is this line that supplies the power that ultimately flows through Karavia to Luano. A third increment of improved transfer capability between the DRC and Zambia can be obtained by up-rating the terminal equipment to 1120 MW and increasing the line capacity between Kolwezi and Luano. The Kolwezi - Luano project would involve the construction of a 449 kilometer 330 kV transmission line from Kolwezi through Solwezi in north-western Zambia to Luano. The cost of up-rating the terminal equipment is estimated at US$ 267,000,000. The cost of building the Kolwezi - Luano line is estimated at US$ 67,100,000. Together, these improvements would increase the transfer capability to about 1000 MW.

The problem of overloading the transformer at Segoditshane could be addressed by installing a third 220/132 kV transformer there. Unlike the existing 60 MVA transformers, it is recommended that the new transformer should be dimensioned at 125 MVA. This will increase the firm capacity at Segoditshane to 120 MVA. This will eliminate the overloading problem and increase the transfer capability between South Africa and Zimbabwe to 700 MW. This will also improve the robustness of the BPC system and will greatly enhance its system stability. The estimated cost for this project is US$ 2,744,000.

A second increment of increased transfer capability would be obtained by building a second 411km 400 kV transmission line from Insukamini (Zimbabwe), through Phokoje (Botswana) to Matimba (South Africa). This project will also include the installation of 2 x 150 MVA capacitor banks at Insukamini. The cost of these improvements is estimated to be US$ 76,419,000.

To increase the transfer capability all the way from Zambia would require up-rating the Kafue - Muzuma - Victoria Falls line from 220 kV to 330 kV, and constructing a 330 kV line from Victoria Falls to Hwange. The estimated cost of this project is US$ 30,402,000.

The total costs is thus US$ 106,821,000. The transfer capability following the improvements is 980 MW.

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An increase in transmission capacity from 980 MW to 1,200 MW would occur if internal transmission reinforcements were completed in the ZESA system associated with the Gokwe Power Station. Since these would be attributed to the Gokwe Plant, no cost estimates are presented.

Table 2-7 organizes the above discussion into phases and costs per kilowatt of incremental transfer capability. Table 2-7 shows that what are called the Phase 1 projects provide substantial additional transfer capability at relatively little cost.

2.3.1.3 New Interconnections

In addition to the improvements discussed above, two new interconnections have been proposed for Zambia. The proposed 330 kV line from Pensulo to Mwakibete Substation in Tanzania would provide about 200 MW on transfer capability, at an estimated cost of 1998 US$ 152,880,000. Section 3 discusses this project in more detail.

An interconnection between Zambia and Malawi was studied at the pre-feasibility level in a joint exercise of the power utilities of Malawi, Zambia, and South Africa. The 220 kV, 167 MW line would have 305 kilometers in Zambia and 125 kilometers in Malawi. Estimated cost is about US$ 50 million. However, the results of a Power System Development and Operation Study (Master Plan) for Malawi completed by an international consortium in December 1998 demonstrated that the interconnection to Mozambique is clearly superior to the interconnection to Zambia due to its lower capital cost. If no reasonable agreement for the interconnection with Mozambique can be reached, the interconnection with Zambia could replace it. If the Mozambique line is limited to 200 MW, the Zambia interconnection would also be needed about 2015 – 2020, depending on load growth and other factors.

Table 2-7. Improvements to Increase Transfer Capability

	Initial Transfer Rating (MW)	Improvement	Cost (millions US$)	End Transfer Rating (MW)	Added Capability (MW)	Per Unit Cost ($/kW)
SNEL To ZESCO Transfer Path						
Phase 1	250	Luano CVTs and line traps	0.1	310	60	2
Phase 2	310	2nd Luano-Karavia220 kV line	17.4	500	190	92
Phase 3	500	DC terminals and Kolwezi-Luano 330 kV line	334	1,000	500	668
ZESCO To ESKOM Transfer Path						
Phase 1	250	Segoditshane transformer	2.7	700	450	6
Phase 2	700	Insukamini 400 kV line; new Vic Falls - Hwange 330 kV line; upgrade Kaafue - Vic Falls 220 kV line to 330 kV	107	980	280	382
Phase 3	980	ZESA improvements for Gokwe	0	1200	220	0

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2.3.2 Other Countries

The most important transmission constraints regarding the market for power for Zambian projects are addressed in the section above. With respect to the overall transmission situation in Southern Africa we offer the following summary.

South Africa is by far the largest market in the region. ESKOM designs the transmission system on an N - 1 basis, so that under normal conditions there are no significant constraints within the country. ESKOM's DC link to Cahora Bassa is sufficient to accept that plant's entire output, and its links to Namibia, Mozambique, Swaziland, and Botswana are adequate to support any probable level of trade. Its link to Zimbabwe is discussed in the section above.

The Government of Malawi has signed a memorandum of understanding with the Government of Mozambique for an interconnection between Blantyre and the Matambo substation in Mozambique. The 220 kV line would have transfer capacity of 200 MW and a length of about 210 kilometers, of which 80 would be in Malawi. Swedpower completed a feasibility study in 1996. Estimated cost of the line is US$ 25 million. The Government of Malawi would like to finance it as a partially or wholly independently owned project, or through donor funds. As noted in the section above, this interconnection is favored over the possible interconnection with Zambia.

2.3.3 Conclusion

Two projects that will increase transfer capability seem so low in cost relative to their potential benefits that for the purposes of this study we assume they will be implemented. These projects are:

- Installing a new transformer at Segoditshane, which will improve transfer capability between ESKOM and ZESA by 450 MW at a cost of US$ 2,744,000.
- Upgrading the current-voltage transformers and line traps at Luano, which will improve transfer capability between the DRC and Zambia by 60 MW as a cost of US$105,000.

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Section 3 Potential Zambian Power Projects Under Consideration

3.1 *Summary*

The key project costs affecting project economics are summarized in Table 3-1.

Table 3-1. Key Cost Parameters For Projects

Project	Size (MW)[2]	Cost (millions US$)[1] Investment	Interest During Construction[3]	Operations & Maintenance	Construction time (years)
Kafue Gorge Lower	600	594.3	145.6	3.4	7
Itezhi-tezhi[4]	120	95.1	16.6	1.2	5
Transmission for Itezhi-tezhi	NA	35.0	2.4	0.3	2
Zambia/Tanzania Interconnection	200	191.5	20.0	4.2	3

1. Based on References 2 and 3 adjusted to year 2000. An allowance of 25% of total investment costs was made for IPP development costs for the hydro projects and 20% for the transmission projects.
2. Installed capacity for hydro projects and transfer capability for interconnection.
3. At 7% real interest rate
4. Investment value does not include investment required for transmission.

Generation of the hydroelectric projects was estimated using operation modeling of the Kafue and Zambezi River systems, discussed in Section 2.2.4. Line usage of the interconnection was based on multi-area modeling of the Southern Africa power market taking into consideration transmission constraints between sub-markets, discussed further in Section 3. Descriptions of the proposed projects follow.

3.2 *Hydroelectric Projects*

The operation of the proposed hydro projects is closely related to that of existing dam and power facilities on the Kafue River. These are described below followed by descriptions of the proposed hydroelectric projects.

3.2.1 Existing Facilities on the Kafue River

The Kafue river is now controlled with two dams and reservoirs. The Itezhi-tezhi (Itezhi-tezhi) dam and reservoir provides the main storage of about 5.6 billion cubic meters (live storage about five billion cubic meters), but with no associated power plant. It is about 230 km upstream from the Kafue Gorge Upper dam. The dam and reservoir at Kafue Gorge Upper provide additional storage of about one billion cubic meters. The Itezhi-tezhi reservoir can store about 65% of the average inflow above its dam, while the Kafue

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Gorge Upper reservoir can store about 10% of the average inflow above the Kafue Gorge Upper dam.[1]

The yearly average inflows show considerable variation, as illustrated in Figure 3-1. The minimum yearly average inflow at the Itezhi-tezhi reservoir was 65 cubic meters per second (m^3/sec) in 1921/2; the maximum was 826 m^3/sec in 1977/8.

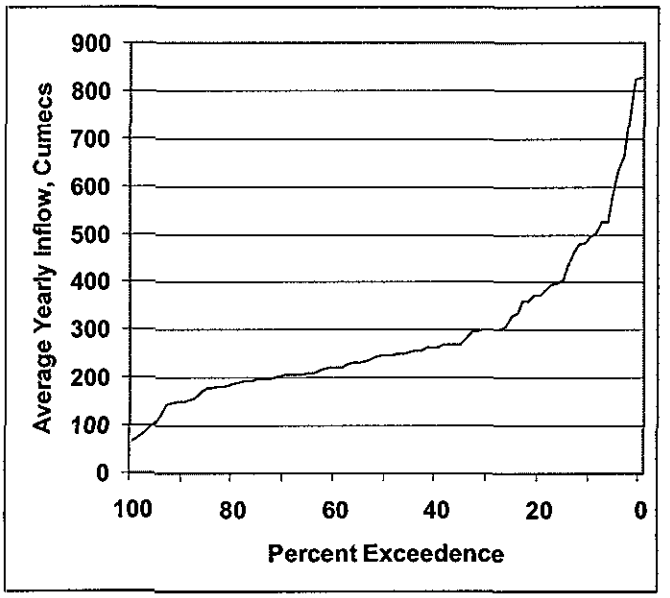

Figure 3-1. Distribution Of Average Yearly Flows Into Itezhi-tezhi

3.2.2 Kafue Gorge Lower

The Kafue Gorge Lower (Kafue Gorge Lower) project is located in the Kafue Gorge, about 65 km upstream from the confluence of the Kafue and Zambezi rivers and 2 km downstream from the discharge of the tailwater tunnel of the existing 900 MW Kafue Gorge power plant, which we will refer to as the Kafue Gorge Upper (Kafue Gorge Upper) plant. Kafue Gorge Lower will develop the remaining 200 meters of the 600 meter head in the Kafue Gorge. Kafue Gorge Upper uses the other 400 meters. The project has been studied several times, most recently in the Feasibility Study Of The Kafue Gorge Lower Hydroelectric Project, prepared by Harza Engineering Company and Rankin Engineering and completed in May 1995 (Reference 2).

[1] The average inflow at the Itezhi-tezhi reservoir site was approximately 280 cubic meters per second (m^3/sec), equivalent to an total yearly inflow of 8.8 billion cubic meters. Average inflow is about 55 m^3/sec between the Itezhi-tezhi and Kafue Gorge Upper dams. However, the inflows below Itezhi-tezhi are roughly balanced by evaporation and transpiration in the reservoirs at Itezhi-tezhi and Kafue Gorge Upper, and the waterways in between. Thus the estimated average yearly inflow to the reservoir at Kafue Gorge Lower is about the same as the inflow to Itezhi-tezhi.

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The proposed dam for the Kafue Gorge Lower project will rise 52 meters above the existing stream bed (elevation 534 meters) to a top elevation of 586 meters, with a structural height of 62 meters above its sound rock bed. The dam type may be either concrete faced rock fill dam (CFRD) or roller compacted concrete (RCC). Reservoir capacity at maximum elevation of 582 meters will be about 5.5 million cubic meters. Live storage of 2.2 million cubic meters above elevation 574 meters is only about 0.05% of the live storage capacity of the Itezhi-tezhi reservoir.

An underground cavern will house the power generation facilities. There will be four 150 MW Francis turbines, each with a design head of about 186 meters (all units operating), a design discharge of 88.3 m^3/sec, and a synchronous speed of 250 rpm. The units will discharge into a tailrace tunnel which will carry the water about 7.8 km, ultimately discharging back into the Kafue river in the Kafue Gorge with a minimum tailwater elevation of 384 meters.

Each unit will be equipped with a generator rated for maximum continuous output of 165 MVA at rated voltage of 13.8 kV. A separate 330/13.8 kV transformer will serve each generator. Gas-insulated switchgear will be located next to the transformers in the underground transformer hall. High voltage cables will connect the transformer hall to line terminations at the surface. Two 330 kV transmission lines will connect the surface terminations at Kafue Gorge Lower to the switchyard at Kafue Gorge Upper, a distance of about 3.5 km.

At design conditions, the Kafue Gorge Lower plant will generate 600 MW while passing 353 m^3/sec of water. At 353 m^3/sec the reservoir has enough live storage for about 1.7 hours of full power operation.

At design conditions, the Kafue Gorge Upper plant will generate 900 MW while passing 270 m^3/sec of water. Therefore Kafue Gorge Lower cannot operate at 600 MW continuously unless substantial water is bypassing the Kafue Gorge Upper turbines (spilling), which would normally only occur infrequently when the reservoir was in danger of overflowing during a wet hydrologic year. If Kafue Gorge Upper were operating at full output and Kafue Gorge Lower started operating when the Kafue Gorge Lower reservoir was full, Kafue Gorge Lower could operate at full output for about 7.3 hours.

The operation of Kafue Gorge Lower is entirely dependent on the operation of Kafue Gorge Upper for its water and must follow its operation with only a few hours delay. Kafue Gorge Upper's available head is about twice that of Kafue Gorge Lower, and normally Kafue Gorge Lower would have nearly the same amount of water as Kafue Gorge Upper. Over any period longer than a few hours Kafue Gorge Lower should generate about half as much energy as Kafue Gorge Upper. It could deliver it at a different rate, for example in more of a peaking mode.

3.2.3 Itezhi-tezhi

The existing dam at Itezhi-tezhi was completed in 1978 to regulate the flow of the Kafue river, in conjunction with the overall development of the power generation facilities at Kafue Gorge. Construction of a power plant there has long been contemplated. In April

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1999 Harza Engineering Company and Rankin Engineering Consultants completed a Feasibility Study of the Itezhi-tezhi Hydroelectric Project (Reference 3)

The existing conventional earth fill dam has a maximum height of about 51 meters with its top at elevation 1035. The maximum and minimum operating levels of the reservoir are 1030.5 and 1006. If operated according to optimized rule curves, the vast majority of the operation will be between elevations of 1024 and 1030.5 meters. Recently soil borings were made along the crest of the dam to a depth of 7.5 meters to explore the condition of the dam's core. The material was found to be a well-compacted sandy/silt/clay and showed no signs of desiccation, indicating that the core is in good condition.

An underground cavern will house the power generation facilities. There will be two Kaplan turbines, each with a design net head of about 40 meters, a design discharge of 156 m^3/sec, and a synchronous speed of 176 rpm. The units will each be rated at 56.3 MW, with a maximum capability of 60 MW. Turbine centerline will be elevation 976 meters, about 10 meters below tailwater elevation. The units will discharge into a tailrace tunnel that will be connected to one of the existing diversion tunnels, which discharges immediately down river from the dam. .

Each unit will be equipped with a generator rated for maximum continuous output of 67 MVA at a power factor of 0.9 and rated voltage of 13.8 kV. A separate 220/13.8 kV transformer will serve each generator. 220kV cable will connect the transformers to air-insulated switchgear in a surface switchyard .

The proposed transmission connection will be a single circuit 220 kV line from the switchyard to Mazuma substation. a distance of about 220 km. The line cost was estimated to be about $29 million and involve losses of 3.5 MW (2.9%) on peak and 15.1 GWh (2.3%) of energy per year, based on annual average energy production.

3.2.4 Hydro Operation Studies

The hydro operations studies were conducted to show the interaction of the new hydro projects with other hydro plants on the Kafue and Zambezi Rivers. This modeling is based on maximizing total generation from all hydro stations. There is currently no agreements that require such operation; however, for various reasons the current operators of these stations (ZESCO, ZESA and Hidroelectrica Cahora Bassa) appear to act cooperatively. The operation of new projects by private parties will make the formalization of joint operating agreements of critical importance.

Table 3-2 summarizes the results of these studies. The following observations can be made:

- The Kafue Gorge Lower project alone could generate 3,780 GWh on the average. In addition, improved water management would result in an increase in average generation at Kafue Gorge Upper and in Zambezi River hydro stations, primarily at Kariba North and South for a total increase in generation of almost 6,300 GWh annually.

- Itezhi-tezhi alone would generate 520 GWh per year on the average, but would result in a nearly 2,000 GWh annual increase in generation at Kafue Gorge Upper.
- With both plants operating, Kafue Gorge Lower would generate less than without Itezhi-tezhi and the beneficial effect of their operation on the generation at other plant is somewhat less than that of Kafue Gorge Lower alone.

Table 3-2 Summary of Hydro Operations Analysis

Hydro additions	Kafue Gorge Lower average generation (GWh)	Itezhi-tezhi average generation (GWh)	Net change in generation at Kafue Gorge Upper (GWh)	Net change in generation on hydro plants on Zambezi (GWh)	Total net increase in generation (GWh)
Kafue Gorge Lower alone	3780	0	1375	1137	6292
Itezhi-tezhi alone	0	520	1975	66	2561
Both projects	3303	519	1989	69	5880

We have reservations about these results and feel that they should only be considered preliminary.[1] However, the results do illustrate the common sense concept that adding constraints, such as a new plant with its own operating requirements, could affect other plants on the same river system.

3.3 *Interconnection With Tanzania*

A team consisting of representative from ZESCO, ESKOM, and TANESCO completed an inter-utility technical feasibility study for a transmission interconnection between Zambia and Tanzania in 1995 (Reference 5). The result was a proposal for a 330 kV transmission line interconnection from Pensulo Substation in Zambia to Mwakibete Substation in Tanzania. The premise was that surplus power in Zambia would be a cheaper source for Tanzania's growing demand than building its own new resources, even considering the cost of the line. In addition the routing of the 330 kV line through Zambia's Kasama Substation would strengthen the electrical system in its Northern and Luapula provinces.

The governments of the Republic of Zambia and the United Republic of Tanzania signed an Inter-Governmental Memorandum of Understanding (MOU) in June 1997. The objective of the MOU is to establish a framework under which the signatories pronounce their clear intention to enhance regional power cooperation through the establishment of a transmission line interconnection that will facilitate electricity trading. The intention was for each government to authorize its national utility to enter into the necessary agreements for the establishment and operation of the interconnection, subject to approval by the governments.

[1] For example, it is difficult to imagine a mechanism through which adding a relatively small power plant at the existing Itezhi-tezhi dam and reservoir could increase generation at Kafue Gorge Upper by almost 2,000 GWh/year, far more than the generation at Itezhi-tezhi. It would seem that whatever pattern of releases produced the additional generation would be possible without the new power plant. This issue requires more investigation.

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ZESCO and TANESCO signed an Inter-utility MOU in July 1997.Its objective is to establish the basic principles under which the interconnection will be constructed and operated and the objectives that it aims to achieve, including:

- To coordinate and cooperate in the planning, construction, and operation of the line to minimize costs.
- To allow private sector investment in the project.
- That the two utilities shall endeavor to take a participating share of say 20% in the firms that build the lines in their respective countries.
- To provide assistance to the contractors regarding the execution of the work.
- To guarantee power trading between the two utilities for a period of 15 - 20 years at a good price.

ZESCO and TANESCO has already (in April 1997) signed a Co-operation Agreement providing for mutual supply of technical information, services, and joint planning.

The 1995 feasibility study recommended a project with the following parameters:

- 330 kV AC
- From Pensulo through Kasama Substation in Zambia to Mwakibete
- Line length 697 km
- Transfer capability 200 MW

A team from the same utilities, but with legal and financial experts in addition to the 1995 study's technical experts, completed a Financial Justification Investigation in April 1998 (Reference 6).

3.4 *References*

1. Kafue Gorge Lower Independent Power Project. Burns and McDonnell, The Dahlgreen Group, McKenna and Company Report 96-417-4
2. Kafue Gorge Lower Hydroelectric Project Feasibility Report. Harza Engineering and Rankin Engineering; May, 1995
3. Feasibility Study of the Itezhi-tezhi Hydroelectric Project. Harza Engineering and Rankin Engineering; April, 1999
4. Itezhi-tezhi/Kafue Gorge Operating Procedure Draft Final Report. SADC AAA.3.4, Hydroelectric Hydrological Assistance Project - Phase 2, Shawinigan Engineering, January 1993
5. Zambia – Tanzania 330 kV Transmission Interconnection Study. ESKOM, ZESCO, and TANESCO; September, 1995
6. Zambia – Tanzania 330 kV Transmission Interconnection Financial Justification Investigation. ESKOM, ZESCO, and TANESCO; April 1998

4.1 *Summary*

The generation from hydro projects can displace thermal generation in the system and the projects potentially allow the deferral of investment in new generating capacity elsewhere. Likewise, transmission interconnections provide opportunities to displace higher cost with lower cost generation. With adequate reliability, interconnections can also result in the deferral of new generation investment. Generation displacement and investment deferral are referred to as generation and investment benefits and the size of these benefits in indicative of the value of a given project in a given market. Both Kafue Gorge Lower and Itezhi-tezhi projects have added value in that their operation increases the net output of Kafue Gorge Upper and Kariba projects.[1]

The value of the Kafue Gorge Lower hydroelectric, Itezhi-tezhi hydroelectric and Zambia/Tanzania interconnection were calculated for the southern African power market. Detailed investment plans and generation dispatch for Zambia, Zimbabwe, Mozambique, Tanzania, South Africa, Botswana and Namibia were considered with and without these projects. The ELFIN power generation market simulation package[2] was used estimate the impact on generation displacement and investment deferral over a range of conditions in this market.

4.1.1 Kafue Gorge Lower Alone

Table 4-1 shows the results of the analysis for the Kafue Gorge Lower hydroelectric project. The Base Case value of the project was estimated to be 49 US$ per MWh based on commercial operation in 2007 (expressed in 2000 US currency). The direct commercial benefits are 38 $/MWh.

Approximately 25 percent of the benefits of the project (i.e., 11 US$ per MWh) are due to a net increase in generation at Kafue Gorge Upper and at Kariba. While these are legitimate benefits of the project, a developer of Kafue Gorge Lower would not realize these benefits for through direct sales. Some form of production sharing agreement would be required for the developer to realize any benefit from increases in generation at Kafue Gorge Upper and at Kariba and it is likely the revenue from any increases in generation would be shared rather than accruing only to the owners of Kafue Gorge Lower.

A number of factors were considered which affect this calculated value including the following: regional demand growth; the entry date of the project; some of the key characteristics of the generation deferred by the project, namely the cost of South African coal and the investment cost for new South African coal-fired generating plants; and the

[1] The results of hydro operations modeling of the interaction of hydro projects are discussed in Section 3. In summary: 1) the operation of Kafue Gorge Lower alone would increase the net output of Kafue Gorge Upper and Kariba by 2,512 GWh; 2) the operation of Itezhi-tezhi alone would increase their net output by 2,041 GWh; and their operation together would increase their net output by 2,058 GWh.

[2] The ELFIN package is licensed from the Environmental Defense Fund.

development of other projects which can compete with Kafue Gorge Lower. Synergistic impacts of joint development of Kafue Gorge Lower with Itezhi-tezhi hydroelectric project or the Zambia/Tanzania interconnection were also considered.

Lower than expected load growth or the development of other projects in the region have a negative impact on the value of Kafue Gorge Lower. The most significant of these factors is low load growth, which we estimate could reduce the direct benefits to 16 $/MWh from the Base Case value of 38 $/MWh. Growth in the Base Case is primarily met new coal-fired capacity in the eastern part of South Africa supplemented with combustion turbines for peaking. The development of other regional projects in the same time that compete with Kafue Gorge Lower for limited transmission capacity in the southern African power market, or projects that defer the need to add coal-fired capacity in South Africa, tend to reduce the value of the project. Either the development of Mpanda Uncua or the re-commissioning of approximately 3,000 MW of "mothballed" coal-fired capacity in South Africa would reduce the value of a Kafue Gorge Lower by over 20 percent, assuming commercial operation in 2007.

High load growth, or delaying the entry of Kafue Gorge Lower into the market would result in a slight increase in project value under Base Case assumptions. The impact of these factors would be greater with the development of other competing projects.

The development of the transmission system can also affect the value of the project. An increase in the transfer capability between Zambia and the DRC prior to 2007 would have the effect of increasing the amount of power from the Inga hydroelectric project that could be used in the southern African power market and significantly reducing the value of the project. On the other hand the completion of a 200 MW interconnection between Zambia and Tanzania does not have a significant impact on the economic value of the hydro projects.[1]

[1] While the Tanzanian Interconnection was found to have a minimal impact on the economics of the hydro projects from a regional point of view, there would be a positive commercial interaction between the hydro and the interconnection projects. The interconnection would present the potential for higher value off-take contracts for hydro exports and the hydro production in Zambia would have some potential security of supply advantages over generation in South Africa for supplying Tanzania.

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Table 4-1. Summary Results for the Kafue Gorge Lower Project

	Value of Kafue Gorge Lower Project							Compared with Base Case	
	Present Worth of Benefits[1]			Levelized US$/MWh of Project Generation				Per Unit Present Worth of Total Benefits	Per Unit of Project Generation[2]
	Total in 2000	*Per Unit in Year of Installation ($/kW)*		*Indirect Benefits*	*Direct Benefits*				
Sensitivity Case	*(millions US$)*	*Total Benefits*	*Direct Com-mercial*	due to increased hydro generation[3]	due to displaced generation	due to deferred investment	*Total*	%	*($/MWh)*
Base Case	1553	4156	3223	11.1	16.7	21.6	49.4	-	-
Regional Demand Growth									
Low	742	1986	1369	7.3	11.0	5.2	23.6	47.8%	-25.9
Entry Date									
2010	1334	4375	3456	10.9	16.5	24.6	52.0	105.3%	2.6
2015	959	4410	3515	10.6	16.0	25.8	52.5	106.1%	3.0
Cost of New Coal-fired Plants									
Low	1451	3884	2950	11.1	16.7	18.4	46.2	93.4%	-3.2
High	1655	4429	3496	11.1	16.7	24.9	52.7	106.6%	3.2
Cost of South African Coal									
Low	1488	3982	3119	10.3	15.4	21.6	47.3	95.8%	2.1
High	1618	4331	3328	11.9	17.9	21.6	51.5	104.2%	-2.1
Development of Other Competing Projects									
Demothballing of Eskom Plants	1207	3231	2487	8.8	13.3	16.3	38.4	77.7%	-11.0
Mpanda Uncua	1172	3136	2447	8.2	12.3	16.8	37.3	75.4%	-12.1
Hwange Extension & Gokwe North	1424	3812	2952	10.2	15.4	19.7	45.3	91.7%	-4.1
SA Pumped Storage	1508	4036	3070	11.5	17.3	19.2	48.0	97.1%	-1.4
Western 750 MW Project	1306	3495	2547	11.3	17.0	13.3	41.6	84.1%	-7.9
Development of Transmission Projects									
Increased DRC/Zambia Transmission Capacity	1243	3326	2485	10.0	15.0	14.5	39.5	80.0%	-9.9
Interconnection with Tanzania	1601	4286	3301	11.7	17.6	21.6	50.9	103.1%	1.4

1. Present worth of operating and investment cost savings at 7% discount rate.
2. Positive values indicate benefits greater than the Base Case. Negative values indicate benefits that are lower than those of the Base Case.
3. Benefits due to net increase in generation at Kafue Gorge Upper and Kariba.

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4.1.2 Itezhi-tezhi Alone

Table 4-2 shows the results for the analysis of the Itezhi-tezhi project for 2007 commercial operation. This project's direct benefits are close to those of Kafue Gorge Lower in terms of present worth of benefits per kW of installed capacity and substantially higher per unit of generation. The higher per unit value of total benefits in comparison with Kafue Gorge Lower is based on the following three factors: 1) the net increase in generation at Kafue Gorge Upper and Kariba associated with the project is several times project output compared with 66 percent for Kafue Gorge Lower; 2) with lower annual generation than Kafue Gorge Lower, a greater proportion of the generation it displaces in the southern African power market is high value oil-fired generation from combustion; and 3) it was assumed that it could defer the same amount of investment, proportional to its firm capacity, as Kafue Gorge Lower, giving it higher investment benefits per unit of generation.

Approximately 70 percent of the project total benefits are due to increases in net generation at Kafue Gorge Upper and at Kariba, which should be considered preliminary. As with Kafue Gorge Lower, the developer of Itezhi-tezhi will not realize these benefits without some sort of agreement with the owners of the other projects.

Table 4-2 Summary Results for the Itezhi-tezhi Project

	Value of Itezhi-tezhi Project							Compared with Base Case	
	Present Worth of Benefits[1]			Levelized US$/MWh of Project Generation				Per Unit Present Worth of Total Benefits	Per Unit of Project Generation[2]
	Total in 2000	*Per Unit in Year of Installation ($/kW)*		*Indirect Benefits*	*Direct Benefits*				
Sensitivity Case	*(millions US$)*	*Total Benefits*	*Direct Com-mercial*	due to increased hydro generation[3]	due to displaced generation	due to deferred investment	*Total*	*%*	*($/MWh)*
Base Case	770	10299	2981	126.7	32.3	19.3	178.3	-	-
Regional Demand Growth									
Low	242	3239	778	37.8	9.6	2.3	49.8	31.4%	-128.5
Entry Date									
2010	646	10587	3164	128.5	32.7	22.0	183.3	102.8%	5.0
2015	532	12243	3547	165.1	42.1	25.3	232.5	118.9%	54.2
Cost of New Coal-fired Plants									
Low	757	10132	2814	126.7	32.3	16.4	175.4	98.4%	-2.9
High	782	10467	3149	126.7	32.3	22.2	181.2	101.6%	2.9
Cost of South African Coal									
Low	745	9970	2915	122.1	31.1	19.3	172.6	96.8%	5.7
High	794	10629	3048	131.2	33.4	19.3	184.0	103.2%	-5.7

1. Present worth of operating and investment cost savings at 7% discount rate.
2. Positive values indicate benefits greater than the Base Case. Negative values indicate benefits that are lower than those of the Base Case.
3. Benefits due to net increase in generation at Kafue Gorge Upper and Kariba.

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4.1.3 Joint Development

Table 4-3 shows the economic results for the each project alone, for the two projects together and the incremental value of second project if the other is installed first.

The incremental benefits of either of the projects if the other is built first is significantly less than the benefits of that project on its own. This effect is partially to do with the market as the incremental value of supply declines. However, the major cause is the projected interaction of the projects based on the hydro operations modeling. By itself, Kafue Gorge Lower is projected to increase non-project generation by 2,512 GWh; this is projected to decrease to 2,059 if both projects are developed. This causes Itezhi-tezhi to have a negative incremental value if Kafue Gorge Lower is already in place.

As a consequence, if these impacts are confirmed any procedures developed for sharing of the costs and benefits of changes in system generation may need to recognize their "first-come first-served" nature. In the example, if the developer of Itezhi-tezhi were to negotiate an agreement to realize the benefits associated with the net increase in generation at Kafue Gorge and Kariba, the developer of Kafue Gorge Lower could be liable for the penalty associated with the incremental development of that project.

Table 4-3 Value of Developing Both Projects

Project	Present Worth of Benefits[1]			Levelized US$/MWh of Project Generation			
	Total in 2000	*Per Unit in Year of Installation ($/kW)*		*Indirect Benefits*	*Direct Benefits*		
	(millions US$)	*Total Benefits*	*Direct Commercial*	due to increased hydro generation	due to displaced generation	due to deferred investment	*Total*
Itezhi-tezhi alone	770	10299	2981	126.7	32.3	19.3	178.3
Kafue Gorge Lower alone	1553	4156	3223	11.1	16.7	21.6	49.4
Development of Itezhi-tezhi then Kafue Gorge Lower[2]	1459	3841	3014	11.8	16.1	26.8	54.6
Development Kafue Gorge Lower then Itezhi-tezhi[3]	1547	4360	3550	9.1	15.8	23.9	48.7
Incremental value of Kafue Gorge Lower if Itezhi-tezhi built first	689	2259	2949	-9.4	11.9	28.2	30.8
Incremental value of Itezhi-tezhi if Kafue Gorge Lower built first	-6	-100	1330	-262.8	10.6	233.9	-18.3

1. Present worth of operating and investment cost savings at 7% discount rate.
2. Itezhi-tezhi in 2007 and Kafue Gorge Lower in 2010.
3. Kafue Gorge Lower in 2007 and Itezhi-tezhi in 2010.

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4.1.4 Interconnection with Tanzania

Table 4-4 shows the results of the analysis of the Zambian/Tanzanian interconnection. The potential benefits of an interconnection include increased system reliability, exploitation of system diversity, the potential for seasonal exchanges, achieving greater fuel diversity and greater economies of scale in sizing new generation projects. In the analysis we conducted, we compared a 200 MW interconnection installed in 2003 to continued operation with Tanzania isolated at the high voltage level.

The relative cost of generation in Tanzania and the interconnection southern African region results in the interconnection being used primarily to displace high cost generation in Tanzania. It is likely that an interconnection could result in the deferral of capital investment in new generation in Tanzania; however, our analysis did not take credit for this. In our Base Case analysis we have assumed that the development of Songo Songo gas would support generation at the Mbungo, Dar-es-Salaam and Mtwara plants and that a significant number of liquid-fueled combustion turbines in addition to the Kihansi, Rumakali and Mpanga hydro projects would be required to meet demand growth. Under such a pattern of growth, the marginal cost of generation in Tanzania would remain higher than in any of the sub-markets considered. Under the Base Case assumptions the value of the interconnection would be over US$ 3000 per kW of transfer capability in the year of installation.

Lower than expected growth in the region, including Tanzania, and/or the development of less expensive supply in Tanzania would reduce the value of the interconnection. We estimate that under low regional growth, its value would be approximately half of the estimate in the Base Case if it began operation in 2003. If gas developments were adequate to support all new combustion turbines at a price of US$ 2.5 per GJ, the volume and value of the Tanzanian imports market would also be reduced. We estimate the value of the interconnection to be slightly over a quarter of its Base Case value it this were to occur.

Under all cases considered, the marginal cost of generation in Tanzania declines after 2003 then increases steadily after 2005. Therefore, delaying the interconnection also tends to increase its value slightly.

In the Base Case transmission analysis of there are no generation additions in Zambia. Imports to Tanzania are achieved primarily through increasing thermal generation in South Africa. South African generation would also be supplying the Zambia system which would be in deficit by the midway through the coming decade.

In the next sections we present the key Base Case assumptions and additional details of the Base Case analysis of the hydro projects and interconnection.

Table 4-4 Summary Results for the Tanzania/Zambia Interconnection

		Value of Zambia-Tanzania Interconnection					Compared with Base Case	
	Projected Average Line Loading	Present Worth[1]		Levelized US$/MWh of Net Energy Transmitted			Per Unit Present Worth of Benefits	Per Unit of Energy Transmitted[2]
Sensitivity Case	(%)	*(millions US$)*	*$/kW*[3]	*Operating Benefits*	*Investment Benefits*	*Total*	*%*	*($/MWh)*
Base Case[4]	69%	537	3289	40.8	0.0	40.8	-	-
Regional Demand Growth								
Low	60%	287	1757	20.2	0.0	20.2	53.4%	-20.7
Entry Date								
2005	62%	509	3569	46.5	0.0	46.5	108.5%	5.6
2010	76%	439	4322	52.9	0.0	52.9	131.4%	12.1
With Zambian Hydro Projects								
Kafue Gorge Lower	68%	513	3142	39.2	0.0	39.2	95.5%	-1.6
Intezhi-tezhi	66%	514	3151	39.2	0.0	39.2	95.8%	-1.7
Both projects[5]	68%	491	3007	37.7	0.0	37.7	91.4%	-3.1
Tanzanian Development Plans								
High Natural Gas Use	60%	146	892	14.4	0.0	14.4	27.1%	-26.5

1. Present worth of operating and investment cost savings at 7% discount rate.
2. Expressed per unit of net Tanzanian imports. Positive values indicate benefits greater than the Base Case. Negative values indicate benefits that are lower than those of the Base Case.
3. Present worth interconnection benefits in year of installation per unit of interconnection transfer capacity.
4. The Base Case for interconnection evaluation is defined as initial operation of the interconnection in 2003 without Kafue Gorge
5. The development of both assumes Itezhi-tezhi in 2007 and Kafue Gorge Lower in 2010.

4.2 *Summary of Base Case Assumptions*

Key Base Case assumptions include:

- Annual regional growth of 2.7% in energy demand in southern Africa. Key sub-market growth rate are 2.2% per year in Zambia, 8% in Tanzania and 4.1% in Zimbabwe.
- The following key transmission constraints:
  - Zambia/Democratic Republic of the Congo - a single circuit 220 KV line with transfer capability of 250 MW; upgrading to 310 MW in 2003 through replacing the current-voltage transformers and traps at the Luano substation in Zambia.
  - Zambia/Zimbabwe - twin circuit 330 KV line at Kariba with transfer capability of 1,000 MW.
  - Zimbabwe/South Africa - predominant power flow is on the 400 KV line from Zimbabwe to South Africa through Botswana. Current transfer capability is 250 MW, limited by transformer capacity of 220/132 kV transformers at Segoditshane substation in Botswana. The Base Case assumptions are that a third 220/132kV transformer will be installed at Segoditshane increasing transfer capability to 700 MW by 2003 and that a second 400 KV Zimbabwe/South Africa line from further increasing capacity to 1300 MW by 2010.
- Most new generating capacity in the region is made up of coal-fired plant equipped with flue-gas desulfurization, supplemented by liquid-fueled peaking combustion turbines. Most new generation aside from the projects under consideration are located in South Africa in the Base Case
- A 2007 entry date for the hydro projects and 2003 for the Tanzanian interconnection .

4.3 *Base Case Results*

4.3.1 Kafue Gorge Lower

4.3.1.1 Generation Displacement

The generation that is displaced by the Kafue Gorge Lower project varies over time. This is illustrated in Figure 4-1[1]. When the project begins operation in 2007 in the Base Case, it allows the deferral of investment in combustion turbine capacity that would otherwise have to be installed in that year. The project would primarily displace coal-based energy from existing plant and some peaking energy from liquid-fuel combustion turbines that

[1] The generation displacement shown in Figure 4-1 is associated with the direct generation of Kafue Gorge Lower. The project results in a net increase in generation from Kafue Gorge Upper and Kariba which would displace additional thermal generation.

otherwise would have been installed, and generation from pumped storage plants in South Africa. About two thirds of the coal-based energy displaced is from the Kendal, Majuba and Tutuka plants.

In 2011, a coal plant that would have otherwise have begun operation is delayed and from then on, the primary energy that is displaced is the output of the coal-fired plant that would have otherwise come on line.

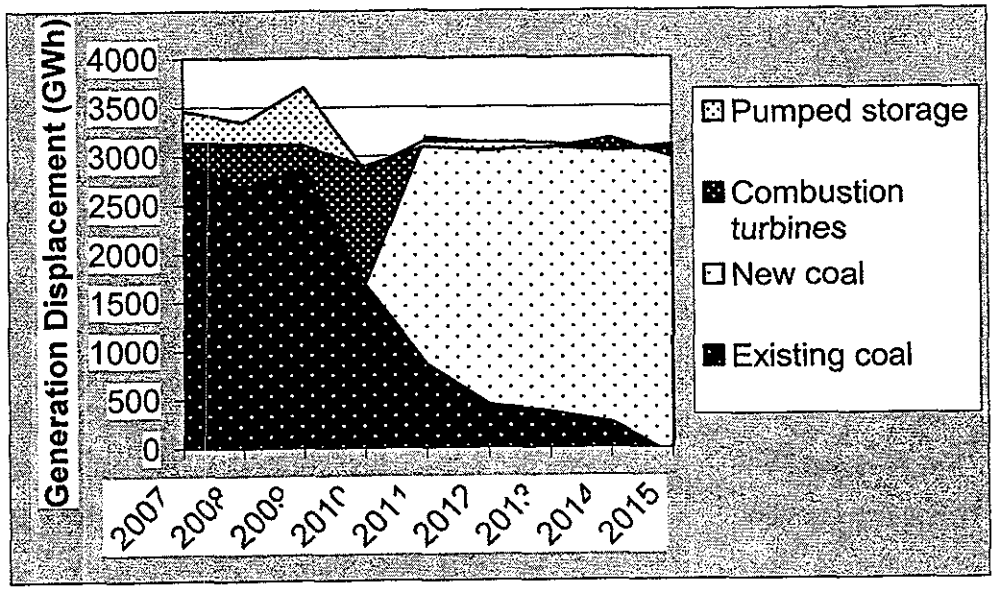

Figure 4-1. Kafue Gorge Lower Generation Displacement by Generation Type

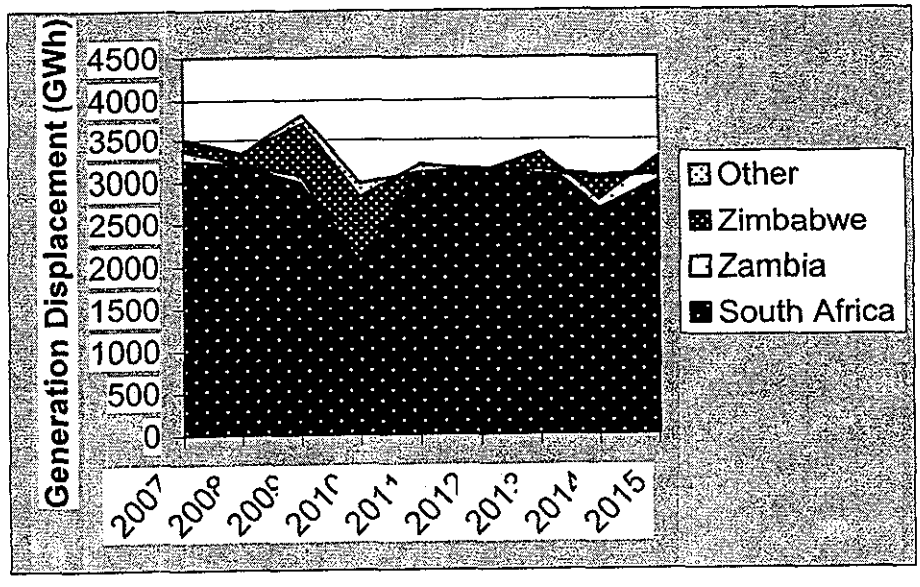

Figure 4-2. Kafue Gorge Lower Generation Displacement by Sub-market

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In the Base Case, the coal-fired plant that is deferred by Kafue Gorge Lower is located in South Africa. Most of the coal-fired generation from existing plants that is displace prior to 2011 is located in South Africa as well. In addition, small amounts of thermal generation are displaced in Zimbabwe and Zambia and elsewhere as shown in Figure 4-2.

4.3.1.2 Components of Value

Figure 4-3 shows the annual value of the deferred investment and displaced generation of the Kafue Gorge Lower project over the study period. (Investment savings are displayed on the basis of their levelized annual values.) The generation displacement that is caused by the project is of two types. First, there is the direct displace caused by generation from the project. Second, the project would result in changes to the generation patterns at Kafue Gorge Upper and Kariba and a net increase in generation from those plants. This increased generation would also displace thermal generation in the power market.

The value of the project varies from year to year because different generation from different plants is displaced and different generation projects are deferred.

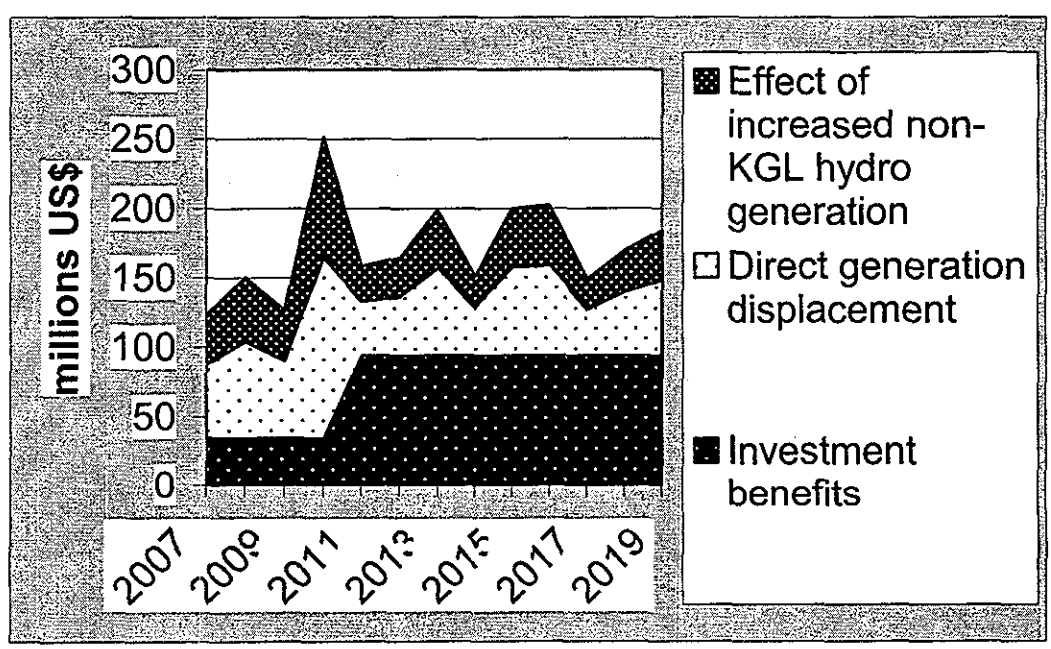

Figure 4-3. Annual Estimate of Value of Kafue Gorge Lower

4.3.1.3 Reduction in Air Emissions and Water Usage

In addition to the avoidance of the cost of generation from other facilities, the generation from Zambian hydro projects will also result in less emissions and water use by those facilities. Most of this reduction is in the populous eastern part of South Africa where pollution is most severe. The current environmental regulatory regime does not easily translate these environmental impacts into monetary savings.

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SOx, NOx, and Particulate Emissions

SOx emissions have been linked to acid rain and various health problems, and NOx emissions have been linked to acid rain, photochemical smog, and tropospheric ozone (greenhouse effect). Particulates, the most visible emission from power plants, have been linked with respiratory problems and damage to property.

South Africa currently has guidelines for maintaining air quality, but no national standards. Flue-gas desulfurization and NOx controls do not exist on, and are not required on, existing coal-fired generation plants, nor on new units being added at Majuba. Particulate emissions are controlled by baghouse technology at ESKOM's large plants.

Greenhouse Gas Emissions

Global warming has become an issue of international concern. The United Nations Framework Convention, adopted at the 1992 Earth Summit in Rio de Janeiro, provides the framework for international cooperation in combating global warming. South Africa signed that agreement in 1993 and participated in the third Framework Convention on Climate Change in Kyoto in December 1997. Under the Kyoto Protocol the original OECD countries, 11 former members of the Soviet bloc, and the European Union committed to reducing greenhouse gas emissions to 1990 levels by 2000. South Africa has not been required to make commitments to greenhouse gas reduction under current agreements because of its classification as a developing country. The rationale for this is that developed countries are responsible for over two thirds of past emissions and some 75% of current emissions. They are best positioned to protect themselves from damage, while developing countries tend to have low per-capita emissions, are in the greatest need of economic development, and are more vulnerable to climate change impacts. However, as in so many areas, South Africa does fit easily into the developed/developing country categories. It is the largest producer of greenhouse gases in Africa and the 18th largest producer in the world and still may come under pressure to reduce greenhouse gas production at some time in the future. Approximately 80% of greenhouse gas production is CO2.

Water Usage

Water is the limiting resource in South Africa. This has led ESKOM to be world leader in the application of dry cooling technology. Reduction of water use is valued at the cost of desalinated water in ESKOM's internal studies.

Impact of Project on Base Case Plan

SOx, and NOx, reductions are shown in Figure 4-4. Water and CO2 reductions are illustrated in Figure 4-5. In 2007, the majority of generation displaced is from existing coal-fired plant which does not have flue-gas desulfurization (FGD). Emission reduction per unit of project generation is at its highest at this point. By the end of the study, the generation displaced is primarily from a new coal-fired plant with FGD and with low-NOx emission burners. The emission reductions in SOx and NOx decrease accordingly. Likewise, the amount of water usage reduction declines as the generation displacement

goes from existing plants, many of which have wet cooling systems, to a new coal-fired plant with dry cooling.

The amount of generation that is displaced from simple cycle combustion turbines affects the reduction in particulate emissions and of CO2. In the years in which significant combustion turbine generation is displaced prior to 2010, the level of particulate and CO2 emission reduction declines.

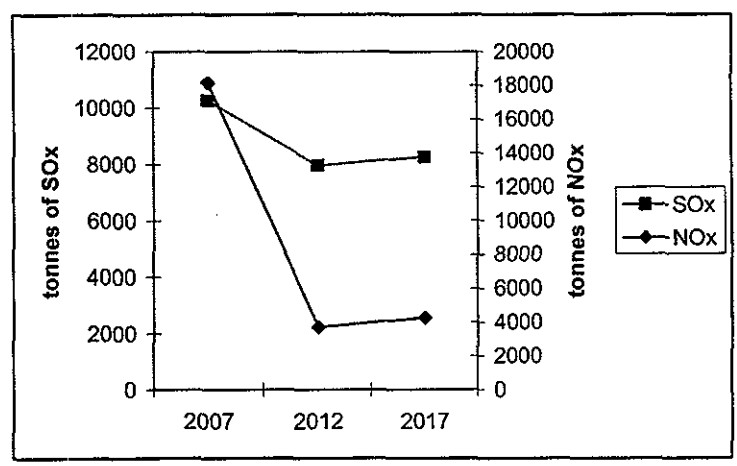

Figure 4-4. SOx and NOx Emission Reduction with Kafue Gorge Lower Generation[1]

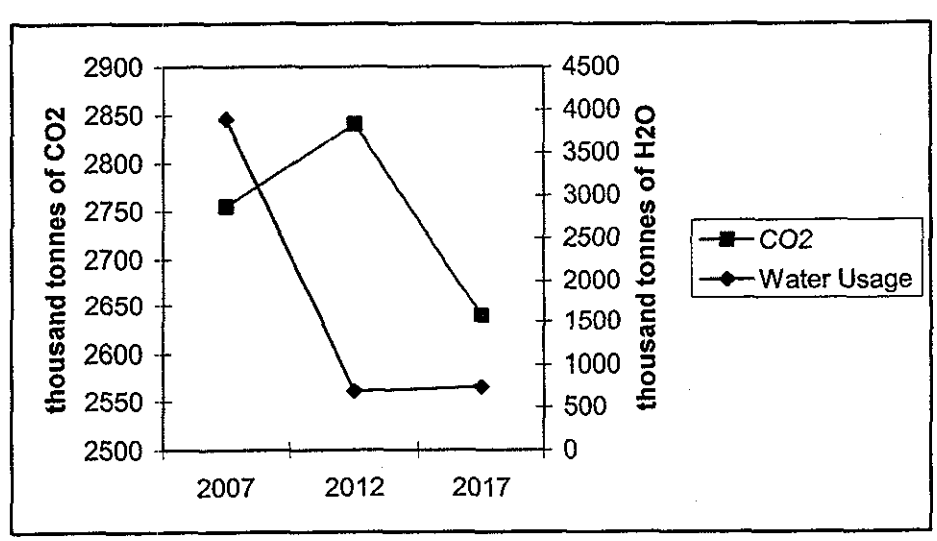

Figure 4-5. CO2 Emission and Water Usage Reduction with Kafue Gorge Lower Generation[2]

[1] Estimated emission reductions are based on those directly related to the generation at Kafue Gorge Lower. Net increases in the generation at Kafue Gorge Upper and Kariba would also result in emission reductions.
[2] Same as above

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4.3.2 Itezhi-tezhi

If the Itezhi-tezhi plant is installed in 2007, the same types of investment deferment and generation displacement would occur elsewhere in the southern African power market. Estimated generation displacement for Itezhi-tezhi is shown in Figure 4-6. Different patterns of generation at Itezhi-tezhi can be expected to result in somewhat different patterns of generation displacement as compared to Kafue Gorge Lower with a higher percentage of peaking generation.

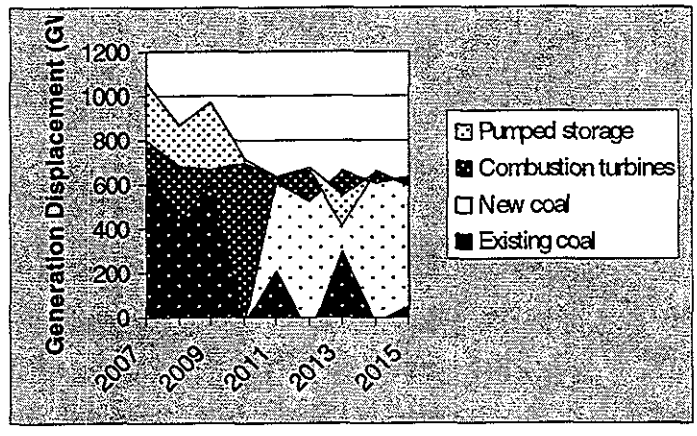

Figure 4-6. Itezhi-tezhi Generation Displacement by Generation Type[1]

In addition, as a percentage of its own output, Itezhi-tezhi has a much larger impact on the generation at other projects. Therefore, as a percentage of its total value, a very high percentage is due to increases in generation at other plants. Figure 4-7 illustrates this.

4.3.3 Zambia/Tanzania Interconnection

We have analyzed the impact of a 200 MW transmission interconnection between Zambia and Tanzania on the generation patterns in the southern African power market. Tanzania is currently experiencing power shortages and its marginal cost of generation is significantly higher than the countries that are interconnected in the Southern African Power Pool. Figure 4-8 shows our estimate of the annual marginal costs of generation in Tanzania and other sub-markets in the Base Case. The higher cost of generation in Tanzania is primarily based on its use of liquid fuels in diesels and combustion turbines. Greater use of natural gas will reduce its marginal cost, but it will still remain higher than in other sub-markets.

[1] Estimated generation displacement is based on those directly related to the generation at Itezhi-tezhi. Net increases in the generation at Kafue Gorge Upper and Kariba would also result in displacement of thermal generation in the southern African power market.

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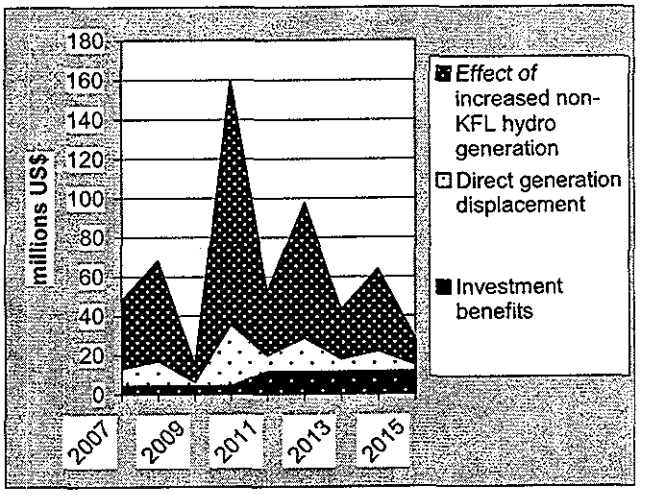

Figure 4-7. Annual Estimate of Value of Itezhi-tezhi[1]

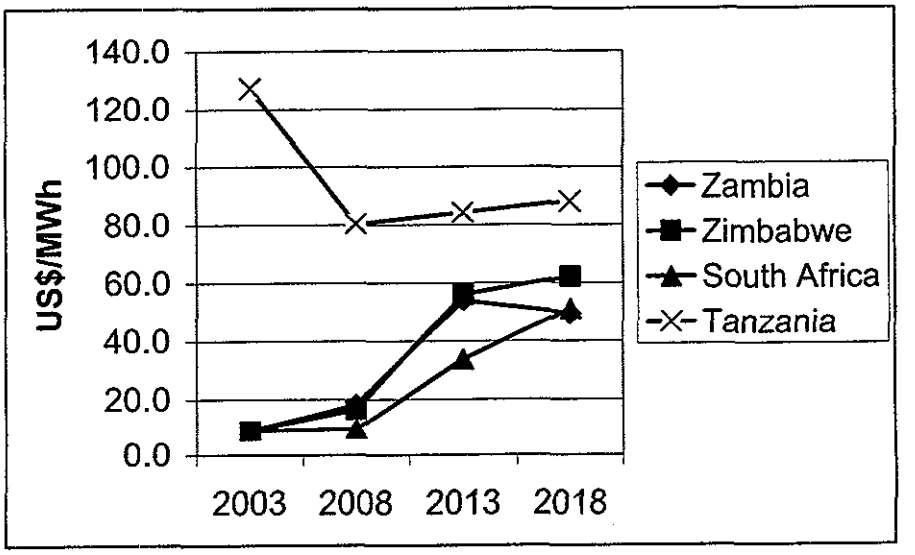

Figure 4-8. Annual Marginal Costs of Generation in Various Sub-markets

A Zambian/Tanzanian interconnection would allow liquid-fuel generation in Tanzania to be displaced by imports. Figure 4-9 shows the projected change in generation patterns that an interconnection would allow in the Base Case if there were no change in generation investments in Tanzania. The increase coal-fired generation would be from plants in South Africa and in Zimbabwe.

[1] The deferment of coal-fired capacity in 2011 results in slightly operating dis-benefits in 2011 and 2012. The impact of the project on the generation at other Zambian hydro projects leverages this dis-benefits into overall negative benefits for the project in these two years.

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Figure 4-10 shows the annual savings associated with the interconnection in the Base Case.

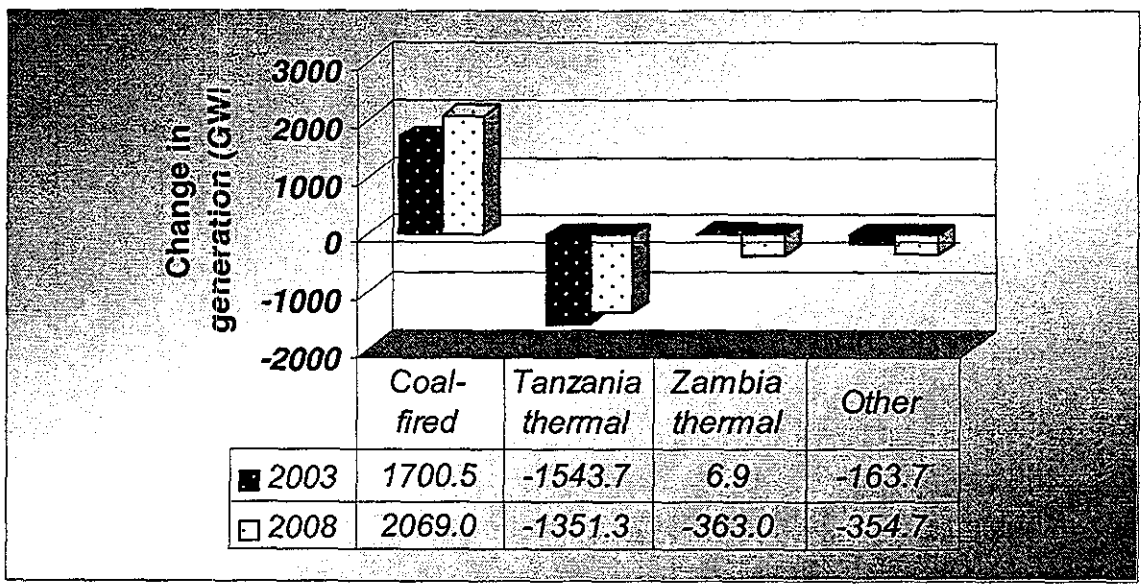

Figure 4-9. Impact of Zambia/Tanzania Interconnection on Generation

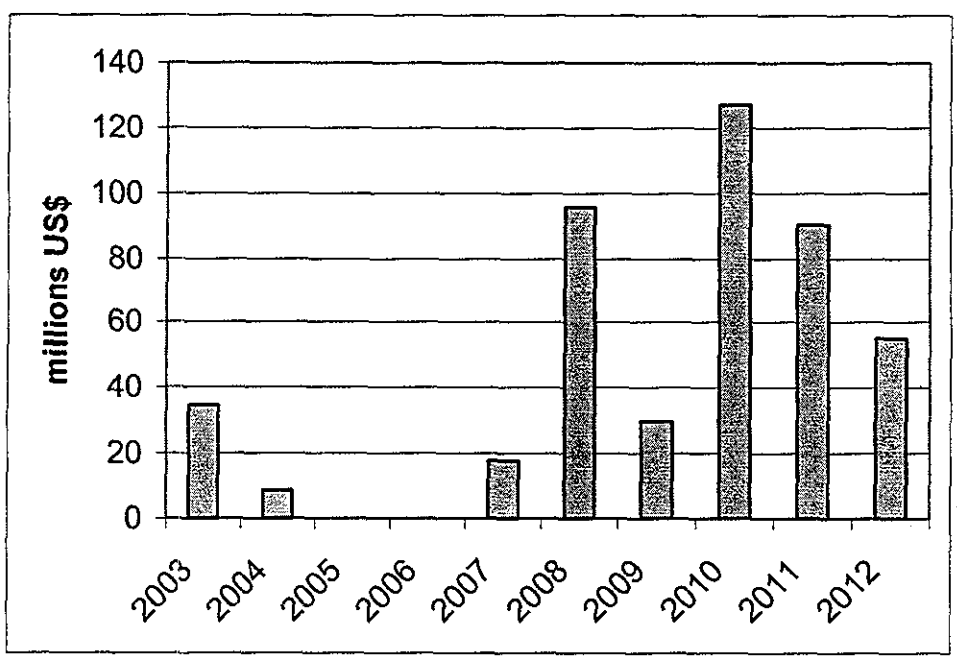

Figure 4-10. Monetary Benefits of Zambia/Tanzania Interconnection in Base Case

The following section addresses the sensitivity analysis that was performed.

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4.4 *Key Sensitivity Factors for Zambian Hydro Projects*

4.4.1 Domestic Demand for Power

We tested the impact on low Zambia demand on the value of the Itezhi-tezhi project. Lower demand results in greater amounts of exports, more instances of transmission constraints limiting exports and less opportunities for the hydro projects to displace thermal generation domestically. Zambian electricity sales growth is projected to increase by 2.1 percent per year over the next decade in the Base Case. A lower load growth of 0.4 percent per year was considered with other growth rates for the various sub-markets remaining constant. This results in an almost 40 percent decline in the value of Itezhi-tezhi.

4.4.2 Regional Demand for Power

Average electricity sales growth in the Base Case is about 2.7% per year over the coming decade. A lower value of about 1.1 percent per year was used to test the impact of a lower regional growth rate on the value of Kafue Gorge Lower and Itezhi-tezhi.

Lower load growth results in the project deferring capacity investment later than is true in the Base Case. The first additions are required in 2015 in the Low Growth demand scenario versus 2007 in the Base Case. The project also displaces lower cost generation because existing plants, with lower operating costs than new units, play a more prominent role during the study period than is true in the Base Case.

The opposite is true for the High Growth scenario. New capacity is required by 2003 and marginal generating costs are much higher than in the Base Case. However, since the earliest that the projects could be in operation is 2007, the higher growth rate does not have a significant impact on their value.

The value of Kafue Gorge Lower, assuming a 2003 commercial operation date, would decline by about 50% in the low growth demand scenario compared with the Base Case. This is equivalent to a 31% decrease for each percentage point decline in electricity sales growth compared to the Base Case.

The value of Itezhi-tezhi declines more dramatically with lower load growth to about 18 percent of its Base Case value.

4.4.3 Entry Date

Commercial operation of the hydro projects in 2007 underlies the Base Case analysis. Each project is able to immediately defer capital investment in combustion turbines at this date. Delay of commercial operation until closer to the time that capital investment in coal fired plant in 2011 results in some increase the value of the projects.

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4.4.4 Cost of New Coal-fired Plants

In the Base Case, the hydro projects defer a new 635 MW coal-fired plant at 1200 US$/kW beginning in 2010, with the value adjusted to reflect differences in firm capacity. This present worth of savings, at 7% discount rate, associated with this deferral accounts for approximately 35 % of the overall value of Kafue Gorge Lower and 11% of the value of Itezhi-tezhi in the Base Case. Overall generation benefits would vary plus or minus 5% for Kafue Gorge Lower and 2% for Itezhi-tezhi with a plus or minus 15% change in capital cost compared with the Base Case.

4.4.5 Cost of New South African Coal

- The Base Case delivered cost of coal supplied to new coal-fired plant is 0.68 US$/GJ. Coal is assumed to supplied 50% from an adjacent mine and 50% from other sources requiring transportation. The cost of the coal from the adjacent mine is based on:
- The cost from mid-cost collieries, such as Khutala, Kriel and New Vaal
- Plus a 10% real cost increase
- Plus another 15% increase to reflect the effect of 100% private mine development.

The cost of coal delivered from other mines was estimated as the same as current mid-cost collieries plus a 10% real cost increase plus 0.28 US$/GJ for transportation.

Overall generation benefits would vary plus or minus 5% for Kafue Gorge Lower and 2% with a plus or minus 15% change in coal cost.

4.4.6 Re-commissioning of ESKOM Mothballed Plant

We investigated the impact of re-commissioning of the Camden, Grootvlei, and Komati plants in South Africa, with a combined capacity of about 3000 MW, on the value of the Kafue Gorge Lower project. We have not selected demothballing of these plants for the Base Case because of commercial and environmental regulation uncertainties. If commercial uncertainties can be overcome and environmental regulations allow the demothballing without retrofitting of flue-gas desulfurization equipment, demothballing of these units should be a competitive option. We have developed alternative generation development plans with and without the Kafue Gorge Lower projects that include the demothballing option.

In the Base Case new capacity is required in the power market in 2007. If Camden, Grootvlei, and Komati are re-commissioned, new capacity is not required until 2011. Therefore, investment-related savings in generation would decline as compared to the Base Case, reflecting the later deferral of the investment in new coal-fired plant. Demothballing would also decrease operating savings. The combined decline in investment and operating cost savings would amount to about 22 percent of the overall generation benefits of the Base Case.

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4.4.7 Development of Mpanda Uncua

The development plan that includes Mpanda Uncua (sized for mid-merit operation was included as part of the sensitivity analysis for Kafue Gorge Lower project. This project compete Mpanda Uncua will compete for the same part of the market as Kafue Gorge Lower and if it is developed at the same time, the value of the project will be reduced by about 25 percent.

4.4.8 Development of Coal-based Projects in Zimbabwe

In the Base Case we assume that transmission transfer capability between Zimbabwe and South Africa is 700 MW. Under this assumption, if the Gokwe North or Hwange extension projects are developed resulting in deferred construction of new coal-based projects in South Africa, the impact on the Kafue Gorge Lower project would be minimal. If current transmission constraints have not been removed, greater generation in Zimbabwe could result in transmission constraints that would limit sales from Zambia.

4.4.9 Development of Pumped Storage

Some of the Base Case estimate of value of the Zambian hydro projects can be attributed to deferred investment in simple cycle combustion turbines and displacement of their generation. If new pumped storage plants can more economically serve the peaking needs of the South African market than simple cycle combustion turbines, the value of the projects would decline.

If a single 3x330 MW pumped storage plant were installed at the median cost of 1000 US$/kW, the present worth of the value of the Kafue Gorge Lower project would decline by less than two percent.

It is possible that additional sensitivity analysis of Base Case assumptions, particularly those which affect the cost of off-peak generation, could affect the amount of pumped storage capacity that could economically be added to the system. However, we would not expect that additional pumped storage installations would have a significant effect on the value of the Kafue Gorge Lower project assuming Base Case growth.

4.4.10 Development of Generation Project in the West

There are currently several proposed projects in western South Africa and Namibia including the 750-1500 MW Kudu project and a 1000 MW plant in Cape Town, based on gas from the Kudu field, the 350 MW Rainbow Millenium project. This region depends upon imports from eastern South Africa and the development of capacity here frees up coal-fired capacity in the east for use elsewhere in the region. We used a generic 750 MW gas-based development in western South Africa/Namibia to measure the impact such a project might have on the value of Kafue Gorge Lower if it was developed around 2005. Our estimation is that such a development would reduce the value of the Kafue Gorge Lower project by 10% to 15%.

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4.4.11 Increasing of DRC-Zambia Transfer Capability

Supply from the Inga project in the DRC to the southern African region is limited by the DRC-Zambia transfer capability. We tested the effect of increasing transfer capability with the corresponding supply from Inga. The transfer capability was increased to 465 MW in 2008 by completing a second 220 kV line between the Karavia substation (DRC) and Luano and installation of 144 MVA of shunt capacitors at Karavia and to 945 MW in by up-rating the terminal equipment at the Kolowezi substation associated with the Inga/Kolowezi DC line from 520 MW to 1120 MW and completing a 330 kV line from Kolwezi to Luano. The effect of the increased supply from the DRC was to decrease the value of the Kafue Gorge Lower project by 20%.

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Appendix A Regional Load Forecasts

A.1 INTRODUCTION

Electricity demand growth scenarios to the year 2030 have been developed for the SAPP countries as a basis for the Power Market Study. These demand scenarios were used directly in project evaluation analysis. Three demand growth scenarios were developed: Base Case, Low Load Growth and High Load Growth. This Appendix documents the data assumptions used in developing these scenarios, and the resulting load forecasts presented by country. Energy requirements were forecasted at the bulk delivery points (high voltage substations). This amount has to be increased by high voltage transmission losses to calculate the net output at the power plants. Sales to final customers could be calculated by reducing forecasted amounts for losses in the distribution networks.

A.2 BASE CASE LOAD FORECASTS

The Base Case results for domestic sales and peak load growth are summarized in Tables A-1 and A-2.

Table A-1
Base Case Load Forecast (GWh)

Country	2000	2005	2010	2015	2020	2025	2030
South Africa	181,279	204,982	231,792	262,117	296,419	335,221	379,115
Zimbabwe	13,338	16,314	19,954	24,407	29,853	36,514	44,662
Zambia	7,074	7,852	8,760	9,895	11,312	13,077	15,273
Tanzania	2,946	4,331	6,368	9,363	13,767	20,242	29,763
Botswana	1,764	1,838	1,914	1,994	2,076	2,163	2,253
Namibia	1,781	2,416	3,278	4,447	6,032	8,182	11,100
North Mozambique	231	288	359	447	557	695	866
South Mozambique	1,426	4,930	5,368	5,913	6,592	7,438	8,492

Table A-2
Base Case Peak Loads (MW)

Country	2000	2005	2010	2015	2020	2025	2030
South Africa	29,826	33,818	38,346	43,481	49,305	55,910	63,401
Zimbabwe	2,123	2,628	3,254	3,980	4,868	5,954	7,283
Zambia	1,162	1,312	1,487	1,706	1,977	2,316	2,735
Tanzania	527	783	1,162	1,709	2,512	3,694	5,431
Botswana	291	361	464	483	503	524	546
Namibia	346	575	1,005	1,363	1,849	2,509	3,403
North Mozambique	32	40	50	63	78	98	122
South Mozambique	203	798	1,005	1,107	1,234	1,393	1,590

A.3 LOW GROWTH SCENARIO

Tables A-3 and A-4 show the Low Load Growth scenario results for energy consumption and peak load growth, respectively.

Table A-3
Low Growth Load Forecast (GWh)

Country	2000	2005	2010	2015	2020	2025	2030
South Africa	184,252	193,348	202,897	212,925	223,454	234,511	246,122
Zimbabwe	13,657	15,451	17,482	19,779	22,378	25,318	28,645
Zambia	7,171	7,340	7,543	7,838	8,234	8,739	9,363
Tanzania	3,011	4,029	5,392	7,216	9,657	12,923	17,294
Botswana	1,893	2,336	2,883	3,559	4,393	5,422	6,693
Namibia	1,822	2,313	2,936	3,726	4,730	6,003	7,620
North Mozambique	229	259	293	332	375	425	481
South Mozambique	1,413	1,599	1,809	2,047	2,315	2,620	2,964

Table A-4
Low Growth Peak Loads (MW)

Country	2000	2005	2010	2015	2020	2025	2030
South Africa	30,301	31,883	33,548	35,301	37,147	39,089	41,135
Zimbabwe	2,090	2,393	2,741	3,101	3,509	3,970	4,492
Zambia	1,143	1,190	1,241	1,309	1,393	1,497	1,622
Tanzania	517	699	945	1,264	1,692	2,264	3,029
Botswana	301	443	674	832	1,027	1,268	1,565
Namibia	341	531	868	1,102	1,399	1,775	2,254
North Mozambique	31	35	40	45	51	58	66
South Mozambique	191	251	329	372	421	476	539

A.4 HIGH GROWTH SCENARIO

The High Growth Scenario results for sales and peak load growth are summarized in Tables A-5 and A-6, respectively.

Table A-5
High Growth Load Forecast (GWh)

Country	2000	2005	2010	2015	2020	2025	2030
South Africa	183,425	223,854	273,332	333,926	408,181	499,243	610,999
Zimbabwe	13,580	18,173	24,319	32,544	43,552	58,282	77,995
Zambia	7,193	8,665	10,460	12,750	15,688	19,476	23,885
Tanzania	3,000	4,831	7,780	12,530	20,180	32,501	52,343
Botswana	1,887	2,746	3,998	5,820	8,473	12,335	17,956
Namibia	1,793	2,515	3,528	4,948	6,940	9,733	13,651
North Mozambique	240	329	451	618	846	1,159	1,589
South Mozambique	1,481	5,183	5,934	6,963	8,372	10,304	12,950

Table A-6
High Growth Peak Loads (MW)

Country	2000	2005	2010	2015	2020	2025	2030
South Africa	31,108	38,112	46,718	57,300	70,321	86,354	106,110
Zimbabwe	2,161	2,927	3,966	5,307	7,102	9,504	12,719
Zambia	1,181	1,445	1,769	2,185	2,723	3,421	4,259
Tanzania	537	873	1,420	2,286	3,682	5,931	9,551
Botswana	311	539	969	1,411	2,054	2,990	4,353
Namibia	348	598	1,082	1,517	2,128	2,984	4,185
North Mozambique	33	46	63	87	119	163	223
South Mozambique	211	779	971	1,163	1,427	1,789	2,284

Appendix B Existing and Potential Power Resources

This appendix presents an overview of the existing generating units in the South African Power Pool countries, and the description of their technical characteristics used in the power system analysis.

B.1 GENERATION SYSTEM IN ZAMBIA

Generation plants in Zambia are owned by ZESCO and ZCCM. Operational characteristics of thermal stations in Zambia are listed in Table B.1, and for hydro stations in Table B.2.

Table B.1
Thermal Power Stations in Zambia

Name of Station	Total Net Maximum Capacity (MW)	Heat Rate at Max. Capacity (kJ/kWh)	Fixed O&M Cost (US $/kW)	Variable O&M Cost (USc/kWh)	Unit Forced Outage Rate (%)	Planned Outages (%)
Combustion Turbines	106	11 700	55	0.2	10	5

Table B.2
Hydro Power Stations in Zambia

Name of Station	Number and Nom. Capacity (MW)	Total Net Maximum Capacity (MW)	Fixed O&M Cost (USc/kWh)	Variable O&M Cost (USc/kWh)	Average Annual Generation (GWh)
Kafue Gorge		900	0	0.1	4860
Kariba North	600	600	0	0.1	3153
Victoria Falls	108	108	0	0.1	640
Other Hydro	62	62	0	0.1	298
Planned Additions					
Kafue Gorge Lower	4 x 150	600	0	0.1	3033
Itezhi-tezhi	2 x 60	120	0	0.1	642

B.2. GENERATION SYSTEM IN SOUTH AFRICA

Generation stations in South Africa are owned by ESKOM, municipal governments, and private investors. ESKOM is the South African national utility, and owns a majority of generating stations. Capacity and generation of power stations in South Africa is by far the largest in the South African Power Pool.

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B.2.1 ESKOM Generation System

Capacity and generation of ESKOM stations ranks it as one of the biggest utilities in the world. Operational characteristics of ESKOM thermal power stations are listed in Table B.3, and for hydro and pumped-storage stations in Table B.4.

Table B.3
ESKOM Thermal Stations

Name of Station	Number and Nomin. Capacity (MW)	Total Net Maximum Capacity (MW)	Heat Rate at Max. Capacity 1) (kJ/kWh)	Variable O&MCost 2) (USc/kWh)	Unit Forced Outage Rate (%)	Planned Outages (%)
Coal						
Arnot	6 x 350	1980	9810	0.48	5	10
Camden	8 x 200	1520	10630	0.48	5	10
Duvha	6 x 600	3450	9940	0.48	5	10
Grootvlei	6 x 200	1130	10630	0.48	5	10
Hendrina	10 x 200	1900	10290	0.48	5	10
Kendal	6 x 686	3840	9990	0.48	5	10
Komati	5 x 100 4 x 125	891	11500	0.48	5	10
Kriel	6 x 500	2850	9780	0.48	5	10
Lethabo	6 x 618	3558	9820	0.48	5	10
Majuba 1-3	3 x 657	1836	10000	0.48	5	10
Matimba	6 x 665	3690	10240	0.48	5	10
Matla	6 x 600	3450	9650	0.48	5	10
Tutuka	6 x 609	3510	9690	0.48	5	10
Nuclear						
Koeberg	2 x 965	1840	11556	0.80	10	20
Gas Turbine						
Acacia	3 x 57	171	12000	0.82	10	5
PortRex	3 x 57	171	9690	0.82	10	5
Planned Additions						
Majuba 4-6	3 x 657	1836	10000	0.48	5	10
Cape Town	3 x 250	750	8500	0.82	5	5
Generic Coal	1 x 665	635	10285	0.48	5	10
Generic Gas	1 x 275	260	9500	0.82	10	5

1) Heat rates for thermal power stations are estimated from available historical numbers for fuel use and generation at each station.

Future committed additions to the system that were considered defined from the planning perspective are additions of 3 more units of the same type at the Majuba plant (for the total of 6 units) to be added by the year 2003.

Long-term unit forced outage rates and planned outages are estimated based on average historical values. Planned outage time is defined as a percentage of time during each year when station is scheduled for regular or planned maintenance or inspections. Unit forced outage rate is defined as a percentage of time unit is not available to generate electricity due to unplanned failures or outages not counting the time allocated for planned outages.

Table B.4
ESKOM Hydro and Pumped-Storage Power Stations

Name of Station	Number and Nomin. Capacity (MW)	Total Net Maximum Capacity (MW)	Variable O&M Cost (US c/kWh)	Average Annual Generation (GWh)	Efficiency (%)
Gariep	4 x 90	360	0.1	725	N/A
Vanderkloof	2 x 120	240	0.1	740	N/A
Colly Wobbles	3 x 14	42	0.1	165	N/A
First Falls	2 x 3	6	0.1	15	N/A
Second Falls	2 x 5.5	11	0.1	25	N/A
Ncora A&B	2 x 0.4, 1 x 1.3	2	0.1	2.5	N/A
Pumped-Storage Stations					
Drakensberg	4 x 250	1000	0.1	N/A	75%
Palmiet	2 x 200	400	0.1	N/A	75%

B.2.2 Municipal and Privately Owned Generation Units

Operational characteristics of municipal and privately owned thermal power stations are listed in Table B.5, and hydro and pumped-storage stations in Table B.6. Long-term unit forced outage rate for municipal and private thermal power stations is estimated at 10%, somewhat higher than for ESKOM thermal units.

Table B.5
Municipal and Private Thermal Stations

Name of Station	Maximum Capacity (MW)	Heat Rate at Max. Capacity 1) (kJ/kWh)	Variable O&M Cost (US c/kWh)	Unit Forced Outage Rate (%)	Planned Outages (%)
Municipal Coal					

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Athlone	180	10300	0.48	10	10
Kroonstad	30	11000	0.48	10	10
Swartkops	240	10300	0.48	10	10
Bloemfontein	102	10500	0.48	10	10
Kelvin	600	9800	0.48	10	10
Orlando	300	10300	0.48	10	10
Rooiwal	300	10300	0.48	10	10
Pretoria West	180	10300	0.48	10	10
Municipal Gas Turbine					
Roggebaai	40	12000	0.82	5	10
Athlone	40	12000	0.82	5	10
Port Elizabeth	20	12000	0.82	5	10
Johannesburg	160	12000	0.82	5	10
Pretoria West	24	12000	0.82	5	10
Private Coal					
Sasol Synth Fuels	600	9800	0.48	10	10
Sasol Chem Ind	128	10300	0.48	10	10
Private Bagasse					
Maidstone Mill	29	11000	0.48	10	10

1) Heat rates for municipal and private thermal power stations are estimated based on type and size of the unit.

Table B.6
Municipal and Private Hydro and Pumped-Storage Power Stations

Name of Station	Capacity of Units (MW)	Variable O&M Cost (US c/kWh)	Average Annual Generation (GWh)	Efficiency (%)
Lydenburg	2	0.1	9	N/A
Ceres	1	0.1	0.4	N/A
Piet Retief	1	0.1	0.7	N/A
Friedenheim	3	0.1	13	N/A
Pumped-Storage				
Steenbras	180	0.1	N/A	75%

B.3 GENERATION SYSTEM IN ZIMBABVE

Operational characteristics of existing and planned thermal stations in Zimbabwe are listed in Table B.7, and for hydro stations in Table B.8.

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Table B.7
Thermal Power Stations in Zimbabwe

Name of Station	Number and Nom. Capacity (MW)	Total Net Maximum Capacity (MW)	Heat Rate at Max. Capacity (kJ/kWh)	Variable O&M Cost (USc/kWh)	Unit Forced Outage Rate (%)	Planned Outages (%)
Hwange	4 x 230	856	10 000	0.48	5	10
Munyati	1 X 70	60	10 300	0.48	5	10
Harare	3 x 35	80	11 000	0.48	5	10
Bulawayo	1 x 70	60	10 300	0.48	5	10
Planned Additions						
Hwange 7&8	2 x 350	660	10 000	0.48	5	10
Gokwe	4 x 350	1320	9 810	0.48	5	10

Fixed resource additions are also 1 more units of the same type at Munyati, Bulawayo, and Harare plants to be added in 2008.

Table B.8
Hydro Power Stations in Zimbabwe

Name of Station	Number and Nom. Capacity (MW)	Total Net Maximum Capacity (MW)	Fixed O&M Cost (Usc/kWh)	Variable O&M Cost (USc/kWh)	Average Annual Generation (GWh)
Kariba South	3 x 222	666	0	0.1	2167

B.4 GENERATION SYSTEM IN MOZAMBIQUE

Operational characteristics of thermal stations in Mozambique are listed in Table B.9, and for hydro stations in Table B.10.

Table B.9
Thermal Power Stations in Mozambique

Name of Station	Number and Nom. Capacity (MW)	Total Net Maximum Capacity (MW)	Heat Rate at Max. Capacity (kJ/kWh)	Variable O&M Cost (USc/kWh)	Unit Forced Outage Rate (%)	Planned Outages (%)
Maputo GT		78	10 000	0.82	5	10

Table B.10
Hydro Power Stations in Mozambique

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Name of Station	Number and Nom. Capacity (MW)	Total Net Maximum Capacity (MW)	Fixed O&M Cost (Usc/kWh)	Variable O&M Cost (USc/kWh)	Average Annual Generation (GWh)
Cahora Bassa		1846	0	0.1	10000
Corumana		16	0	0.1	36
Planned Additions					
Mpanda Uncua	6 x 120	720	0	0.1	1815

Generation capability at Cahora Bassa plant is more that local consumption at Mozambique. It was assumed that possible output from Cahora Bassa will be consumed in other SAPP countries. Most of the energy will be purchased by ESKOM starting at the present capacity of 1477 MW and yearly energy of 9000 GWh. Purchases from Cahora Bassa are planned to increase to 1850 MW and 10000 GWh in year 2004.

B.5 GENERATION SYSTEM IN CONGO

Operational characteristics of Inga hydro station that could provide imports to SAPP countries is presented in Table B.11.

Table B.11
Hydro Power Station in Congo

Name of Station	Number and Nom. Capacity (MW)	Total Net Maximum Capacity (MW)	Fixed O&M Cost (Usc/kWh)	Variable O&M Cost (USc/kWh)	Average Annual Generation (GWh)
Inga		1000	0	0.1	6132

B.6 GENERATION SYSTEM IN BOTSWANA

Operational characteristics of thermal station in Botswana are presented in Table B.10.

Table B.10
Thermal Power Stations in Botswana

Name of Station	Number and Nom. Capacity (MW)	Total Net Maximum Capacity (MW)	Heat Rate at Max. Capacity (kJ/kWh)	Variable O&M Cost (USc/kWh)	Unit Forced Outage Rate (%)	Planned Outages (%)
Coal Units	4 x 29	108	12 000	0.48	5	10

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B.7 GENERATION SYSTEM IN NAMIBIA

Generation plants in Namibia are owned by NamPower. NamPower is Namibia's national utility and the primary source of electricity. Operational characteristics of NamPower thermal stations are listed in Table B.11, and for hydro stations in Table B.12. Namibian power system is interconnected and operated synchronously with the South African power system.

Table B.11
Thermal Power Stations in Namibia

Name of Station	Number and Nom. Capacity (MW)	Total Net Maximum Capacity (MW)	Heat Rate at Max. Capacity (kJ/kWh)	Fixed O&M Cost (US $/kW)	Variable O&M Cost (USc/kWh)	Unit Forced Outage Rate (%)	Planned Outages (%)
Van Eck	4 x 30	114	15 400	55	0.2	6	6
Walvis Bay	4 X 6	24	11 694	1.1	0.7	5	4

Table B.12
Hydro Power Stations in Namibia

Name of Station	Number and Nom. Capacity (MW)	Total Net Maximum Capacity (MW)	Fixed O&M Cost (USc/kWh)	Variable O&M Cost (USc/kWh)	Average Annual Generation (GWh)
Ruacana	3 x 81	243	0	0.1	1017

B.8 GENERATION SYSTEM IN TANZANIA

Operational characteristics of thermal stations in Tanzania are listed in Table B.13, and for hydro stations in Table B.14. Namibian power system is interconnected and operated synchronously with the South African power system.

Table B.13
Thermal Power Stations in Tanzania

Name of Station	Number and Nom. Capacity (MW)	Total Net Maximum Capacity (MW)	Heat Rate at Max. Capacity (kJ/kWh)	Variable O&M Cost (USc/kWh)	Unit Forced Outage Rate (%)	Planned Outages (%)
Ubongo GT	2 x 18.5	37	12 050	0.82	5	10
Ubongo Diesel	10 x 5	50	13 000	0.82	5	10
Mtwara	1 x 15	15	10 000	0.82	5	10
Dar-es-Salam	2 x 37.5	75	10 000	0.82	5	10

Planned Additions						
Dar-es-Salam (new)	2 x 50	100	10 000	0.82	5	10
IPTL	10 x 10	100	12 000	0.82	5	10
Generic Gas Turbines	1 x 50	50	12 050	0.82	5	10

Table B.14
Hydro Power Stations in Tanzania

Name of Station	Number and Nom. Capacity (MW)	Total Net Maximum Capacity (MW)	Fixed O&M Cost (USc/kWh)	Variable O&M Cost (USc/kWh)	Average Annual Generation (GWh)
Combined Hydro		396	0	0.1	1435
Planned Additions					
Kihansi	5 x 60	300	0	0.1	1051
Mpanga	2 x 80	160	0	0.1	560
Rumakali	4 x 50	200	0	0.1	700

For hydro plants we assumed that units will gradually be added to Kihansi hydro from 2001-2014 period, for Mpanga by 2012, and for Rumakali by 2010. For thermal plants we assumed that new Dar-es-salam units will come on line in 2004 and 2005, IPTL units by 2002. In case when Tanzanian system stays isolated, additional capacity requirements were provided by new generic gas turbine plants.

B.9 TRANSMISSION INTERCONNECTIONS

Transmission interconnections and assumed upgrades to the transmission system are presented in Table B-15.

Table B.15
Transmission Interconnections

Countries	Capacity (MW)
South Africa - Botswana	250 , upgrade to 700 in 2003
Zimbabwe - Botswana	250 , upgrade to 700 in 2003
Zimbabwe - Zambia	1000
Congo – Zambia	250, upgrade to 310 in 2003, to 465 in 2008, and 945 in 2010
Mozambique (North) - Zimbabwe	500, upgrade to 600 in 2004
Mozambique (North) – South Africa	2000, upgrade to 4000 in 2004
Mozambique (South) – South Africa	400, upgrade to 600 in 2001

Zambia – Tanzania	0, upgrade to 200 in 2007

B.10 EXPANSION PLANS

B.10.1 Approach

The value of every new power project dependents of the structure of the power system in which the project will operate. New projects in Zambia will be connected into the Zambian power system, but will operate in the integrated power system of the South African Power Pool. Therefore, for the market analysis we modeled the operation and expansion of the complete power pool. New power projects in other SAPP countries that could have an effect on the value of Zambian projects were also modeled.

Generation power system production simulation and expansion analysis was performed using the Elfin model. Elfin model was developed by the Environmental Defense Fund (EDF) over two decades of intense development and upgrades. This package is used for simulating the operation of power systems, developing least-cost generation plans, and simulating a competitive generation market.

For the purposes of the developing the generation plan, the steps taken by the model are the following:

- The operation of the South African Power Pool is simulated on a month-by-month basis. Units are dispatched to minimize overall costs, except for a few "must-run" resources that are assumed to be dispatched regardless of economics.
- The effects of scheduled and forced outages are calculated and the amount of energy that cannot be met by the generation system is calculated. This value grows with demand for a given level of generation capacity.
- Adding a new plant to the resource mix reduces fuel and O&M costs, and also reduces the costs associated with unserved energy and capacity shortage. When these cost reductions are large enough to offset the operating and investment-related costs of the new plant, it may be added to the resource plan.
- ELFIN evaluates many combinations of resource additions and selects from that set the combination that produces the lowest discounted cost, including the operating costs of existing plants and the operating and investment-related costs of new plants.

Calculation of new project value is performed by making two generation system simulation runs. First simulation is performed without the new project, then second simulation is performed with the new project added at zero cost. For the second simulation the power development plan with the new project is modified (new capacity additions are reduced) from the run without the new project. New development plan is created to have approximately the same timing and total capacity addition as the development plan without the new project. The output of the new project will reduce the

level of generation from other existing plants, and thus the cost of their operation. Eventually, the presence of the new project also reduces the need for new plants and their associated investment and operating costs. Thus the total production costs are lower in the case where the new project is added. Difference between two simulations gives the value new project will have in the system.

B.10.2 Results

Based on the developed load forecasts presented in Appendix A, and existing and committed resources in the region, we developed expansion plans to simulate need for new capacity additions by the year 2019. Expansion plans were developed for the Base Case Growth scenario and for the Low Growth scenario. As the main expansion alternatives we used generic conventional coal and combustion turbines presented in Table B-3.

Conventional pulverized coal plants have been the mainstay of South Africa's power generation development. Our information is that there are economic reserves of coal adequate to support another 24 x 635 MW units within relatively easy transmission distance to the existing transmission system. Combustion turbines operating in a simple cycle mode are a common solution for systems requiring peaking generation. We have considered simple cycle combustion turbines using distillate fuel oil for fuel.

Development plans were first developed without the Zambian hydro project. These plans are summarized in Table B-16. Under the Base Case Growth scenario, 4 940 MW of simple cycle combustion turbine capacity and 10 795 MW of coal-fired capacity is required by the year 2019.

Table B.16
Base Case Generation Development Plan

Year	Base Case Growth	
	New Coal Plant (MW)	New Gas Turbine (MW)
2007		3 x 260
2008		5 x 260
2009		
2010		2 x 260
2011	1 x 635	1 x 260
2012	1 x 635	2 x 260
2013	2 x 635	
2014	2 x 635	
2015	2 x 635	2 x 260
2016	2 x 635	

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2017	2 x 635	1 x 260
2018	3 x 635	2 x 260
2019	2 x 635	

After developing resource plans we then performed with/without analysis described in B.10.1 for both Kafue Gorge Lower and Itezhi-tezhi projects.

Scenario Analysis

We also recognize that there are many uncertainties associated with the expansion of the South African Power Pool. For this reason, we investigated the effect of load growth on the development plan, and a number of variations on the development plan. The variations on the development plans were developed using the Base Case expansion scenario, and substituting similar capacity of generic projects with named project likely to be have an effect on new Zambian projects. These variations included assumed construction of:

- Mothballed plants
- Mpanda Uncua
- Gokwe North and Hwange
- Pumped storage plants
- Combined cycle in Western RSA
- Increased transmission capacity to Congo

Table B-17 summarizes the changes to the Base Case generation development plans with additions of these specific units. For all these scenarios the same analysis described for the Base Case was applied for both Kafue Gorge Lower and Itezhi-tezhi projects.

We also analyzed value of Zambian projects under the low load growth scenario. Table B-18 summarizes Low Load Growth development plan. Under the Low Growth scenario no new coal-fired plants are required to be added to the system during the study period. The first simple cycle combustion turbine is not required until 2015 for the total of 2860 MW to be added by the year 2019.

Table B.17
Scenario Generation Development Plans

Scenario	Change to the Base Case
Mothballed plants (3 600 MW)	displace all GT's until 2010 11 GT's and 1 Coal in 2011 9 GT's and 2 Coal in 2012 3 GT's and 4 Coal in 2014 5 Coal from 2015
Mpanda Uncua (6 x 400)	displaces 10 GT's until 2010, 7 GT's and 1 Coal in 2011,

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	4 GT's and 2 Coal in 2014, 4 Coal from 2015
Gokwe North and Hwange (2 x 350 + 2 x 330)	displaces 2 GT's 2007-2010 , 2 Coal starting in 2011
Pumped Storage Plants (21 x 333 MW)	displaces all GT's
Combined Cycle in Western RSA (1 x 750 MW)	displaces 3 GT's in 2007-2010 , 1 Coal from 2011
Increased Transmission to DRC (to 945 MW)	1 GT in 2008-2009, 3GT's in 2010 , 1 Coal from 2011

Table B.18
Low Load Development Plan

Year	Low Load Growth	
	New Coal Plant (MW)	New Gas Turbine (MW)
2015		2 x 260
2016		2 x 260
2017		2 x 260
2018		2 x 260
2019		3 x 260

Appendix C Detailed Results

This appendix summarizes results of power system simulation analysis. Presented are results for the Base Case for the several selected years: 2005, 2010, 2015 and 2019. Generation power system production simulation and expansion analysis was performed using the Elfin model. After optimizing the system development, we performed three Elfin simulations: without new Zambian projects, for the same system including Kafue Gorge Lower or Itezhi-tezhi replacing similar size of new coal or gas turbine projects. We present three corresponding outputs in this Appendix.

Detailed outputs list all power plants operating in the system in a specific year. For each power plant results contain summary of plant technical characteristics, plant generation, fuel use, capacity factor, fuel and operating and maintenance costs, percentage of time plant is the marginal plant, and the marginal cost. For the pumped-storage units output presents the amount of pumped energy and associated generation. Output also lists key system parameters such as: system peak load, total available generation, energy-not-served (ENS), loss-of-load probability (LOLP), and system total and average marginal costs.

Run 1 -- 2005 -- Simulation R.22.0.0 - Without Zambian projects, medium 9 May 00 13:25 Ver 2.13b26 p. 79

		Peak capacity MW	Units	Com-mit. %	Outage FOR %	Outage MOR %	Energy GWh Load	Pump	Dump	Total	Cap. fac. %	Fuel use PJ	Heat rate kJ/kWh	Fuel $/GJ	$/MWh Fuel	O&M	Tot.	Rank * Dis-patch	Marginal time %	Marginal cost $/MWh	Fuel +OM M$
arnoCW	Arnot	990	3	100	5.0	10.0	7414	1	0	7415	85.5	72.7	9810	0.47	4.6	4.8	9.4	11	0.00	8.0	69.78
arn1CW	Arnot - Reserve	330	1	100	5.0	10.0	2471	0	0	2472	85.5	24.2	9810	0.47	4.6	4.8	9.4	12	0.00	8.0	23.26
duvhCW	Duvha (1-3)	1725	3	100	5.0	10.0	12920	0	0	12920	85.5	128	9940	0.40	4.0	4.8	8.8	6	0.00	7.3	113.39
duv1CW	Duvha (4-6)	1725	3	100	5.0	10.0	12913	7	0	12920	85.5	128	9940	0.40	4.0	4.8	8.8	5	0.00	8.0	113.38
hendCM	Hendrina	1900	10	100	5.0	10.0	14231	0	0	14231	85.5	146	10290	0.37	3.8	4.8	8.6	3	0.00	7.3	122.49
kendCW	Kendal	3840	6	100	5.0	10.0	24660	0	0	24660	73.3	253	10249	0.44	4.5	4.8	9.3	9	13.89	8.5	229.57
krieCW	Kriel	2850	6	100	5.0	10.0	20448	28	0	20476	82.0	202	9871	0.45	4.4	4.8	9.2	10	5.88	8.2	189.23
lethCW	Lethabo	3558	6	100	5.0	10.0	26565	49	0	26613	85.4	261	9823	0.44	4.3	4.8	9.1	8	0.73	8.1	242.77
maj1CW	Majuba Units 1-3	1836	3	58.3	5.0	10.0	4879	0	0	4879	30.3	55.2	11323	0.70	7.9	4.8	12.7	21	4.12	10.4	62.09
maj2CW	Majuba Units 4-6	2007	3	59.2	5.0	10.0	4987	0	0	4987	28.4	57.9	11603	0.70	8.1	4.8	12.9	20	3.70	10.4	64.45
matiCW	Matimba	3690	6	100	5.0	10.0	27169	62	0	27231	84.2	280	10268	0.40	4.1	4.8	8.9	7	3.78	8.1	242.56
matlCW	Matla	3450	6	96.4	5.0	10.0	24890	0	0	24890	82.4	240	9650	0.40	3.9	4.8	8.7	4	0.00	7.9	215.55
tutuCW	Tutuka	3510	6	76.1	5.0	10.0	12227	0	0	12227	39.8	132	10783	0.54	5.8	4.8	10.6	17	10.87	9.1	129.88
koebCW	Koeberg	1840	2	-M-	10.0	20.0	11200	0	0	11200	69.5	131	11653	0.31	3.6	8.0	11.6	1	0.14	10.8	130.15
collHE	Colly Wobbles	42	1		0.0	0.0	165	0	0	165	44.8				0.0	1.0	1.0	164	0.35	9.2	0.16
	{Run of river}	{ 8}					{ 74}	{ 0}	{ 0}	{ 74	100}								{ 0.00}		
	{Pondage}	{ 34}					{ 91}		{ 0}	{ 91	31.0}								{ 0.35}		
gariHE	Gariep	360	1		0.0	0.0	723	0	0	723	22.9				0.0	1.0	1.0	164	2.57	9.8	0.72
	{Run of river}	{ 18}					{ 158}	{ 0}	{ 0}	{ 158	100}								{ 0.00}		
	{Pondage}	{ 342}					{ 565}		{ 0}	{ 565	18.9}								{ 2.57}		
vandHE	Vanderkloof	240	1		0.0	0.0	740	0	0	740	35.2				0.0	1.0	1.0	164	2.03	9.4	0.74
	{Run of river}	{ 24}					{ 210}	{ 0}	{ 0}	{ 210	100}								{ 0.00}		
	{Pondage}	{ 216}					{ 530}		{ 0}	{ 530	28.0}								{ 2.03}		
ehydHE	ESKOM Small Hydro	19	1		0.0	0.0	42	0	0	42	25.2				0.0	1.0	1.0	166	0.09	10.3	0.04
	{Run of river}	{ 4}					{ 35}	{ 0}	{ 0}	{ 35	100}								{ 0.00}		
	{Pondage}	{ 15}					{ 7}		{ 0}	{ 7	5.2}								{ 0.09}		
acacCP	Acacia	171	3		10.0	5.0	11	0	0	11	0.7	0.1	12000	6.33	75.9	8.2	84.1	180	0.13	84.1	0.91
ptrxCP	Port Rex	171	3		5.0	5.0	10	0	0	10	0.7	0.1	12000	6.33	75.9	8.2	84.1	181	0.12	84.1	0.83
krooCM	Kroonstad	30	1	72.6	10.0	10.0	49	0	0	49	18.7	0.6	12858	0.72	9.3	4.8	14.1	19	0.02	12.2	0.69
swarCM	Swartkops	240	1	50.2	10.0	10.0	450	0	0	450	21.4	5.5	12153	0.72	8.8	4.8	13.6	24	0.18	10.8	6.13
bloeCM	Bloemfontein	102	1	49.4	10.0	10.0	187	0	0	187	20.9	2.3	12391	0.72	9.0	4.8	13.8	28	0.06	11.0	2.57
kelvCW	Kelvin	600	1	53.7	10.0	10.0	1239	0	0	1239	23.6	14.3	11534	0.72	8.4	4.8	13.2	22	0.72	10.5	16.30
rooiCW	Rooiwal	300	1	50.2	10.0	10.0	561	0	0	561	21.4	6.8	12162	0.72	8.8	4.8	13.6	25	0.21	10.8	7.64
precCM	Pretoria West-coa	180	1	50.2	10.0	10.0	336	0	0	336	21.3	4.1	12174	0.72	8.8	4.8	13.6	26	0.12	10.8	4.58
roggCP	Roggebaai	40	1		10.0	5.0	2	0	0	2	0.6	0.0	12000	6.33	75.9	8.2	84.1	182	0.02	84.1	0.16
athgCP	Athlone - gas	120	3		10.0	5.0	5	0	0	5	0.5	0.1	12000	6.33	75.9	8.2	84.1	183	0.07	84.1	0.46
portCP	Port Elizabeth	20	1		10.0	5.0	1	0	0	1	0.5	0.0	12000	6.33	75.9	8.2	84.1	184	0.01	84.1	0.07
johaCP	Johannesburg	160	1		10.0	5.0	7	0	0	7	0.5	0.1	12000	6.33	75.9	8.2	84.1	185	0.08	84.1	0.56
pretCP	Pretoria West-gas	24	1		10.0	5.0	1	0	0	1	0.4	0.0	12000	6.33	75.9	8.2	84.1	186	0.01	84.1	0.07
mhydHE	Municipal Hydro (	7	1		0.0	0.0	23	0	0	23	37.5				0.0	1.0	1.0	164	0.04	9.8	0.02
	{Run of river}	{ 2}					{ 18}	{ 0}	{ 0}	{ 18	100}								{ 0.00}		
	{Pondage}	{ 5}					{ 5}		{ 0}	{ 5	12.5}								{ 0.04}		
maidCM	Maidstone Mill	29	1	75.5	10.0	10.0	153	0	0	153	60.1	1.8	11800	0.00	0.0	4.8	4.8	2	0.00	0.0	0.73
sassCW	Sasol Synth Fuels	600	1	53.7	10.0	10.0	1222	0	0	1222	23.2	14.2	11587	0.72	8.4	4.8	13.2	23	0.59	10.5	16.12
sascCM	Sasol Chem Ind	128	1	50.2	10.0	10.0	238	0	0	238	21.2	2.9	12185	0.72	8.8	4.8	13.6	27	0.08	10.8	3.25
inteEN	Interruptible Loa	745	1		0.0	0.0	0	0	0	0	0.0				0.0	0.0	0.0	0	0.00	0.0	0.00
vaneCM	Van Eck	114	4	5.0	6.0	6.0	44	0	0	44	4.4	0.7	15400	1.80	27.7	2.0	29.7	29	0.00	0.0	1.30
ruacHE	Ruacana Falls	243	1		0.0	0.0	1016	0	0	1016	47.7				0.0	1.0	1.0	164	1.97	9.2	1.02

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        {Run of river}  {  24}                  {  210}{   0}{  0}{ 210  100}                                        {  0.00}
        {Pondage}       { 219}                  {  806}      {  0}{ 806 42.0}                                        {  1.97}
walvCP Walvis Bay         24  4        5.0  4.0     2    0    0     2  0.9  0.0 11694  6.33 74.0  7.0 81.0      178  0.02 81.0   0.16
hwanCW Hwange            920  4 75.5   5.0 10.0  3814    0    0  3814 47.3 40.5 10626  0.47  5.0  4.8  9.8       13  2.90  8.6  37.35
munyCW Munyati            60  1 75.5   5.0 10.0   244    0    0   244 46.4  2.7 11038  0.47  5.2  4.8 10.0       15  0.18  8.7   2.43
haraCW Harare            102  3 75.5   5.0 10.0   293    0    0   293 32.8  3.7 12475  0.47  5.9  4.8 10.7       16  0.30  9.2   3.13
bulaCW Bulawayo           60  1 75.5   5.0 10.0   243    0    0   243 46.3  2.7 11042  0.47  5.2  4.8 10.0       14  0.18  8.7   2.43
karsHE Kariba South      666  1        0.0  0.0  2165    0    0  2165 37.1                     0.0  0.0  0.0      164  4.88  9.6   0.00
        {Run of river}  { 150}                  { 1314}{   0}{  0}{1314  100}                                        {  0.00}
        {Pondage}       { 516}                  {  851}      {  0}{ 851 18.8}                                        {  4.88}
kafuHE Kafue Gorge       900  1        0.0  0.0  4858    0    0  4858 61.6                     0.0  0.0  0.0      164  5.74  9.1   0.00
        {Run of river}  { 300}                  { 2628}{   0}{  0}{2628  100}                                        {  0.00}
        {Pondage}       { 600}                  { 2230}      {  0}{2230 42.4}                                        {  5.74}
karnHE Kariba North      600  1        0.0  0.0  2165    0    0  2165 41.2                     0.0  0.0  0.0      164  4.26  9.6   0.00
        {Run of river}  { 150}                  { 1314}{   0}{  0}{1314  100}                                        {  0.00}
        {Pondage}       { 450}                  {  851}      {  0}{ 851 21.6}                                        {  4.26}
vicfHE Victoria Falls    108  1        0.0  0.0   666    0    0   666 70.4                     0.0  0.0  0.0      164  0.66  8.9   0.00
        {Run of river}  {  30}                  {  263}{   0}{  0}{ 263  100}                                        {  0.00}
        {Pondage}       {  78}                  {  403}      {  0}{ 403 59.0}                                        {  0.66}
zahyHE Other Zambia Hydr  24  1        0.0  0.0    47    0    0    47 22.3                     0.0  0.0  0.0      164  0.18  9.9   0.00
        {Run of river}  {   3}                  {   26}{   0}{  0}{  26  100}                                        {  0.00}
        {Pondage}       {  21}                  {   21}      {  0}{  21 11.2}                                        {  0.18}
luseHE Lusemfwa           18  1        0.0  0.0    75    0    0    75 47.5                     0.0  0.0  0.0      164  0.12  9.8   0.00
        {Run of river}  {   6}                  {   53}{   0}{  0}{  53  100}                                        {  0.00}
        {Pondage}       {  12}                  {   22}      {  0}{  22 21.3}                                        {  0.12}
muluHE Mulungushi         24  1        0.0  0.0   120    0    0   120 57.0                     0.0  0.0  0.0      164  0.16  9.2   0.00
        {Run of river}  {   8}                  {   70}{   0}{  0}{  70  100}                                        {  0.00}
        {Pondage}       {  16}                  {   50}      {  0}{  50 35.6}                                        {  0.16}
zagtCP GT in Zambia      296  1       10.0  5.0    24    0    0    24  0.9  0.3 11700  6.33 74.0  8.2 82.2      179  0.27 82.2   1.98
ingaLE Inga for export  1000  1        0.0  0.0  6130    0    0  6130 70.0                     0.0  0.0  0.0      159  8.53  8.7   0.00
morpCW Botswana coal     116  4 52.8   5.0 10.0   334    0    0   334 32.8  4.4 13135  0.47  6.2  4.8 11.0       18  0.24  8.9   3.66
cbasLE Cahora Bassa     1846  1        0.0  0.0  9996    0    0  9996 61.8                     0.0  0.0  0.0      159 15.74  8.7   0.00
mpgtCP Maputo gas turbin  78  1       10.0  5.0   114    0    0   114 16.7  1.1 10000  6.33 63.3  8.2 71.5      177  0.07 71.5   8.16
coruLE Corumanu hydro     16  1        0.0  0.0    36    0    0    36 25.6                     0.0  0.0  0.0      164  0.18  9.7   0.00
ps-1CP Drakensburg      1000  2                    59                 59  0.7                          1.0  1.0      176  1.07 10.9   0.06
        {pumping}      {1000}                   { 78}                                                              157  0.56  8.2
ps-2CP Palmiett          400  2                    43                 43  1.2                          1.0  1.0      175  0.50 10.7   0.04
        {pumping}       { 400}                   { 57}                                                              157  0.31  8.2
ps-3CP Steenbras         180  1                     9                  9  0.6                          1.0  1.0      176  0.18 11.2   0.01
        {pumping}       { 180}                   { 12}                                                              156  0.08  8.2
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Total firm 46374 + CS = 46374 21.1% reserve    245632  147    0 245779   2220.8                        8.4          99.91  9.6 2073.0
Committed  42471      = 42471 10.9%       ENS       4.76       LOLP      0.000919 ( 0.335 days)  Energy Not Served  0.09 1000   4.76
after MOR  42471      = 42471 10.9%       ==================   Commit target 40201 MW  5.0%      Avg. Marginal Cost (RC) 10.5
after FOR  40523      = 40523  5.8%       Load 245637 GWh      Spin. target    957 MW  2.5%              (dispatch cost) 11.1
Peak         ( 6pm Thu) 38287             Prob. of not meeting commit target:  0.4%

Production :                Fuel   Dump  Var. O&M   ENS     VOMCST    VOMBEN Priced Emis. Total var-    FOMCST    FOMBEN  Total prod-
      cost :                (FC)         (OM,ON)                                (PE)     iable cost                        uction cost
   summary :   (M$)       993.73 - 0.00 +   0.00 + 4.76 + 1079.31 -    0.00 +    0.00   =   2077.80 +   44.97 -    0.00 =     2122.77
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Run 1 -- 2010 -- Simulation R.22.0.0 - Without Zambian projects, medium 9 May 00 13:25 Ver 2.13b26 p. 152

		Peak capacity MW	Units	Commit. %	Outage FOR %	Outage MOR %	Energy GWh Load	Pump	Dump	Total	Cap. fac. %	Fuel use PJ	Heat rate kJ/kWh	Fuel $/GJ	$/MWh Fuel	O&M	Tot. Dispatch	Rank *	Marginal time %	Marginal cost $/MWh	Fuel +OM M$
arnoCW	Arnot	990	3	92.5	5.0	10.0	6885	0	0	6885	79.4	67.5	9810	0.47	4.6	4.8	9.4	11	0.00	8.0	64.79
arn1CW	Arnot - Reserve	330	1	91.5	5.0	10.0	2270	0	0	2270	78.5	22.3	9810	0.47	4.6	4.8	9.4	12	0.00	8.0	21.36
duvhCW	Duvha (1-3)	1725	3	100	5.0	10.0	12920	0	0	12920	85.5	128	9940	0.40	4.0	4.8	8.8	5	0.00	7.3	113.39
duv1CW	Duvha (4-6)	1725	3	100	5.0	10.0	12919	1	0	12920	85.5	128	9940	0.40	4.0	4.8	8.8	6	0.00	8.0	113.39
hendCM	Hendrina	1900	10	100	5.0	10.0	14231	0	0	14231	85.5	146	10290	0.37	3.8	4.8	8.6	3	0.00	7.3	122.49
kendCW	Kendal	3840	6	100	5.0	10.0	27425	261	0	27686	82.3	278	10050	0.44	4.4	4.8	9.2	9	6.64	8.5	255.32
krieCW	Kriel	2850	6	97.5	5.0	10.0	20488	78	0	20567	82.4	202	9808	0.45	4.4	4.8	9.2	10	1.99	8.2	189.49
lethCW	Lethabo	3558	6	100	5.0	10.0	26620	21	0	26642	85.5	262	9820	0.44	4.3	4.8	9.1	8	0.03	8.1	242.99
maj1CW	Majuba Units 1-3	1836	3	100	5.0	10.0	11030	196	0	11226	69.8	117	10449	0.70	7.3	4.8	12.1	20	5.44	10.4	136.00
maj2CW	Majuba Units 4-6	2007	3	100	5.0	10.0	10941	222	0	11163	63.5	119	10691	0.70	7.5	4.8	12.3	19	6.49	10.4	137.12
matiCW	Matimba	3690	6	100	5.0	10.0	27479	79	0	27558	85.3	282	10246	0.40	4.1	4.8	8.9	7	1.30	8.1	245.21
matlCW	Matla	3450	6	98.7	5.0	10.0	25517	0	0	25517	84.4	246	9650	0.40	3.9	4.8	8.7	4	0.00	7.9	220.98
tutuCW	Tutuka	3510	6	96.9	5.0	10.0	22445	307	0	22751	74.0	225	9899	0.54	5.3	4.8	10.1	17	8.21	9.1	230.83
koebCW	Koeberg	1840	2	-M-	10.0	20.0	11296	22	0	11319	70.2	132	11624	0.32	3.7	8.0	11.7	1	0.39	10.8	132.45
collHE	Colly Wobbles	42	1		0.0	0.0	165	0	0	165	44.7				0.0	1.0	1.0	163	0.31	26.4	0.16
	{Run of river}	{ 8}					{ 74}	{ 0}	{ 0}	{ 74	100}								{ 0.00}		
	{Pondage}	{ 34}					{ 91}		{ 0}	{ 91	30.9}								{ 0.31}		
gariHE	Gariep	360	1		0.0	0.0	723	0	0	723	22.9				0.0	1.0	1.0	165	2.43	31.2	0.72
	{Run of river}	{ 18}					{ 158}	{ 0}	{ 0}	{ 158	100}								{ 0.00}		
	{Pondage}	{ 342}					{ 565}		{ 0}	{ 565	18.9}								{ 2.43}		
vandHE	Vanderkloof	240	1		0.0	0.0	740	0	0	740	35.2				0.0	1.0	1.0	163	1.50	37.8	0.74
	{Run of river}	{ 24}					{ 210}	{ 0}	{ 0}	{ 210	100}								{ 0.00}		
	{Pondage}	{ 216}					{ 530}		{ 0}	{ 530	28.0}								{ 1.50}		
ehydHE	ESKOM Small Hydro	19	1		0.0	0.0	42	0	0	42	25.2				0.0	1.0	1.0	168	0.08	61.9	0.04
	{Run of river}	{ 4}					{ 35}	{ 0}	{ 0}	{ 35	100}								{ 0.00}		
	{Pondage}	{ 15}					{ 7}		{ 0}	{ 7	5.3}								{ 0.08}		
acacCP	Acacia	171	3		10.0	5.0	25	0	0	25	1.7	0.3	12000	6.65	79.8	8.2	88.0	173	0.26	88.0	2.18
ptrxCP	Port Rex	171	3		5.0	5.0	23	0	0	23	1.5	0.3	12000	6.65	79.8	8.2	88.0	174	0.24	88.0	2.01
kelvCW	Kelvin	600	1	94.9	10.0	10.0	2713	191	0	2904	55.3	30.7	10583	0.74	7.9	4.8	12.7	22	1.94	10.6	36.78
rooiCW	Rooiwal	300	1	96.4	10.0	10.0	1312	59	0	1371	52.2	15.5	11288	0.74	8.4	4.8	13.2	23	0.97	11.0	18.08
roggCP	Roggebaai	40	1		10.0	5.0	5	0	0	5	1.3	0.1	12000	6.65	79.8	8.2	88.0	175	0.05	88.0	0.41
athgCP	Athlone - gas	120	3		10.0	5.0	13	0	0	13	1.2	0.2	12000	6.65	79.8	8.2	88.0	176	0.14	88.0	1.15
portCP	Port Elizabeth	20	1		10.0	5.0	2	0	0	2	1.2	0.0	12000	6.65	79.8	8.2	88.0	177	0.02	88.0	0.18
johaCP	Johannesburg	160	1		10.0	5.0	16	0	0	16	1.1	0.2	12000	6.65	79.8	8.2	88.0	178	0.18	88.0	1.41
pretCP	Pretoria West-gas	24	1		10.0	5.0	2	0	0	2	1.0	0.0	12000	6.65	79.8	8.2	88.0	179	0.01	88.0	0.19
mhydHE	Municipal Hydro (	7	1		0.0	0.0	23	0	0	23	37.5				0.0	1.0	1.0	167	0.03	55.0	0.02
	{Run of river}	{ 2}					{ 18}	{ 0}	{ 0}	{ 18	100}								{ 0.00}		
	{Pondage}	{ 5}					{ 5}		{ 0}	{ 5	12.5}								{ 0.03}		
maidCM	Maidstone Mill	29	1	76.8	10.0	10.0	157	0	0	157	61.7	1.8	11800	0.00	0.0	4.8	4.8	2	0.00	4.8	0.75
sassCW	Sasol Synth Fuels	600	1	96.2	10.0	10.0	2676	165	0	2841	54.1	30.3	10673	0.74	7.9	4.8	12.7	21	1.99	10.6	36.18
sascCM	Sasol Chem Ind	128	1	93.4	10.0	10.0	534	18	0	552	49.2	6.3	11359	0.74	8.4	4.8	13.2	24	0.39	11.0	7.31
gtueCP	New Gas Turbine (	2600	10		10.0	5.0	1619	0	0	1619	7.1	15.4	9500	6.65	63.2	8.2	71.4	169	10.83	71.4	115.54
inteEN	Interruptible Loa	745	1		0.0	0.0	0	0	0	0	0.0				0.0	0.0	0.0	0	0.00	0.0	0.00
vaneCM	Van Eck	114	4	44.3	6.0	6.0	394	0	0	394	39.5	6.1	15400	1.85	28.4	2.0	30.4	25	0.00	0.0	12.00
ruacHE	Ruacana Falls	243	1		0.0	0.0	1016	0	0	1016	47.7				0.0	1.0	1.0	163	1.54	17.1	1.02
	{Run of river}	{ 24}					{ 210}	{ 0}	{ 0}	{ 210	100}								{ 0.00}		
	{Pondage}	{ 219}					{ 806}		{ 0}	{ 806	42.0}								{ 1.54}		
walvCP	Walvis Bay	24	4		5.0	4.0	4	0	0	4	2.0	0.1	11694	6.65	77.7	7.0	84.7	171	0.04	84.7	0.36

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hwanCW	Hwange	920	4	68.2	5.0	10.0	4431	52	0	4483	55.6	45.1	10059	0.47	4.7	4.8	9.5	13	0.85	8.6	42.71
munyCW	Munyati	120	2	62.8	5.0	10.0	524	8	0	533	50.7	5.5	10373	0.47	4.9	4.8	9.7	14	0.10	8.7	5.16
haraCW	Harare	136	4	61.9	5.0	10.0	526	16	0	541	45.5	6.1	11218	0.47	5.3	4.8	10.1	16	0.22	9.2	5.45
bulaCW	Bulawayo	120	2	61.2	5.0	10.0	510	9	0	518	49.3	5.4	10374	0.47	4.9	4.8	9.7	15	0.10	8.7	5.02
karsHE	Kariba South	666	1		0.0	0.0	2165	0	0	2165	37.1				0.0	0.0	0.0	167	3.94	33.4	0.00
	{Run of river}	{ 150}					{ 1314}	{ 0}	{ 0}	{1314	100}								{ 0.00}		
	{Pondage}	{ 516}					{ 851}		{ 0}	{ 851	18.8}								{ 3.94}		
kafuHE	Kafue Gorge	900	1		0.0	0.0	4858	0	0	4858	61.6				0.0	0.0	0.0	163	5.20	16.8	0.00
	{Run of river}	{ 300}					{ 2628}	{ 0}	{ 0}	{2628	100}								{ 0.00}		
	{Pondage}	{ 600}					{ 2230}		{ 0}	{2230	42.4}								{ 5.20}		
karnHE	Kariba North	600	1		0.0	0.0	2165	0	0	2165	41.2				0.0	0.0	0.0	167	3.43	33.4	0.00
	{Run of river}	{ 150}					{ 1314}	{ 0}	{ 0}	{1314	100}								{ 0.00}		
	{Pondage}	{ 450}					{ 851}		{ 0}	{ 851	21.6}								{ 3.43}		
vicfHE	Victoria Falls	108	1		0.0	0.0	666	0	0	666	70.4				0.0	0.0	0.0	163	0.55	13.3	0.00
	{Run of river}	{ 30}					{ 263}	{ 0}	{ 0}	{ 263	100}								{ 0.00}		
	{Pondage}	{ 78}					{ 403}		{ 0}	{ 403	59.0}								{ 0.55}		
zahyHE	Other Zambia Hydr	24	1		0.0	0.0	47	0	0	47	22.3				0.0	0.0	0.0	167	0.13	53.0	0.00
	{Run of river}	{ 3}					{ 26}	{ 0}	{ 0}	{ 26	100}								{ 0.00}		
	{Pondage}	{ 21}					{ 21}		{ 0}	{ 21	11.2}								{ 0.13}		
luseHE	Lusemfwa	18	1		0.0	0.0	75	0	0	75	47.5				0.0	0.0	0.0	165	0.10	35.5	0.00
	{Run of river}	{ 6}					{ 53}	{ 0}	{ 0}	{ 53	100}								{ 0.00}		
	{Pondage}	{ 12}					{ 22}		{ 0}	{ 22	21.3}								{ 0.10}		
muluHE	Mulungushi	24	1		0.0	0.0	120	0	0	120	57.0				0.0	0.0	0.0	163	0.15	21.6	0.00
	{Run of river}	{ 8}					{ 70}	{ 0}	{ 0}	{ 70	100}								{ 0.00}		
	{Pondage}	{ 16}					{ 50}		{ 0}	{ 50	35.6}								{ 0.15}		
zagtCP	GT in Zambia	296	1		10.0	5.0	437	0	0	437	16.8	5.1	11700	6.65	77.8	8.2	86.0	172	0.51	86.0	37.55
ingaLE	Inga for export	1000	1		0.0	0.0	6130	0	0	6130	70.0				0.0	0.0	0.0	160	6.92	9.7	0.00
morpCW	Botswana coal	116	4	50.4	5.0	10.0	404	7	0	411	40.4	5.0	12141	0.47	5.7	4.8	10.5	18	0.09	8.9	4.32
cbasLE	Cahora Bassa	1846	1		0.0	0.0	9997	0	0	9997	61.8				0.0	0.0	0.0	160	12.77	9.7	0.00
mpgtCP	Maputo gas turbin	78	1		10.0	5.0	338	0	0	338	49.5	3.4	10000	6.65	66.5	8.2	74.7	170	0.23	74.7	25.24
coruLE	Corumanu hydro	16	1		0.0	0.0	36	0	0	36	25.6				0.0	0.0	0.0	163	0.14	30.7	0.00
ps-1CP	Drakensburg	1000	2				812			812	9.3					1.0	1.0	168	4.18	25.6	0.81
	{pumping}	{1000}						1082}										155	2.68	20.1	
ps-2CP	Palmiett	400	2				329			329	9.4					1.0	1.0	168	1.67	25.4	0.33
	{pumping}	{ 400}						{433}										155	1.07	20.3	
ps-3CP	Steenbras	180	1				142			142	9.0					1.0	1.0	168	0.75	25.8	0.14
	{pumping}	{ 180}						{195}										155	0.48	19.8	

Total firm 48576 + CS = 48576 10.6% reserve 279384 1710 0 281094 2539.4 9.2 99.75 22.6 2589.8
Committed 48031 = 48031 9.3% ENS 15.42 LOLP 0.002484 (0.907 days) Energy Not Served 0.25 1000 15.42
after MOR 48031 = 48031 9.3% ========== Commit target 46137 MW 5.0% Avg. Marginal Cost (RC) 25.0
after FOR 45704 = 45704 4.0% Load 279400 GWh Spin. target 1098 MW 2.5% (dispatch cost) 28.4
Peak (6pm Thu) 43940 Prob. of not meeting commit target: 46.3%

Production cost summary :	Fuel (FC)	Dump	Var. O&M (OM,ON)	ENS	VOMCST	VOMBEN	Priced Emis. (PE)	Total variable cost	FOMCST	FOMBEN	Total production cost
(M$)	1338.16 -	0.00 +	0.00 +	15.4 +	1251.59 -	0.00 +	0.00 =	2605.17 +	44.97 -	0.00 =	2650.15

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Run 1 -- 2015 -- Simulation R.22.0.0 - Without Zambian projects, medium 9 May 00 13:25 Ver 2.13b26 p. 227

		Peak capacity MW	Units	Com-mit. %	Outage FOR %	Outage MOR %	Energy GWh Load	Pump	Dump	Total	Cap. fac. %	Fuel use PJ	Heat rate kJ/kWh	Fuel $/GJ	$/MWh Fuel	O&M	Tot.	Rank Dis-patch *	Marginal time %	Marginal cost $/MWh	Fuel +OM M$
arnoCW	Arnot	990	3	96.4	5.0	10.0	7142	0	0	7142	82.4	70.1	9810	0.47	4.6	4.8	9.4	11	0.00	8.0	67.21
arn1CW	Arnot - Reserve	330	1	95.1	5.0	10.0	2348	0	0	2348	81.2	23.0	9810	0.47	4.6	4.8	9.4	12	0.00	8.0	22.10
duvhCW	Duvha (1-3)	1725	3	100	5.0	10.0	12920	0	0	12920	85.5	128	9940	0.40	4.0	4.8	8.8	5	0.00	0.0	113.39
duv1CW	Duvha (4-6)	1725	3	100	5.0	10.0	12920	0	0	12920	85.5	128	9940	0.40	4.0	4.8	8.8	6	0.00	8.0	113.39
hendCM	Hendrina	1900	10	100	5.0	10.0	14231	0	0	14231	85.5	146	10290	0.37	3.8	4.8	8.6	3	0.00	7.3	122.49
kendCW	Kendal	3840	6	100	5.0	10.0	28330	82	0	28412	84.5	284	10009	0.44	4.4	4.8	9.2	9	2.66	8.5	261.51
krieCW	Kriel	2850	6	99.1	5.0	10.0	21080	61	0	21141	84.7	207	9782	0.45	4.4	4.8	9.2	10	0.52	8.2	194.54
lethCW	Lethabo	3558	6	100	5.0	10.0	26645	2	0	26647	85.5	262	9820	0.44	4.3	4.8	9.1	8	0.00	8.1	243.04
maj1CW	Majuba Units 1-3	1836	3	100	5.0	10.0	12941	79	0	13020	81.0	132	10112	0.70	7.1	4.8	11.9	20	3.33	10.4	154.66
maj2CW	Majuba Units 4-6	2007	3	100	5.0	10.0	13840	91	0	13931	79.2	142	10158	0.70	7.1	4.8	11.9	19	4.11	10.4	165.92
matiCW	Matimba	3690	6	100	5.0	10.0	27612	25	0	27637	85.5	283	10240	0.40	4.1	4.8	8.9	7	0.07	8.1	245.86
mat1CW	Matla	3450	6	100	5.0	10.0	25840	0	0	25840	85.5	249	9650	0.40	3.9	4.8	8.7	4	0.00	7.9	223.77
tutuCW	Tutuka	3510	6	100	5.0	10.0	25306	128	0	25434	82.7	248	9750	0.54	5.3	4.8	10.1	17	4.53	9.1	255.99
koebCW	Koeberg	1840	2	-M-	10.0	20.0	11510	5	0	11515	71.4	133	11577	0.33	3.8	8.0	11.8	1	0.26	10.9	135.65
collHE	Colly Wobbles	42	1		0.0	0.0	165	0	0	165	44.8				0.0	1.0	1.0	172	0.25	45.6	0.16
	{Run of river}	{ 8}					{ 74}	{ 0}	{ 0}	{ 74	100}								{ 0.00}		
	{Pondage}	{ 34}					{ 91}		{ 0}	{ 91	31.0}								{ 0.25}		
gariHE	Gariep	360	1		0.0	0.0	723	0	0	723	22.9				0.0	1.0	1.0	172	1.78	50.2	0.72
	{Run of river}	{ 18}					{ 158}	{ 0}	{ 0}	{ 158	100}								{ 0.00}		
	{Pondage}	{ 342}					{ 565}		{ 0}	{ 565	18.9}								{ 1.78}		
vandHE	Vanderkloof	240	1		0.0	0.0	741	0	0	741	35.2				0.0	1.0	1.0	172	1.45	51.5	0.74
	{Run of river}	{ 24}					{ 210}	{ 0}	{ 0}	{ 210	100}								{ 0.00}		
	{Pondage}	{ 216}					{ 530}		{ 0}	{ 530	28.0}								{ 1.45}		
ehydHE	ESKOM Small Hydro	19	1		0.0	0.0	42	0	0	42	25.2				0.0	1.0	1.0	173	0.08	78.1	0.04
	{Run of river}	{ 4}					{ 35}	{ 0}	{ 0}	{ 35	100}								{ 0.00}		
	{Pondage}	{ 15}					{ 7}		{ 0}	{ 7	5.3}								{ 0.08}		
acacCP	Acacia	171	3		10.0	5.0	51	0	0	51	3.4	0.6	12000	6.99	83.8	8.2	92.0	177	0.39	92.0	4.68
ptrxCP	Port Rex	171	3		5.0	5.0	46	0	0	46	3.1	0.6	12000	6.99	83.8	8.2	92.0	178	0.38	92.0	4.26
rooiCW	Rooiwal	300	1	99.8	10.0	10.0	1893	15	0	1908	72.6	20.1	10527	0.76	8.0	4.8	12.8	25	0.65	11.1	24.46
roggCP	Roggebaai	40	1		10.0	5.0	10	0	0	10	2.7	0.1	12000	6.99	83.8	8.2	92.0	179	0.08	92.0	0.88
athgCP	Athlone - gas	120	3		10.0	5.0	27	0	0	27	2.6	0.3	12000	6.99	83.8	8.2	92.0	180	0.23	92.0	2.49
portCP	Port Elizabeth	20	1		10.0	5.0	4	0	0	4	2.4	0.1	12000	6.99	83.8	8.2	92.0	181	0.04	92.0	0.39
johaCP	Johannesburg	160	1		10.0	5.0	32	0	0	32	2.3	0.4	12000	6.99	83.8	8.2	92.0	182	0.27	92.0	2.92
pretCP	Pretoria West-gas	24	1		10.0	5.0	4	0	0	4	1.7	0.0	12000	6.99	83.8	8.2	92.0	183	0.02	92.0	0.33
mhydHE	Municipal Hydro (	7	1		0.0	0.0	23	0	0	23	37.5				0.0	1.0	1.0	172	0.03	70.5	0.02
	{Run of river}	{ 2}					{ 18}	{ 0}	{ 0}	{ 18	100}								{ 0.00}		
	{Pondage}	{ 5}					{ 5}		{ 0}	{ 5	12.5}								{ 0.03}		
maidCM	Maidstone Mill	29	1	94.5	10.0	10.0	194	0	0	194	76.5	2.3	11800	0.00	0.0	4.8	4.8	2	0.00	0.0	0.93
sassCW	Sasol Synth Fuels	600	1	100	10.0	10.0	3844	30	0	3873	73.7	38.7	9998	0.76	7.6	4.8	12.4	21	1.28	10.7	48.10
sascCM	Sasol Chem Ind	128	1	99.8	10.0	10.0	801	7	0	808	72.0	8.5	10544	0.76	8.0	4.8	12.8	26	0.28	11.1	10.37
coagCW	Generic Coal	4445	7	98.7	5.0	10.0	22523	252	0	22775	58.5	241	10583	0.74	7.8	4.8	12.6	23	17.05	11.9	287.72
coa1CW	Generic Coal 100	100	1	89.4	5.0	10.0	361	13	0	374	42.7	4.0	10809	0.74	8.0	4.8	12.8	22	0.41	11.9	4.79
coa5CW	Generic Coal 500	535	1	87.8	5.0	10.0	1805	70	0	1874	40.0	20.3	10817	0.74	8.0	4.8	12.8	24	2.21	12.0	24.01
gtueCP	New Gas Turbine (	3900	15		10.0	5.0	4899	0	0	4899	14.3	46.5	9500	6.99	66.4	8.2	74.6	173	19.73	74.6	365.35
inteEN	Interruptible Loa	745	1		0.0	0.0	0	0	0	0	0.0				0.0	0.0	0.0	0	0.00	0.0	0.00
vaneCM	Van Eck	114	4	64.3	6.0	6.0	570	0	0	570	57.1	8.8	15400	1.89	29.2	2.0	31.2	27	0.00	0.0	17.76
ruacHE	Ruacana Falls	243	1		0.0	0.0	1016	0	0	1016	47.7				0.0	1.0	1.0	170	1.45	33.4	1.02
	{Run of river}	{ 24}					{ 210}	{ 0}	{ 0}	{ 210	100}								{ 0.00}		

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{Pondage}	{ 219}					{ 806}		{ 0}	{ 806	42.0}								{ 1.45}			
walvCP Walvis Bay	24	4		5.0	4.0	8	0	0	8	3.8	0.1	11694	6.99	81.7	7.0	88.7	175	0.06	88.7	0.71
hwanCW Hwange	920	4	76.3	5.0	10.0	5206	11	0	5217	64.7	52.2	10000	0.47	4.7	4.8	9.5	13	0.05	8.6	49.56
munyCW Munyati	120	2	68.4	5.0	10.0	605	2	0	606	57.7	6.2	10301	0.47	4.8	4.8	9.6	14	0.01	8.7	5.85
haraCW Harare	136	4	66.6	5.0	10.0	663	3	0	667	56.0	7.3	11004	0.47	5.2	4.8	10.0	16	0.02	9.2	6.65
bulaCW Bulawayo	120	2	65.3	5.0	10.0	576	2	0	578	55.0	6.0	10301	0.47	4.8	4.8	9.6	15	0.01	8.7	5.57
karsHE Kariba South	666	1		0.0	0.0	2166	0	0	2166	37.1				0.0	0.0	0.0	172	3.49	48.6	0.00
{Run of river}	{ 150}					{ 1314}	{ 0}	{ 0}	{1314	100}								{ 0.00}		
{Pondage}	{ 516}					{ 852}		{ 0}	{ 852	18.8}								{ 3.49}		
kafuHE Kafue Gorge	900	1		0.0	0.0	4859	0	0	4859	61.6				0.0	0.0	0.0	170	4.24	31.3	0.00
{Run of river}	{ 300}					{ 2628}	{ 0}	{ 0}	{2628	100}								{ 0.00}		
{Pondage}	{ 600}					{ 2231}		{ 0}	{2231	42.5}								{ 4.24}		
karnHE Kariba North	600	1		0.0	0.0	2166	0	0	2166	41.2				0.0	0.0	0.0	172	3.05	48.6	0.00
{Run of river}	{ 150}					{ 1314}	{ 0}	{ 0}	{1314	100}								{ 0.00}		
{Pondage}	{ 450}					{ 852}		{ 0}	{ 852	21.6}								{ 3.05}		
vicfHE Victoria Falls	108	1		0.0	0.0	666	0	0	666	70.4				0.0	0.0	0.0	170	0.49	23.9	0.00
{Run of river}	{ 30}					{ 263}	{ 0}	{ 0}	{ 263	100}								{ 0.00}		
{Pondage}	{ 78}					{ 403}		{ 0}	{ 403	59.0}								{ 0.49}		
zahyHE Other Zambia Hydr	24	1		0.0	0.0	47	0	0	47	22.3				0.0	0.0	0.0	172	0.13	70.5	0.00
{Run of river}	{ 3}					{ 26}	{ 0}	{ 0}	{ 26	100}								{ 0.00}		
{Pondage}	{ 21}					{ 21}		{ 0}	{ 21	11.2}								{ 0.13}		
luseHE Lusemfwa	18	1		0.0	0.0	75	0	0	75	47.5				0.0	0.0	0.0	172	0.08	52.2	0.00
{Run of river}	{ 6}					{ 53}	{ 0}	{ 0}	{ 53	100}								{ 0.00}		
{Pondage}	{ 12}					{ 22}		{ 0}	{ 22	21.3}								{ 0.08}		
muluHE Mulungushi	24	1		0.0	0.0	120	0	0	120	57.1				0.0	0.0	0.0	170	0.11	39.8	0.00
{Run of river}	{ 8}					{ 70}	{ 0}	{ 0}	{ 70	100}								{ 0.00}		
{Pondage}	{ 16}					{ 50}		{ 0}	{ 50	35.6}								{ 0.11}		
zagtCP GT in Zambia	296	1		10.0	5.0	801	0	0	801	30.9	9.4	11700	6.99	81.8	8.2	90.0	176	0.84	90.0	72.03
ingaLE Inga for export	1000	1		0.0	0.0	6130	0	0	6130	70.0				0.0	0.0	0.0	170	6.07	11.8	0.00
morpCW Botswana coal	116	4	63.9	5.0	10.0	545	1	0	546	53.7	6.6	12002	0.47	5.6	4.8	10.4	18	0.01	8.9	5.70
cbasLE Cahora Bassa	1846	1		0.0	0.0	9997	0	0	9997	61.8				0.0	0.0	0.0	170	11.27	11.8	0.00
mpgtCP Maputo gas turbin	78	1		10.0	5.0	500	0	0	500	73.2	5.0	10000	6.99	69.9	8.2	78.1	174	0.08	78.1	39.07
coruLE Corumanu hydro	16	1		0.0	0.0	36	0	0	36	25.7				0.0	0.0	0.0	172	0.11	53.2	0.00
ps-1CP Drakensburg	1000	2				417			417	4.8					1.0	1.0	172	2.08	30.4	0.42
{pumping}	{1000}						{556}										170	1.66	25.8	
ps-2CP Palmiett	400	2				169			169	4.8					1.0	1.0	172	0.83	30.3	0.17
{pumping}	{ 400}						{222}										170	0.67	26.1	
ps-3CP Steenbras	180	1				73			73	4.6					1.0	1.0	172	0.37	30.7	0.07
{pumping}	{ 180}						{100}										170	0.30	25.3	

Total firm	54356	+ CS =	54356	8.3%	reserve	318261	878	0	319139	2921.1					10.4		99.53	32.0	3307.5	
Committed	54142	=	54142	7.8%		ENS	34.63		LOLP	0.004651	(1.698 days)			Energy Not Served			0.47	1000	34.63	
after MOR	54142	=	54142	7.8%		==========			Commit target	52712 MW	5.0%			Avg. Marginal Cost (RC)				36.5		
after FOR	51470	=	51470	2.5%		Load 318296 GWh			Spin. target	1255 MW	2.5%					(dispatch cost)		49.1		
Peak	(6pm Thu)		50202			Prob. of not meeting commit target: 73.8%														

Production :		Fuel	Dump	Var. O&M	ENS	VOMCST	VOMBEN	Priced Emis.	Total var-	FOMCST	FOMBEN	Total prod-
cost :		(FC)		(OM,ON)				(PE)	iable cost			uction cost
summary :	(M$)	1857.50 -	0.00 +	0.00 +	34.6 +	1449.96 -	0.00 +	0.00 =	3342.08 +	44.97 -	0.00 =	3387.05

Run 1 -- 2019 -- Simulation R.22.0.0 - Without Zambian projects, medium 9 May 00 13:25 Ver 2.13b26 p. 287

		Peak capacity MW	Units	Com-mit. %	Outage FOR %	Outage MOR %	Energy GWh Load	Pump	Dump	Total	Cap. fac. %	Fuel use PJ	Heat rate kJ/kWh	Fuel $/GJ	$/MWh Fuel	O&M	Tot.	Rank Dis-patch *	Marginal time %	Marginal cost $/MWh	Fuel +OM M$
arnoCW	Arnot	990	3	100	5.0	10.0	7415	0	0	7415	85.5	72.7	9810	0.47	4.6	4.8	9.4	2	0.00	8.0	69.78
arn1CW	Arnot - Reserve	330	1	100	5.0	10.0	2472	0	0	2472	85.5	24.2	9810	0.47	4.6	4.8	9.4	3	0.00	8.0	23.26
duvhCW	Duvha (1-3)	1725	3	100	5.0	10.0	12920	0	0	12920	85.5	128	9940	0.40	4.0	4.8	8.8	4	0.00	0.0	113.39
duv1CW	Duvha (4-6)	1725	3	100	5.0	10.0	12920	0	0	12920	85.5	128	9940	0.40	4.0	4.8	8.8	5	0.00	8.0	113.39
hendCM	Hendrina	1900	10	100	5.0	10.0	14231	0	0	14231	85.5	146	10290	0.37	3.8	4.8	8.6	6	0.00	7.3	122.49
kendCW	Kendal	3840	6	100	5.0	10.0	28634	59	0	28692	85.3	287	9994	0.44	4.4	4.8	9.2	7	0.78	8.5	263.89
krieCW	Kriel	2850	6	100	5.0	10.0	21328	11	0	21340	85.5	209	9781	0.45	4.4	4.8	9.2	8	0.11	8.2	196.35
lethCW	Lethabo	3558	6	100	5.0	10.0	26649	0	0	26649	85.5	262	9820	0.44	4.3	4.8	9.1	9	0.00	8.1	243.06
maj1CW	Majuba Units 1-3	1836	3	100	5.0	10.0	13435	19	0	13454	83.7	135	10044	0.70	7.0	4.8	11.8	10	1.53	10.4	159.18
maj2CW	Majuba Units 4-6	2007	3	100	5.0	10.0	14527	35	0	14563	82.8	147	10064	0.70	7.0	4.8	11.8	11	2.10	10.4	172.49
matiCW	Matimba	3690	6	100	5.0	10.0	27634	4	0	27637	85.5	283	10240	0.40	4.1	4.8	8.9	12	0.01	8.1	245.86
matlCW	Matla	3450	6	100	5.0	10.0	25840	0	0	25840	85.5	249	9650	0.40	3.9	4.8	8.7	13	0.00	7.9	223.77
tutuCW	Tutuka	3510	6	100	5.0	10.0	25944	34	0	25978	84.5	252	9711	0.54	5.2	4.8	10.0	14	1.95	9.1	260.92
koebCW	Koeberg	1840	2	-M-	10.0	20.0	11561	1	0	11562	71.7	134	11566	0.33	3.9	8.0	11.9	1	0.17	11.0	137.04
collHE	Colly Wobbles	42	1		0.0	0.0	165	0	0	165	44.8				0.0	1.0	1.0	173	0.21	59.4	0.16
	{Run of river}	{ 8}					{ 74}	{ 0}	{ 0}	{ 74	100}								{ 0.00}		
	{Pondage}	{ 34}					{ 91}		{ 0}	{ 91	31.0}								{ 0.21}		
gariHE	Gariep	360	1		0.0	0.0	723	0	0	723	22.9				0.0	1.0	1.0	173	1.60	58.7	0.72
	{Run of river}	{ 18}					{ 158}	{ 0}	{ 0}	{ 158	100}								{ 0.00}		
	{Pondage}	{ 342}					{ 565}		{ 0}	{ 565	18.9}								{ 1.60}		
vandHE	Vanderkloof	240	1		0.0	0.0	741	0	0	741	35.2				0.0	1.0	1.0	173	1.17	56.4	0.74
	{Run of river}	{ 24}					{ 210}	{ 0}	{ 0}	{ 210	100}								{ 0.00}		
	{Pondage}	{ 216}					{ 530}		{ 0}	{ 530	28.0}								{ 1.17}		
ehydHE	ESKOM Small Hydro	19	1		0.0	0.0	42	0	0	42	25.2				0.0	1.0	1.0	173	0.07	81.5	0.04
	{Run of river}	{ 4}					{ 35}	{ 0}	{ 0}	{ 35	100}								{ 0.00}		
	{Pondage}	{ 15}					{ 7}		{ 0}	{ 7	5.3}								{ 0.07}		
acacCP	Acacia	171	3		10.0	5.0	38	0	0	38	2.5	0.5	12000	7.27	87.3	8.2	95.5	175	0.34	95.5	3.62
ptrxCP	Port Rex	171	3		5.0	5.0	34	0	0	34	2.3	0.4	12000	7.27	87.3	8.2	95.5	176	0.31	95.5	3.22
roggCP	Roggebaai	40	1		10.0	5.0	7	0	0	7	2.0	0.1	12000	7.27	87.3	8.2	95.5	177	0.06	95.5	0.65
athgCP	Athlone - gas	120	3		10.0	5.0	20	0	0	20	1.9	0.2	12000	7.27	87.3	8.2	95.5	178	0.18	95.5	1.86
portCP	Port Elizabeth	20	1		10.0	5.0	3	0	0	3	1.8	0.0	12000	7.27	87.3	8.2	95.5	179	0.03	95.5	0.29
johaCP	Johannesburg	160	1		10.0	5.0	24	0	0	24	1.7	0.3	12000	7.27	87.3	8.2	95.5	180	0.23	95.5	2.33
pretCP	Pretoria West-gas	24	1		10.0	5.0	3	0	0	3	1.6	0.0	12000	7.27	87.3	8.2	95.5	181	0.02	95.5	0.31
mhydHE	Municipal Hydro (	7	1		0.0	0.0	23	0	0	23	37.5				0.0	1.0	1.0	173	0.03	78.8	0.02
	{Run of river}	{ 2}					{ 18}	{ 0}	{ 0}	{ 18	100}								{ 0.00}		
	{Pondage}	{ 5}					{ 5}		{ 0}	{ 5	12.5}								{ 0.03}		
maidCM	Maidstone Mill	29	1	100	10.0	10.0	206	0	0	206	81.0	2.4	11800	0.00	0.0	4.8	4.8	15	0.00	0.0	0.99
sassCW	Sasol Synth Fuels	600	1	100	10.0	10.0	4078	11	0	4089	77.8	40.4	9882	0.78	7.7	4.8	12.5	16	0.74	10.9	51.04
sascCM	Sasol Chem Ind	128	1	100	10.0	10.0	864	1	0	865	77.2	9.0	10399	0.78	8.1	4.8	12.9	17	0.17	11.3	11.15
coagCW	Generic Coal	10160	16	98.1	5.0	10.0	57651	9	0	57660	64.8	605	10484	0.76	7.9	4.8	12.7	18	32.82	12.1	733.24
coalCW	Generic Coal 100	100	1	74.7	5.0	10.0	297	0	0	297	33.9	3.2	10886	0.76	8.2	4.8	13.0	19	0.29	12.1	3.86
coa5CW	Generic Coal 500	535	1	76.6	5.0	10.0	1562	0	0	1562	33.3	17.0	10878	0.76	8.2	4.8	13.0	20	1.65	12.1	20.33
gtueCP	New Gas Turbine (	4940	19		10.0	5.0	6573	0	0	6573	15.2	62.4	9500	7.27	69.1	8.2	77.3	173	23.31	77.3	507.94
inteEN	Interruptible Loa	745	1		0.0	0.0	0	0	0	0	0.0				0.0	0.0	0.0	0	0.00	0.0	0.00
vaneCM	Van Eck	114	4	63.0	6.0	6.0	560	0	0	560	56.1	8.6	15400	1.93	29.8	2.0	31.8	21	0.00	0.0	17.79
ruacHE	Ruacana Falls	243	1		0.0	0.0	1016	0	0	1016	47.7				0.0	1.0	1.0	172	1.27	44.5	1.02
	{Run of river}	{ 24}					{ 210}	{ 0}	{ 0}	{ 210	100}								{ 0.00}		
	{Pondage}	{ 219}					{ 806}		{ 0}	{ 806	42.0}								{ 1.27}		

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walvCP Walvis Bay          24  4       5.0  4.0     7    0    0     7  3.2  0.1 11694  7.27 85.0  7.0 92.0      174  0.06 92.0   0.62
hwanCW Hwange             920  4 54.9  5.0 10.0  3841    0    0  3841 47.7 38.4 10000  0.47  4.7  4.8  9.5       22  0.00  0.0  36.49
munyCW Munyati            120  2 44.2  5.0 10.0   407    0    0   407 38.7  4.2 10300  0.47  4.8  4.8  9.6       23  0.00  8.7   3.92
haraCW Harare             136  4 42.4  5.0 10.0   443    0    0   443 37.2  4.9 11000  0.47  5.2  4.8 10.0       24  0.00  0.0   4.42
bulaCW Bulawayo           120  2 41.0  5.0 10.0   379    0    0   379 36.0  3.9 10300  0.47  4.8  4.8  9.6       25  0.00  8.7   3.65
karsHE Kariba South       666  1       0.0  0.0  2166    0    0  2166 37.1                     0.0  0.0  0.0      173  3.08 58.1   0.00
       {Run of river}   { 150}                  { 1314}{  0}{ 0}{1314  100}                                        { 0.00}
       {Pondage}        { 516}                  {  852}     { 0}{  852 18.9}                                        { 3.08}
kafuHE Kafue Gorge        900  1       0.0  0.0  4859    0    0  4859 61.6                     0.0  0.0  0.0      171  3.68 32.2   0.00
       {Run of river}   { 300}                  { 2628}{  0}{ 0}{2628  100}                                        { 0.00}
       {Pondage}        { 600}                  { 2231}     { 0}{2231 42.4}                                        { 3.68}
karnHE Kariba North       600  1       0.0  0.0  2166    0    0  2166 41.2                     0.0  0.0  0.0      173  2.68 58.1   0.00
       {Run of river}   { 150}                  { 1314}{  0}{ 0}{1314  100}                                        { 0.00}
       {Pondage}        { 450}                  {  852}     { 0}{  852 21.6}                                        { 2.68}
vicfHE Victoria Falls     108  1       0.0  0.0   666    0    0   666 70.4                     0.0  0.0  0.0      172  0.45 40.3   0.00
       {Run of river}   {  30}                  {  263}{  0}{ 0}{  263  100}                                        { 0.00}
       {Pondage}        {  78}                  {  403}     { 0}{  403 59.0}                                        { 0.45}
zahyHE Other Zambia Hydr   24  1       0.0  0.0    47    0    0    47 22.3                     0.0  0.0  0.0      173  0.11 78.8   0.00
       {Run of river}   {   3}                  {   26}{  0}{ 0}{   26  100}                                        { 0.00}
       {Pondage}        {  21}                  {   21}     { 0}{   21 11.3}                                        { 0.11}
luseHE Lusemfwa           18  1       0.0  0.0    75    0    0    75 47.5                     0.0  0.0  0.0      173  0.07 61.2   0.00
       {Run of river}   {   6}                  {   53}{  0}{ 0}{   53  100}                                        { 0.00}
       {Pondage}        {  12}                  {   22}     { 0}{   22 21.3}                                        { 0.07}
muluHE Mulungushi         24  1       0.0  0.0   120    0    0   120 57.0                     0.0  0.0  0.0      171  0.10 51.8   0.00
       {Run of river}   {   8}                  {   70}{  0}{ 0}{   70  100}                                        { 0.00}
       {Pondage}        {  16}                  {   50}     { 0}{   50 35.6}                                        { 0.10}
zagtCP GT in Zambia       296  1      10.0  5.0  1104    0    0  1104 42.6 12.9 11700  7.27 85.1  8.2 93.3      172  0.86 93.3 102.98
ingaLE Inga for export   1000  1       0.0  0.0  6130    0    0  6130 70.0                     0.0  0.0  0.0      169  5.16 12.1   0.00
morpCW Botswana coal      116  4 39.4  5.0 10.0   353    0    0   353 34.8  4.2 12000  0.47  5.6  4.8 10.4       26  0.00  0.0   3.69
cbasLE Cahora Bassa      1846  1       0.0  0.0  9998    0    0  9998 61.8                     0.0  0.0  0.0      169  9.52 12.1   0.00
mpgtCP Maputo gas turbin   78  1      10.0  5.0   583    1    0   584 85.5  5.8 10000  7.27 72.7  8.2 80.9      152  0.00 80.9  47.27
coruLE Corumanu hydro      16  1       0.0  0.0    36    0    0    36 25.7                     0.0  0.0  0.0      173  0.10 62.7   0.00
ps-1CP Drakensburg       1000  2                   87                 87  1.0                          1.0  1.0      181  0.95 13.5   0.09
       {pumping}        {1000}                     {116}                                                           163  0.65 10.2
ps-2CP Palmiett           400  2                   35                 35  1.0                          1.0  1.0      181  0.38 13.4   0.04
       {pumping}        { 400}                     { 47}                                                           163  0.26 10.2
ps-3CP Steenbras          180  1                   15                 15  1.0                          1.0  1.0      181  0.17 13.9   0.02
       {pumping}        { 180}                     { 21}                                                           163  0.12 10.2
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Total firm 60811 + CS = 60811  8.8% reserve    353658  184    0 353842   3281.1                      11.0          99.59 34.5 3909.4
Committed  60576      = 60576  8.3%       ENS      30.86       LOLP      0.004089 ( 1.493 days)  Energy Not Served  0.41 1000  30.86
after MOR  60576      = 60576  8.3%       ==================   Commit target 58712 MW  5.0%      Avg. Marginal Cost (RC) 38.4
after FOR  57546      = 57546  2.9%       Load 353689 GWh      Spin. target   1398 MW  2.5%              (dispatch cost) 49.8
Peak         ( 6pm Thu) 55916             Prob. of not meeting commit target: 70.2%

Production :                Fuel   Dump  Var. O&M   ENS     VOMCST    VOMBEN Priced Emis. Total var-    FOMCST    FOMBEN  Total prod-
     cost :                 (FC)          (OM,ON)                              (PE)      iable cost                          uction cost
  summary :   (M$)       2283.84 - 0.00 +   0.00 + 30.9 + 1625.53 -    0.00 +    0.00   =   3940.23 +   44.97 -    0.00 =     3985.20

Run  1 -- 2005 --  Simulation R.22.1.0-With Kafue Gorge Lower, medium load                 9 May 00  14:02  Ver 2.13b26  p.   79
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		Peak capacity MW	week	Units	Com-mit. %	-Outage- FOR %	MOR %	------Energy------- GWh Load	Pump	Dump	Total	Cap. fac. %	Fuel use PJ	Heat rate kJ/kWh	Fuel $/ GJ	-------$/MWh----- Fuel	O&M	Tot.	Rank • Dis-patch	-Marginal- time %	cost $/MWh	Fuel +OM M$
arnoCW	Arnot	990		3	100	5.0	10.0	7414	1	0	7415	85.5	72.7	9810	0.47	4.6	4.8	9.4	11	0.00	8.0	69.78
arn1CW	Arnot - Reserve	330		1	100	5.0	10.0	2471	0	0	2472	85.5	24.2	9810	0.47	4.6	4.8	9.4	12	0.00	8.0	23.26
duvhCW	Duvha (1-3)	1725		3	100	5.0	10.0	12920	0	0	12920	85.5	128	9940	0.40	4.0	4.8	8.8	6	0.00	7.3	113.39
duv1CW	Duvha (4-6)	1725		3	100	5.0	10.0	12913	7	0	12920	85.5	128	9940	0.40	4.0	4.8	8.8	5	0.00	8.0	113.38
hendCM	Hendrina	1900		10	100	5.0	10.0	14231	0	0	14231	85.5	146	10290	0.37	3.8	4.8	8.6	3	0.00	7.3	122.49
kendCW	Kendal	3840		6	100	5.0	10.0	24660	0	0	24660	73.3	253	10249	0.44	4.5	4.8	9.3	9	13.89	8.5	229.57
krieCW	Kriel	2850		6	100	5.0	10.0	20448	28	0	20476	82.0	202	9871	0.45	4.4	4.8	9.2	10	5.88	8.2	189.23
lethCW	Lethabo	3558		6	100	5.0	10.0	26565	49	0	26613	85.4	261	9823	0.44	4.3	4.8	9.1	8	0.73	8.1	242.77
maj1CW	Majuba Units 1-3	1836		3	58.3	5.0	10.0	4879	0	0	4879	30.3	55.2	11323	0.70	7.9	4.8	12.7	21	4.12	10.4	62.09
maj2CW	Majuba Units 4-6	2007		3	59.2	5.0	10.0	4987	0	0	4987	28.4	57.9	11603	0.70	8.1	4.8	12.9	20	3.70	10.4	64.45
matiCW	Matimba	3690		6	100	5.0	10.0	27169	62	0	27231	84.2	280	10268	0.40	4.1	4.8	8.9	7	3.78	8.1	242.56
matlCW	Matla	3450		6	96.4	5.0	10.0	24890	0	0	24890	82.4	240	9650	0.40	3.9	4.8	8.7	4	0.00	7.9	215.55
tutuCW	Tutuka	3510		6	76.1	5.0	10.0	12227	0	0	12227	39.8	132	10783	0.54	5.8	4.8	10.6	17	10.87	9.1	129.88
koebCW	Koeberg	1840		2	-M-	10.0	20.0	11200	0	0	11200	69.5	131	11653	0.31	3.6	8.0	11.6	1	0.14	10.8	130.15
collHE	Colly Wobbles	42		1		0.0	0.0	165	0	0	165	44.8				0.0	1.0	1.0	164	0.35	9.2	0.16
	{Run of river}	{ 8}						{ 74}	{ 0}	{ 0}	{ 74	100}								{ 0.00}		
	{Pondage}	{ 34}						{ 91}		{ 0}	{ 91	31.0}								{ 0.35}		
gariHE	Gariep	360		1		0.0	0.0	723	0	0	723	22.9				0.0	1.0	1.0	164	2.57	9.8	0.72
	{Run of river}	{ 18}						{ 158}	{ 0}	{ 0}	{ 158	100}								{ 0.00}		
	{Pondage}	{ 342}						{ 565}		{ 0}	{ 565	18.9}								{ 2.57}		
vandHE	Vanderkloof	240		1		0.0	0.0	740	0	0	740	35.2				0.0	1.0	1.0	164	2.03	9.4	0.74
	{Run of river}	{ 24}						{ 210}	{ 0}	{ 0}	{ 210	100}								{ 0.00}		
	{Pondage}	{ 216}						{ 530}		{ 0}	{ 530	28.0}								{ 2.03}		
ehydHE	ESKOM Small Hydro	19		1		0.0	0.0	42	0	0	42	25.2				0.0	1.0	1.0	166	0.09	10.3	0.04
	{Run of river}	{ 4}						{ 35}	{ 0}	{ 0}	{ 35	100}								{ 0.00}		
	{Pondage}	{ 15}						{ 7}		{ 0}	{ 7	5.2}								{ 0.09}		
acacCP	Acacia	171		3		10.0	5.0	11	0	0	11	0.7	0.1	12000	6.33	75.9	8.2	84.1	180	0.13	84.1	0.91
ptrxCP	Port Rex	171		3		5.0	5.0	10	0	0	10	0.7	0.1	12000	6.33	75.9	8.2	84.1	181	0.12	84.1	0.83
krooCM	Kroonstad	30		1	72.6	10.0	10.0	49	0	0	49	18.7	0.6	12858	0.72	9.3	4.8	14.1	19	0.02	12.2	0.69
swarCM	Swartkops	240		1	50.2	10.0	10.0	450	0	0	450	21.4	5.5	12153	0.72	8.8	4.8	13.6	24	0.18	10.8	6.13
bloeCM	Bloemfontein	102		1	49.4	10.0	10.0	187	0	0	187	20.9	2.3	12391	0.72	9.0	4.8	13.8	28	0.06	11.0	2.57
kelvCW	Kelvin	600		1	53.7	10.0	10.0	1239	0	0	1239	23.6	14.3	11534	0.72	8.4	4.8	13.2	22	0.72	10.5	16.30
rooiCW	Rooiwal	300		1	50.2	10.0	10.0	561	0	0	561	21.4	6.8	12162	0.72	8.8	4.8	13.6	25	0.21	10.8	7.64
precCM	Pretoria West-coa	180		1	50.2	10.0	10.0	336	0	0	336	21.3	4.1	12174	0.72	8.8	4.8	13.6	26	0.12	10.8	4.58
roggCP	Roggebaai	40		1		10.0	5.0	2	0	0	2	0.6	0.0	12000	6.33	75.9	8.2	84.1	182	0.02	84.1	0.16
athgCP	Athlone - gas	120		3		10.0	5.0	5	0	0	5	0.5	0.1	12000	6.33	75.9	8.2	84.1	183	0.07	84.1	0.46
portCP	Port Elizabeth	20		1		10.0	5.0	1	0	0	1	0.5	0.0	12000	6.33	75.9	8.2	84.1	184	0.01	84.1	0.07
johaCP	Johannesburg	160		1		10.0	5.0	7	0	0	7	0.5	0.1	12000	6.33	75.9	8.2	84.1	185	0.08	84.1	0.56
pretCP	Pretoria West-gas	24		1		10.0	5.0	1	0	0	1	0.4	0.0	12000	6.33	75.9	8.2	84.1	186	0.01	84.1	0.07
mhydHE	Municipal Hydro (	7		1		0.0	0.0	23	0	0	23	37.5				0.0	1.0	1.0	164	0.04	9.8	0.02
	{Run of river}	{ 2}						{ 18}	{ 0}	{ 0}	{ 18	100}								{ 0.00}		
	{Pondage}	{ 5}						{ 5}		{ 0}	{ 5	12.5}								{ 0.04}		
maidCM	Maidstone Mill	29		1	75.5	10.0	10.0	153	0	0	153	60.1	1.8	11800	0.00	0.0	4.8	4.8	2	0.00	0.0	0.73
sassCW	Sasol Synth Fuels	600		1	53.7	10.0	10.0	1222	0	0	1222	23.2	14.2	11587	0.72	8.4	4.8	13.2	23	0.59	10.5	16.12
sascCM	Sasol Chem Ind	128		1	50.2	10.0	10.0	238	0	0	238	21.2	2.9	12185	0.72	8.8	4.8	13.6	27	0.08	10.8	3.25
inteEN	Interruptible Loa	745		1		0.0	0.0	0	0	0	0	0.0				0.0	0.0	0.0	0	0.00	0.0	0.00
vaneCM	Van Eck	114		4	5.0	6.0	6.0	44	0	0	44	4.4	0.7	15400	1.80	27.7	2.0	29.7	29	0.00	0.0	1.30
ruacHE	Ruacana Falls	243		1		0.0	0.0	1016	0	0	1016	47.7				0.0	1.0	1.0	164	1.97	9.2	1.02
	{Run of river}	{ 24}						{ 210}	{ 0}	{ 0}	{ 210	100}								{ 0.00}		
	{Pondage}	{ 219}						{ 806}		{ 0}	{ 806	42.0}								{ 1.97}		

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walvCP Walvis Bay          24  4       5.0  4.0     2    0   0     2  0.9  0.0 11694  6.33 74.0  7.0 81.0      178  0.02 81.0   0.16
hwanCW Hwange             920  4 75.5  5.0 10.0  3814    0   0  3814 47.3 40.5 10626  0.47  5.0  4.8  9.8       13  2.90  8.6  37.35
munyCW Munyati             60  1 75.5  5.0 10.0   244    0   0   244 46.4  2.7 11038  0.47  5.2  4.8 10.0       15  0.18  8.7   2.43
haraCW Harare             102  3 75.5  5.0 10.0   293    0   0   293 32.8  3.7 12475  0.47  5.9  4.8 10.7       16  0.30  9.2   3.13
bulaCW Bulawayo            60  1 75.5  5.0 10.0   243    0   0   243 46.3  2.7 11042  0.47  5.2  4.8 10.0       14  0.18  8.7   2.43
karsHE Kariba South       666  1       0.0  0.0  2165    0   0  2165 37.1                    0.0  0.0  0.0      164  4.88  9.6   0.00
       {Run of river}   { 150}                  { 1314}{  0}{ 0}{1314  100}                                      { 0.00}
       {Pondage}        { 516}                  {  851}     { 0}{ 851 18.8}                                      { 4.88}
kafuHE Kafue Gorge        900  1       0.0  0.0  4858    0   0  4858 61.6                    0.0  0.0  0.0      164  5.74  9.1   0.00
       {Run of river}   { 300}                  { 2628}{  0}{ 0}{2628  100}                                      { 0.00}
       {Pondage}        { 600}                  { 2230}     { 0}{2230 42.4}                                      { 5.74}
karnHE Kariba North       600  1       0.0  0.0  2165    0   0  2165 41.2                    0.0  0.0  0.0      164  4.26  9.6   0.00
       {Run of river}   { 150}                  { 1314}{  0}{ 0}{1314  100}                                      { 0.00}
       {Pondage}        { 450}                  {  851}     { 0}{ 851 21.6}                                      { 4.26}
vicfHE Victoria Falls     108  1       0.0  0.0   666    0   0   666 70.4                    0.0  0.0  0.0      164  0.66  8.9   0.00
       {Run of river}   {  30}                  {  263}{  0}{ 0}{ 263  100}                                      { 0.00}
       {Pondage}        {  78}                  {  403}     { 0}{ 403 59.0}                                      { 0.66}
zahyHE Other Zambia Hydr   24  1       0.0  0.0    47    0   0    47 22.3                    0.0  0.0  0.0      164  0.18  9.9   0.00
       {Run of river}   {   3}                  {   26}{  0}{ 0}{  26  100}                                      { 0.00}
       {Pondage}        {  21}                  {   21}     { 0}{  21 11.2}                                      { 0.18}
luseHE Lusemfwa           18  1       0.0  0.0    75    0   0    75 47.5                    0.0  0.0  0.0      164  0.12  9.8   0.00
       {Run of river}   {   6}                  {   53}{  0}{ 0}{  53  100}                                      { 0.00}
       {Pondage}        {  12}                  {   22}     { 0}{  22 21.3}                                      { 0.12}
muluHE Mulungushi         24  1       0.0  0.0   120    0   0   120 57.0                    0.0  0.0  0.0      164  0.16  9.2   0.00
       {Run of river}   {   8}                  {   70}{  0}{ 0}{  70  100}                                      { 0.00}
       {Pondage}        {  16}                  {   50}     { 0}{  50 35.6}                                      { 0.16}
zagtCP GT in Zambia       296  1      10.0  5.0   24    0   0    24  0.9  0.3 11700  6.33 74.0  8.2 82.2      179  0.27 82.2   1.98
ingaLE Inga for export   1000  1       0.0  0.0 6130    0   0  6130 70.0                    0.0  0.0  0.0      159  8.53  8.7   0.00
morpCW Botswana coal      116  4 52.8  5.0 10.0  334    0   0   334 32.8  4.4 13135  0.47  6.2  4.8 11.0       18  0.24  8.9   3.66
cbasLE Cahora Bassa      1846  1       0.0  0.0 9996    0   0  9996 61.8                    0.0  0.0  0.0      159 15.74  8.7   0.00
mpgtCP Maputo gas turbin   78  1      10.0  5.0  114    0   0   114 16.7  1.1 10000  6.33 63.3  8.2 71.5      177  0.07 71.5   8.16
coruLE Corumanu hydro      16  1       0.0  0.0   36    0   0    36 25.6                    0.0  0.0  0.0      164  0.18  9.7   0.00
ps-1CP Drakensburg       1000  2                   59                59  0.7                         1.0  1.0      176  1.07 10.9   0.06
       {pumping}        {1000}                  { 78}
ps-2CP Palmiett           400  2                   43                43  1.2                         1.0  1.0      175  0.50 10.7   0.04
       {pumping}        { 400}                  { 57}                                                            157  0.31  8.2
ps-3CP Steenbras          180  1                    9                 9  0.6                         1.0  1.0      176  0.18 11.2   0.01
       {pumping}        { 180}                  { 12}                                                            156  0.08  8.2
-----------------------------------------------------------------------------------------------------------------------------------
Total firm 46374 + CS = 46374 21.1% reserve    245632  147   0 245779   2220.8                          8.4          99.91  9.6 2073.0
Committed  42471      = 42471 10.9%       ENS      4.76       LOLP      0.000919 ( 0.335 days)  Energy Not Served  0.09 1000   4.76
after MOR  42471      = 42471 10.9%       ==================  Commit target 40201 MW  5.0%      Avg. Marginal Cost (RC) 10.5
after FOR  40523      = 40523  5.8%       Load 245637 GWh     Spin. target    957 MW  2.5%              (dispatch cost) 11.1
Peak          ( 6pm Thu) 38287            Prob. of not meeting commit target:  0.4%

Production :                Fuel   Dump  Var. O&M   ENS      VOMCST    VOMBEN Priced Emis. Total var-    FOMCST    FOMBEN  Total prod-
      cost :                (FC)         (OM,ON)                                  (PE)     iable cost                         uction cost
   summary :   (M$)       993.73 - 0.00 +   0.00 + 4.76 + 1079.31 -    0.00 +    0.00   =   2077.80 +   44.97 -    0.00 =      2

Run  1 -- 2010 --  Simulation R.22.1.0-With Kafue Gorge Lower, medium load                 9 May 00  14:02  Ver 2.13b26  p.  152

                  Peak week Un- Com- -Outage-  ------Energy------- Cap. Fuel  Heat  Fuel -------$/MWh----- Rank -Marginal-   Fuel
                   capacity its mit. FOR  MOR          GWh          fac.  use  rate   $/ Fuel  O&M Tot. Dis-  *  time cost   +OM
```


115

	MW		%	%	%	Load	Pump	Dump	Total	%	PJ	kJ/kWh	GJ				patch	%	$/MWh	M$
arnoCW Arnot	990	3	91.2	5.0	10.0	6790	0	0	6790	78.3	66.6	9810	0.47	4.6	4.8	9.4	12	0.00	8.0	63.90
arn1CW Arnot - Reserve	330	1	90.2	5.0	10.0	2239	0	0	2240	77.5	22.0	9810	0.47	4.6	4.8	9.4	11	0.00	8.0	21.08
duvhCW Duvha (1-3)	1725	3	100	5.0	10.0	12920	0	0	12920	85.5	128	9940	0.40	4.0	4.8	8.8	6	0.00	7.3	113.39
duv1CW Duvha (4-6)	1725	3	100	5.0	10.0	12917	3	0	12920	85.5	128	9940	0.40	4.0	4.8	8.8	5	0.00	8.0	113.39
hendCM Hendrina	1900	10	100	5.0	10.0	14231	0	0	14231	85.5	146	10290	0.37	3.8	4.8	8.6	3	0.00	7.3	122.49
kendCW Kendal	3840	6	100	5.0	10.0	27301	144	0	27445	81.6	276	10065	0.44	4.4	4.8	9.2	9	6.99	8.5	253.27
krieCW Kriel	2850	6	95.3	5.0	10.0	20003	81	0	20084	80.4	197	9811	0.45	4.4	4.8	9.2	10	2.10	8.2	185.08
lethCW Lethabo	3558	6	100	5.0	10.0	26614	17	0	26631	85.4	262	9821	0.44	4.3	4.8	9.1	8	0.17	8.1	242.91
maj1CW Majuba Units 1-3	1836	3	100	5.0	10.0	10603	192	0	10795	67.1	114	10547	0.70	7.4	4.8	12.2	20	5.81	10.4	131.51
maj2CW Majuba Units 4-6	2007	3	100	5.0	10.0	10353	220	0	10573	60.1	115	10840	0.70	7.6	4.8	12.4	19	6.78	10.4	130.98
matiCW Matimba	3690	6	100	5.0	10.0	27455	74	0	27529	85.2	282	10248	0.40	4.1	4.8	8.9	7	1.41	8.1	244.98
matlCW Matla	3450	6	98.5	5.0	10.0	25474	0	0	25475	84.3	246	9650	0.40	3.9	4.8	8.7	4	0.00	7.9	220.61
tutuCW Tutuka	3510	6	97.6	5.0	10.0	21900	286	0	22186	72.2	221	9964	0.54	5.4	4.8	10.2	17	8.44	9.1	225.86
koebCW Koeberg	1840	2	-M-	10.0	20.0	11273	24	0	11297	70.1	131	11629	0.32	3.7	8.0	11.7	1	0.35	10.8	132.22
collHE Colly Wobbles	42	1		0.0	0.0	165	0	0	165	44.7				0.0	1.0	1.0	171	0.32	21.2	0.16
{Run of river}	8					74	0	0	74	100								0.00		
{Pondage}	34					91		0	91	30.9								0.32		
gariHE Gariep	360	1		0.0	0.0	723	0	0	723	22.9				0.0	1.0	1.0	172	2.33	31.9	0.72
{Run of river}	18					158	0	0	158	100								0.00		
{Pondage}	342					565		0	565	18.9								2.33		
vandHE Vanderkloof	240	1		0.0	0.0	740	0	0	740	35.2				0.0	1.0	1.0	172	1.67	29.7	0.74
{Run of river}	24					210	0	0	210	100								0.00		
{Pondage}	216					530		0	530	28.0								1.67		
ehydHE ESKOM Small Hydro	19	1		0.0	0.0	42	0	0	42	25.2				0.0	1.0	1.0	177	0.08	52.2	0.04
{Run of river}	4					35	0	0	35	100								0.00		
{Pondage}	15					7		0	7	5.3								0.08		
acacCP Acacia	171	3		10.0	5.0	23	0	0	23	1.5	0.3	12000	6.65	79.8	8.2	88.0	182	0.24	88.0	2.01
ptrxCP Port Rex	171	3		5.0	5.0	21	0	0	21	1.4	0.3	12000	6.65	79.8	8.2	88.0	183	0.23	88.0	1.85
kelvCW Kelvin	600	1	98.6	10.0	10.0	2681	123	0	2804	53.4	30.3	10790	0.74	8.0	4.8	12.8	21	1.94	10.6	35.95
rooiCW Rooiwal	300	1	96.7	10.0	10.0	1247	64	0	1311	49.9	15.0	11433	0.74	8.5	4.8	13.3	23	0.87	11.0	17.43
roggCP Roggebaai	40	1		10.0	5.0	4	0	0	4	1.2	0.1	12000	6.65	79.8	8.2	88.0	184	0.05	88.0	0.37
athgCP Athlone - gas	120	3		10.0	5.0	12	0	0	12	1.1	0.1	12000	6.65	79.8	8.2	88.0	185	0.13	88.0	1.05
portCP Port Elizabeth	20	1		10.0	5.0	2	0	0	2	1.1	0.0	12000	6.65	79.8	8.2	88.0	186	0.02	88.0	0.16
johaCP Johannesburg	160	1		10.0	5.0	15	0	0	15	1.1	0.2	12000	6.65	79.8	8.2	88.0	187	0.16	88.0	1.30
pretCP Pretoria West-gas	24	1		10.0	5.0	2	0	0	2	0.9	0.0	12000	6.65	79.8	8.2	88.0	188	0.01	88.0	0.17
mhydHE Municipal Hydro (	7	1		0.0	0.0	23	0	0	23	37.5				0.0	1.0	1.0	173	0.03	38.0	0.02
{Run of river}	2					18	0	0	18	100								0.00		
{Pondage}	5					5		0	5	12.5								0.03		
maidCM Maidstone Mill	29	1	81.3	10.0	10.0	166	0	0	166	65.2	2.0	11800	0.00	0.0	4.8	4.8	2	0.00	0.0	0.80
sassCW Sasol Synth Fuels	600	1	96.3	10.0	10.0	2541	126	0	2666	50.7	29.0	10866	0.74	8.1	4.8	12.9	22	1.85	10.6	34.33
sascCM Sasol Chem Ind	128	1	93.5	10.0	10.0	508	25	0	533	47.5	6.1	11472	0.74	8.5	4.8	13.3	24	0.34	11.0	7.10
gtueCP New Gas Turbine (	2080	8		10.0	5.0	1031	0	0	1031	5.7	9.8	9500	6.65	63.2	8.2	71.4	178	7.49	71.4	73.58
inteEN Interruptible Loa	745	1		0.0	0.0	0	0	0	0	0.0				0.0	0.0	0.0	0	0.00	0.0	0.00
vaneCM Van Eck	114	4	42.2	6.0	6.0	376	0	0	376	37.7	5.8	15400	1.85	28.4	2.0	30.4	25	0.00	0.0	11.46
ruacHE Ruacana Falls	243	1		0.0	0.0	1016	0	0	1016	47.7				0.0	1.0	1.0	171	1.58	17.4	1.02
{Run of river}	24					210	0	0	210	100								0.00		
{Pondage}	219					806		0	806	42.0								1.58		
walvCP Walvis Bay	24	4		5.0	4.0	4	0	0	4	2.1	0.1	11694	6.65	77.7	7.0	84.7	180	0.04	84.7	0.37
hwanCW Hwange	920	4	73.8	5.0	10.0	4757	46	0	4802	59.6	48.4	10075	0.47	4.7	4.8	9.5	13	1.08	8.6	45.79
munyCW Munyati	120	2	68.5	5.0	10.0	571	7	0	577	54.9	6.0	10386	0.47	4.9	4.8	9.7	14	0.13	8.7	5.59
haraCW Harare	136	4	75.3	5.0	10.0	636	15	0	652	54.7	7.3	11231	0.47	5.3	4.8	10.1	16	0.28	9.2	6.57
bulaCW Bulawayo	120	2	67.4	5.0	10.0	560	7	0	567	53.9	5.9	10385	0.47	4.9	4.8	9.7	15	0.12	8.7	5.49

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karsHE Kariba South        666  1       0.0  0.0  2165    0   0  2165 37.1                    0.0  0.0  0.0      173  4.10 23.0   0.00
       {Run of river}  { 150}                    { 1314}{  0}{ 0}{1314  100}                                      { 0.00}
       {Pondage}       { 516}                    {  851}     { 0}{ 851 18.8}                                      { 4.10}
kafuHE Kafue Gorge         900  1       0.0  0.0  4858    0   0  4858 61.6                    0.0  0.0  0.0      171  5.19 16.7   0.00
       {Run of river}  { 300}                    { 2628}{  0}{ 0}{2628  100}                                      { 0.00}
       {Pondage}       { 600}                    { 2230}     { 0}{2230 42.4}                                      { 5.19}
kaflHE Kafue Gorge Lower   450  1       0.0  0.0  3035    0   1  3035 77.0                    0.0  0.0  0.0      169  2.23  9.6   0.00
       {Run of river}  { 100}                    {  876}{  0}{ 0}{ 876  100}                                      { 0.00}
       {Pondage}       { 350}                    { 2159}     { 1}{2159 70.4}                                      { 2.23}
karnHE Kariba North        600  1       0.0  0.0  2165    0   0  2165 41.2                    0.0  0.0  0.0      173  3.58 23.0   0.00
       {Run of river}  { 150}                    { 1314}{  0}{ 0}{1314  100}                                      { 0.00}
       {Pondage}       { 450}                    {  851}     { 0}{ 851 21.6}                                      { 3.58}
vicfHE Victoria Falls      108  1       0.0  0.0   666    0   0   666 70.4                    0.0  0.0  0.0      171  0.55 13.5   0.00
       {Run of river}  {  30}                    {  263}{  0}{ 0}{ 263  100}                                      { 0.00}
       {Pondage}       {  78}                    {  403}     { 0}{ 403 59.0}                                      { 0.55}
zahyHE Other Zambia Hydr    24  1       0.0  0.0    47    0   0    47 22.3                    0.0  0.0  0.0      173  0.14 42.2   0.00
       {Run of river}  {   3}                    {   26}{  0}{ 0}{  26  100}                                      { 0.00}
       {Pondage}       {  21}                    {   21}     { 0}{  21 11.2}                                      { 0.14}
luseHE Lusemfwa            18  1       0.0  0.0    75    0   0    75 47.5                    0.0  0.0  0.0      172  0.11 21.9   0.00
       {Run of river}  {   6}                    {   53}{  0}{ 0}{  53  100}                                      { 0.00}
       {Pondage}       {  12}                    {   22}     { 0}{  22 21.3}                                      { 0.11}
muluHE Mulungushi          24  1       0.0  0.0   120    0   0   120 57.0                    0.0  0.0  0.0      171  0.15 21.5   0.00
       {Run of river}  {   8}                    {   70}{  0}{ 0}{  70  100}                                      { 0.00}
       {Pondage}       {  16}                    {   50}     { 0}{  50 35.6}                                      { 0.15}
zagtCP GT in Zambia       296  1      10.0  5.0   247    0   0   247  9.5  2.9 11700  6.65 77.8  8.2 86.0      181  0.56 86.0  21.27
ingaLE Inga for export   1000  1       0.0  0.0  6130    0   0  6130 70.0                    0.0  0.0  0.0      169  6.94  9.6   0.00
morpCW Botswana coal      116  4 63.2  5.0 10.0   507    6   0   513 50.4  6.2 12142  0.47  5.7  4.8 10.5       18  0.11  8.9   5.38
cbasLE Cahora Bassa      1846  1       0.0  0.0  9997    0   0  9997 61.8                    0.0  0.0  0.0      169 12.81  9.6   0.00
mpgtCP Maputo gas turbin   78  1      10.0  5.0   303    0   0   303 44.4  3.0 10000  6.65 66.5  8.2 74.7      179  0.28 74.7  22.63
coruLE Corumanu hydro      16  1       0.0  0.0    36    0   0    36 25.6                    0.0  0.0  0.0      172  0.15 21.6   0.00
ps-1CP Drakensburg       1000  2                   692                692  7.9                         1.0  1.0      177  3.71 27.3   0.69
       {pumping}        {1000}                       {922}                                                        164  2.52 20.8
ps-2CP Palmiett           400  2                   280                280  8.0                         1.0  1.0      177  1.48 27.1   0.28
       {pumping}        { 400}                       {369}                                                        164  1.01 21.0
ps-3CP Steenbras          180  1                   121                121  7.7                         1.0  1.0      177  0.67 27.5   0.12
       {pumping}        { 180}                       {166}                                                        164  0.45 20.4
-------------------------------------------------------------------------------------------------------------------------------------
Total firm 48506 + CS = 48506 10.4% reserve    279384 1457   1 280842   2514.1                      8.9          99.76 19.6 2506.1
Committed  47978      = 47978  9.2%       ENS      15.18       LOLP      0.002449 ( 0.894 days)  Energy Not Served  0.24 1000  15.18
after MOR  47978      = 47978  9.2%       ================   Commit target 46137 MW  5.0%      Avg. Marginal Cost (RC) 22.0
after FOR  45702      = 45702  4.0%       Load 279399 GWh    Spin. target   1098 MW  2.5%              (dispatch cost) 25.4
Peak         ( 6pm Thu) 43940             Prob. of not meeting commit target: 46.7%

Production :                Fuel   Dump  Var. O&M   ENS     VOMCST    VOMBEN Priced Emis. Total var-    FOMCST    FOMBEN  Total prod-
      cost :                (FC)          (OM,ON)                                (PE)     iable cost                        uction cost
  summary :    (M$)      1272.37 - 0.00 +   0.00 + 15.2 + 1233.73 -    0.00 +    0.00   =   2521.28 +   44.97 -    0.00 =     2566.26

Run  1 -- 2015 --  Simulation R.22.1.0-With Kafue Gorge Lower, medium load                 9 May 00  14:02  Ver 2.13b26  p.  227

                   Peak week Un- Com- -Outage-  ------Energy------- Cap. Fuel  Heat  Fuel -------$/MWh----- Rank -Marginal-   Fuel
                    capacity its mit. FOR  MOR          GWh          fac.  use  rate   $/ Fuel  O&M Tot. Dis-  •  time cost   +OM
                        MW       %    %    %   Load Pump Dump Total  %    PJ kJ/kWh  GJ                  patch      %   $/MWh  M$
arnoCW Arnot              990  3 96.4  5.0 10.0  7143    0   0  7143 82.4 70.1  9810  0.47  4.6  4.8  9.4       11  0.00  8.0  67.22
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arn1CW	Arnot - Reserve	330	1	95.1	5.0	10.0	2348	0	0	2348	81.2	23.0	9810	0.47	4.6	4.8	9.4	12	0.00	8.0	22.10
duvhCW	Duvha (1-3)	1725	3	100	5.0	10.0	12920	0	0	12920	85.5	128	9940	0.40	4.0	4.8	8.8	5	0.00	7.3	113.39
duv1CW	Duvha (4-6)	1725	3	100	5.0	10.0	12920	0	0	12920	85.5	128	9940	0.40	4.0	4.8	8.8	6	0.00	8.0	113.39
hendCM	Hendrina	1900	10	100	5.0	10.0	14231	0	0	14231	85.5	146	10290	0.37	3.8	4.8	8.6	3	0.00	7.3	122.49
kendCW	Kendal	3840	6	100	5.0	10.0	28296	87	0	28383	84.4	284	10011	0.44	4.4	4.8	9.2	9	2.61	8.5	261.26
krieCW	Kriel	2850	6	99.2	5.0	10.0	21068	47	0	21116	84.6	207	9785	0.45	4.4	4.8	9.2	10	0.60	8.2	194.33
lethCW	Lethabo	3558	6	100	5.0	10.0	26643	4	0	26647	85.5	262	9820	0.44	4.3	4.8	9.1	8	0.01	8.1	243.04
maj1CW	Majuba Units 1-3	1836	3	100	5.0	10.0	12920	90	0	13010	80.9	132	10114	0.70	7.1	4.8	11.9	20	3.18	10.4	154.56
maj2CW	Majuba Units 4-6	2007	3	100	5.0	10.0	13734	91	0	13825	78.6	141	10174	0.70	7.1	4.8	11.9	19	3.99	10.4	164.82
matiCW	Matimba	3690	6	100	5.0	10.0	27601	21	0	27622	85.5	283	10241	0.40	4.1	4.8	8.9	7	0.23	8.1	245.74
matlCW	Matla	3450	6	100	5.0	10.0	25840	0	0	25840	85.5	249	9650	0.40	3.9	4.8	8.7	4	0.00	7.9	223.77
tutuCW	Tutuka	3510	6	99.7	5.0	10.0	25197	134	0	25332	82.4	247	9751	0.54	5.3	4.8	10.1	17	4.43	9.1	254.98
koebCW	Koeberg	1840	2	-M-	10.0	20.0	11503	5	0	11508	71.4	133	11579	0.33	3.8	8.0	11.8	1	0.26	10.9	135.58
collHE	Colly Wobbles	42	1		0.0	0.0	165	0	0	165	44.8				0.0	1.0	1.0	178	0.25	49.8	0.16
	{Run of river}	{ 8}					{ 74}	{ 0}	{ 0}	{ 74	100}								{ 0.00}		
	{Pondage}	{ 34}					{ 91}		{ 0}	{ 91	31.0}								{ 0.25}		
gariHE	Gariep	360	1		0.0	0.0	723	0	0	723	22.9				0.0	1.0	1.0	179	1.74	49.8	0.72
	{Run of river}	{ 18}					{ 158}	{ 0}	{ 0}	{ 158	100}								{ 0.00}		
	{Pondage}	{ 342}					{ 565}		{ 0}	{ 565	18.9}								{ 1.74}		
vandHE	Vanderkloof	240	1		0.0	0.0	741	0	0	741	35.2				0.0	1.0	1.0	178	1.48	50.1	0.74
	{Run of river}	{ 24}					{ 210}	{ 0}	{ 0}	{ 210	100}								{ 0.00}		
	{Pondage}	{ 216}					{ 530}		{ 0}	{ 530	28.0}								{ 1.48}		
ehydHE	ESKOM Small Hydro	19	1		0.0	0.0	42	0	0	42	25.2				0.0	1.0	1.0	180	0.07	79.6	0.04
	{Run of river}	{ 4}					{ 35}	{ 0}	{ 0}	{ 35	100}								{ 0.00}		
	{Pondage}	{ 15}					{ 7}		{ 0}	{ 7	5.3}								{ 0.07}		
acacCP	Acacia	171	3		10.0	5.0	53	0	0	53	3.6	0.6	12000	6.99	83.8	8.2	92.0	184	0.42	92.0	4.91
ptrxCP	Port Rex	171	3		5.0	5.0	49	0	0	49	3.2	0.6	12000	6.99	83.8	8.2	92.0	185	0.41	92.0	4.48
rooiCW	Rooiwal	300	1	97.6	10.0	10.0	1830	15	0	1845	70.2	19.5	10555	0.76	8.0	4.8	12.8	24	0.63	11.1	23.69
roggCP	Roggebaai	40	1		10.0	5.0	10	0	0	10	2.9	0.1	12000	6.99	83.8	8.2	92.0	186	0.08	92.0	0.92
athgCP	Athlone - gas	120	3		10.0	5.0	28	0	0	28	2.7	0.3	12000	6.99	83.8	8.2	92.0	187	0.24	92.0	2.61
portCP	Port Elizabeth	20	1		10.0	5.0	4	0	0	4	2.6	0.1	12000	6.99	83.8	8.2	92.0	188	0.04	92.0	0.41
johaCP	Johannesburg	160	1		10.0	5.0	33	0	0	33	2.3	0.4	12000	6.99	83.8	8.2	92.0	189	0.29	92.0	3.01
pretCP	Pretoria West-gas	24	1		10.0	5.0	4	0	0	4	1.8	0.0	12000	6.99	83.8	8.2	92.0	190	0.02	92.0	0.35
mhydHE	Municipal Hydro (	7	1		0.0	0.0	23	0	0	23	37.5				0.0	1.0	1.0	179	0.03	72.2	0.02
	{Run of river}	{ 2}					{ 18}	{ 0}	{ 0}	{ 18	100}								{ 0.00}		
	{Pondage}	{ 5}					{ 5}		{ 0}	{ 5	12.5}								{ 0.03}		
maidCM	Maidstone Mill	29	1	91.3	10.0	10.0	188	0	0	188	74.0	2.2	11800	0.00	0.0	4.8	4.8	2	0.00	0.0	0.90
sassCW	Sasol Synth Fuels	600	1	96.7	10.0	10.0	3699	29	0	3729	70.9	37.3	10012	0.76	7.6	4.8	12.4	21	1.23	10.7	46.34
sascCM	Sasol Chem Ind	128	1	94.8	10.0	10.0	748	7	0	754	67.3	8.0	10588	0.76	8.1	4.8	12.9	25	0.27	11.1	9.71
coagCW	Generic Coal	4445	7	98.0	5.0	10.0	21850	238	0	22088	56.7	234	10606	0.74	7.9	4.8	12.7	22	17.37	11.9	279.42
coalCW	Generic Coal 100	100	1	84.7	5.0	10.0	336	14	0	351	40.0	3.8	10825	0.74	8.0	4.8	12.8	23	0.37	11.9	4.49
gtueCP	New Gas Turbine (	3900	15		10.0	5.0	5396	0	0	5396	15.8	51.3	9500	6.99	66.4	8.2	74.6	180	19.73	74.6	402.43
inteEN	Interruptible Loa	745	1		0.0	0.0	0	0	0	0	0.0				0.0	0.0	0.0	0	0.00	0.0	0.00
vaneCM	Van Eck	114	4	63.8	6.0	6.0	568	0	0	568	56.9	8.7	15400	1.89	29.2	2.0	31.2	26	0.00	0.0	17.70
ruacHE	Ruacana Falls	243	1		0.0	0.0	1016	0	0	1016	47.7				0.0	1.0	1.0	178	1.46	37.7	1.02
	{Run of river}	{ 24}					{ 210}	{ 0}	{ 0}	{ 210	100}								{ 0.00}		
	{Pondage}	{ 219}					{ 806}		{ 0}	{ 806	42.0}								{ 1.46}		
walvCP	Walvis Bay	24	4		5.0	4.0	9	0	0	9	4.1	0.1	11694	6.99	81.7	7.0	88.7	182	0.07	88.7	0.76
hwanCW	Hwange	920	4	72.7	5.0	10.0	5008	12	0	5020	62.3	50.2	10000	0.47	4.7	4.8	9.5	13	0.06	8.6	47.69
munyCW	Munyati	120	2	63.6	5.0	10.0	571	2	0	572	54.5	5.9	10301	0.47	4.8	4.8	9.6	14	0.01	8.7	5.52
haraCW	Harare	136	4	61.6	5.0	10.0	621	5	0	626	52.6	6.9	11005	0.47	5.2	4.8	10.0	16	0.02	9.2	6.25
bulaCW	Bulawayo	120	2	59.9	5.0	10.0	538	2	0	539	51.3	5.6	10301	0.47	4.8	4.8	9.6	15	0.01	8.7	5.20
karsHE	Kariba South	666	1		0.0	0.0	2166	0	0	2166	37.1				0.0	0.0	0.0	179	3.58	57.9	0.00

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        {Run of river}  { 150}                  { 1314}{   0}{ 0}{1314  100}                                    { 0.00}
        {Pondage}       { 516}                  {  852}      { 0}{ 852 18.8}                                    { 3.58}
kafuHE Kafue Gorge        900  1       0.0  0.0  4859    0    0  4859 61.6                    0.0  0.0  0.0     178  4.20 35.3   0.00
        {Run of river}  { 300}                  { 2628}{   0}{ 0}{2628  100}                                    { 0.00}
        {Pondage}       { 600}                  { 2231}      { 0}{2231 42.5}                                    { 4.20}
kaflHE Kafue Gorge Lower  450  1       0.0  0.0  3034    0    1  3035 77.0                    0.0  0.0  0.0     178  1.95 18.7   0.00
        {Run of river}  { 100}                  {  876}{   0}{ 0}{ 876  100}                                    { 0.00}
        {Pondage}       { 350}                  { 2158}      { 1}{2159 70.4}                                    { 1.95}
karnHE Kariba North       600  1       0.0  0.0  2166    0    0  2166 41.2                    0.0  0.0  0.0     179  3.12 57.9   0.00
        {Run of river}  { 150}                  { 1314}{   0}{ 0}{1314  100}                                    { 0.00}
        {Pondage}       { 450}                  {  852}      { 0}{ 852 21.6}                                    { 3.12}
vicfHE Victoria Falls     108  1       0.0  0.0   666    0    0   666 70.4                    0.0  0.0  0.0     178  0.46 23.2   0.00
        {Run of river}  {  30}                  {  263}{   0}{ 0}{ 263  100}                                    { 0.00}
        {Pondage}       {  78}                  {  403}      { 0}{ 403 59.0}                                    { 0.46}
zahyHE Other Zambia Hydr   24  1       0.0  0.0    47    0    0    47 22.3                    0.0  0.0  0.0     179  0.13 72.2   0.00
        {Run of river}  {   3}                  {   26}{   0}{ 0}{  26  100}                                    { 0.00}
        {Pondage}       {  21}                  {   21}      { 0}{  21 11.2}                                    { 0.13}
luseHE Lusemfwa           18  1       0.0  0.0    75    0    0    75 47.5                    0.0  0.0  0.0     179  0.09 56.3   0.00
        {Run of river}  {   6}                  {   53}{   0}{ 0}{  53  100}                                    { 0.00}
        {Pondage}       {  12}                  {   22}      { 0}{  22 21.3}                                    { 0.09}
muluHE Mulungushi         24  1       0.0  0.0   120    0    0   120 57.1                    0.0  0.0  0.0     178  0.11 45.5   0.00
        {Run of river}  {   8}                  {   70}{   0}{ 0}{  70  100}                                    { 0.00}
        {Pondage}       {  16}                  {   50}      { 0}{  50 35.6}                                    { 0.11}
zagtCP GT in Zambia      296  1      10.0  5.0   740    0    0   740 28.5  8.7 11700  6.99 81.8  8.2 90.0     183  0.80 90.0  66.56
ingaLE Inga for export  1000  1       0.0  0.0  6130    0    0  6130 70.0                    0.0  0.0  0.0     178  6.06 18.1   0.00
morpCW Botswana coal     116  4 58.1  5.0 10.0   500    2    0   501 49.4  6.0 12028  0.47  5.7  4.8 10.5      18  0.03  8.9   5.24
cbasLE Cahora Bassa     1846  1       0.0  0.0  9996    0    0  9996 61.8                    0.0  0.0  0.0     178 11.19 18.1   0.00
mpgtCP Maputo gas turbin  78  1      10.0  5.0   505    0    0   505 73.9  5.0 10000  6.99 69.9  8.2 78.1     181  0.08 78.1  39.43
coruLE Corumanu hydro     16  1       0.0  0.0    36    0    0    36 25.7                    0.0  0.0  0.0     179  0.11 54.0   0.00
ps-1CP Drakensburg      1000  2                   383              383  4.4                         1.0  1.0     179  2.15 29.8   0.38
        {pumping}      {1000}                      {511}                                                         178  1.66 26.3
ps-2CP Palmiett          400  2                   155              155  4.4                         1.0  1.0     179  0.86 29.7   0.15
        {pumping}       { 400}                      {204}                                                         178  0.66 26.6
ps-3CP Steenbras         180  1                    67               67  4.3                         1.0  1.0     179  0.39 30.1   0.07
        {pumping}       { 180}                      { 92}                                                         178  0.30 25.8
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Total firm 54271 + CS = 54271  8.1% reserve    318261  807   1 319068   2889.2                      10.3          99.52 34.2 3298.0
Committed  54075      = 54075  7.7%       ENS      35.01       LOLP      0.004801 ( 1.752 days)  Energy Not Served  0.48 1000  35.01
after MOR  54075      = 54075  7.7%       ================   Commit target 52712 MW  5.0%      Avg. Marginal Cost (RC) 38.8
after FOR  51429      = 51429  2.4%       Load 318296 GWh    Spin. target   1255 MW  2.5%              (dispatch cost) 49.4
Peak         ( 6pm Thu) 50202             Prob. of not meeting commit target: 75.2%

Production :                Fuel   Dump  Var. O&M   ENS     VOMCST    VOMBEN Priced Emis. Total var-    FOMCST    FOMBEN  Total prod-
      cost :                (FC)          (OM,ON)                              (PE)     iable cost                         uction cost
   summary :   (M$)      1861.24 - 0.00 +   0.00 + 35.0 + 1436.77 -    0.00 +    0.00   =   3333.01 +   44.97 -    0.00 =     3377.98
Run  1 -- 2019 --  Simulation R.22.1.0-With Kafue Gorge Lower, medium load                    9 May 00  14:02  Ver 2.13b26  p.  287

                     Peak week Un- Com- -Outage-  ------Energy-------  Cap. Fuel  Heat  Fuel -------$/MWh----- Rank -Marginal-   Fuel
                      capacity its mit. FOR  MOR          GWh          fac.  use  rate   $/ Fuel  O&M Tot. Dis-  *  time cost   +OM
                          MW       %   %    %   Load Pump Dump Total   %    PJ kJ/kWh  GJ                 patch       %   $/MWh  M$
arnoCW Arnot               990  3  100  5.0 10.0 7415    0    0  7415 85.5 72.7  9810  0.47  4.6  4.8  9.4        2  0.00  8.0  69.78
arn1CW Arnot - Reserve     330  1  100  5.0 10.0 2472    0    0  2472 85.5 24.2  9810  0.47  4.6  4.8  9.4        3  0.00  8.0  23.26
duvhCW Duvha (1-3)        1725  3  100  5.0 10.0 12920   0    0 12920 85.5  128  9940  0.40  4.0  4.8  8.8        4  0.00  7.3 113.39
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duv1CW	Duvha (4-6)	1725	3	100	5.0	10.0	12920	0	0	12920	85.5	128	9940	0.40	4.0	4.8	8.8	5	0.00	8.0	113.39
hendCM	Hendrina	1900	10	100	5.0	10.0	14231	0	0	14231	85.5	146	10290	0.37	3.8	4.8	8.6	6	0.00	7.3	122.49
kendCW	Kendal	3840	6	100	5.0	10.0	28645	57	0	28702	85.3	287	9993	0.44	4.4	4.8	9.2	7	0.82	8.5	263.97
krieCW	Kriel	2850	6	100	5.0	10.0	21332	14	0	21346	85.5	209	9780	0.45	4.4	4.8	9.2	8	0.03	8.2	196.40
lethCW	Lethabo	3558	6	100	5.0	10.0	26649	0	0	26649	85.5	262	9820	0.44	4.3	4.8	9.1	9	0.00	8.1	243.06
maj1CW	Majuba Units 1-3	1836	3	96.9	5.0	10.0	13071	16	0	13086	81.4	131	10044	0.70	7.0	4.8	11.8	10	1.53	10.4	154.83
maj2CW	Majuba Units 4-6	2007	3	99.4	5.0	10.0	14452	28	0	14480	82.4	146	10064	0.70	7.0	4.8	11.8	11	2.21	10.4	171.51
matiCW	Matimba	3690	6	100	5.0	10.0	27635	2	0	27637	85.5	283	10240	0.40	4.1	4.8	8.9	12	0.01	8.1	245.86
matlCW	Matla	3450	6	100	5.0	10.0	25840	0	0	25840	85.5	249	9650	0.40	3.9	4.8	8.7	13	0.00	8.0	223.77
tutuCW	Tutuka	3510	6	100	5.0	10.0	25954	38	0	25992	84.5	252	9710	0.54	5.2	4.8	10.0	14	1.91	9.1	261.05
koebCW	Koeberg	1840	2	-M-	10.0	20.0	11562	2	0	11564	71.7	134	11566	0.33	3.9	8.0	11.9	1	0.17	11.0	137.06
collHE	Colly Wobbles	42	1		0.0	0.0	165	0	0	165	44.8				0.0	1.0	1.0	179	0.20	53.2	0.16
	{Run of river}	{ 8}					{ 74}	{ 0}	{ 0}	{ 74	100}								{ 0.00}		
	{Pondage}	{ 34}					{ 91}		{ 0}	{ 91	31.0}								{ 0.20}		
gariHE	Gariep	360	1		0.0	0.0	723	0	0	723	22.9				0.0	1.0	1.0	179	1.61	59.2	0.72
	{Run of river}	{ 18}					{ 158}	{ 0}	{ 0}	{ 158	100}								{ 0.00}		
	{Pondage}	{ 342}					{ 566}		{ 0}	{ 566	18.9}								{ 1.61}		
vandHE	Vanderkloof	240	1		0.0	0.0	741	0	0	741	35.2				0.0	1.0	1.0	179	1.27	56.6	0.74
	{Run of river}	{ 24}					{ 210}	{ 0}	{ 0}	{ 210	100}								{ 0.00}		
	{Pondage}	{ 216}					{ 530}		{ 0}	{ 530	28.0}								{ 1.27}		
ehydHE	ESKOM Small Hydro	19	1		0.0	0.0	42	0	0	42	25.2				0.0	1.0	1.0	179	0.08	80.1	0.04
	{Run of river}	{ 4}					{ 35}	{ 0}	{ 0}	{ 35	100}								{ 0.00}		
	{Pondage}	{ 15}					{ 7}		{ 0}	{ 7	5.3}								{ 0.08}		
acacCP	Acacia	171	3		10.0	5.0	33	0	0	33	2.2	0.4	12000	7.27	87.3	8.2	95.5	182	0.30	95.5	3.13
ptrxCP	Port Rex	171	3		5.0	5.0	30	0	0	30	2.0	0.4	12000	7.27	87.3	8.2	95.5	183	0.27	95.5	2.87
roggCP	Roggebaai	40	1		10.0	5.0	6	0	0	6	1.8	0.1	12000	7.27	87.3	8.2	95.5	184	0.06	95.5	0.59
athgCP	Athlone - gas	120	3		10.0	5.0	18	0	0	18	1.7	0.2	12000	7.27	87.3	8.2	95.5	185	0.16	95.5	1.68
portCP	Port Elizabeth	20	1		10.0	5.0	3	0	0	3	1.6	0.0	12000	7.27	87.3	8.2	95.5	186	0.03	95.5	0.26
johaCP	Johannesburg	160	1		10.0	5.0	22	0	0	22	1.6	0.3	12000	7.27	87.3	8.2	95.5	187	0.21	95.5	2.09
pretCP	Pretoria West-gas	24	1		10.0	5.0	3	0	0	3	1.4	0.0	12000	7.27	87.3	8.2	95.5	188	0.02	95.5	0.28
mhydHE	Municipal Hydro (	7	1		0.0	0.0	23	0	0	23	37.5				0.0	1.0	1.0	179	0.03	78.9	0.02
	{Run of river}	{ 2}					{ 18}	{ 0}	{ 0}	{ 18	100}								{ 0.00}		
	{Pondage}	{ 5}					{ 5}		{ 0}	{ 5	12.5}								{ 0.03}		
maidCM	Maidstone Mill	29	1	100	10.0	10.0	206	0	0	206	81.0	2.4	11800	0.00	0.0	4.8	4.8	15	0.00	0.0	0.99
sassCW	Sasol Synth Fuels	600	1	95.8	10.0	10.0	3924	9	0	3932	74.8	38.9	9885	0.78	7.7	4.8	12.5	16	0.73	10.9	49.09
sascCM	Sasol Chem Ind	128	1	95.4	10.0	10.0	829	1	0	830	74.0	8.6	10401	0.78	8.1	4.8	12.9	17	0.17	11.3	10.69
coagCW	Generic Coal	10160	16	97.4	5.0	10.0	56519	283	0	56802	63.8	596	10490	0.76	7.9	4.8	12.7	18	32.39	12.1	722.57
coalCW	Generic Coal 100	100	1	69.5	5.0	10.0	265	13	0	277	31.7	3.0	10867	0.76	8.2	4.8	13.0	19	0.29	12.1	3.61
gtueCP	New Gas Turbine (	4940	19		10.0	5.0	6398	0	0	6398	14.8	60.8	9500	7.27	69.1	8.2	77.3	179	23.18	77.3	494.41
inteEN	Interruptible Loa	745	1		0.0	0.0	0	0	0	0	0.0				0.0	0.0	0.0	0	0.00	0.0	0.00
vaneCM	Van Eck	114	4	67.0	6.0	6.0	590	0	0	590	59.1	9.1	15400	1.93	29.8	2.0	31.8	20	0.00	0.0	18.75
ruacHE	Ruacana Falls	243	1		0.0	0.0	1016	0	0	1016	47.7				0.0	1.0	1.0	179	1.20	47.2	1.02
	{Run of river}	{ 24}					{ 210}	{ 0}	{ 0}	{ 210	100}								{ 0.00}		
	{Pondage}	{ 219}					{ 806}		{ 0}	{ 806	42.0}								{ 1.20}		
walvCP	Walvis Bay	24	4		5.0	4.0	6	0	0	6	2.9	0.1	11694	7.27	85.0	7.0	92.0	181	0.05	92.0	0.55
hwanCW	Hwange	920	4	59.6	5.0	10.0	4091	0	0	4091	50.8	40.9	10000	0.47	4.7	4.8	9.5	21	0.00	10.4	38.87
munyCW	Munyati	120	2	50.0	5.0	10.0	447	0	0	447	42.5	4.6	10300	0.47	4.8	4.8	9.6	22	0.00	8.7	4.31
haraCW	Harare	136	4	48.2	5.0	10.0	488	0	0	488	40.9	5.4	11000	0.47	5.2	4.8	10.0	23	0.00	0.0	4.86
bulaCW	Bulawayo	120	2	46.8	5.0	10.0	418	0	0	418	39.7	4.3	10300	0.47	4.8	4.8	9.6	24	0.00	9.2	4.03
karsHE	Kariba South	666	1		0.0	0.0	2166	0	0	2166	37.1				0.0	0.0	0.0	179	2.87	63.4	0.00
	{Run of river}	{ 150}					{ 1314}	{ 0}	{ 0}	{1314	100}								{ 0.00}		
	{Pondage}	{ 516}					{ 852}		{ 0}	{ 852	18.9}								{ 2.87}		
kafuHE	Kafue Gorge	900	1		0.0	0.0	4860	0	0	4860	61.6				0.0	0.0	0.0	177	3.48	32.2	0.00

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        {Run of river}  { 300}                  { 2628}{  0}{ 0}{2628  100}                                        { 0.00}
        {Pondage}       { 600}                  { 2232}     { 0}{2232 42.5}                                        { 3.48}
kaflHE Kafue Gorge Lower  450  1       0.0  0.0  3035    0   1  3035 77.0                   0.0  0.0  0.0      177  1.68 12.1   0.00
        {Run of river}  { 100}                  {  876}{  0}{ 0}{ 876  100}                                        { 0.00}
        {Pondage}       { 350}                  { 2159}     { 1}{2159 70.4}                                        { 1.68}
karnHE Kariba North       600  1       0.0  0.0  2166    0   0  2166 41.2                   0.0  0.0  0.0      179  2.51 63.4   0.00
        {Run of river}  { 150}                  { 1314}{  0}{ 0}{1314  100}                                        { 0.00}
        {Pondage}       { 450}                  {  852}     { 0}{ 852 21.6}                                        { 2.51}
vicfHE Victoria Falls     108  1       0.0  0.0   666    0   0   666 70.4                   0.0  0.0  0.0      179  0.45 37.4   0.00
        {Run of river}  {  30}                  {  263}{  0}{ 0}{ 263  100}                                        { 0.00}
        {Pondage}       {  78}                  {  403}     { 0}{ 403 59.0}                                        { 0.45}
zahyHE Other Zambia Hydr   24  1       0.0  0.0    47    0   0    47 22.3                   0.0  0.0  0.0      179  0.11 78.9   0.00
        {Run of river}  {   3}                  {   26}{  0}{ 0}{  26  100}                                        { 0.00}
        {Pondage}       {  21}                  {   21}     { 0}{  21 11.3}                                        { 0.11}
luseHE Lusemfwa           18  1       0.0  0.0    75    0   0    75 47.6                   0.0  0.0  0.0      179  0.07 67.0   0.00
        {Run of river}  {   6}                  {   53}{  0}{ 0}{  53  100}                                        { 0.00}
        {Pondage}       {  12}                  {   22}     { 0}{  22 21.3}                                        { 0.07}
muluHE Mulungushi         24  1       0.0  0.0   120    0   0   120 57.1                   0.0  0.0  0.0      177  0.10 44.9   0.00
        {Run of river}  {   8}                  {   70}{  0}{ 0}{  70  100}                                        { 0.00}
        {Pondage}       {  16}                  {   50}     { 0}{  50 35.6}                                        { 0.10}
zagtCP GT in Zambia      296  1      10.0  5.0   962    0   0   962 37.1 11.3 11700  7.27 85.1  8.2 93.3      180  0.80 93.3  89.71
ingaLE Inga for export  1000  1       0.0  0.0  6130    0   0  6130 70.0                   0.0  0.0  0.0      177  5.21 12.1   0.00
morpCW Botswana coal     116  4 45.6  5.0 10.0   393    0   0   393 38.6  4.7 12000  0.47  5.6  4.8 10.4       25  0.00  0.0   4.10
cbasLE Cahora Bassa     1846  1       0.0  0.0  9997    0   0  9997 61.8                   0.0  0.0  0.0      177  9.63 12.1   0.00
mpgtCP Maputo gas turbin  78  1      10.0  5.0   559    0   0   559 81.8  5.6 10000  7.27 72.7  8.2 80.9      175  0.05 80.9  45.21
coruLE Corumanu hydro     16  1       0.0  0.0    36    0   0    36 25.7                   0.0  0.0  0.0      179  0.09 62.0   0.00
ps-1CP Drakensburg      1000  2                  220              220  2.5                        1.0  1.0      188  1.35 38.7   0.22
        {pumping}      {1000}                      {293}                                                       170  0.94 30.7
ps-2CP Palmiett          400  2                   89               89  2.5                        1.0  1.0      188  0.54 38.6   0.09
        {pumping}      { 400}                      {117}                                                       170  0.38 31.1
ps-3CP Steenbras         180  1                   39               39  2.4                        1.0  1.0      188  0.24 38.9   0.04
        {pumping}      { 180}                      { 53}                                                       170  0.17 30.1
-------------------------------------------------------------------------------------------------------------------------------------
Total firm 60726 + CS = 60726  8.6% reserve    353657  463   1 354121   3250.0                      10.9          99.59 35.2 3845.5
Committed  60463      = 60463  8.1%       ENS      31.43       LOLP      0.004100 ( 1.496 days)  Energy Not Served  0.41 1000  31.43
after MOR  60463      = 60463  8.1%       ================     Commit target 58712 MW  5.0%      Avg. Marginal Cost (RC) 39.2
after FOR  57461      = 57461  2.8%       Load 353689 GWh      Spin. target   1398 MW  2.5%              (dispatch cost) 50.2
Peak         ( 6pm Thu) 55916             Prob. of not meeting commit target: 71.4%

Production :                Fuel   Dump  Var. O&M   ENS     VOMCST    VOMBEN Priced Emis. Total var-    FOMCST    FOMBEN  Total prod-
     cost :                 (FC)         (OM,ON)                                  (PE)     iable cost                        uction cost
   summary :    (M$)      2235.30 - 0.00 +   0.00 + 31.4 + 1610.21 -    0.00 +    0.00   =   3876.93 +   44.97 -    0.00 =     3921.90

Run  1 -- 2005 --  Simulation R.22.2.0-With Itezhi-tezhi, medium load, average hydrology      9 May 00  14:41  Ver 2.13b26  p.   79

                   Peak week Un- Com- -Outage-  ------Energy-------  Cap. Fuel  Heat  Fuel -------$/MWh----- Rank -Marginal-   Fuel
                    capacity its mit. FOR  MOR          GWh          fac.  use  rate   $/ Fuel  O&M Tot. Dis-  *  time cost   +OM
                       MW        %    %    %   Load Pump Dump Total   %    PJ kJ/kWh  GJ                 patch      %  $/MWh  M$
arnoCW Arnot            990  3  100  5.0 10.0  7414    1    0  7415 85.5 72.7  9810  0.47  4.6  4.8  9.4      11  0.00  8.0  69.78
arn1CW Arnot - Reserve  330  1  100  5.0 10.0  2471    0    0  2472 85.5 24.2  9810  0.47  4.6  4.8  9.4      12  0.00  8.0  23.26
duvhCW Duvha (1-3)     1725  3  100  5.0 10.0 12920    0    0 12920 85.5  128  9940  0.40  4.0  4.8  8.8       6  0.00  7.3 113.39
duv1CW Duvha (4-6)     1725  3  100  5.0 10.0 12913    7    0 12920 85.5  128  9940  0.40  4.0  4.8  8.8       5  0.00  8.0 113.38
hendCM Hendrina        1900 10  100  5.0 10.0 14231    0    0 14231 85.5  146 10290  0.37  3.8  4.8  8.6       3  0.00  7.3 122.49
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kendCW	Kendal	3840	6	100	5.0	10.0	24660	0	0	24660	73.3	253	10249	0.44	4.5	4.8	9.3	9	13.89	8.5	229.57
krieCW	Kriel	2850	6	100	5.0	10.0	20448	28	0	20476	82.0	202	9871	0.45	4.4	4.8	9.2	10	5.88	8.2	189.23
lethCW	Lethabo	3558	6	100	5.0	10.0	26565	49	0	26613	85.4	261	9823	0.44	4.3	4.8	9.1	8	0.73	8.1	242.77
maj1CW	Majuba Units 1-3	1836	3	58.3	5.0	10.0	4879	0	0	4879	30.3	55.2	11323	0.70	7.9	4.8	12.7	21	4.12	10.4	62.09
maj2CW	Majuba Units 4-6	2007	3	59.2	5.0	10.0	4987	0	0	4987	28.4	57.9	11603	0.70	8.1	4.8	12.9	20	3.70	10.4	64.45
matiCW	Matimba	3690	6	100	5.0	10.0	27169	62	0	27231	84.2	280	10268	0.40	4.1	4.8	8.9	7	3.78	8.1	242.56
matlCW	Matla	3450	6	96.4	5.0	10.0	24890	0	0	24890	82.4	240	9650	0.40	3.9	4.8	8.7	4	0.00	7.9	215.55
tutuCW	Tutuka	3510	6	76.1	5.0	10.0	12227	0	0	12227	39.8	132	10783	0.54	5.8	4.8	10.6	17	10.87	9.1	129.88
koebCW	Koeberg	1840	2	-M-	10.0	20.0	11200	0	0	11200	69.5	131	11653	0.31	3.6	8.0	11.6	1	0.14	10.8	130.15
collHE	Colly Wobbles	42	1		0.0	0.0	165	0	0	165	44.8				0.0	1.0	1.0	164	0.35	9.2	0.16
	{Run of river}	{ 8}					{ 74}	{ 0}	{ 0}	{ 74	100}								{ 0.00}		
	{Pondage}	{ 34}					{ 91}		{ 0}	{ 91	31.0}								{ 0.35}		
gariHE	Gariep	360	1		0.0	0.0	723	0	0	723	22.9				0.0	1.0	1.0	164	2.57	9.8	0.72
	{Run of river}	{ 18}					{ 158}	{ 0}	{ 0}	{ 158	100}								{ 0.00}		
	{Pondage}	{ 342}					{ 565}		{ 0}	{ 565	18.9}								{ 2.57}		
vandHE	Vanderkloof	240	1		0.0	0.0	740	0	0	740	35.2				0.0	1.0	1.0	164	2.03	9.4	0.74
	{Run of river}	{ 24}					{ 210}	{ 0}	{ 0}	{ 210	100}								{ 0.00}		
	{Pondage}	{ 216}					{ 530}		{ 0}	{ 530	28.0}								{ 2.03}		
ehydHE	ESKOM Small Hydro	19	1		0.0	0.0	42	0	0	42	25.2				0.0	1.0	1.0	166	0.09	10.3	0.04
	{Run of river}	{ 4}					{ 35}	{ 0}	{ 0}	{ 35	100}								{ 0.00}		
	{Pondage}	{ 15}					{ 7}		{ 0}	{ 7	5.2}								{ 0.09}		
acacCP	Acacia	171	3		10.0	5.0	11	0	0	11	0.7	0.1	12000	6.33	75.9	8.2	84.1	180	0.13	84.1	0.91
ptrxCP	Port Rex	171	3		5.0	5.0	10	0	0	10	0.7	0.1	12000	6.33	75.9	8.2	84.1	181	0.12	84.1	0.83
krooCM	Kroonstad	30	1	72.6	10.0	10.0	49	0	0	49	18.7	0.6	12858	0.72	9.3	4.8	14.1	19	0.02	12.2	0.69
swarCM	Swartkops	240	1	50.2	10.0	10.0	450	0	0	450	21.4	5.5	12153	0.72	8.8	4.8	13.6	24	0.18	10.8	6.13
bloeCM	Bloemfontein	102	1	49.4	10.0	10.0	187	0	0	187	20.9	2.3	12391	0.72	9.0	4.8	13.8	28	0.06	11.0	2.57
kelvCW	Kelvin	600	1	53.7	10.0	10.0	1239	0	0	1239	23.6	14.3	11534	0.72	8.4	4.8	13.2	22	0.72	10.5	16.30
rooiCW	Rooiwal	300	1	50.2	10.0	10.0	561	0	0	561	21.4	6.8	12162	0.72	8.8	4.8	13.6	25	0.21	10.8	7.64
precCM	Pretoria West-coa	180	1	50.2	10.0	10.0	336	0	0	336	21.3	4.1	12174	0.72	8.8	4.8	13.6	26	0.12	10.8	4.58
roggCP	Roggebaai	40	1		10.0	5.0	2	0	0	2	0.6	0.0	12000	6.33	75.9	8.2	84.1	182	0.02	84.1	0.16
athgCP	Athlone - gas	120	3		10.0	5.0	5	0	0	5	0.5	0.1	12000	6.33	75.9	8.2	84.1	183	0.07	84.1	0.46
portCP	Port Elizabeth	20	1		10.0	5.0	1	0	0	1	0.5	0.0	12000	6.33	75.9	8.2	84.1	184	0.01	84.1	0.07
johaCP	Johannesburg	160	1		10.0	5.0	7	0	0	7	0.5	0.1	12000	6.33	75.9	8.2	84.1	185	0.08	84.1	0.56
pretCP	Pretoria West-gas	24	1		10.0	5.0	1	0	0	1	0.4	0.0	12000	6.33	75.9	8.2	84.1	186	0.01	84.1	0.07
mhydHE	Municipal Hydro (	7	1		0.0	0.0	23	0	0	23	37.5				0.0	1.0	1.0	164	0.04	9.8	0.02
	{Run of river}	{ 2}					{ 18}	{ 0}	{ 0}	{ 18	100}								{ 0.00}		
	{Pondage}	{ 5}					{ 5}		{ 0}	{ 5	12.5}								{ 0.04}		
maidCM	Maidstone Mill	29	1	75.5	10.0	10.0	153	0	0	153	60.1	1.8	11800	0.00	0.0	4.8	4.8	2	0.00	0.0	0.73
sassCW	Sasol Synth Fuels	600	1	53.7	10.0	10.0	1222	0	0	1222	23.2	14.2	11587	0.72	8.4	4.8	13.2	23	0.59	10.5	16.12
sascCM	Sasol Chem Ind	128	1	50.2	10.0	10.0	238	0	0	238	21.2	2.9	12185	0.72	8.8	4.8	13.6	27	0.08	10.8	3.25
inteEN	Interruptible Loa	745	1		0.0	0.0	0	0	0	0	0.0				0.0	0.0	0.0	0	0.00	0.0	0.00
vaneCM	Van Eck	114	4	5.0	6.0	6.0	44	0	0	44	4.4	0.7	15400	1.80	27.7	2.0	29.7	29	0.00	0.0	1.30
ruacHE	Ruacana Falls	243	1		0.0	0.0	1016	0	0	1016	47.7				0.0	1.0	1.0	164	1.97	9.2	1.02
	{Run of river}	{ 24}					{ 210}	{ 0}	{ 0}	{ 210	100}								{ 0.00}		
	{Pondage}	{ 219}					{ 806}		{ 0}	{ 806	42.0}								{ 1.97}		
walvCP	Walvis Bay	24	4		5.0	4.0	2	0	0	2	0.9	0.0	11694	6.33	74.0	7.0	81.0	178	0.02	81.0	0.16
hwanCW	Hwange	920	4	75.5	5.0	10.0	3814	0	0	3814	47.3	40.5	10626	0.47	5.0	4.8	9.8	13	2.90	8.6	37.35
munyCW	Munyati	60	1	75.5	5.0	10.0	244	0	0	244	46.4	2.7	11038	0.47	5.2	4.8	10.0	15	0.18	8.7	2.43
haraCW	Harare	102	3	75.5	5.0	10.0	293	0	0	293	32.8	3.7	12475	0.47	5.9	4.8	10.7	16	0.30	9.2	3.13
bulaCW	Bulawayo	60	1	75.5	5.0	10.0	243	0	0	243	46.3	2.7	11042	0.47	5.2	4.8	10.0	14	0.18	8.7	2.43
karsHE	Kariba South	666	1		0.0	0.0	2165	0	0	2165	37.1				0.0	0.0	0.0	164	4.88	9.6	0.00
	{Run of river}	{ 150}					{ 1314}	{ 0}	{ 0}	{1314	100}								{ 0.00}		
	{Pondage}	{ 516}					{ 851}		{ 0}	{ 851	18.8}								{ 4.88}		

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kafuHE Kafue Gorge          900  1        0.0  0.0  4858    0    0  4858 61.6                    0.0  0.0  0.0      164  5.74  9.1   0.00
       {Run of river}   { 300}                     { 2628}{  0}{  0}{2628  100}                                      { 0.00}
       {Pondage}        { 600}                     { 2230}     { 0}{2230 42.4}                                      { 5.74}
karnHE Kariba North         600  1        0.0  0.0  2165    0    0  2165 41.2                    0.0  0.0  0.0      164  4.26  9.6   0.00
       {Run of river}   { 150}                     { 1314}{  0}{  0}{1314  100}                                      { 0.00}
       {Pondage}        { 450}                     {  851}     { 0}{ 851 21.6}                                      { 4.26}
vicfHE Victoria Falls       108  1        0.0  0.0   666    0    0   666 70.4                    0.0  0.0  0.0      164  0.66  8.9   0.00
       {Run of river}   {  30}                     {  263}{  0}{  0}{ 263  100}                                      { 0.00}
       {Pondage}        {  78}                     {  403}     { 0}{ 403 59.0}                                      { 0.66}
zahyHE Other Zambia Hydr     24  1        0.0  0.0    47    0    0    47 22.3                    0.0  0.0  0.0      164  0.18  9.9   0.00
       {Run of river}   {   3}                     {   26}{  0}{  0}{  26  100}                                      { 0.00}
       {Pondage}        {  21}                     {   21}     { 0}{  21 11.2}                                      { 0.18}
luseHE Lusemfwa             18  1        0.0  0.0    75    0    0    75 47.5                    0.0  0.0  0.0      164  0.12  9.8   0.00
       {Run of river}   {   6}                     {   53}{  0}{  0}{  53  100}                                      { 0.00}
       {Pondage}        {  12}                     {   22}     { 0}{  22 21.3}                                      { 0.12}
muluHE Mulungushi           24  1        0.0  0.0   120    0    0   120 57.0                    0.0  0.0  0.0      164  0.16  9.2   0.00
       {Run of river}   {   8}                     {   70}{  0}{  0}{  70  100}                                      { 0.00}
       {Pondage}        {  16}                     {   50}     { 0}{  50 35.6}                                      { 0.16}
zagtCP GT in Zambia         296  1       10.0  5.0    24    0    0    24  0.9  0.3 11700  6.33 74.0  8.2 82.2      179  0.27 82.2   1.98
ingaLE Inga for export     1000  1        0.0  0.0  6130    0    0  6130 70.0                    0.0  0.0  0.0      159  8.53  8.7   0.00
morpCW Botswana coal        116  4 52.8   5.0 10.0   334    0    0   334 32.8  4.4 13135  0.47  6.2  4.8 11.0       18  0.24  8.9   3.66
cbasLE Cahora Bassa        1846  1        0.0  0.0  9996    0    0  9996 61.8                    0.0  0.0  0.0      159 15.74  8.7   0.00
mpgtCP Maputo gas turbin     78  1       10.0  5.0   114    0    0   114 16.7  1.1 10000  6.33 63.3  8.2 71.5      177  0.07 71.5   8.16
coruLE Corumanu hydro        16  1        0.0  0.0    36    0    0    36 25.6                    0.0  0.0  0.0      164  0.18  9.7   0.00
ps-1CP Drakensburg         1000  2                  59                 59  0.7                         1.0  1.0      176  1.07 10.9   0.06
       {pumping}         {1000}                     {  78}                                                          157  0.56  8.2
ps-2CP Palmiett             400  2                  43                 43  1.2                         1.0  1.0      175  0.50 10.7   0.04
       {pumping}         { 400}                     {  57}                                                          157  0.31  8.2
ps-3CP Steenbras            180  1                   9                  9  0.6                         1.0  1.0      176  0.18 11.2   0.01
       {pumping}         { 180}                     {  12}                                                          156  0.08  8.2
-------------------------------------------------------------------------------------------------------------------------------------
Total firm 46374 + CS = 46374 21.1% reserve    245632  147    0 245779   2220.8                    8.4          99.91  9.6 2073.0
Committed  42471      = 42471 10.9%      ENS      4.76      LOLP      0.000919 ( 0.335 days)  Energy Not Served  0.09 1000   4.76
after MOR  42471      = 42471 10.9%      ================  Commit target 40201 MW  5.0%      Avg. Marginal Cost (RC) 10.5
after FOR  40523      = 40523  5.8%      Load 245637 GWh   Spin. target    957 MW  2.5%            (dispatch cost) 11.1
Peak         ( 6pm Thu) 38287            Prob. of not meeting commit target:  0.4%

Production :              Fuel   Dump  Var. O&M  ENS     VOMCST    VOMBEN Priced Emis. Total var-    FOMCST    FOMBEN  Total prod-
      cost :              (FC)         (OM,ON)                              (PE)      iable cost                          uction cost
   summary :   (M$)      993.73 - 0.00 +   0.00 + 4.76 + 1079.31 -    0.00 +    0.00  =   2077.80 +   44.97 -    0.00 =     2122.77

Run  1 -- 2010 --  Simulation R.22.2.0-With Itezhi-tezhi, medium load, average hydrology      9 May 00  14:41  Ver 2.13b26  p.  152

                   Peak week Un- Com- -Outage-  ------Energy-------  Cap. Fuel  Heat  Fuel -------$/MWh----- Rank -Marginal-  Fuel
                    capacity its mit. FOR  MOR          GWh          fac. use  rate   $/ Fuel  O&M Tot. Dis-  *  time cost  +OM
                      MW       %    %    %   Load Pump Dump Total  %   PJ kJ/kWh  GJ                 patch      %  $/MWh  M$
arnoCW Arnot           990  3 93.0  5.0 10.0 6919    0    0 6919 79.8 67.9  9810 0.47  4.6  4.8  9.4      11  0.00  8.0 65.12
arn1CW Arnot - Reserve 330  1 91.8  5.0 10.0 2277    0    0 2277 78.8 22.3  9810 0.47  4.6  4.8  9.4      12  0.00  8.0 21.43
duvhCW Duvha (1-3)    1725  3  100  5.0 10.0 12920   0    0 12920 85.5 128  9940 0.40  4.0  4.8  8.8       5  0.00  7.3 113.39
duv1CW Duvha (4-6)    1725  3  100  5.0 10.0 12919   1    0 12920 85.5 128  9940 0.40  4.0  4.8  8.8       6  0.00  8.0 113.39
hendCM Hendrina       1900 10  100  5.0 10.0 14231   0    0 14231 85.5 146 10290 0.37  3.8  4.8  8.6       3  0.00  7.3 122.49
kendCW Kendal         3840  6  100  5.0 10.0 27384 242    0 27626 82.1 278 10054 0.44  4.4  4.8  9.2       9  6.78  8.5 254.81
krieCW Kriel          2850  6 97.2  5.0 10.0 20412  80    0 20492 82.1 201  9808 0.45  4.4  4.8  9.2      10  2.01  8.2 188.81
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lethCW	Lethabo	3558	6	100	5.0	10.0	26627	21	0	26649	85.5	262	9820	0.44	4.3	4.8	9.1	8	0.03	8.1	243.06
maj1CW	Majuba Units 1-3	1836	3	99.7	5.0	10.0	10772	197	0	10969	68.2	115	10501	0.70	7.4	4.8	12.2	20	5.54	10.4	133.28
maj2CW	Majuba Units 4-6	2007	3	99.9	5.0	10.0	10669	227	0	10896	62.0	117	10754	0.70	7.5	4.8	12.3	19	6.62	10.4	134.32
matiCW	Matimba	3690	6	100	5.0	10.0	27476	89	0	27565	85.3	282	10245	0.40	4.1	4.8	8.9	7	1.17	8.1	245.27
matlCW	Matla	3450	6	99.0	5.0	10.0	25602	0	0	25603	84.7	247	9650	0.40	3.9	4.8	8.7	4	0.00	7.9	221.72
tutuCW	Tutuka	3510	6	98.5	5.0	10.0	22468	302	0	22769	74.1	226	9930	0.54	5.4	4.8	10.2	17	8.54	9.1	231.39
koebCW	Koeberg	1840	2	-M-	10.0	20.0	11286	22	0	11308	70.2	131	11627	0.32	3.7	8.0	11.7	1	0.38	10.8	132.34
collHE	Colly Wobbles	42	1		0.0	0.0	165	0	0	165	44.8				0.0	1.0	1.0	172	0.30	26.4	0.16
	{Run of river}	{ 8}					{ 74}	{ 0}	{ 0}	{ 74	100}								{ 0.00}		
	{Pondage}	{ 34}					{ 91}		{ 0}	{ 91	30.9}								{ 0.30}		
gariHE	Gariep	360	1		0.0	0.0	723	0	0	723	22.9				0.0	1.0	1.0	174	2.56	32.5	0.72
	{Run of river}	{ 18}					{ 158}	{ 0}	{ 0}	{ 158	100}								{ 0.00}		
	{Pondage}	{ 342}					{ 565}		{ 0}	{ 565	18.9}								{ 2.56}		
vandHE	Vanderkloof	240	1		0.0	0.0	740	0	0	740	35.2				0.0	1.0	1.0	172	1.46	36.6	0.74
	{Run of river}	{ 24}					{ 210}	{ 0}	{ 0}	{ 210	100}								{ 0.00}		
	{Pondage}	{ 216}					{ 530}		{ 0}	{ 530	28.0}								{ 1.46}		
ehydHE	ESKOM Small Hydro	19	1		0.0	0.0	42	0	0	42	25.2				0.0	1.0	1.0	177	0.08	62.9	0.04
	{Run of river}	{ 4}					{ 35}	{ 0}	{ 0}	{ 35	100}								{ 0.00}		
	{Pondage}	{ 15}					{ 7}		{ 0}	{ 7	5.3}								{ 0.08}		
acacCP	Acacia	171	3		10.0	5.0	28	0	0	28	1.9	0.3	12000	6.65	79.8	8.2	88.0	182	0.28	88.0	2.44
ptrxCP	Port Rex	171	3		5.0	5.0	26	0	0	26	1.7	0.3	12000	6.65	79.8	8.2	88.0	183	0.27	88.0	2.26
kelvCW	Kelvin	600	1	97.9	10.0	10.0	2737	189	0	2926	55.7	31.2	10649	0.74	7.9	4.8	12.7	21	2.00	10.6	37.20
rooiCW	Rooiwal	300	1	95.6	10.0	10.0	1274	59	0	1333	50.7	15.1	11353	0.74	8.4	4.8	13.2	23	0.95	11.0	17.65
roggCP	Roggebaai	40	1		10.0	5.0	5	0	0	5	1.5	0.1	12000	6.65	79.8	8.2	88.0	184	0.06	88.0	0.46
athgCP	Athlone - gas	120	3		10.0	5.0	15	0	0	15	1.4	0.2	12000	6.65	79.8	8.2	88.0	185	0.16	88.0	1.29
portCP	Port Elizabeth	20	1		10.0	5.0	2	0	0	2	1.3	0.0	12000	6.65	79.8	8.2	88.0	186	0.03	88.0	0.20
johaCP	Johannesburg	160	1		10.0	5.0	18	0	0	18	1.3	0.2	12000	6.65	79.8	8.2	88.0	187	0.20	88.0	1.59
pretCP	Pretoria West-gas	24	1		10.0	5.0	2	0	0	2	1.1	0.0	12000	6.65	79.8	8.2	88.0	188	0.02	88.0	0.21
mhydHE	Municipal Hydro (	7	1		0.0	0.0	23	0	0	23	37.5				0.0	1.0	1.0	176	0.03	48.8	0.02
	{Run of river}	{ 2}					{ 18}	{ 0}	{ 0}	{ 18	100}								{ 0.00}		
	{Pondage}	{ 5}					{ 5}		{ 0}	{ 5	12.5}								{ 0.03}		
maidCM	Maidstone Mill	29	1	83.5	10.0	10.0	171	0	0	171	67.2	2.0	11800	0.00	0.0	4.8	4.8	2	0.00	0.0	0.82
sassCW	Sasol Synth Fuels	600	1	94.7	10.0	10.0	2582	148	0	2730	51.9	29.4	10750	0.74	8.0	4.8	12.8	22	1.94	10.6	34.92
sascCM	Sasol Chem Ind	128	1	91.0	10.0	10.0	511	25	0	537	47.9	6.1	11374	0.74	8.5	4.8	13.3	24	0.36	11.0	7.11
gtueCP	New Gas Turbine (	2080	8		10.0	5.0	1243	0	0	1243	6.8	11.8	9500	6.65	63.2	8.2	71.4	178	8.98	71.4	88.70
inteEN	Interruptible Loa	745	1		0.0	0.0	0	0	0	0	0.0				0.0	0.0	0.0	0	0.00	0.0	0.00
vaneCM	Van Eck	114	4	51.3	6.0	6.0	457	0	0	457	45.8	7.0	15400	1.85	28.4	2.0	30.4	25	0.00	30.4	13.92
ruacHE	Ruacana Falls	243	1		0.0	0.0	1016	0	0	1016	47.7				0.0	1.0	1.0	172	1.60	19.2	1.02
	{Run of river}	{ 24}					{ 210}	{ 0}	{ 0}	{ 210	100}								{ 0.00}		
	{Pondage}	{ 219}					{ 806}		{ 0}	{ 806	42.0}								{ 1.60}		
walvCP	Walvis Bay	24	4		5.0	4.0	5	0	0	5	2.5	0.1	11694	6.65	77.7	7.0	84.7	180	0.05	84.7	0.44
hwanCW	Hwange	920	4	73.4	5.0	10.0	4743	53	0	4796	59.5	48.3	10076	0.47	4.7	4.8	9.5	13	1.10	8.6	45.74
munyCW	Munyati	120	2	67.1	5.0	10.0	558	8	0	566	53.8	5.9	10392	0.47	4.9	4.8	9.7	14	0.14	8.7	5.48
haraCW	Harare	136	4	71.2	5.0	10.0	596	16	0	612	51.4	6.9	11250	0.47	5.3	4.8	10.1	16	0.29	9.2	6.17
bulaCW	Bulawayo	120	2	64.8	5.0	10.0	537	7	0	544	51.8	5.7	10395	0.47	4.9	4.8	9.7	15	0.13	8.7	5.27
karsHE	Kariba South	666	1		0.0	0.0	2165	0	0	2165	37.1				0.0	0.0	0.0	176	4.14	28.8	0.00
	{Run of river}	{ 150}					{ 1314}	{ 0}	{ 0}	{1314	100}								{ 0.00}		
	{Pondage}	{ 516}					{ 851}		{ 0}	{ 851	18.8}								{ 4.14}		
kafuHE	Kafue Gorge	900	1		0.0	0.0	4858	0	0	4858	61.6				0.0	0.0	0.0	172	5.08	21.9	0.00
	{Run of river}	{ 300}					{ 2628}	{ 0}	{ 0}	{2628	100}								{ 0.00}		
	{Pondage}	{ 600}					{ 2230}		{ 0}	{2230	42.4}								{ 5.08}		
itezHE	Itezhi-tezhi	80	1		0.0	0.0	628	0	0	628	89.6				0.0	0.0	0.0	169	0.33	9.0	0.00
	{Run of river}	{ 20}					{ 175}	{ 0}	{ 0}	{ 175	100}								{ 0.00}		

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        {Pondage}        {  60}                  {  453}     {  0}{ 453 86.1}                                          {  0.33}
karnHE Kariba North       600  1        0.0  0.0  2165    0    0  2165 41.2                  0.0  0.0  0.0      176  3.61 28.8   0.00
        {Run of river}   { 150}                  { 1314}{   0}{  0}{1314  100}                                        { 0.00}
        {Pondage}        { 450}                  {  851}     {  0}{ 851 21.6}                                          { 3.61}
vicfHE Victoria Falls     108  1        0.0  0.0   666    0    0   666 70.4                  0.0  0.0  0.0      172  0.56 23.3   0.00
        {Run of river}   {  30}                  {  263}{   0}{  0}{ 263  100}                                        { 0.00}
        {Pondage}        {  78}                  {  403}     {  0}{ 403 59.0}                                          { 0.56}
zahyHE Other Zambia Hydr   24  1        0.0  0.0    47    0    0    47 22.3                  0.0  0.0  0.0      176  0.14 49.2   0.00
        {Run of river}   {   3}                  {   26}{   0}{  0}{  26  100}                                        { 0.00}
        {Pondage}        {  21}                  {   21}     {  0}{  21 11.2}                                          { 0.14}
luseHE Lusemfwa           18  1        0.0  0.0    75    0    0    75 47.5                  0.0  0.0  0.0      174  0.10 31.6   0.00
        {Run of river}   {   6}                  {   53}{   0}{  0}{  53  100}                                        { 0.00}
        {Pondage}        {  12}                  {   22}     {  0}{  22 21.3}                                          { 0.10}
muluHE Mulungushi         24  1        0.0  0.0   120    0    0   120 57.0                  0.0  0.0  0.0      172  0.14 26.5   0.00
        {Run of river}   {   8}                  {   70}{   0}{  0}{  70  100}                                        { 0.00}
        {Pondage}        {  16}                  {   50}     {  0}{  50 35.5}                                          { 0.14}
zagtCP GT in Zambia       296  1       10.0  5.0   253    0    0   253  9.8  3.0 11700  6.65 77.8  8.2 86.0      181  0.60 86.0  21.76
ingaLE Inga for export   1000  1        0.0  0.0  6130    0    0  6130 70.0                  0.0  0.0  0.0      169  6.92  9.7   0.00
morpCW Botswana coal      116  4 59.7   5.0 10.0   475    6    0   482 47.4  5.9 12167  0.47  5.7  4.8 10.5       18  0.12  8.9   5.06
cbasLE Cahora Bassa      1846  1        0.0  0.0  9997    0    0  9997 61.8                  0.0  0.0  0.0      169 12.77  9.7   0.00
mpgtCP Maputo gas turbin   78  1       10.0  5.0   312    0    0   312 45.7  3.1 10000  6.65 66.5  8.2 74.7      179  0.25 74.7  23.30
coruLE Corumanu hydro      16  1        0.0  0.0    36    0    0    36 25.6                  0.0  0.0  0.0      172  0.15 26.4   0.00
ps-1CP Drakensburg       1000  2                  804            804  9.2                       1.0  1.0      177  3.97 36.0   0.80
        {pumping}       {1000}                     1072}                                                       164  2.81 28.9
ps-2CP Palmiett           400  2                  326            326  9.3                       1.0  1.0      177  1.59 35.9   0.33
        {pumping}        { 400}                    {429}                                                       164  1.12 29.2
ps-3CP Steenbras          180  1                  141            141  8.9                       1.0  1.0      177  0.71 36.2   0.14
        {pumping}        { 180}                    {193}                                                       164  0.51 28.3
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Total firm 48136 + CS = 48136  9.6% reserve    279379 1694   0 281073   2535.8                          9.1          99.68 22.7 2546.8
Committed  47771      = 47771  8.7%       ENS      19.91       LOLP      0.003163 ( 1.155 days)  Energy Not Served  0.32 1000  19.91
after MOR  47771      = 47771  8.7%       ================     Commit target 46137 MW  5.0%      Avg. Marginal Cost (RC) 25.8
after FOR  45485      = 45485  3.5%       Load 279399 GWh      Spin. target   1098 MW  2.5%              (dispatch cost) 30.4
Peak         ( 6pm Thu) 43940             Prob. of not meeting commit target: 57.5%

Production :                Fuel   Dump  Var. O&M   ENS     VOMCST    VOMBEN Priced Emis. Total var-    FOMCST    FOMBEN  Total prod-
      cost :                (FC)          (OM,ON)                                  (PE)     iable cost                        uction cost
   summary :    (M$)      1300.42 - 0.00 +   0.00 + 19.9 + 1246.36 -    0.00 +    0.00   =   2566.69 +   44.97 -    0.00 =     2611.66

Run  1 -- 2015 --  Simulation R.22.2.0-With Itezhi-tezhi, medium load, average hydrology       9 May 00  14:41  Ver 2.13b26  p.  227

                    Peak week Un- Com- -Outage-  ------Energy-------  Cap. Fuel  Heat  Fuel -------$/MWh----- Rank -Marginal-   Fuel
                     capacity its mit. FOR  MOR          GWh          fac.  use  rate   $/ Fuel  O&M Tot. Dis-  *  time cost   +OM
                        MW       %    %    %   Load Pump Dump Total   %    PJ kJ/kWh   GJ                 patch      %   $/MWh  M$
arnoCW Arnot             990  3  100  5.0 10.0  7415    0    0  7415 85.5 72.7  9810  0.47  4.6  4.8  9.4      11  0.00  8.0  69.78
arn1CW Arnot - Reserve   330  1  100  5.0 10.0  2472    0    0  2472 85.5 24.2  9810  0.47  4.6  4.8  9.4      12  0.00  8.0  23.26
duvhCW Duvha (1-3)      1725  3  100  5.0 10.0 12920    0    0 12920 85.5  128  9940  0.40  4.0  4.8  8.8       5  0.00  7.3 113.39
duv1CW Duvha (4-6)      1725  3  100  5.0 10.0 12920    0    0 12920 85.5  128  9940  0.40  4.0  4.8  8.8       6  0.00  8.0 113.39
hendCM Hendrina         1900 10  100  5.0 10.0 14231    0    0 14231 85.5  146 10290  0.37  3.8  4.8  8.6       3  0.00  7.3 122.49
kendCW Kendal           3840  6  100  5.0 10.0 28310   83    0 28393 84.4  284 10010  0.44  4.4  4.8  9.2       9  2.58  8.5 261.34
krieCW Kriel            2850  6  100  5.0 10.0 21254   48    0 21303 85.3  208  9784  0.45  4.4  4.8  9.2      10  0.58  8.2 196.05
lethCW Lethabo          3558  6  100  5.0 10.0 26646    3    0 26649 85.5  262  9820  0.44  4.3  4.8  9.1       8  0.00  8.1 243.06
maj1CW Majuba Units 1-3 1836  3 96.8  5.0 10.0 12526  102    0 12628 78.5  128 10112  0.70  7.1  4.8 11.9      20  3.10 10.4 150.00
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maj2CW	Majuba Units 4-6	2007	3	99.8	5.0	10.0	13743	128	0	13871	78.9	141	10163	0.70	7.1	4.8	11.9	19	3.79	10.4	165.26
matiCW	Matimba	3690	6	100	5.0	10.0	27605	23	0	27627	85.5	283	10241	0.40	4.1	4.8	8.9	7	0.20	8.1	245.78
matlCW	Matla	3450	6	99.4	5.0	10.0	25687	0	0	25687	85.0	248	9650	0.40	3.9	4.8	8.7	4	0.00	7.9	222.45
tutuCW	Tutuka	3510	6	100	5.0	10.0	25278	145	0	25422	82.7	248	9750	0.54	5.3	4.8	10.1	17	4.31	9.1	255.88
koebCW	Koeberg	1840	2	-M-	10.0	20.0	11508	8	0	11516	71.4	133	11577	0.33	3.8	8.0	11.8	1	0.24	10.9	135.66
collHE	Colly Wobbles	42	1		0.0	0.0	165	0	0	165	44.8				0.0	1.0	1.0	179	0.24	44.1	0.16
	{Run of river}	{ 8}					{ 74}	{ 0}	{ 0}	{ 74	100}								{ 0.00}		
	{Pondage}	{ 34}					{ 91}		{ 0}	{ 91	31.0}								{ 0.24}		
gariHE	Gariep	360	1		0.0	0.0	723	0	0	723	22.9				0.0	1.0	1.0	179	1.71	49.3	0.72
	{Run of river}	{ 18}					{ 158}	{ 0}	{ 0}	{ 158	100}								{ 0.00}		
	{Pondage}	{ 342}					{ 565}		{ 0}	{ 565	18.9}								{ 1.71}		
vandHE	Vanderkloof	240	1		0.0	0.0	741	0	0	741	35.2				0.0	1.0	1.0	179	1.41	50.7	0.74
	{Run of river}	{ 24}					{ 210}	{ 0}	{ 0}	{ 210	100}								{ 0.00}		
	{Pondage}	{ 216}					{ 530}		{ 0}	{ 530	28.0}								{ 1.41}		
ehydHE	ESKOM Small Hydro	19	1		0.0	0.0	42	0	0	42	25.2				0.0	1.0	1.0	180	0.08	78.1	0.04
	{Run of river}	{ 4}					{ 35}	{ 0}	{ 0}	{ 35	100}								{ 0.00}		
	{Pondage}	{ 15}					{ 7}		{ 0}	{ 7	5.3}								{ 0.08}		
acacCP	Acacia	171	3		10.0	5.0	49	0	0	49	3.2	0.6	12000	6.99	83.8	8.2	92.0	184	0.38	92.0	4.47
ptrxCP	Port Rex	171	3		5.0	5.0	45	0	0	45	3.0	0.5	12000	6.99	83.8	8.2	92.0	185	0.36	92.0	4.10
rooiCW	Rooiwal	300	1	98.0	10.0	10.0	1856	21	0	1877	71.4	19.8	10526	0.76	8.0	4.8	12.8	24	0.62	11.1	24.06
roggCP	Roggebaai	40	1		10.0	5.0	9	0	0	9	2.6	0.1	12000	6.99	83.8	8.2	92.0	186	0.08	92.0	0.85
athgCP	Athlone - gas	120	3		10.0	5.0	26	0	0	26	2.5	0.3	12000	6.99	83.8	8.2	92.0	187	0.22	92.0	2.40
portCP	Port Elizabeth	20	1		10.0	5.0	4	0	0	4	2.4	0.0	12000	6.99	83.8	8.2	92.0	188	0.04	92.0	0.38
johaCP	Johannesburg	160	1		10.0	5.0	30	0	0	30	2.2	0.4	12000	6.99	83.8	8.2	92.0	189	0.26	92.0	2.79
pretCP	Pretoria West-gas	24	1		10.0	5.0	3	0	0	3	1.6	0.0	12000	6.99	83.8	8.2	92.0	190	0.02	92.0	0.31
mhydHE	Municipal Hydro (	7	1		0.0	0.0	23	0	0	23	37.5				0.0	1.0	1.0	179	0.03	70.5	0.02
	{Run of river}	{ 2}					{ 18}	{ 0}	{ 0}	{ 18	100}								{ 0.00}		
	{Pondage}	{ 5}					{ 5}		{ 0}	{ 5	12.5}								{ 0.03}		
maidCM	Maidstone Mill	29	1	97.2	10.0	10.0	200	0	0	200	78.7	2.4	11800	0.00	0.0	4.8	4.8	2	0.00	0.0	0.96
sassCW	Sasol Synth Fuels	600	1	99.1	10.0	10.0	3793	42	0	3835	73.0	38.4	10002	0.76	7.6	4.8	12.4	21	1.20	10.7	47.63
sascCM	Sasol Chem Ind	128	1	98.2	10.0	10.0	787	9	0	796	71.0	8.4	10543	0.76	8.0	4.8	12.8	25	0.27	11.1	10.22
coagCW	Generic Coal	4445	7	98.5	5.0	10.0	22615	443	0	23058	59.2	244	10569	0.74	7.8	4.8	12.6	22	16.87	11.9	291.07
coa5CW	Generic Coal 500	535	1	88.1	5.0	10.0	1842	145	0	1988	42.4	21.4	10759	0.74	8.0	4.8	12.8	23	2.15	12.0	25.37
gtueCP	New Gas Turbine (	3900	15		10.0	5.0	4820	0	0	4820	14.1	45.8	9500	6.99	66.4	8.2	74.6	180	19.71	74.6	359.45
inteEN	Interruptible Loa	745	1		0.0	0.0	0	0	0	0	0.0				0.0	0.0	0.0	0	0.00	0.0	0.00
vaneCM	Van Eck	114	4	69.5	6.0	6.0	617	0	0	617	61.7	9.5	15400	1.89	29.2	2.0	31.2	26	0.00	0.0	19.22
ruacHE	Ruacana Falls	243	1		0.0	0.0	1016	0	0	1016	47.7				0.0	1.0	1.0	178	1.46	29.2	1.02
	{Run of river}	{ 24}					{ 210}	{ 0}	{ 0}	{ 210	100}								{ 0.00}		
	{Pondage}	{ 219}					{ 806}		{ 0}	{ 806	42.0}								{ 1.46}		
walvCP	Walvis Bay	24	4		5.0	4.0	8	0	0	8	3.7	0.1	11694	6.99	81.7	7.0	88.7	182	0.06	88.7	0.69
hwanCW	Hwange	920	4	72.6	5.0	10.0	4985	11	0	4996	62.0	50.0	10000	0.47	4.7	4.8	9.5	13	0.05	8.6	47.46
munyCW	Munyati	120	2	65.0	5.0	10.0	581	2	0	582	55.4	6.0	10301	0.47	4.8	4.8	9.6	14	0.01	8.7	5.61
haraCW	Harare	136	4	63.5	5.0	10.0	639	3	0	643	53.9	7.1	11004	0.47	5.2	4.8	10.0	16	0.02	9.2	6.41
bulaCW	Bulawayo	120	2	62.2	5.0	10.0	555	2	0	557	53.0	5.7	10301	0.47	4.8	4.8	9.6	15	0.01	8.7	5.37
karsHE	Kariba South	666	1		0.0	0.0	2166	0	0	2166	37.1				0.0	0.0	0.0	179	3.46	50.1	0.00
	{Run of river}	{ 150}					{ 1314}	{ 0}	{ 0}	{1314	100}								{ 0.00}		
	{Pondage}	{ 516}					{ 852}		{ 0}	{ 852	18.8}								{ 3.46}		
kafuHE	Kafue Gorge	900	1		0.0	0.0	4859	0	0	4859	61.6				0.0	0.0	0.0	178	4.26	24.3	0.00
	{Run of river}	{ 300}					{ 2628}	{ 0}	{ 0}	{2628	100}								{ 0.00}		
	{Pondage}	{ 600}					{ 2231}		{ 0}	{2231	42.5}								{ 4.26}		
itezHE	Itezhi-tezhi	80	1		0.0	0.0	628	0	0	628	89.6				0.0	0.0	0.0	173	0.29	10.4	0.00
	{Run of river}	{ 20}					{ 175}	{ 0}	{ 0}	{ 175	100}								{ 0.00}		
	{Pondage}	{ 60}					{ 453}		{ 0}	{ 453	86.1}								{ 0.29}		

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karnHE Kariba North        600  1        0.0  0.0  2166    0   0  2166 41.2                    0.0  0.0  0.0      179  3.02 50.1   0.00
       {Run of river}   { 150}                    { 1314}{  0}{ 0}{1314  100}                                      { 0.00}
       {Pondage}        { 450}                    {  852}     { 0}{ 852 21.6}                                      { 3.02}
vicfHE Victoria Falls      108  1        0.0  0.0   665    0   0   665 70.3                    0.0  0.0  0.0      178  0.48 23.9   0.00
       {Run of river}   {  30}                    {  263}{  0}{ 0}{ 263  100}                                      { 0.00}
       {Pondage}        {  78}                    {  403}     { 0}{ 403 58.9}                                      { 0.48}
zahyHE Other Zambia Hydr    24  1        0.0  0.0    47    0   0    47 22.3                    0.0  0.0  0.0      179  0.13 70.5   0.00
       {Run of river}   {   3}                    {   26}{  0}{ 0}{  26  100}                                      { 0.00}
       {Pondage}        {  21}                    {   21}     { 0}{  21 11.2}                                      { 0.13}
luseHE Lusemfwa            18  1        0.0  0.0    75    0   0    75 47.5                    0.0  0.0  0.0      179  0.08 53.8   0.00
       {Run of river}   {   6}                    {   53}{  0}{ 0}{  53  100}                                      { 0.00}
       {Pondage}        {  12}                    {   22}     { 0}{  22 21.3}                                      { 0.08}
muluHE Mulungushi          24  1        0.0  0.0   120    0   0   120 57.1                    0.0  0.0  0.0      178  0.12 48.1   0.00
       {Run of river}   {   8}                    {   70}{  0}{ 0}{  70  100}                                      { 0.00}
       {Pondage}        {  16}                    {   50}     { 0}{  50 35.6}                                      { 0.12}
zagtCP GT in Zambia       296  1       10.0  5.0   783    0   0   783 30.2  9.2 11700  6.99 81.8  8.2 90.0      183  0.93 90.0  70.45
ingaLE Inga for export   1000  1        0.0  0.0  6130    0   0  6130 70.0                    0.0  0.0  0.0      178  5.94 11.7   0.00
morpCW Botswana coal      116  4 60.9   5.0 10.0   525    1   0   526 51.8  6.3 12002  0.47  5.6  4.8 10.4       18  0.01  8.9   5.49
cbasLE Cahora Bassa      1846  1        0.0  0.0  9997    0   0  9997 61.8                    0.0  0.0  0.0      178 11.31 11.8   0.00
mpgtCP Maputo gas turbin   78  1       10.0  5.0   465    0   0   465 68.0  4.6 10000  6.99 69.9  8.2 78.1      181  0.06 78.1  36.27
coruLE Corumanu hydro      16  1        0.0  0.0    36    0   0    36 25.7                    0.0  0.0  0.0      179  0.11 54.6   0.00
ps-1CP Drakensburg       1000  2                  578            578  6.6                         1.0  1.0      179  2.55 40.0   0.58
       {pumping}        {1000}                       {770}                                                       178  2.08 33.2
ps-2CP Palmiett           400  2                  234            234  6.7                         1.0  1.0      179  1.02 39.9   0.23
       {pumping}        { 400}                       {308}                                                       178  0.83 33.6
ps-3CP Steenbras          180  1                  101            101  6.4                         1.0  1.0      179  0.46 40.2   0.10
       {pumping}        { 180}                       {139}                                                       178  0.37 32.5
-------------------------------------------------------------------------------------------------------------------------------------
Total firm 54336 + CS = 54336  8.2% reserve    318261 1217   0 319478   2915.5                      10.3          99.53 32.5 3292.4
Committed  54128      = 54128  7.8%       ENS      34.48       LOLP      0.004736 ( 1.729 days)  Energy Not Served  0.47 1000  34.48
after MOR  54128      = 54128  7.8%       ==================   Commit target 52712 MW  5.0%      Avg. Marginal Cost (RC) 37.1
after FOR  51461      = 51461  2.5%       Load 318296 GWh      Spin. target   1255 MW  2.5%              (dispatch cost) 49.2
Peak         ( 6pm Thu) 50202             Prob. of not meeting commit target: 74.2%

Production :                Fuel   Dump  Var. O&M   ENS     VOMCST    VOMBEN Priced Emis. Total var-    FOMCST    FOMBEN  Total prod-
      cost :                (FC)          (OM,ON)                                (PE)     iable cost                         uction cost
   summary :    (M$)      1845.42 - 0.00 +   0.00 + 34.5 + 1447.00 -    0.00 +    0.00   =   3326.90 +   44.97 -    0.00 =     3371.87
Run  1 -- 2019 --  Simulation R.22.2.0-With Itezhi-tezhi, medium load, average hydrology       9 May 00  14:41  Ver 2.13b26  p.  287

                    Peak week Un- Com- -Outage-  ------Energy------- Cap. Fuel  Heat  Fuel -------$/MWh----- Rank -Marginal-   Fuel
                     capacity its mit. FOR  MOR          GWh          fac. use  rate   $/ Fuel  O&M Tot. Dis-  *  time cost   +OM
                        MW       %    %    %   Load Pump Dump Total   %   PJ kJ/kWh  GJ                 patch      %   $/MWh  M$
arnoCW Arnot               990  3  100  5.0 10.0 7415    0    0  7415 85.5 72.7  9810 0.47  4.6  4.8  9.4       2  0.00  8.0 69.78
arn1CW Arnot - Reserve     330  1  100  5.0 10.0 2472    0    0  2472 85.5 24.2  9810 0.47  4.6  4.8  9.4       3  0.00  8.0 23.26
duvhCW Duvha (1-3)        1725  3  100  5.0 10.0 12920   0    0 12920 85.5  128  9940 0.40  4.0  4.8  8.8       4  0.00  7.3 113.39
duv1CW Duvha (4-6)        1725  3  100  5.0 10.0 12920   0    0 12920 85.5  128  9940 0.40  4.0  4.8  8.8       5  0.00  8.0 113.39
hendCM Hendrina           1900 10  100  5.0 10.0 14231   0    0 14231 85.5  146 10290 0.37  3.8  4.8  8.6       6  0.00  7.3 122.49
kendCW Kendal             3840  6  100  5.0 10.0 28636  58    0 28694 85.3  287  9994 0.44  4.4  4.8  9.2       7  0.93  8.5 263.90
krieCW Kriel              2850  6  100  5.0 10.0 21331  15    0 21346 85.5  209  9780 0.45  4.4  4.8  9.2       8  0.04  8.2 196.40
lethCW Lethabo            3558  6  100  5.0 10.0 26649   0    0 26649 85.5  262  9820 0.44  4.3  4.8  9.1       9  0.00  8.1 243.06
maj1CW Majuba Units 1-3   1836  3 97.2  5.0 10.0 13086  16    0 13102 81.5  132 10047 0.70  7.0  4.8 11.8      10  1.61 10.4 155.03
maj2CW Majuba Units 4-6   2007  3 99.5  5.0 10.0 14440  35    0 14475 82.3  146 10067 0.70  7.0  4.8 11.8      11  2.29 10.4 171.48
matiCW Matimba            3690  6  100  5.0 10.0 27635   3    0 27637 85.5  283 10240 0.40  4.1  4.8  8.9      12  0.01  8.1 245.86
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matlCW	Matla	3450	6	100	5.0	10.0	25840	0	0	25840	85.5	249	9650	0.40	3.9	4.8	8.7	13	0.00	7.9	223.77
tutuCW	Tutuka	3510	6	100	5.0	10.0	25935	19	0	25954	84.4	252	9713	0.54	5.2	4.8	10.0	14	2.11	9.1	260.71
koebCW	Koeberg	1840	2	-M-	10.0	20.0	11560	1	0	11561	71.7	134	11566	0.33	3.9	8.0	11.9	1	0.18	11.0	137.03
collHE	Colly Wobbles	42	1		0.0	0.0	165	0	0	165	44.8				0.0	1.0	1.0	177	0.21	41.6	0.16
	{Run of river}	{ 8}					{ 74}	{ 0}	{ 0}	{ 74	100}								{ 0.00}		
	{Pondage}	{ 34}					{ 91}		{ 0}	{ 91	31.0}								{ 0.21}		
gariHE	Gariep	360	1		0.0	0.0	723	0	0	723	22.9				0.0	1.0	1.0	180	1.64	58.2	0.72
	{Run of river}	{ 18}					{ 158}	{ 0}	{ 0}	{ 158	100}								{ 0.00}		
	{Pondage}	{ 342}					{ 565}		{ 0}	{ 565	18.9}								{ 1.64}		
vandHE	Vanderkloof	240	1		0.0	0.0	741	0	0	741	35.2				0.0	1.0	1.0	177	1.23	50.7	0.74
	{Run of river}	{ 24}					{ 210}	{ 0}	{ 0}	{ 210	100}								{ 0.00}		
	{Pondage}	{ 216}					{ 530}		{ 0}	{ 530	28.0}								{ 1.23}		
ehydHE	ESKOM Small Hydro	19	1		0.0	0.0	42	0	0	42	25.2				0.0	1.0	1.0	180	0.07	81.3	0.04
	{Run of river}	{ 4}					{ 35}	{ 0}	{ 0}	{ 35	100}								{ 0.00}		
	{Pondage}	{ 15}					{ 7}		{ 0}	{ 7	5.3}								{ 0.07}		
acacCP	Acacia	171	3		10.0	5.0	33	0	0	33	2.2	0.4	12000	7.27	87.3	8.2	95.5	182	0.29	95.5	3.15
ptrxCP	Port Rex	171	3		5.0	5.0	31	0	0	31	2.1	0.4	12000	7.27	87.3	8.2	95.5	183	0.28	95.5	2.93
roggCP	Roggebaai	40	1		10.0	5.0	6	0	0	6	1.8	0.1	12000	7.27	87.3	8.2	95.5	184	0.06	95.5	0.60
athgCP	Athlone - gas	120	3		10.0	5.0	18	0	0	18	1.7	0.2	12000	7.27	87.3	8.2	95.5	185	0.17	95.5	1.70
portCP	Port Elizabeth	20	1		10.0	5.0	3	0	0	3	1.6	0.0	12000	7.27	87.3	8.2	95.5	186	0.03	95.5	0.27
johaCP	Johannesburg	160	1		10.0	5.0	22	0	0	22	1.6	0.3	12000	7.27	87.3	8.2	95.5	187	0.21	95.5	2.12
pretCP	Pretoria West-gas	24	1		10.0	5.0	3	0	0	3	1.4	0.0	12000	7.27	87.3	8.2	95.5	188	0.02	95.5	0.29
mhydHE	Municipal Hydro (	7	1		0.0	0.0	23	0	0	23	37.5				0.0	1.0	1.0	180	0.03	77.3	0.02
	{Run of river}	{ 2}					{ 18}	{ 0}	{ 0}	{ 18	100}								{ 0.00}		
	{Pondage}	{ 5}					{ 5}		{ 0}	{ 5	12.5}								{ 0.03}		
maidCM	Maidstone Mill	29	1	93.8	10.0	10.0	195	0	0	195	76.6	2.3	11800	0.00	0.0	4.8	4.8	15	0.00	0.0	0.93
sassCW	Sasol Synth Fuels	600	1	95.0	10.0	10.0	3884	8	0	3892	74.1	38.5	9890	0.78	7.7	4.8	12.5	16	0.80	10.9	48.60
sascCM	Sasol Chem Ind	128	1	94.0	10.0	10.0	815	0	0	815	72.7	8.5	10410	0.78	8.1	4.8	12.9	17	0.18	11.3	10.51
coagCW	Generic Coal	10160	16	98.7	5.0	10.0	56977	11	0	56988	64.0	598	10499	0.76	7.9	4.8	12.7	18	33.38	12.1	725.32
coa5CW	Generic Coal 500	535	1	82.1	5.0	10.0	1622	0	0	1622	34.6	17.7	10906	0.76	8.2	4.8	13.0	19	1.85	12.1	21.14
gtueCP	New Gas Turbine (	4940	19		10.0	5.0	6138	0	0	6138	14.2	58.3	9500	7.27	69.1	8.2	77.3	180	22.39	77.3	474.29
inteEN	Interruptible Loa	745	1		0.0	0.0	0	0	0	0	0.0				0.0	0.0	0.0	0	0.00	0.0	0.00
vaneCM	Van Eck	114	4	68.2	6.0	6.0	603	0	0	603	60.3	9.3	15400	1.93	29.8	2.0	31.8	20	0.00	0.0	19.13
ruacHE	Ruacana Falls	243	1		0.0	0.0	1016	0	0	1016	47.7				0.0	1.0	1.0	177	1.28	41.2	1.02
	{Run of river}	{ 24}					{ 210}	{ 0}	{ 0}	{ 210	100}								{ 0.00}		
	{Pondage}	{ 219}					{ 806}		{ 0}	{ 806	42.0}								{ 1.28}		
walvCP	Walvis Bay	24	4		5.0	4.0	6	0	0	6	2.9	0.1	11694	7.27	85.0	7.0	92.0	181	0.05	92.0	0.56
hwanCW	Hwange	920	4	68.7	5.0	10.0	4681	0	0	4681	58.1	46.8	10000	0.47	4.7	4.8	9.5	21	0.00	0.0	44.47
munyCW	Munyati	120	2	61.8	5.0	10.0	547	0	0	547	52.0	5.6	10300	0.47	4.8	4.8	9.6	22	0.00	0.0	5.27
haraCW	Harare	136	4	60.6	5.0	10.0	608	0	0	608	51.0	6.7	11000	0.47	5.2	4.8	10.0	23	0.00	0.0	6.06
bulaCW	Bulawayo	120	2	59.7	5.0	10.0	528	0	0	528	50.2	5.4	10300	0.47	4.8	4.8	9.6	24	0.00	0.0	5.09
karsHE	Kariba South	666	1		0.0	0.0	2166	0	0	2166	37.1				0.0	0.0	0.0	180	2.94	56.1	0.00
	{Run of river}	{ 150}					{ 1314}	{ 0}	{ 0}	{1314	100}								{ 0.00}		
	{Pondage}	{ 516}					{ 852}		{ 0}	{ 852	18.9}								{ 2.94}		
kafuHE	Kafue Gorge	900	1		0.0	0.0	4859	0	0	4859	61.6				0.0	0.0	0.0	177	3.72	32.0	0.00
	{Run of river}	{ 300}					{ 2628}	{ 0}	{ 0}	{2628	100}								{ 0.00}		
	{Pondage}	{ 600}					{ 2231}		{ 0}	{2231	42.4}								{ 3.72}		
itezHE	Itezhi-tezhi	80	1		0.0	0.0	628	0	0	628	89.6				0.0	0.0	0.0	177	0.28	12.0	0.00
	{Run of river}	{ 20}					{ 175}	{ 0}	{ 0}	{ 175	100}								{ 0.00}		
	{Pondage}	{ 60}					{ 453}		{ 0}	{ 453	86.1}								{ 0.28}		
karnHE	Kariba North	600	1		0.0	0.0	2166	0	0	2166	41.2				0.0	0.0	0.0	180	2.56	56.1	0.00
	{Run of river}	{ 150}					{ 1314}	{ 0}	{ 0}	{1314	100}								{ 0.00}		
	{Pondage}	{ 450}					{ 852}		{ 0}	{ 852	21.6}								{ 2.56}		

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vicfHE Victoria Falls      108  1       0.0  0.0   666    0   0   666 70.4                    0.0  0.0  0.0      177  0.46 33.0   0.00
       {Run of river}  {  30}                    {  263}{  0}{ 0}{ 263  100}                                        { 0.00}
       {Pondage}       {  78}                    {  403}     { 0}{ 403 59.0}                                        { 0.46}
zahyHE Other Zambia Hydr   24  1       0.0  0.0    47    0   0    47 22.3                    0.0  0.0  0.0      180  0.11 78.6   0.00
       {Run of river}  {   3}                    {   26}{  0}{ 0}{  26  100}                                        { 0.00}
       {Pondage}       {  21}                    {   21}     { 0}{  21 11.3}                                        { 0.11}
luseHE Lusemfwa            18  1       0.0  0.0    75    0   0    75 47.5                    0.0  0.0  0.0      180  0.07 58.3   0.00
       {Run of river}  {   6}                    {   53}{  0}{ 0}{  53  100}                                        { 0.00}
       {Pondage}       {  12}                    {   22}     { 0}{  22 21.3}                                        { 0.07}
muluHE Mulungushi          24  1       0.0  0.0   120    0   0   120 57.1                    0.0  0.0  0.0      177  0.10 44.5   0.00
       {Run of river}  {   8}                    {   70}{  0}{ 0}{  70  100}                                        { 0.00}
       {Pondage}       {  16}                    {   50}     { 0}{  50 35.6}                                        { 0.10}
zagtCP GT in Zambia       296  1      10.0  5.0  1069    1   0  1070 41.3 12.5 11700  7.27 85.1  8.2 93.3      179  0.90 93.3  99.80
ingaLE Inga for export   1000  1       0.0  0.0  6130    0   0  6130 70.0                    0.0  0.0  0.0      177  5.22 12.1   0.00
morpCW Botswana coal      116  4 58.7  5.0 10.0   501    0   0   501 49.3  6.0 12000  0.47  5.6  4.8 10.4       25  0.00  0.0   5.23
cbasLE Cahora Bassa      1846  1       0.0  0.0  9997    0   0  9997 61.8                    0.0  0.0  0.0      177  9.64 12.1   0.00
mpgtCP Maputo gas turbin   78  1      10.0  5.0   579    0   0   579 84.7  5.8 10000  7.27 72.7  8.2 80.9      176  0.02 80.9  46.84
coruLE Corumanu hydro      16  1       0.0  0.0    36    0   0    36 25.7                    0.0  0.0  0.0      178  0.10 50.5   0.00
ps-1CP Drakensburg       1000  2                   79                79  0.9                         1.0  1.0      188  0.86 13.4   0.08
       {pumping}       {1000}                      {106}                                                           169  0.53 10.0
ps-2CP Palmiett           400  2                   32                32  0.9                         1.0  1.0      188  0.34 13.2   0.03
       {pumping}       { 400}                      { 42}                                                           169  0.21 10.0
ps-3CP Steenbras          180  1                   14                14  0.9                         1.0  1.0      188  0.15 13.7   0.01
       {pumping}       { 180}                      { 19}                                                           169  0.09 10.0
-----------------------------------------------------------------------------------------------------------------------------------
Total firm 60791 + CS = 60791  8.7% reserve    353659  167   0 353826   3276.2                    10.9          99.62 33.4 3866.7
Committed  60517      = 60517  8.2%       ENS      29.11       LOLP      0.003769 ( 1.376 days)  Energy Not Served  0.38 1000  29.11
after MOR  60517      = 60517  8.2%       ==================   Commit target 58712 MW  5.0%      Avg. Marginal Cost (RC) 37.0
after FOR  57494      = 57494  2.8%       Load 353689 GWh      Spin. target   1398 MW  2.5%              (dispatch cost) 47.1
Peak         ( 6pm Thu) 55916             Prob. of not meeting commit target: 70.5%

Production :                Fuel   Dump  Var. O&M   ENS     VOMCST    VOMBEN Priced Emis. Total var-    FOMCST    FOMBEN  Total prod-
      cost :                (FC)          (OM,ON)                                (PE)     iable cost                        uction cost
   summary :    (M$)      2245.98 - 0.00 +   0.00 + 29.1 + 1620.71 -    0.00 +    0.00   =   3895.80 +   44.97 -    0.00 =     3940.78
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Evaluation Of Projects

Final Report

Assistance To Zambia's Office For Promoting Private Power Investment
Task 2: Analyze Project Interactions
Task 4b: Project Recommendations

Prepared under Contract for:
United States Agency for International Development
LAG-I-00-98-00006-00

Bechtel National, Inc. *July 2000*

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Acronyms And Abbreviations

AC	Alternating current
DC	Direct current
ESKOM	South Africa's national electric utility
GRZ	Government of the Republic of Zambia
GWh	Gigawatt-hour
IDC	Interest during construction
IPP	Independent power producer
km	Kilometer
kW	Kilowatt
kWh	Kilowatt-hour
kV	Kilovolt
m	Meter
m^3/sec	Cubic meters per second
MOU	Memorandum Of Understanding
MVA	Megavolt-ampere
MW	Megawatt
MWh	Megawatt-hour
OPPPI	Office for Promoting Private Power Investment
O&M	Operation and maintenance
rpm	Revolutions per minute
SAPP	Southern African Power Pool
TANESCO	Tanzania Electric Supply Company
US	United States
USAID	United States Agency for International Development
ZCCM	Zambia Consolidated Copper Mines
ZESA	Zimbabwe Electricity Supply Authority
ZESCO	Zambia Electricity Supply Corporation

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Executive Summary

The United States Agency for International Development has selected Bechtel/Nexant to assist Zambia's Office For Promoting Private Power Investment (OPPPI) in conducting Phase 1 of a three phase project leading to preparation of solicitation documents for private development of new hydropower plants and transmission lines. Phases 2 and 3 of the project will be funded from other sources and performed by other consultants.

The Government of the Republic of Zambia has tentatively selected a first round of four projects for which model solicitation procedures for private development may be prepared. These projects are the Kafue Gorge Lower hydro project, the Itezhi-tezhi hydro project, the transmission interconnection from Zambia to Tanzania, and grid expansion into the Mkushi farming area in Central Province. Perhaps the most crucial of the Phase 1 activities is to review these projects and recommend whether OPPPI should proceed with preparing solicitation documents for them.

The primary basis for our recommendations is an evaluation of the projects' costs and benefits, with due regard for how their interactions affect those factors. Most of the costs associated with the projects have been estimated in existing feasibility studies. In the Southern African Power Market Study (Task 1 of this project) we estimated the value (benefits) of three of the projects (all but the Mkushi project, which requires a different analytical approach). In Task 4b we reviewed and analyzed the Mkushi project and produced the report Evaluation Of Grid Extension Into The Mkushi Farming Area, which provided the recommendations which are summarized in this report.

This current report, Evaluation Of Projects, is the product of the work of Task 2: Analyze Project Interactions and Task 4b: Project Recommendations. We integrate the results of the previous work with the work on those Tasks to provide a set of recommendations regarding the individual projects and related matters.

Our evaluation produced the following conclusions:

- The Zambia - Tanzania interconnection is economically viable as a stand alone project considering Base Case conditions.
- Kafue Gorge Lower and Itezhi-tezhi are also economically viable as stand alone projects considering Base Case conditions.
- However, there are risks involved. The hydro projects have unfavorable economics if regional yearly demand growth is 1.1% versus 2.7% in the Base Case. The interconnection has unfavorable economics if much more natural gas becomes available for power generation than was assumed in the Base Case.
- Kafue Gorge Lower has the potential to be commercially viable with or without the other projects. However, building Kafue Gorge Lower first may reduce Itezhi-tezhi's benefit/cost ratio below breakeven. Further study should be undertaken before basing any final decisions on these results.
- The Mkushi Electrification project does not appear to be viable as a privately-financed commercial venture.

Based on these conclusions we recommend that OPPPI:

- Initiate the process of developing solicitation documents for the Zambia - Tanzania interconnection.
- Initiate the process of developing solicitation documents for the Kafue Gorge Lower hydro power plant.
- Initiate the process of developing solicitation documents for the Itezhi-tezhi hydro power plant, but be prepared to review that decision upon the completion of the hydro operations modeling studies referred to below.
- Develop a hydro operations modeling capability and refine the estimates of expected generation at Kafue Gorge Lower, Itezhi-tezhi, and existing plants.
- Use this capability to support the following activities:
  - Developing a preferred operating regime based on the policy/risk preferences of the GRZ.
  - Establishing the expected output of the existing and potential new hydro plants.
  - Confirming the decision to proceed with Itezhi-tezhi.
  - Developing joint operating agreements to govern the operation of the Kafue river system as a whole.
  - Developing contractual arrangements for the projects.
- Not prepare model solicitation procedures for private development of grid extension into the Mkushi farming area at this time.

Section 1 Introduction

1.1 *Background*

The United States Agency for International Development (USAID) has selected Bechtel/Nexant to assist Zambia's Office For Promoting Private Power Investment (OPPPI) in conducting Phase 1 of a three phase project leading to preparation of solicitation documents for private development of new hydropower plants and transmission lines. Phases 2 and 3 of the project will be funded from other sources and performed by other consultants. Phase 1 lays the foundation for the work of Phases 2 and 3 through market and economic analysis, project selection, and establishing schedules and resource needs for OPPPI.

The Phase 1 Project has eight Tasks requiring a total of eight deliverables. This report provides the deliverables for Task 2: Analyze Project Interactions, and Task 4b: Project Recommendations.

1.2 *Objectives*

The objective of Task 4b is to provide a summary evaluation of Kafue Gorge Lower, Itezhi-tezhi, Zambia - Tanzania Interconnection and Mkushi Electrification projects and provide recommendations on how OPPPI should proceed on a coordinated basis.

1.3 *General Approach*

All four of the projects have been evaluated in other feasibility studies. These studies were reviewed as part of Task 3, Document Review. One of the factors that have changed since the completion of feasibility studies is the criteria that the projects should be developed privately. Commercial structures appropriate for project development and current and projected market conditions are now of greater importance. Power purchase agreements for Kafue Gorge Lower and for Itezhi-tezhi have been developed by others and were reviewed as part of Task 3. Task 2, Southern Africa Power Market Study, provides insight into current market conditions. The results of Task 3 and Task 2 were used in this report to develop a coordinated plan for the hydro and interconnection projects. The Mkushi Electrification project was evaluated as part of Task 4a, Evaluation of Grid Expansion into the Mkushi Farming Area. Summary results of that task are presented in this report as a basis for overall program recommendations to OPPPI.

1.3.1 Mkushi Electrification

For the Mkushi electrification project we estimate the cost of delivered energy and compared with that of small diesel generation. This comparison is the fundamental test of grid extension projects. If a project passes this test, there may be barriers to commercial viability. However, as we shall see, the Mkushi project does not require additional evaluation.

1.3.2 Hydro and Interconnection Projects

The hydro projects and the Tanzania interconnection have strong interactions with other projects and their value depends on the nature of the market. Figure 1-1 summarizes the approach taken to reflect these factors in the evaluation of these projects. This analysis was divided into cost analysis, hydro operation analysis, and market analysis. In the cost analysis, investment and operations and maintenance costs, as summarized in Section 2, were estimated over the lifetime of the project. Income tax liabilities to a independent power producer (IPP) developer were also estimated on a fully-taxed basis.

The hydro operation and market analysis was conducted as part of the Southern Africa Power Market Study (the Task 2 Report). The objective of that study was to estimate the value of each project to the Southern African regional system, primarily defined as the interconnected Southern African Power Pool. A joint modeling approach was used to capture both the interaction of hydroelectric plants on the Kafue and Zambezi Rivers (hydro operations analysis performed by OPPPI staff) and the operation of the Southern African regional power market (market analysis performed by Nexant). OPPPI staff used the Valoragua hydro simulation model to represent the interaction of hydro plants on the Kafue and Zambezi Rivers. Nexant performed the market analysis using the ELFIN Generation Planning and Market Simulation Model. The ELFIN model, developed by the Environmental Defense Fund and licensed to Nexant, was used to represent the operation of the regional market

For hydro projects, the value was estimated based on the benefit of displacing thermal generation and deferring capital investment in generating capacity in the rest of the regional system. For the interconnection, the value was calculated based on the operating savings that could be achieved through connecting Tanzania to the regional system. End effects corrections were made to adjust the results of market simulation analysis to the full life of projects.

We considered the full range of hydrologic conditions in the hydro operations modeling. In the market analysis we only considered average hydrologic conditions. The consideration of the full range of hydrologic conditions was not possible in the time allotted for this analysis. The potential effect on the results is difficult to predict because the consideration would have both positive and negative effects on project value.

Based on the hydro operations analysis, we found that the proposed new hydro projects have a substantial effect on the operation of existing hydroelectric stations, sometimes allowing them to increase their generation. While this is a benefit of the project, the IPP developer of the project would find it difficult to realize a commercial gain out of the benefit unless there was some sort of coordinated operating agreement among the operators of different projects. For this reason, we have divided the estimates of value into direct commercial benefits that could be achieved through direct sale from the project and indirect benefits that could only be realized by the developer if there were a coordinated operating agreement.

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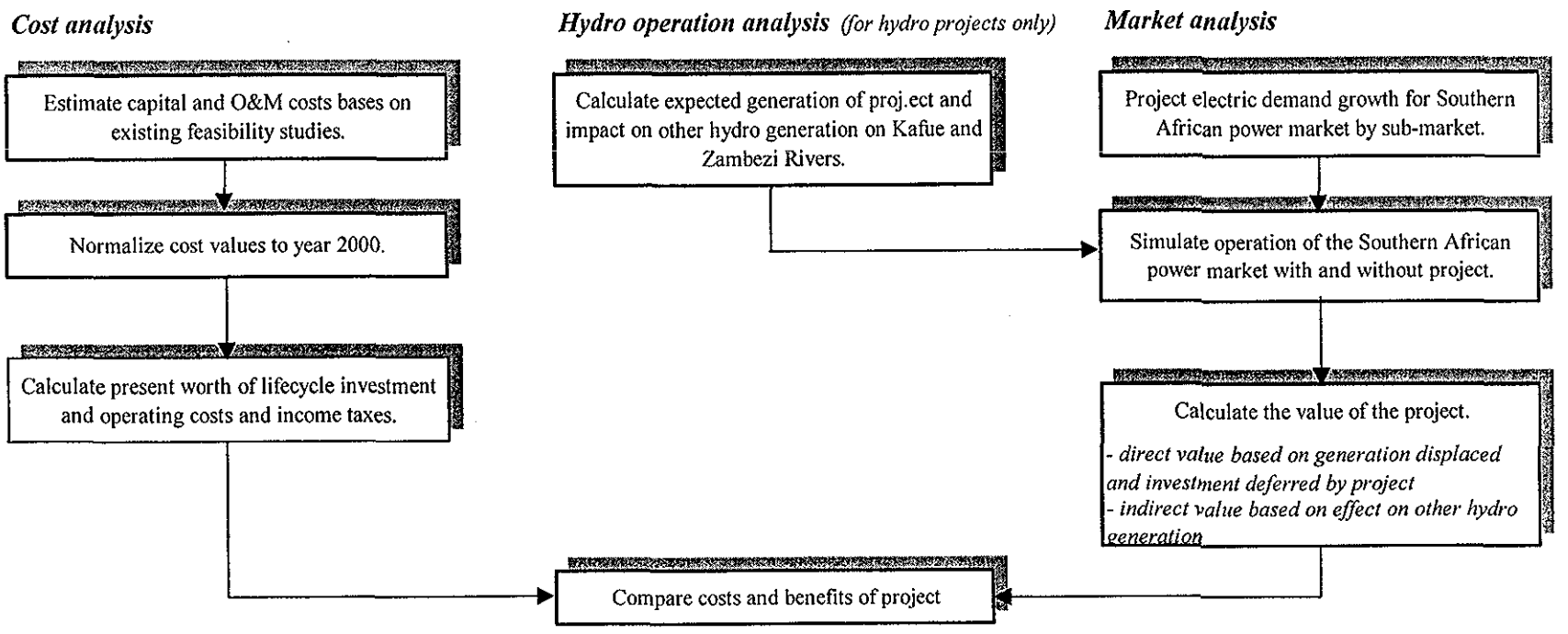

Figure 1-1. Project Evaluation Approach for Hydro and Interconnection Projects

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Transmission projects also have indirect benefits in increasing system reliability and allowing greater economies of scale in the development of new projects. Our analysis is conservative in that it does not credit these benefits.

The size of the direct commercial benefits estimated are an indication of the maximum price that could be negotiated in an open market. If the developer were to negotiate such a price, other parties should be economically indifferent. However, they would not receive any net benefit from purchases at this price and so would not have a strong motivation to buy. Therefore, the estimated value to a developer, as reflected in the price, would be somewhat less that the values estimated.

Benefit-cost ratios were calculated from the point of view of the developer based on receiving a price that reflects the entire value of the project to the region. This ratio was calculated with and without income taxes consider both direct commercial benefits and for the total benefits of the project. A commercially viable project would have a benefit-cost ratio somewhat above 1.0. This would allow a developer to be fully compensated for its costs, receive a reasonable profit, and be able to negotiate a price that also would be beneficial to purchasers.

1.3.3 Criteria for Developing a Coordinated Plan

The criteria for developing recommendations for individual projects were profitability under expected market conditions and ability to mitigate the risk of adverse market conditions. All of the projects have associated social benefits; however, since the projects are to be developed by private parties, the social benefits were not given weight in the evaluation. The coordinated plan was developed on the basis of the following:

- Given two economically and financially viable projects, lower capital-cost projects were developed first.
- Projects that could best complement the existing power system and current market conditions were given priority.
- Project synergies were considered so as to maximize the benefits of the group of projects recommended for development.

All costs, revenues, and currency values presented in this report are expressed in year 2000 US$ unless otherwise stated.

1.4 *Organization Of This Report*

The characteristics of the projects are presented in Section 2. This section includes a presentation of the results of the hydro operations modeling that was used as a basis for determining the market value of the hydro projects under consideration. The evaluation of project costs and benefits is presented in Section 3. Our conclusions and program recommendations for OPPPI are presented in Section 4.

Section 2 Description of Projects Under Consideration

2.1 *Summary*

Two hydroelectric projects (Kafue Gorge Lower and Itezhi-tezhi), one transmission interconnection project to Tanzania, and the Mkushi Electrification project were evaluated. The key project costs affecting project economics are summarized in Table 2-1.

Table 2-1. Key Cost Parameters For Projects

Project	Size (MW)[2]	Cost (millions US$)[1] Investment	Interest During Construction[3]	Operations & Maintenance	Construction time (years)
Kafue Gorge Lower	600	594.3	145.6	3.4	7
Itezhi-tezhi[4]	120	95.1	16.6	1.2	5
Transmission for Itezhi-tezhi	NA	35.0	2.4	0.3	2
Zambia/Tanzania Interconnection	200	191.5	20.0	4.2	3
Mkushi Electrification	11.9	41.6	1.7	2.0	6

1. Based on References 2, 3, and 6, respectively, adjusted to year 2000. An allowance of 25% of total investment costs was made for IPP development costs for the hydro projects and 20% for the transmission projects.
2. Installed capacity for hydro projects, transfer capability for interconnection and peak load for electrification projects.
3. At 7% real interest rate
4. Investment value does not include $29 million that would be required for transmission.

Generation of the hydroelectric projects was estimated using operation modeling of the Kafue and Zambezi River systems, discussed in Section 2.2.4. Line usage of the interconnection was based on multi-area modeling of the Southern Africa power market taking into consideration transmission constraints between sub-markets, discussed further in Section 3. The estimated demand for the Mkushi area is 25.9 GWh.[1]

Descriptions of the proposed projects follow.

2.2 *Hydroelectric Projects*

The operation of the proposed hydro projects is closely related to that of existing dam and power facilities on the Kafue River. These are described below followed by descriptions of the proposed hydroelectric projects.

[1] This demand is based on References 7 and 8 and may have changed since those studies were conducted. We did not perform an independent evaluation of demand in the Mkushi area

2.2.1 Existing Facilities on the Kafue River

The Kafue river is now controlled with two dams and reservoirs. The Itezhi-tezhi dam and reservoir provides the main storage of about 5.6 billion cubic meters (live storage about five billion cubic meters), but with no associated power plant. It is about 230 km upstream from the Kafue Gorge Upper dam. The dam and reservoir at Kafue Gorge Upper provide additional storage of about one billion cubic meters. The Itezhi-tezhi reservoir can store about 65% of the average inflow above its dam, while the Kafue Gorge Upper reservoir can store about 10% of the average inflow above the Kafue Gorge Upper dam.[1]

The yearly average inflows show considerable variation, as illustrated in Figure 2-1. The minimum yearly average inflow at the Itezhi-tezhi reservoir was 65 cubic meters per second (m^3/sec) in 1921/2; the maximum was 826 m^3/sec in 1977/8.

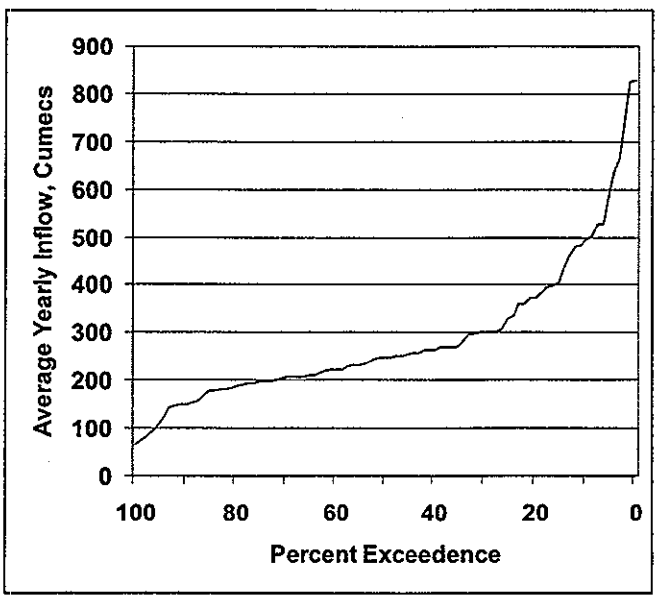

Figure 2-1. Distribution Of Average Yearly Flows Into Itezhi-tezhi

[1] The average inflow at the Itezhi-tezhi reservoir site was approximately 280 cubic meters per second (m^3/sec), equivalent to an total yearly inflow of 8.8 billion cubic meters. Average inflow is about 55 m^3/sec between the Itezhi-tezhi and Kafue Gorge Upper dams. However, the inflows below Itezhi-tezhi are roughly balanced by evaporation and transpiration in the reservoirs at Itezhi-tezhi and Kafue Gorge Upper, and the waterways in between. Thus the estimated average yearly inflow to the reservoir at Kafue Gorge Lower is about the same as the inflow to Itezhi-tezhi.

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2.2.2 Kafue Gorge Lower

The Kafue Gorge Lower project is located in the Kafue Gorge, about 65 km upstream from the confluence of the Kafue and Zambezi rivers and 2 km downstream from the existing 900 MW Kafue Gorge power plant, which we will refer to as the Kafue Gorge Upper plant. Kafue Gorge Lower will develop the remaining 200 meters of the 600 meter head in the Kafue Gorge. Kafue Gorge Upper uses the other 400 meters. The project has been studied several times, most recently in the Feasibility Study Of The Kafue Gorge Lower Hydroelectric Project, prepared by Harza Engineering Company and Rankin Engineering and completed in May 1995 (Reference 2).

The proposed dam for the Kafue Gorge Lower project will rise 52 meters above the existing stream bed (elevation 534 meters) to a top elevation of 586 meters, with a structural height of 62 meters above its sound rock bed. The dam type may be either concrete faced rock fill dam or roller compacted concrete. Reservoir capacity at maximum elevation of 582 meters will be about 5.5 million cubic meters. Live storage of 2.2 million cubic meters above elevation 574 meters is only about 0.05% of the live storage capacity of the Itezhi-tezhi reservoir.

An underground cavern will house the power generation facilities. There will be four 150 MW Francis turbines, each with a design head of about 186 meters (all units operating), a design discharge of 88.3 m^3/sec, and a synchronous speed of 250 rpm. The units will discharge into a tailrace tunnel which will carry the water about 7.8 km, ultimately discharging back into the Kafue river in the Kafue Gorge with a minimum tailwater elevation of 384 meters.

Each unit will be equipped with a generator rated for maximum continuous output of 165 MVA at rated voltage of 13.8 kV. A separate 330/13.8 kV transformer will serve each generator. Gas-insulated switchgear will be located next to the transformers in the underground transformer hall. High voltage cables will connect the transformer hall to line terminations at the surface. Two 330 kV transmission lines will connect the surface terminations at Kafue Gorge Lower to the switchyard at Kafue Gorge Upper, a distance of about 3.5 km.

At design conditions, the Kafue Gorge Lower plant will generate 600 MW while passing 353 m^3/sec of water. At 353 m^3/sec the reservoir has enough live storage for about 1.7 hours of full power operation.

At design conditions, the Kafue Gorge Upper plant will generate 900 MW while passing 270 m^3/sec of water. Therefore Kafue Gorge Lower cannot operate at 600 MW continuously unless substantial water is bypassing the Kafue Gorge Upper turbines (spilling), which would normally only occur infrequently when the reservoir was in danger of overflowing during a wet hydrologic year. If Kafue Gorge Upper were operating at full output and Kafue Gorge Lower started operating when the Kafue Gorge Lower reservoir was full, Kafue Gorge Lower could operate at full output for about 7.3 hours.

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The operation of Kafue Gorge Lower is entirely dependent on the operation of Kafue Gorge Upper for its water and must follow its operation with only a few hours delay. Kafue Gorge Upper's available head is about twice that of Kafue Gorge Lower, and normally Kafue Gorge Lower would have nearly the same amount of water as Kafue Gorge Upper. Over any period longer than a few hours Kafue Gorge Lower should generate about half as much energy as Kafue Gorge Upper. It could deliver it at a different rate, for example in more of a peaking mode.

2.2.3 Itezhi-tezhi

The existing dam at Itezhi-tezhi was completed in 1978 to regulate the flow of the Kafue river, in conjunction with the overall development of the power generation facilities at Kafue Gorge. Construction of a power plant there has long been contemplated. In April 1999 Harza Engineering Company and Rankin Engineering Consultants completed a Feasibility Study of the Itezhi-tezhi Hydroelectric Project (Reference 3)

The existing conventional earth fill dam has a maximum height of about 51 meters with its top at elevation 1035. The maximum and minimum operating levels of the reservoir are 1030.5 and 1006. If operated according to optimized rule curves, the vast majority of the operation will be between elevations of 1024 and 1030.5 meters. Recently soil borings were made along the crest of the dam to a depth of 7.5 meters to explore the condition of the dam's core. The material was found to be a well-compacted sandy/silt/clay and showed no signs of desiccation, indicating that the core is in good condition.

An underground cavern will house the power generation facilities. There will be two Kaplan turbines, each with a design net head of about 40 meters, a design discharge of 156 m^3/sec, and a synchronous speed of 176 rpm. The units will each be rated at 56.3 MW, with a maximum capability of 60 MW. Turbine centerline will be elevation 976 meters, about 10 meters below tailwater elevation. The units will discharge into a tailrace tunnel that will be connected to one of the existing diversion tunnels, which discharges immediately down river from the dam. .

Each unit will be equipped with a generator rated for maximum continuous output of 67 MVA at a power factor of 0.9 and rated voltage of 13.8 kV. A separate 220/13.8 kV transformer will serve each generator. 220kV cable will connect the transformers to air-insulated switchgear in a surface switchyard .

The proposed transmission connection will be a single circuit 220 kV line from the switchyard to Muzuma substation. a distance of about 220 km. The line cost was estimated to be about $29 million and involve losses of 3.5 MW (2.9%) on peak and 15.1 GWh (2.3%) of energy per year, based on annual average energy production.

2.2.4 Hydro Operation Studies

The hydro operations studies were conducted to show the interaction of the new hydro projects with other hydro plants on the Kafue and Zambezi Rivers. This modeling is based on maximizing total generation from all hydro stations. There are currently no

agreements that require such operation. The operation of new projects by private parties will make the formalization of joint operating agreements of critical importance.

Table 2-2 summarizes the results of these studies. The following observations can be made:

- The Kafue Gorge Lower project alone could generate 3,780 GWh on the average. In addition, improved water management would result in an increase in average generation at Kafue Gorge Upper and in Zambezi River hydro stations, primarily at Kariba North and South for a total increase in generation of almost 6,300 GWh annually.
- Itezhi-tezhi alone would generate 520 GWh per year on the average, but would result in a nearly 2,000 GWh annual increase in generation at Kafue Gorge Upper.
- With both plants operating, Kafue Gorge Lower would generate less than without Itezhi-tezhi and the beneficial effect of their operation on the generation at other plant is somewhat less than that of Kafue Gorge Lower alone.

We have reservations about these results and believe that they should only be considered preliminary.[1] However, the results do illustrate the common sense concept that adding constraints, such as a new plant with its own operating requirements, could affect other plants on the same river system.

Table 2-2. Summary of Hydro Operations Analysis

Hydro additions	Kafue Gorge Lower average generation (GWh)	Itezhi-tezhi average generation (GWh)	Net change in generation at Kafue Gorge Upper (GWh)	Net change in generation on hydro plants on Zambezi (GWh)	Total net increase in generation (GWh)
Kafue Gorge Lower alone	3780	0	1375	1137	6292
Itezhi-tezhi alone	0	520	1975	66	2561
Both projects	3303	519	1989	69	5880

2.3 *Interconnection With Tanzania*

A team consisting of representative from Zambia Electricity Supply Corporation (ZESCO), ESKOM, and Tanzania Electric Supply Company (TANESCO) completed an inter-utility technical feasibility study for a transmission interconnection between Zambia and Tanzania in 1995 (Reference 5). The result was a proposal for a 330 kV transmission line interconnection from Pensulo Substation in Zambia to Mwakibete Substation in Tanzania. The premise was that surplus power in Zambia would be a cheaper source for

[1] For example, it is difficult to imagine a mechanism through which adding a relatively small power plant at the existing Itezhi-tezhi dam and reservoir could increase generation at Kafue Gorge Upper by almost 2,000 GWh/year, far more than the generation at Itezhi-tezhi. It would seem that whatever pattern of releases produced the additional generation would be possible without the new power plant. This issue requires more investigation.

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Tanzania's growing demand than building its own new resources, even considering the cost of the line. In addition the routing of the 330 kV line through Zambia's Kasama Substation would strengthen the electrical system in its Northern and Luapula provinces.

The governments of the Republic of Zambia and the United Republic of Tanzania signed an Inter-Governmental Memorandum of Understanding (MOU) in June 1997. The objective of the MOU is to establish a framework under which the signatories pronounce their clear intention to enhance regional power cooperation through the establishment of a transmission line interconnection that will facilitate electricity trading. The intention was for each government to authorize its national utility to enter into the necessary agreements for the establishment and operation of the interconnection, subject to approval by the governments.

ZESCO and TANESCO signed an Inter-utility MOU in July 1997. Its objective is to establish the basic principles under which the interconnection will be constructed and operated and the objectives that it aims to achieve, including:

- To coordinate and cooperate in the planning, construction, and operation of the line to minimize costs.
- To allow private sector investment in the project.
- That the two utilities shall endeavor to take a participating share of say 20% in the firms that build the lines in their respective countries.
- To provide assistance to the contractors regarding the execution of the work.
- To guarantee power trading between the two utilities for a period of 15 - 20 years at a good price.

ZESCO and TANESCO had already (in April 1997) signed a Co-operation Agreement providing for mutual supply of technical information, services, and joint planning.

The 1995 feasibility study recommended a project with the following parameters:

- 330 kV AC
- From Pensulo through Kasama Substation in Zambia to Mwakibete
- Line length 697 km
- Transfer capability 200 MW

A team from the same utilities, but with legal and financial experts in addition to the 1995 study's technical experts, completed a Financial Justification Investigation in April 1998 (Reference 6).

2.4 *Mkushi Electrification*

The Mkushi Farm Block is a major commercial farming area in Central Province occupying about 176 thousand hectares and comprising over 150 commercial farms. Agricultural activities range from the growing of maize, tobacco, soy and vegetables to

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cattle ranching, Irrigation of wheat, vegetable and coffee crops is at present carried out only on a limited scale, although this is increasing. A very limited area of the area is provided with electricity from an existing 33 kV system and much of that irrigation which does take place is diesel powered. The principal function of the proposed electrification project is to provide power supplies for irrigation pumping during the dry season to enable wheat to be grown and production of other irrigated crops to be increased, and to establish refrigeration and other facilities to increase agricultural production in the area.

The proposed Mkushi electrification has been studied in a number of reports.[1] The major elements of the proposed electrification in Reference 7 include the following:

- A 330/33 kV Central substation that provides the main power supply for the new and existing loads
- Five 33/11 kV substations supplied from Central at 33 kV[2]
- 11 kV distribution networks originating from each of the five 33/11 kV substations
- Improvements to existing substations at Mkushi Farmers and Mkushi Boma (township).

Some loads would be served directly from the 33 kV lines, in cases where they are closer to the load than an 11 kV line. Estimated lengths total 600 km of 11 kV and 33 kV lines. The system would serve about 200 farm consumers and a number of smaller loads in Mkushi Boma.

The consultants also proposed an all 33 kV system, which had the technical advantages of lower losses, better voltage profiles, and more potential for expansion. The line routes were essentially the same in either case.

A later report (Reference 8) used the same basic layout within the Mkushi farming area. It sought to find lower cost alternatives. The additional options differed primarily in the source of the power supply, that is the higher voltage transmission connection to the main system. The five options were:

1. A 66/33/11 kV scheme supplied from Serenje
2. A 66/11 kV scheme supplied from Serenje
3. A 66/33/11 kV scheme supplied from Lunsemfwa (Mita Hills Dam, based on the existing Zambia Consolidated Copper Mines (ZCCM) hydro generation in that area)
4. A 66/11 kV scheme supplied from Lunsemfwa
5. A 330/33/11 kV scheme supplied from the a new Central substation, quite similar to the basic design from Reference 7.

[1] We had access to References 7 and 8.

[2] One of the 33/11 kV substations is proposed as part of the Central substation

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2.5 *References*

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5. Zambia – Tanzania 330 kV Transmission Interconnection Study. ESKOM, ZESCO, and TANESCO; September, 1995
6. Zambia – Tanzania 330 kV Transmission Interconnection Financial Justification Investigation. ESKOM, ZESCO, and TANESCO; April 1998
7. Mkushi Electrification Scheme, Project Design Report, Merz and McLellan, June 1988
8. Mkushi Electrification Scheme, Review of Supply Operations, Merz and McLellan, November 1993

3.1 *Summary of Base Case Economic Analysis for Hydro and Interconnection Projects*

Table 3-1 summarizes the economic analysis of the Kafue Gorge Lower, Itezhi-tezhi, and Tanzanian Interconnection projects under Base Case conditions. These conditions include:

- Annual regional growth of 2.7% in energy demand in southern Africa. Key sub-market growth rate are 2.2% per year in Zambia, 8% in Tanzania and 4.1% in Zimbabwe.
- The following key transmission constraints:
  - Zambia/Democratic Republic of the Congo- a single circuit 220 KV line with transfer capability of 250 MW; upgrading to 310 MW in 2003 through replacing the current-voltage transformers and traps at the Luano substation in Zambia; completing a second 220 kV line between the Karavia substation (Democratic Republic of the Congo) and Luano and installation of 144 MVA of shunt capacitors at Karavia to increase transfer capability to 465 MW in 2008; and increasing capability to 945 MW in 2010 by up-rating the terminal equipment at the Kolowezi substation associated with the Inga/Kolowezi DC line from 520 MW to 1120MW and completing a 330 kV line from Kolwezi to Luano.
  - Zambia/Zimbabwe- twin circuit 330 KV line at Kariba with transfer capability of 1,000 MW.
  - Zimbabwe/South Africa- predominant power flow is on the 400 KV line from Zimbabwe to South Africa through Botswana. Current transfer capability is 250 MW, limited by transformer capacity of 220/132 kV transformers at Segoditshane substation in Botswana. The Base Case assumptions are that a third 220/132kV transformer will be installed at Segoditshane increasing transfer capability to 700 MW by 2003 and that a second 400 KV Zimbabwe/South Africa line from further increasing capacity to 1300 MW by 2010.
- Most new generating capacity in the region is made up of coal-fired plant equipped with flue-gas desulfurization, supplemented by liquid-fueled peaking combustion turbines. Most new generation aside from the projects under consideration are located in South Africa in the Base Case
- A 2007 entry date for the hydro projects and 2003 for the Tanzanian interconnection
- Only one project is considered at a time. There are different results if more than one project is implemented.

Table 3-1. Summary of Economic Evaluation of Hydro and Interconnection Projects

Project	Present Worth of Cost (US$/kW)[1]				Present Worth of Potential Commericial Value (Year 2000 US$/kW)[2]			Ratios			
								Direct Benefits/ Costs		Total Benefits/ Costs	
	Investment	Operations & Maintenance	Income Taxes[3]	Total	Direct Commercial Benefits	Indirect Benefits	Total	with taxes	without taxes	with taxes	without taxes
Kafue Gorge Lower	1743	76	460	2279	3223	933	4156	1.4	1.8	1.8	2.3
Itezhi-tezhi without required transmission	1315	139	347	1802	2981	7318	10299	1.7	2.1	5.7	7.1
Itezhi-tezhi with required transmission	1698	172	456	2325	2981	7318	10299	1.3	1.6	4.4	5.5
Zambia/Tanzania Interconnection	1297	281	367	1944	3289	0	3289	1.7	2.1	1.7	2.1

1. Present worth at 7% real discount rate in year of installation (2003) expressed in year 2000 US$. Values based on References 2, 3 and 4 estimates, respectively, adjusted to year 2000 values. Investment costs include return on equity and debt repayment. Debt rate is 6% per year. Return on equity is 15% for hydro projects and 10% for transmission projects. Hydro projects are financed with 70% debt and transmission projects with 50% debt. Income taxes estimated at 38% income tax rate. Per kW values based on installed capacity for hydro projects and transfer capability for transmission.

2. Present worth of benefits based on Base Case market conditions in Southern Africa Power Market Study in the year of installation (2003) and expressed in year 2000 US$. Direct commercial benefits represent value of direct generation displacement and investment deferral within SAPP achieved by the project. Indirect commercial benefits apply to hydro projects and refer to positive impact on other hydro projects. These benefits could be commericially realized by through project through agreements with other entities.

3. Taxes that would be paid by a fully-taxed privately-owned entity.

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The effect of worst-case conditions and the effect of developing more than one of the projects will be considered later in this section.[1]

Under Base Case conditions, all three projects have benefit-cost ratios of 1.3 or greater even if the developers were to be fully taxed. The benefit-cost ratios associated with direct commercial benefits should be thought of as the maximum revenue per unit of cost that could be achieved from the point of view of the developer.[2] The benefit-cost ratios of the hydro projects are higher if the indirect benefits of the project to other hydro operators are considered. The benefit-cost ratios associated with total benefits could be realized by developers, and in many cases purchasers, only if there were operating agreements rewarding projects for beneficial effects on overall hydro system generation. Some observations follow:

- All three projects are economically viable and have the potential for commercial viability considering Base Case conditions.
- The Tanzanian Interconnection has the highest direct value per unit of cost. This value is based on displacing the high marginal cost thermal generation in Tanzania with lower cost generation available outside the country.
- The Itezhi-tezhi project has the lowest capital cost, but also the lowest direct commercial value per unit of cost of the three projects if the cost of transmission is included in the project.

Based on their positive impact on generation at existing plants as calculated in the hydro operation studies, the results show corresponding economic benefits for both Kafue Gorge Lower and Itezhi-tezhi.[3] We have identified the following two ways for these indirect benefits to be translated into commercial terms for the developer/operator of the projects:

1. Some of the indirect impacts could be reflected in the power purchase agreement with ZESCO, if ZESCO were the buyer and continued to operate Kafue Gorge Upper
2. An operating agreement that provided for some form of sharing of overall river system.

In any case Kafue Gorge Lower will need some kind of operating agreement with Kafue Gorge Upper because its generation is so highly dependent on the operation of that station.

[1] A full range of sensitivity analysis to the value of the projects was performed as part of the Southern African Power Market Study. Only the worst-case conditions, defined as the sensitivity case having the largest negative impact on project value, are presented in this report as a way of simplifying presentation.
[2] It is likely that there would be some sharing of benefits with the purchaser resulting in a lower ratio; however, the project would be unattractive to the developer at less than 1.0.
[3] As we have stated earlier, we have some reservations about the preliminary results of the operation studies. Further analysis could show a different effect. However, the approaches enumerated would apply to indirect impacts, whether positive or negative.

3.2 *Economic Analysis of Mkushi Electrification Project*

The economics of the Mkushi Electrification project is summarized in Table 3-3. The delivered cost of energy is over 250 US$/MWh, even if the IPP developer were forgiven income taxes. Diesel generation would be competitive with the grid extension at this price. If prices were to cover costs, farmers would find electricity as expensive as diesel generation, except that most costs would be fixed. The IPP developer would not find the project commercially viable if the price were less. This is a fundamental economic difficulty that cannot be avoided with different project ownership structures.

Greater demand could bring economies of scale. We have indications that demand has grown beyond the levels estimated in previous studies of this project. However, much more than marginal improvement would be required before this project would be commercially viable.

Table 3-2. Summary of Economic Evaluation of Mkushi Electrification

Annualized Costs (millions US$)	
Investment	4.0
Operations & maintenance	2.0
Income Taxes3	1.4
Received energy	0.5
Total	8.0
Annual demand (GWh)	25.9
Cost of delivered energy (US$/MWh)	
if IPP developer taxed	307.8
If developer not taxed	254.4

3.3 *Consideration of Worst Case Conditions for Hydro and Interconnection Projects*

A range of sensitivity analysis was performed to tests the value of the projects under consideration under various demand and development scenarios. Low regional load growth (1.1% versus 2.7% in the Base Case) was found to have the most adverse impact on the hydro projects. Factors that could decrease the future marginal cost of generation in Tanzania had the most negative impact on the value of the Tanzanian Interconnection.[1] We specifically considered the cases in which new gas finds off the Tanzanian coast

[1] Low regional load growth was found to actually increase the value of the interconnection. Causal factors include more excess generation in the region for transfer to Tanzania and delay of hydro projects in Tanzania.

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would be adequate to support all existing thermal generation, except diesels, and all generation from new thermal capacity.

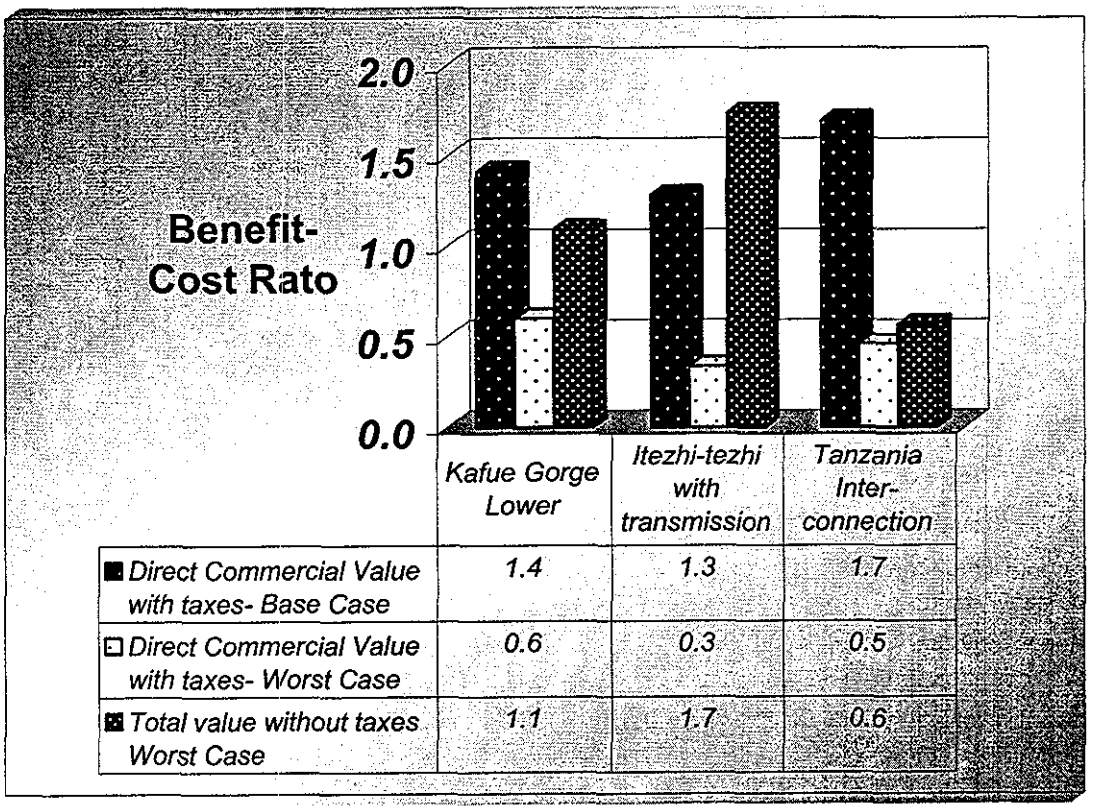

Figure 3-1. Effect of Worst-Case Conditions

Figure 3-1 summarizes the worst-case analysis. We can make the following observations:

- The benefit-cost ratios, as observed by a private developer who is fully taxed, are below 1.0 for all projects in the worst case. Based on these conditions, power purchase agreements for the hydro projects or payment under a transmission service agreement for the interconnection are unlikely to be commercially attractive to a developer.
- If power purchase or transmission service agreement prices were based on Base Case conditions, the purchasers would be taking the risks associated with worst-case conditions.
- Even with worst-case assumptions, there would be some potential for the hydro projects to reach commercial project viability through tax incentives to the developer and operating agreements that resulted in developers (or power purchasers) sharing in the benefits to other projects.

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- In the case of Kafue Gorge Lower, indirect benefits would be primarily to non-ZESCO stations. It would not be possible to factor these benefits into the power purchase agreement if ZESCO were the purchaser.
- In the case of Itezhi-tezhi, the indirect benefits of the project would be primarily to Kafue Gorge Upper. If ZESCO were the power purchaser and continued to operate Kafue Gorge Upper, the indirect benefits could be reflected in the power purchase agreement.
- A benefit of the interconnection that has not been evaluated is that Tanzania that could provide exports to Zambia during dry seasons.[1] The value of this benefit would increase under our worst-case conditions in which thermal generation in Tanzania would be fired by natural gas.

This analysis provides an indication of how the economics of the projects could be affected by worst-case conditions. However, there are risk mitigation strategies that can be employed to reduce the impact of worst-case conditions. Generally, these strategies will reduced the profitability of projects under expected conditions. Examples of risk mitigation measures for the projects under consideration are:

- Allowing flexibility to defer hydro projects if growth prior to 2007 does not meet some specified target.
- Long-term power purchase agreements with Tanzanian customers in the case of the interconnection
- Use of multiple power purchase agreements, or back-to-back power purchase agreements for hydro projects committing some output to export.
- Developing hydro projects consecutively rather than in parallel.

3.4 *Consideration of Project Synergies*

The Base Case analysis been based on an investigation of each project separately. The economics of each of the hydro projects is affected if both are developed, primarily because of hydrologic interaction. Furthermore, the Tanzanian interconnection affects the value of the export market for hydro generation.

Figure 3-2 shows that Base Case results for Kafue Gorge Lower considering only direct commercial benefits of the project with the developer fully taxed and impact of the other the other projects on those economics. If Itezhi-tezhi were built in 2007 followed by Kafue Gorge Lower, the benefit-cost ratio associated with direct commercial benefits and full taxation (i.e., the maximum revenue per unit of cost that could be realized by a fully-taxed developer) would fall from 1.4 to 1.3.[2] On the other hand, if the Tanzanian

[1] Our market analysis only considered average hydro conditions. Therefore, almost all benefits of the interconnection were the result of displacing generation in Tanzania.

[2] The projected interaction of the two projects and the impacts on other parts of the system rely on the results of the hydro operations modeling. As noted previously, these results must be viewed cautiously and further study should be undertaken before basing any final decisions on them.

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interconnection were developed prior to Kafue Gorge Lower, its benefit-cost ratio would be enhanced because of increased access to the high-value Tanzanian power market.

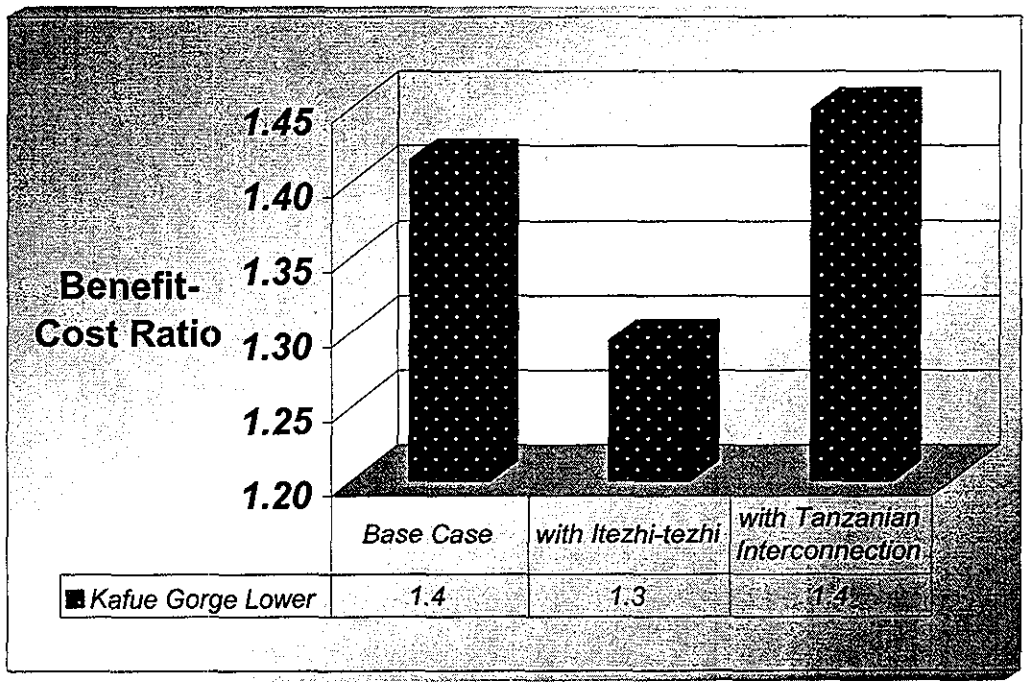

Figure 3-2. Dependence of Kafue Gorge Lower on the Development of Other Projects

Building Itezhi-tezhi first has a moderate negative impact on the project economics of Kafue Gorge Lower. Figure 3-3 displays results showing the effect on Itezhi-tezhi economics if Kafue Gorge Lower is built first. As before, the ratios shown reflect direct commercial benefits and full taxation of the developer. The costs for Itezhi-tezhi include the cost of transmission required to connect the project to the system. On its own, Itezhi-tezhi project appears to be commercially viable; however, it would not be economic to develop the project if Kafue Gorge Lower is developed first.

The projected interaction of the hydro projects is based on using the Valoragua model. With further resources devoted to hydro operation modeling it may be possible to develop an operating strategy that would meet the overall water management and power generation goals for Kafue and Zambezi River facilities with both projects operating in a commercially viable mode. The results of this study clearly show that this is an important issue.

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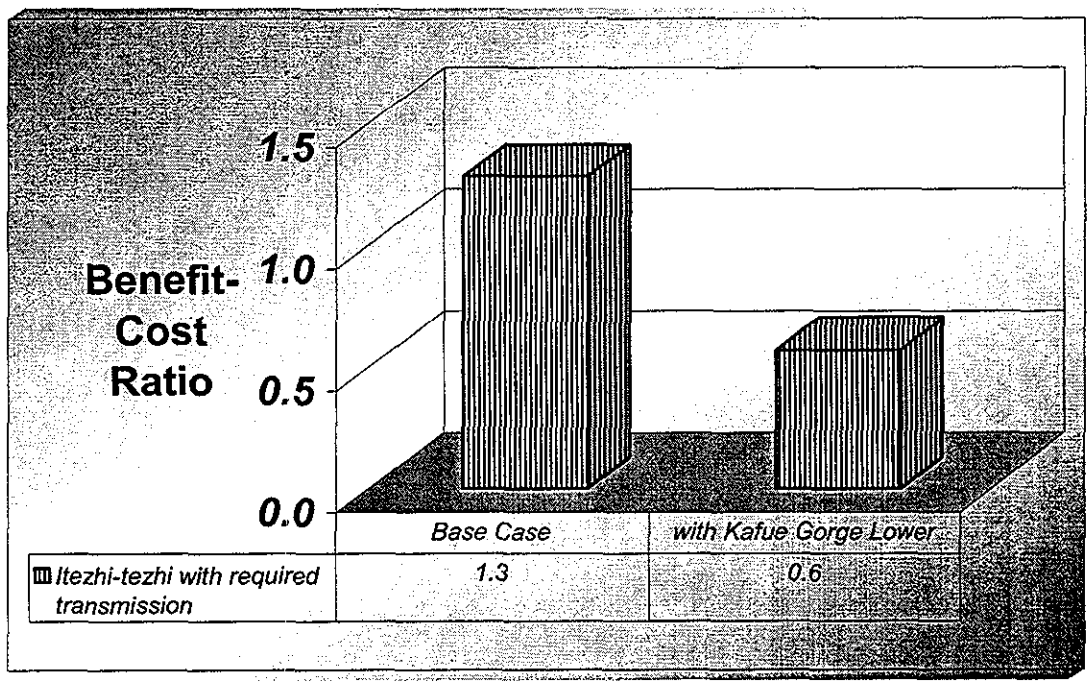

Figure 3-3. Dependence of Itezhi-tezhi Economics on Development of Kafue Gorge Lower

The Tanzanian Interconnection appears to be a commercially viable project even if further Zambian hydro projects are not developed according to our Base Case results. The development of the hydro resources does not affect the regional economic value of the interconnection; however, the interconnection would open opportunities for long-term power sales to Tanzania from Zambian export projects. This would increase the value of Zambian power exports and would improve the project economics of Kafue Gorge Lower, which will rely on substantial exports after it begins operation.

In summary, our analysis indicates the following:

- Kafue Gorge Lower has the potential to be commercially viable with or without the other projects.
- Building Kafue Gorge Lower first may reduce Itezhi-tezhi's benefit/cost ratio below breakeven. However, further study should be undertaken before basing any final decisions on these results.
- The Tanzanian Interconnection enhances the commercial value of the Kafue Gorge Lower project by providing access to a high value export market.
- The Itezhi-tezhi project does not influence the value of the interconnection, because of the domestic scope of the project.

Section 4 Conclusions and Recommendations

Our analysis leads to the following conclusions:

- The Zambia - Tanzania interconnection is economically viable as a stand alone project considering Base Case conditions.
- Kafue Gorge Lower and Itezhi-tezhi are also economically viable as stand alone projects considering Base Case conditions.
- However, there are risks involved. The hydro projects have unfavorable economics if regional yearly demand growth is 1.1% versus 2.7% in the Base Case. The interconnection has unfavorable economics if much more natural gas becomes available for power generation than was assumed in the Base Case.
- Kafue Gorge Lower has the potential to be commercially viable with or without the other projects. However, building Kafue Gorge Lower first may reduce Itezhi-tezhi's benefit/cost ratio below breakeven. Further study should be undertaken before basing any final decisions on these results.
- The Mkushi Electrification project does not appear to be viable as a privately-financed commercial venture.

Given the results of our analysis, we recommend the following:

- OPPPI should initiate the process of developing solicitation documents for the Zambia - Tanzania interconnection.
- OPPPI should initiate the process of developing solicitation documents for the Kafue Gorge Lower hydro power plant.
- OPPPI should initiate the process of developing solicitation documents for the Itezhi-tezhi hydro power plant, but be prepared to review that decision upon the completion of the hydro operations modeling studies referred to below.
- OPPPI should develop a hydro operations modeling capability and refine the estimates of expected generation at Kafue Gorge Lower, Itezhi-tezhi, and existing plants.
- OPPPI should use this capability to support the following activities:
  - Developing a preferred operating regime based on the policy/risk preferences of the GRZ.
  - Establishing the expected output of the existing and potential new hydro plants.
  - Confirming the decision to proceed with Itezhi-tezhi.
  - Developing joint operating agreements to govern the operation of the Kafue river system as a whole.
  - Developing contractual arrangements for the projects.
- OPPPI should not prepare model solicitation procedures for private development of grid extension into the Mkushi farming area at this time.

Document Review

Final Report

Assistance To Zambia's Office For Promoting Private Power Investment
Task 3: Document Review

Prepared under Contract for:
United States Agency for International Development
LAG-I-00-98-00006-00

Bechtel National, Inc. *July 2000*

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Acronyms And Abbreviations

AC	Alternating current
BOM	Build - own- maintain
BOOT	Build - own - operate - transfer
CEC	Copperbelt Energy Corporation
DC	Direct current
DRC	Democratic Republic of the Congo
ERB	Energy Regulation Board
ESCOM	Electricity Supply Corporation of Malawi
ESKOM	South Africa's national electric utility
GRZ	Government of the Republic of Zambia
GWh	Gigawatt-hour
IA	Implementation agreement
IDC	Interest during construction
IPP	Independent power producer
km	Kilometer
kV	Kilovolt
kW	Kilowatt
kWh	Kilowatt-hour
m	Meter
m^3/sec	Cubic meters per second
MOU	Memorandum Of Understanding
MVA	Megavolt-ampere
MVAR	Megavolt-ampere reactive
MW	Megawatt
OPPPI	Office for Promoting Private Power Investment
O&M	Operation and maintenance
PPA	Power purchase agreement
SADC	Southern African Development Community
SAPP	Southern African Power Pool
SCADA	System control and data acquisition

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Acronyms And Abbreviations

SNEL	Societe Nationale d'Electricite, the DRC's national electric utility
TANESCO	Tanzania Electric Supply Company
TAU	Technical and Administrative Unit (of SADC, for energy sector)
TSA	Transmission service agreement
US	United States
USAID	United States Agency for International Development
ZESA	Zimbabwe Electricity Supply Authority
ZESCO	Zambia Electricity Supply Corporation
ZCCM	Zambia Consolidated Copper Mines
ZPA	Zambia Privatization Agency

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Executive Summary

The Government of the Republic of Zambia has tentatively selected a first round of four projects for which model solicitation procedures for private development may be prepared. These projects are the Kafue Gorge Lower hydro project, the Itezhi-tezhi hydro project, the transmission interconnection from Zambia to Tanzania, and grid expansion into the Mkushi farming area in Central Province. One of the areas to be addressed in Task 4 of this project is to review the four projects and recommend whether the Office for Promoting Private Power Investment (OPPPI) should proceed with preparing solicitation documents for them.

Part of the process of developing sufficient understanding of the situation to make sound recommendations is to review existing relevant documentation. This report is the product of Task 3, which performs that review.

This report summarizes a review of about 50 documents organized in nine categories:

- Laws
- Policies
- Feasibility Studies And General Information Relating To The Projects Of Interest
- Electricity Planning And Demand Forecasting
- Southern African Power Pool
- Private Investment And Investment Incentives
- ZESCO
- Relating to the Process of Selecting and Contracting With Private Investors
- General

We left copies of all the documents in OPPPI's files for potential use by OPPPI staff and other interested parties, such as private power developers. We offer the following conclusions based on the review of documents:

Feasibility Studies

Bearing in mind that a private developer would want to review the key information and revise it to reflect current conditions, we conclude that the studies for the hydro projects appear to provide a sufficient starting point for such review and potential revision.

However, we believe that there is enough uncertainty in the level of expected generation at all three Kafue rive power plants, and their impact on each other, that additional study of that issue is necessary, to protect the interests of Zambia.

The transmission interconnection study does not address a key issue, namely whether the project would be economically attractive to Zambia or Tanzania or their electric utilities. However, this current project of assistance to OPPPI provides information on that point.

The Mkushi grid extension study is outdated and would need to be extensively revised to form the basis for further activities.

Private Ownership

The existing legal framework and the actual participation of private owners in the economy in general and the power sector in particular should give some level of comfort to potential private investors regarding the climate for private ownership.

Foreign Ownership

The existing legal framework and the actual participation of foreign private owners in the economy in general and the power sector in particular should give some level of comfort to potential foreign private investors regarding the climate for foreign ownership.

Electric Sector Regulation

Good regulation is a combination of laws, institutions, practices, and the good intentions of the regulators and their staff. In Zambia the laws and institutions could be improved by removing some discretion from the hands of the Minister, but by and large the regulatory process has worked reasonably well so far. The interest of knowledgeable private parties in expanding their power sector activities is an encouraging sign regarding the regulatory climate.

Incentives and Assistance

The incentives and other assistance described in the documents reviewed will reduce the cost and risk of private development in a manner that a private developer could take into account in its cost proposal.

Regional Trade

The physical and administrative infrastructure for the developers of Kafue Gorge Lower and/or Itezhi-tezhi to engage in regional trade are reasonably in place. However, these arrangements have not been tested by actual successful private power trade.

A relatively low-cost solution could nearly triple the transfer capability to South Africa, by far the largest market.

Agreements Supporting the Solicitation Process

The Implementation, Power Purchase, and Transmission Service Agreements identify and present possible resolutions to many of the issues that must be addressed in a final document. As such, they should make it easier and quicker to come to agreement.

The Power Purchase Agreement provisions regarding the dispatch and payment procedures for a private hydro plant are not suitable for Kafue Gorge Lower. The provisions are not well suited for a system involving operation of a river system to maximize the joint output of all plants in the river system, which seems desirable for the Kafue river system. In addition, they put all risk of poor hydrology on the developer.

All these issues will need to be addressed. For example, the Transmission Service Agreement bases payments on the availability of the facilities, not on their use. An analogous approach for the hydro plants would put all risk of poor hydrology on the buyer. It will take careful consideration to develop a payment scheme that allocates risks

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and provides operational incentives that will encourage efficient operation from the point of view of all parties.

1.1 *Background*

The United States Agency for International Development (USAID) has selected Bechtel/Nexant to assist Zambia's Office For Promoting Private Power Investment (OPPPI) in conducting Phase 1 of a three phase project leading to preparation of solicitation documents for private development of new hydropower plants and transmission lines. Phases 2 and 3 of the project will be funded from other sources and performed by other consultants. Phase 1 lays the foundation for the work of Phases 2 and 3 through market and economic analysis, project selection, and establishing schedules and resource needs for OPPPI.

The Phase 1 Project has eight Tasks requiring a total of eight deliverables. This report is the deliverable for Task 3, Document Review.

The Government of the Republic of Zambia (GRZ) has tentatively selected a first round of four projects for which model solicitation procedures for private development may be prepared. These projects are the Kafue Gorge Lower hydro project, the Itezhi-tezhi hydro project, the transmission interconnection from Zambia to Tanzania, and grid expansion into the Mkushi farming area in Central Province. One of the areas to be addressed in Task 4 of this project is to review the four projects and recommend whether OPPPI should proceed with preparing solicitation documents for them.

Part of the process of developing sufficient understanding of the situation to make sound recommendations is to review existing relevant documentation.

1.2 *Objectives*

Our initial objective for this task was to identify, collect, copy, and review the relevant documents. As our work proceeded it became apparent that many of the documents would be of interest to potential private project developers. A secondary objective thus became to summarize the documents and leave copies for such parties, so that they could decide whether a particular document was valuable and conveniently copy and review it in detail if they wished.

1.3 *Approach*

The first step was to identify the relevant documents. We were aware of and had obtained copies of some of the relevant documents in our previous work. The World Bank Terms of Reference for their project providing the next phase of Assistance to OPPPI included a short list of documents recommended to be reviewed. OPPPI itself had already collected some documents by the time we began work. With these documents as a starting point, the remaining steps were to:

- Review the bibliographies of the documents we already had and select other references that appeared relevant.

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- Discuss with OPPPI and others what other documents might be useful.
- Develop a complete list of all documents to review.
- Determine where the documents could be obtained.
- Gather the documents, copy, and return originals as necessary.
- Review the documents and develop an understanding of the projects and the general environment for private power investment that will affect their likely attractiveness for potential private investors.
- Summarize the documents.
- Leave copies in OPPPI's files for potential use by OPPPI staff and other interested parties.

1.4 *Organization Of This Report*

The remainder of this report is organized as follows:

- Section 2 presents a list of the documents reviewed, organized by category.
- Section 3 provides a summary of each document.
- Section 4 presents our discussion of key issues based on our review.

2.1 *Categories Of Documents*

Section 3 provides summaries of the documents listed below by category. Section 2.1.10 lists the documents which may be of interest but which we were not able to locate.

2.1.1 Laws

The Energy Regulation Act. 28 April 1995

The Electricity Act. 28 April 1995

The Investment Act, 1993. 8 September, 1993

The Privatization Act, 1992. 4 July, 1992

Zambezi River Authority Act, No. 17 of 1987, including Agreement between Governments of Zambia and Zimbabwe for the joint development and utilization of the water of the Zambezi River. July 1987

The Water Act, Cap 198 (re-numbered from Cap 312)

The Environmental Protection and Pollution Control Act. No. 12 of 1990

2.1.2 Policies

National Energy Policy. Government of the Republic of Zambia Ministry of Energy and Water Development; May 1994

National Water Policy. Government of the Republic of Zambia Ministry of Energy and Water Development; November 1994

2.1.3 Feasibility Studies And General Information Relating To The Projects Of Interest

KGL Independent Power Project. Burns and McDonnell, The Dahlgreen Group, KcKenna and Company Report 96-417-4

Kafue Gorge Lower Hydroelectric Project Feasibility Report. Harza Engineering and Rankin Engineering; May, 1995

Kafue Gorge (refers to Upper) Hydroelectric Power Project - Project Report (one volume) and Project Report on Main Storage Reservoir (another volume). SWECO; April 1967 and April 1968.

Feasibility Study of the Itezhi-tezhi Hydroelectric Project. Harza Engineering and Rankin Engineering; April, 1999

Itezhi-tezhi/Kafue Gorge Operating Procedure. SADC AAA.3.4; Hydrological Assistance Project – Phase 2; Shawinigan Engineering; January,1993

Zambia – Tanzania 330 kV Transmission Interconnection Study. ESKOM, ZESCO, and TANESCO; September, 1995

Zambia – Tanzania 330 kV Transmission Interconnection Financial Justification Investigation. ESKOM, ZESCO, and TANESCO; April 1998

Mkushi Electrification Scheme Project Design Report. Merz and McLellan, June 1988.

Mkushi Electrification Scheme Review of Supply Options (Draft). Merz and McLellan, November 1993.

2.1.4 Electricity Planning And Demand Forecasting

Zaire - Zambia Interconnection Reinforcement Study. SNEL, ZESCO, ESKOM, January 1997.

SNEL - ZESCO - ZESA - BPC - ESKOM Transfer Capability Study Progress Report. SAPP/SADC, 25 January - 9 February 1999, Lusaka

Zambia – Malawi Transmission Interconnection Options, Executive Summary. ESKOM, ZESCO, and TANESCO; November, 1996

Twenty Year Power System Development Plan for Zambia. EKONO Energy; June 1996

Feasibility Study Of The Development Of Hydroelectric Power In The Luapula And Northern Areas Of Zambia, Volume 4 of 6 - Load Forecast Report. Harza Engineering Company International, in association with Ekono Energy, March 2000

2.1.5 Southern African Power Pool

Southern African Power Pool Inter Utility Memorandum of Understanding. 8 December 1995

Southern African Power Pool Agreement Between Operating Members. 8 December 1995

Southern African Power Pool Operating Guidelines. 14 August 1996.

Southern African Power Pool Annual Report 1999; Annual Review Report. April 1997 - March 1999

2.1.6 Private Investment And Investment Incentives

Framework and Package of Incentives for Private Sector Participation in Hydropower Generation and Transmission Development. Government of the Republic of Zambia Ministry of Water and Energy Development; October, 1998

Zambia Privatization Agency Progress Report No. 13. 1 July 1998 to 31 December 1998

Zambia Privatization Agency Status Report as of 30 April 2000

2.1.7 ZESCO

ZESCO Statistics Yearbook of Electric Energy 1998-1999. Issued by the Statistics Section

Government of the Republic of Zambia - ZESCO Performance Contract II, 1st April 2000 - 31 March 2003.

Project Agreement - Power Rehabilitation Project, 15 June 1998. CR.3042_ZA, between International Development Association and ZESCO.

Development Credit Agreement (Power Rehabilitation Project) between Republic of Zambia and International Development Association. Credit Number 3042-ZA, June 15, 1998

Zambia Power Rehabilitation Project - CR.3042_ZM, Supervision Mission (February 2000), Aide-Memoire. World Bank

ZESCO Electricity Tariff Study Final Report. SwedPower, November, 1999

2.1.8 Relating To The Process Of Selecting And Contracting With Private Investors

Request for Expressions of Interest in developing Kafue Gorge Lower. Zambia National Tender Board, January, 2000

Company Pre-qualification Form (for submitting Expression of Interest for developing Kafue Gorge Lower). Zambia National Tender Board, January, 2000

Request for Expressions of Interest in developing Itezhi-tezhi. Zambia National Tender Board, May, 2000

Company Pre-qualification Form (for submitting Expression of Interest for developing Itezhi-tezhi). Zambia National Tender Board, May, 2000

Standard Implementation Agreement. International Resources Group; July, 1997

Standard Power Purchase Agreement. International Resources Group; July, 1997

Standard Transmission Services Agreement. International Resources Group; July, 1997

2.1.9 General

Energy Statistics Bulletin 1974-1996. Government of the Republic of Zambia, Ministry of Energy and Water Development; March, 1998

Comparison of Electricity Prices in the Southern African Region. ZESCO Economics, Pricing, and Regulation Department, January 2000.

2.1.10 Documents Not Located

The Competition And Fair Trading Act. No. 18 of 1994

Whatever Act removes currency restrictions.

The Energy Act, 1995, if such an Act exists.

Documents describing the laws, codes, etc., that describe and specify all taxes and similar charges for which an independent project may be liable

Merz and McLellan Feasibility Study March 1983 Phase 1 Report (established the model for agricultural development of the Mkushi area and the forecast of electrical load). The April 1985 Phase 2 Report established the electrification scheme and irrigation and electrification activities, and addressed other issues.

The SAPP Planning or Operating Sub-committee documents which specify the interim procedures regarding wheeling rates and conditions.

Zambia: The Business Environment for Foreign Direct Investment in the Country's Infrastructure. Foreign Investment Advisory Service (a joint service of the IFC and World Bank); April, 1999

3.1 *Summary Of Documents*

The summaries below provide a brief overview of the documents, noting the key points from the likely viewpoint of a potential private investor in one of the projects of interest. We have tried to present at least information sufficient for a reader to determine whether further review is necessary for his or her purposes.

Section 3.1.10 lists some documents which may be of interest but which we were not able to locate. Where possible we provide some information on the document, but this is somewhat speculative and should not be viewed as being as firmly founded as the other summaries.

3.1.1 Laws

The Energy Regulation Act. 28 April 1995

Summary

The purpose of the Act is to establish the Energy Regulation Board (ERB), define its functions and powers, provide for the licensing of energy-related undertakings, repeal the National Energy Council Act and the Zambia Electricity Supply Act, and provide for matters incidental to those activities.

The Act:

- Establishes the ERB.
- There is no specific provision that directly repeals the National Energy Council Act or the Zambia Electricity Supply Act.

The ERB's functions include:

- Monitoring the efficiency and performance of energy sector undertakings.
- Receiving and investigating complaints from consumers on price adjustments made or services provided.
- Regulate price adjustments and services provided through attaching appropriate license conditions.
- Regulate the location or construction of energy facilities through license conditions; receive and investigate complaints in this area.
- In conjunction with the Zambia Competition Commission, monitor the levels and structures of competition within the energy sector, with a view to promote competition within the energy sector.
- In conjunction with the Zambia Standards Bureau, design standards with regard to the quality, safety, and reliability of supply of energy and fuels.
- In conjunction with other GRZ agencies, formulate measures to minimize the environmental impact of energy production and supply.

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- Make recommendations to the Minister as to measures to be taken through regulations to be made under this Act.

The ERB licensing duties and powers include:

- Each electricity undertaking must have a license issued by the ERB, except the Minister, by statutory instrument, can declare that an undertaking is not an undertaking for the purposes of this Act.
- The Act outlines the licensing procedures, including:
  - Any person can apply for a license, in the form prescribed by the Minister
  - Without further proceedings, the ERB can reject the application as not being in the public interest.
  - Notice of license applications must be published in the Gazette
  - The public can inspect the application and object to the granting of a license.
  - The applicant can respond to the objections
  - The ERB may convene meetings with the applicant, objectors, and the general public to discuss the application.
  - In determining the application, the ERB shall take into account the public interest and the merits of any objections.
- The ERB may grant or refuse to grant the license.
- If granted, the license may include a wide range of conditions such as payment of fees, conditions for changing rates, publication of notices regarding rates, providing the ERB various kinds of information, non-discrimination, fines and penalties for breaches of conditions, and others.
- There are provisions for revoking a license if the licensee does not fulfill its obligations. The licensee must be given a chance to be heard before revoking.
- A licensee faced with revocation, refusal to renew, or refusal to transfer may appeal to the Minister, whose decision on an appeal is final, subject to appeal to the High Court on a point of law.
- The ERB has various powers to enforce license conditions, including appointing and using inspectors.
- The ERB is not self-funding. License fees paid become part of the general revenues of the GRZ. The ERB's funds are appropriated by Parliament, or come from grants and donations.
- The Minister is empowered to make regulations with respect to this Act.
- The ERB consists of three full time and four part time members, appointed by the Minister. The Minister can remove members at his discretion.

There are various provisions relating to how the ERB conducts its business, non-disclosure, and so on.

The Schedule describes the membership of the ERB, their terms, and rules governing the ERB's procedures.

The Act gives the ERB the powers it needs to regulate the energy sector. However, it leaves considerable discretion in the hands of the Minister, including declaring an undertaking exempt from its provisions, making regulations, and removing ERB members.

The Electricity Act. 28 April 1995

Summary

The purpose of the Act is to regulate the generation, transmission, distribution, and supply of electricity, and to provide for matters incidental with those activities.

- All electricity generation, transmission, distribution, and supply undertakings (except those less than 100 kW supplying for operator's own use) are subject to the act.
- The Minister may declare any transmission line to be a common carrier.
- Must seek Minister's approval to increase or decrease rated generating capacity or contractual rights to import power. Minister's decision is final, subject to appeal to the High Court on a point of law.
- Subject to license terms, must supply electricity to every consumer who can make satisfactory arrangements for payment under a contract of supply with the operator.
- Charges for services to be determined according to license conditions.
- OK to charge different consumers different rates depending on their amount of consumption, regularity of demand, time of demand, costs to the operator of furnishing supply, or other circumstances approved by the Board.
- Must give notice to consumers of proposed changes in charges. Consumer can contest change with Board. Board will decide.
- Cannot shut off or reduce supply unless the consumer fails to pay or comply with conditions of supply.
- Procedures are outlined for suspending or revoking licenses if operator neglects its obligations.
- Undertakings greater than 100 kW shall submit details of the plant information to the Board and Minister as they prescribe, and shall comply with any requirement of the Minister or Board for the purpose of facilitating co-ordination with existing or future undertakings.

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- Undertakings must also provide information regarding their activities and operations, as required by the Board or Minister, and notice of any serious accidents.
- License not to be issued within area subject to jurisdiction of local authority unless with the consent of that authority, which shall not be unreasonably withheld.
- Addresses land issues such as compulsory acquisition, land rights, rights of entry, transmission lines over land and buildings, tree trimming, offenses and penalties, and other administrative items.
- Addresses offenses and penalties.
- The Minister is empowered to make regulations with respect to this Act.

The Act addresses many of the important issues in the electricity industry. However, it leaves considerable discretion in the hands of the Minister, and several areas where authority is shared and/or ambiguous.

The Investment Act, 1993. 8 September, 1993

Summary

The purpose of the Act is to revise the law relating to investment in Zambia so as to provide a comprehensive legal framework for investment in Zambia, to repeal the Investment Act of 1991, and to provide for matters incidental to those activities.

- Repeals Investment Act of 1991.
- Notwithstanding that repeal, the Investment Center shall continue to exist as if constituted by this Act.

Functions of the Investment Center include:

- Promote investment in Zambia.
- Monitor performance of enterprises approved by it and enforce compliance with the terms and conditions of investment certificates approved under the Act.
- Assist in securing from government agencies, etc., permission, licenses, land, etc., needed for establishing or operating a business enterprise.
- Provide consultancy services to investors.
- Collect and disseminate information on laws, regulations, etc..
- Assist investors in finding and acquiring land, water, electric power, transport and communication services, and other services needed by the investor.
- Many other related functions.

Other provisions of the Act include:

- Establishes the Investment Board, the governing body of the Center.

- Provides for the right of investors to transfer certain classes of funds (dividends, loan payments, etc.) out of Zambia.

Investment Certificates:

- Any person investing in a business enterprise may apply for and Investment Certificate, except that specified industries (defined in the Second Schedule) must first obtain the necessary licenses, etc., from the relevant ministry or body.
- The Board shall within six weeks issue a Certificate, with general or special incentives, if the application is in accordance with the Act and the business activity complies with Zambian laws and regulations.
- Any rejected application must include the reasons for rejection, and the decision is subject to appeal to the Minister and then the High Court.
- A Certificates authorizes the holder to make all necessary arrangements for the business, contains terms and conditions and incentives, and must be used within 12 months of date of issue.
- May be suspended or cancelled for several reasonable causes.

General Incentives:

- Apply to any investor investing in a business under the Act.
- Specify presumably favorable tax rates that will apply for different types of activities.
- Specify capital allowances that will apply for different types of investments, e.g., buildings, farm improvements, etc..
- Other tax incentives.
- Investor can apply to establish and operate a bonded factory.
- Extra incentives for small scale and village enterprises.
- Investor of equivalent of US$250,000 and who employs at least 10 persons is entitled to a self employment permit or resident permit, and work permits for at least 10 expatriate employees.

Special Incentives:

- Apply to certain categories of investor: exporter of non-traditional products, agriculture-related, tourism, import substitution, and rural.
- Can obtain work permits for up to five expatriate employees.
- Get an exemption from customs duties, sales duties, and sales tax.

Amendments of 1 April 1996 and 21 April 1998 delete the Special Incentives and the exemption from customs duties in one part of the general incentives, define non-traditional products to be everything except minerals or electricity, change the

percentages for capital allowances, and change the provision relating to loss carry-forward.

The First Schedule describes the membership of the Investment Board, their terms, rules governing the Board's procedures, and its sources of funds. It specifies that there shall be a Director-General appointed by the Board who will be the chief executive officer of the Center.

The Second Schedule defines the specified industries, which are generally related to arms or aircraft; poisons, drugs, or hazardous materials; and currency or security documents.

The Third Schedule is a blank form Application for an Investment Certificate. The Fourth Schedule is a blank Investment Certificate.

The Privatization Act, 1992. 4 July, 1992

Summary

The purpose of the Act is to provide for the privatization and commercialization of State owned enterprises, to establish the Zambia Privatization Agency (ZPA) and define its functions, to provide for the sale of shares in State-owned enterprises, and to provide for matters incidental to those activities.

The Act:

- Establishes the ZPA.
- Defines its membership and related items.
- Specifies rules governing its procedures.
- Provides for its administration, including the appointment of a Director who is the Chief Executive Officer of the agency, a Deputy Director, and a Secretary.

The general function of the ZPA is to plan, manage, implement, and control the privatization of State-owned enterprises. More specifically, its functions are:

- Recommend privatization policy guidelines to the Cabinet.
- Oversee all aspects of the privatization program and monitor its progress.
- Prepare the long term divestiture sequence plan and submit to Cabinet for approval.
- Recommend to the Cabinet the most appropriate method of sale for each enterprise.
- Generate valuations of enterprises to be privatizes.
- Set pre-qualification criteria for potential buyers or investors and seek potential investors.
- Evaluate offers.
- Ensure that monopolies are not created in the process of privatization.
- Prepare the necessary documentation to effect privatization.

- Maintain records, safeguard information, and ensure confidentiality of information.
- Maintain close liaison with all relevant institutions in the privatization process.
- Publicize the activities of the privatization program.

The procedures for privatization are:

- A State-owned enterprise shall be privatized in accordance with the divestiture sequence plan.
- Minister of Finance may retain a "golden share" in a State owned enterprise.
- The shares shall be allotted by the ZPA.
- The share holders shall provide the ZPA such information as it requires.
- An enterprise scheduled for privatization shall carry out the recommendations of the ZPA for preparing for privatization and undertake many specified activities designed to facilitate privatization, such as keep all business records up to date, prepare a 2-3 year investment and financing plan, clear up to the extent possible all contractual, legal, and other obligations, and many others.
- The ZPA may privatize in any method it sees fit, including public offering of shares and management or employee buyouts.
- The valuation shall be done by independent valuers, with certain restrictions on the valuation process.
- There are various provisions to avoid conflicts of interest.
- The buyer may be a citizen of Zambia or a person who is not a citizen of Zambia.
- The Minister of Finance shall establish a Privatization Trust Fund to hold shares in trust for the citizens of Zambia.
- Foreign investors are entitled to incentives under the Investment Act in some circumstances.
- There will be an independent negotiating team for each sale.
- ZPA may convert an enterprise scheduled for privatization which is not a public company into a public company.
- The Act provides for the funs of the ZPA and the disposal of the proceeds of the sale of enterprises.

The Act was amended on 1 April 1996. The amendments are primarily technical or clarifications and do not represent important changes to ZPA's functions and activities.

The Act provides certain protections to maintain the ZPA's independence in the privatization process: Once the Cabinet approves divestiture sequence plan, and that a particular enterprise is to be privatized, then ZPA has complete discretion in the privatization so long as it follows its procedures. ZPA may employ any method of

privatization it considers appropriate, there are independent valuers, independent negotiating teams, and the Minister of Finance shall sign the final Sales Agreement to transfer shares to the selected bidder.

Zambezi River Authority Act, No. 17 of 1987, including Agreement between Governments of Zambia and Zimbabwe for the joint development and utilization of the water of the Zambezi River. July 1987

Summary

The Act is the legislation supporting the implementation of the Agreement. The Agreement provides for the continued existence of the Central African Power Corporation as the Zambezi River Authority. It provides for the organization and procedures of the Zambezi River Authority, and its functions. Its primary function is to operate, monitor, and maintain the Kariba dam and reservoir. Among the Agreements provisions are:

- Equal sharing of powers, board members, etc., by Zambia and Zimbabwe. At the highest level, the Council of Ministers, all decisions must be unanimous to take effect. There is also a Board of Directors responsible for the policy, control, and management of the Zambezi River Authority, subject to the overall direction of the Council.
- Equal sharing of costs and benefits of the existing facilities.
- The Zambezi River Authority to investigate and make recommendations regarding the desirability of constructing new dams on the Zambezi River.
- Equal sharing of costs and benefits of any new dams, if both Zambia and Zimbabwe desire an equal share.
- The assets of Central African Power Company to be distributed based on the general principle that the immovable assets in the territory of each state will be allocated to the National electricity Undertaking of that state.
- Annexure 1 sets forth the working arrangements for the joint operation of the interconnected systems of Zimbabwe Electricity Supply Authority (ZESA) and Zambia Electricity Supply Corporation (ZESCO), addressing such issues as spinning reserve, outage coordination, and many others.
- Annexure 2 sets forth the working arrangements for the sharing of energy form Kariba dam. The basic provision is that the available water will be shared equally.

The Water Act, Cap 198 (re-numbered from Cap 312)

Summary

This Act governs the ownership, control, and use of water in Zambia. It provides that the ownership of all water is vested in the President, and its diversion and apportionment shall be made in terms of the Act, except that a landowner has the right to take free of

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charge "private water" (primarily water bodies wholly within the boundaries of a property, and wells) occurring on this land.

The Act establishes a Water Board which grants in whole or in part (or denies) applications for the use of water, which may be made by any person for primary, secondary, or tertiary purposes. The Water Board may attach conditions to the grant, award compensation to affected registered owners of water rights, revoke, vary, or amend registered rights concerned in another application (but the applicant must compensate as the Water Board directs), and make such order as to costs as it deems just.

The act includes various provisions governing the use of water, the procedures and composition of the Water Board, charges and fees, applications, record keeping, and others. With respect to hydro power development the key provisions include:

- Primary use is for domestic purposes and the support of animal life.
- Secondary use is for irrigation and pisciculture.
- Tertiary use is for mechanical and industrial purposes, and power generation.
- The "right of storage" is the right to occupy land belonging to another by submerging it by means of a dam or weir, and includes the right of passage.
- For an undertaking of public importance or general utility, the Water Board may authorize tertiary use if its public advantages outweigh its disadvantages, subject to payment of compensation of holders of existing secondary or tertiary rights.
- The Water Board may grant a right of passage or a right of abutment to a person having a water right, so that that right may be exercised in the use of the water.
- Water rights can be renewed, subject to application to and approval of the Water Board.

The Environmental Protection and Pollution Control Act. No. 12 of 1990

Summary

Most of the provisions of this act are directed at controlling environmental damage from water pollution, air pollution, by waste discharges, from pesticides and toxic substances, by noise, and by ionizing radiation.

It establishes the Environmental Council whose general functions are to do all things necessary to protect the environment and control pollution for the health and welfare of persons, animals, plants, and the environment. It provides for its membership, administrative procedures, and inspectorate, and has general provisions. Among the Environmental
Council's many more specific functions are to:

- Advise the GRZ on the formulation of policies relating to natural resources and the environment.
- Advise on any aspect of conservation.

- Identify projects for which environmental impact assessment (EIAs) are necessary.
- Consider and advise on all major development projects at an initial stage and request information on them.
- Carry out any other activities relating to the protection of the environment and the control of pollution which are necessary or conducive tot he better performance of its functions under the act.
- Administer and enforce measures for the protection of the environment and the prevention of pollution of the environment.

Although it is not clear from the act itself, we understand that the Environmental Council would review and evaluate the Environmental Impact Assessment for each major project, which would involve getting input from all stakeholders and might involve public hearings, and approve or deny approval for the project. After approval of the Environmental Impact Assessment a mitigation plan would be put in place.

3.1.2 Policies

National Energy Policy. Government of the Republic of Zambia Ministry of Energy and Water Development; May 1994

Summary

The Ministry of Energy and Water Development undertook a consultative process in 1993 through which a National Energy Policy was developed, and ultimately approved as a formal document by the GRZ in 1994. Its general objective is to promote optimum supply and utilization of energy, especially indigenous forms, to facilitate the socio-economic development of the country and maintenance of a safe and healthy environment. It notes the need for a viable institutional structure to ensure attaining the objectives. Specific policy elements include:

Electricity

- Restructuring the electricity industry to improve service delivery through:
  - Liberalization so that other companies can get involved in the electricity business.
  - Ensuring that the operations of ZESCO are, in the short term, commercialized.
  - Immediate privatization of the distribution function of ZESCO.
- Improving accessibility to electricity.
- Promoting electrification of productive areas and social institutions (schools, clinics).
- Developing the hydro potential to take advantage of the strategic location of the country in the sub-region by:

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  - Giving priority to the construction of Kafue gorge lower power station considering that some infrastructure is already in place.
  - Ascertaining the available hydro potential on rivers located in high rainfall areas, e.g. Luapula river.
  - Promoting interconnection with neighboring countries in order to increase security of supply and secure markets for power export.
  - Developing other sites like Kariba North Extension, Itezhi-tezhi, Batoka, etc. depending on the market and such developments should take into account environmental impacts.
  - Ensuring the existence of up to date electricity Master Plans.
- Review existing legislation on electricity in order to bring it into conformity with the new macro-economic environment.
- Promote the technological development and wider application of new and renewable sources of energy (NRSE), and information dissemination and education and training about NRSE.
- Promote efficient energy use practices in all sectors of the economy.
- Substitute, wherever possible, local energy resources for imported ones.

Tariff Policy

- Pricing should reflect both the cost and the true economic value of a commodity and thereby provide the right signals to consumers.
- Ensure that electricity prices take account of all the economic costs. The pricing formula should be based on the long run marginal cost method which takes into account the following:
  - Replacement cost.
  - Operational costs.
  - Incentive for efficiency, reliability, safety, and environmental standards.
  - Profit.

Institutional

- Implement the necessary institutional reforms, including establishing organizations or assigning responsibilities to existing organizations:
  - Ministry of Energy and Water Development
  - Department of Energy
  - ERB
- Amend, enact, or repeal legislation to achieve these changes.

- To the extent possible, put energy sector investment in the hands of the private sector.
- Seek donor support to render assistance in:
  - Improving management skills.
  - Institutional capacity building.
  - Investment in energy infrastructure expansion or rehabilitation.

National Water Policy. Government of the Republic of Zambia Ministry of Energy and Water Development; November 1994

Summary

The Ministry of Energy and Water Development undertook a consultative process in 1993 through which a National Water Policy was developed, and ultimately approved as a formal document by the GRZ in 1994. Its general objective is promoting a sustainable water resources development with a view to facilitate an equitable provision of adequate quantity and quality of water for all competing groups of users at acceptable costs and ensuring security of supply under varying conditions. It notes the need for a well-defined institutional structure to ensure attaining the objectives. The document includes three main sections. The first provides background by highlighting the role of water in national development and the current water resource base in the country. It notes that energy is the life-blood of any economy, and that Zambia's electricity is almost all hydro power. The second comprises the main policy measures and outlines strategies for implementation. The third presents the institutional and legal reforms needed for effective implementation of the policy.

Most of the document addresses issues associated with non-hydro power water use. With respect to issues that might affect hydro power development, specific policy elements include:

- According high priority to the water sector in view of its paramount role to all social-economic activities.
- Vesting ownership of water resources in the country under the state control.
- Promoting water resources development through an integrated management approach.
- Undertaking environmental impact assessments prior to implementation of any developmental project.
- Defining clear institutional responsibilities of all stakeholders in the water sector for effective management and co-ordination.
- Developing an appropriate institutional and legal framework for effective management of the water resources.
- Recognizing water as an economic good.

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- Ensuring that water tariffs take account of all the economic costs.

3.1.3 Feasibility Studies And General Information Relating To The Projects Of Interest

KGL Independent Power Project. Burns and McDonnell, The Dahlgreen Group, McKenna and Company Report 96-417-4

Summary

This work focused on the development of the Kafue Gorge Lower project as an independent power project. Its objective was to review and evaluate the framework in Zambia for the for the successful future advertisement of the Kafue Gorge Lower to the independent power market and recommend a preliminary framework for areas in need of change. It consists of a review of the technical and business issues associated with Kafue Gorge Lower, a discussion of the relationship of the project to the world of private power finance, and a review of the legal and policy framework in Zambia to support private power initiatives. There are five main sections:

- Independent power producer (IPP) objectives and contract issues

This addresses options for ZESCO participation, the need to resolve ZESCO restructuring issues, the need to know the water in the Kafue river system will be managed and controlled, key issues for developers that need to be addressed in the Request For Proposals, contract structure options, key issues that need to be resolved before issuing the Request For Proposals, and conclusions and recommendations.

- Project options and economic assessment

This develops some assumptions regarding issues such as plant output and the added costs for private development vs. sovereign development.

- Area market review

This reviews the status of the electric power market in the surrounding countries.

- Legal and policy framework for Zambia

This reviews the key laws and policies affecting Kafue Gorge Lower as an IPP, including the Zambezi River Authority Act, the National Energy Policy, the Electricity Act, the Energy Regulation Act, the Agreement for the joint development and utilization of the water of the Zambezi river for the production of energy, the Water Act, the environmental Protection and Pollution Control Act, the Customs and Excise Act, the State Proceeding Act, the Competition and Fair Trading Act, and the Standards Act. It discusses the adequacy of the power sector legislative framework for private sector participation and identifies the lack of clear separation of government authority between the Minister and the Electricity Regulatory Board as n important shortcoming.

- Preliminary framework for the Request For Proposals process

This addresses issues associated with financing hydro projects, a framework for bidding, a strategy for success, the principles of sound project finance, and other issues.

Appendix C summarizes legal and policy issues that need to be addressed to resolve possible problems regarding private sector participation in the power sector. Appendix C also summarizes business and technical issues that need to be resolved prior to advertising for the private development of Kafue Gorge Lower. These issues include defining the objectives of the privatization effort, identifying the lead issuer, defining the domestic market including resolving electricity industry restructuring, defining how the GRZ is going to participate in mitigating certain risks, and many others.

Kafue Gorge Lower Hydroelectric Project Feasibility Report. Harza Engineering and Rankin Engineering; May, 1995

Summary

This report describes the project setting and project and provides a construction schedule and cost estimate, economic and financial evaluation, and an environmental assessment. It includes an executive summary and three volumes of appendices.

The Kafue Gorge Lower project is located in the Kafue Gorge, about 65 km upstream from the confluence of the Kafue and Zambezi rivers and 2 km downstream from the tailrace discharge from the existing 900 MW Kafue Gorge power plant, which we will refer to as the Kafue Gorge Upper plant. Kafue Gorge Lower will develop the remaining 200 meters of the 600 meter head in the Kafue Gorge.

The dam for the Kafue Gorge Lower project will rise 52 meters above the existing stream bed (elevation 534 meters) to a top elevation of 586 meters, with a structural height of 62 meters above its sound rock bed. The study could not establish a clear advantage for either type, so the dam type may be either concrete faced rock fill dam or roller compacted concrete. Reservoir capacity at maximum elevation of 582 meters will be about 5.5 million m^3, with live storage of 2.2 million m^3.

There will be four 150 MW Francis turbines, each with a design head of about 186 meters (all units operating) and a design discharge of 88.3 m^3/sec. The units will discharge into a tailrace tunnel which will carry the water about 7.8 km, ultimately discharging back into the Kafue river in the Kafue Gorge with a minimum tailwater elevation of 384 meters.

Each unit will be equipped with a generator rated for maximum continuous output of 165 MVA at rated voltage of 13.8 kV. A separate 330/13.8 kV transformer will serve each generator. Gas-insulated switch gear will be located next to the transformers in the underground transformer hall. High voltage cables will connect the transformer hall to line terminations at the surface. Two 330 kV transmission lines will connect the surface terminations at Kafue Gorge Lower to the switchyard at Kafue Gorge Upper, a distance of about 3.5 km.

Based on the results of a simulation of the entire Kafue river system, including Itezhi-tezhi, Kafue Gorge Upper, and Kafue Gorge Lower, and the associated dams and reservoirs, the report recommends an operating approach that would result in yearly average energy production of 3,033 GWh for Kafue Gorge Lower. Minimum and

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maximum were 1,024 GWh and 4,379 GWh during the study period of 1906 through 1992. The report reduces the simulation average values by 6% to account for maintenance outages and power plant use.

The report estimates 60 months for total project construction time from mobilization to commercial operation for either dam alternative, and total construction cost of $431 million in 1995 US$, not including interest during construction (IDC) and some other costs included in Harza's later similar study for Itezhi-tezhi. The estimated annual O&M cost is 1% of construction cost, which amounts to $7.2/kW-year.

The economic analysis compares the cost of energy from Kafue Gorge Lower to Itezhi-tezhi, to the Batoka project on the Zambezi, and to a coal-fired plant. It concludes that Itezhi-tezhi has slightly lower costs and should be seriously considered, whereas Kafue Gorge Lower is lower in cost than Batoka or the coal-fired plant.

The environmental assessment section includes a listing of mitigation measures.

Kafue Gorge (refers to Upper) Hydroelectric Power Project - Project Report (one volume) and Project Report on Main Storage Reservoir (another volume). SWECO; April 1967 and April 1968.

Summary

The Project Report provides a power balance, and descriptions of the Kafue river basin, the need for regulation of the river (reservoir capacity), alternatives for the potential power development of the Kafue gorge including Kafue Gorge Lower, and the design and construction of the preferred dam and power plant, including capital cost estimates, and an evaluation of the cost of power. The report refers to 125 MW units, but this is just the output at the peak of the turbine efficiency curve. The units would be capable of at least 150 MW at peak output.

The project was to be built in stages. The first stage was the dam and power plant at Kafue Gorge (Upper). The second stage was to be the dam at Itezhi-tezhi.

The Project Report on Main Storage Reservoir addresses in more detail than the Project Report the hydrology and other aspects of the Kafue River basin, the regulation requirements, the potential reservoirs, the choice of reservoirs (Itezhi-tezhi was selected), and the dam/reservoir site conditions, description, design, construction, and cost.

Feasibility Study of the Itezhi-tezhi Hydroelectric Project. Harza Engineering and Rankin Engineering; April, 1999

Summary

This study includes four volumes: an Executive Summary, the Main Report (which for convenience also includes the Executive Summary), a volume of Appendices, and an Environmental Impact Assessment.

The project would involve installing power generation facilities at the existing dam and reservoir. The existing dam at Itezhi-tezhi was completed in 1978 to regulate the flow of the Kafue river, in conjunction with the overall development of the power generation

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facilities at Kafue Gorge. Construction of a power plant there has long been contemplated.

The existing conventional earth fill dam has a maximum height of about 51 meters with its top at elevation 1035 and is in good condition. The maximum and minimum operating levels of the reservoir are 1030.5 and 1006. The reservoir's storage capacity of about six billion m^3 is sufficient to hold about 68% of an average year's inflow.

The study describes the existing facilities and the project setting, including hydrology, need for the project, geology, climate, socio-economic conditions, and environmental setting.

The report includes the results of project definition studies, which concluded that 120 MW was the optimal plant size, an underground powerhouse is preferred due to lower cost, and the dam should not be raised.

There will be two Kaplan turbines, each with a design net head of about 40 meters and design discharge of 156 m^3/sec. The units will each be rated at 56.3 MW, with a maximum capability of 60 MW. Turbine centerline will be elevation 976 meters, about 10 meters below tailwater elevation. The units will discharge into a tailrace tunnel that will be connected to one of the existing diversion tunnels, which discharges immediately down river from the dam. Each unit will be equipped with a generator rated for maximum continuous output of 67 MVA at a power factor of 0.9 and rated voltage of 13.8 kV. A separate 220/13.8 kV transformer will serve each generator. 220kV cable will connect the transformers to air-insulated switch gear in a surface switchyard . The proposed transmission connection will be a single circuit 220 kV line from the switchyard to Mazuma substation. a distance of about 220 km. The report estimates 50 months for total project construction time from project development through mobilization to commercial operation.

Based on a simulation using 90 years of historic inflows and an optimized approach to reservoir management, energy production would be 642 GWh/year in an average year and 292 GWh in the lowest year.

The estimated construction cost for the power plant is $73.1 million in 1998 US$. Total estimated power plant capital cost is $104.5 million, including interest during construction, IPP project development, environmental, and escalation during construction. The estimated cost of the transmission line is $28 million.

The economic analysis concluded that the project is economically attractive compared to generating the same energy and capacity from coal and combined cycle plants.

The report includes a project management and staffing section, an environmental impact assessment including mitigation measures, conclusions and recommendations, and references.

Itezhi-tezhi/Kafue Gorge Operating Procedure. SADC AAA.3.4; Hydrological Assistance Project – Phase 2; Shawinigan Engineering; January,1993

Summary

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This study evaluated the hydrology of the Kafue river system and presented several key results:

- It calculated a new operating rule curve for the Itezhi-tezhi reservoir. Following that curve, and using a simulation incorporating every year from 1906/6 through 1991/2, during each month in the worst year Kafue Gorge Upper could generate 430 MW around the clock, or shape the output while providing the same monthly energy deliveries..
- It developed and substantiated an improved procedure for estimating inflows during the dry season.
- The 10,000 year flood cannot be safely routed through the Itezhi-tezhi dam main spillway alone, but can be routed safely when the existing emergency spillway is used.
- It contains tables and graphs presenting hydrologic information on the Kafue river system.

Zambia – Tanzania 330 kV Transmission Interconnection Study. ESKOM, ZESCO, and TANESCO; September, 1995

Summary

The objective of this study was to identify, analyze, and evaluate alternatives for a transmission interconnection between Pensulo substation in Zambia and Mbeya substation in Tanzania. The study included the following elements:

- Established technical planning criteria for analysis of the 66 kV and higher networks.
- Established and validated power system data bases for both countries.
- Used ZESCO and Tanzania Electric Supply Company (TANESCO) medium demand forecasts and forecasts of available generation capacity to determine TANESCO's need to import capacity and energy, and ZESCO's ability to export capacity and energy. It appeared that about 200 MW would be needed and available.
- Established assumed generation patterns and loading sequences for analysis of the electrical performance of the systems.
- Calculated load flows, voltage profiles, etc., to permit evaluation of the electrical performance of the systems.
- Determined internal network strengthening requirements in both systems.
- Determined that the clearly preferred voltage for the interconnection is 330 kV.
- Evaluated two route options, with very similar performance with respect to power transfers between Zambia and Tanzania.

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- Determined that the longer route via Kasama substation would cost about US$ 3 million more, but that would be more than offset by savings due to the strengthening ZESCO's Northern and Luapula networks.
- Summarized the environmental impact of the project and proposed areas to be considered during an environmental assessment.
- Recommended that the interconnection be constructed via the Kasama substation, that a transmission line design optimization be conducted, .
- Noted that the study did not provide a financial justification for the project. It did not consider the economics and financial impacts of the assumed trade in electricity.

Zambia – Tanzania 330 kV Transmission Interconnection Financial Justification Investigation. ESKOM, ZESCO, and TANESCO; April 1998

Summary

This study was an outgrowth of the Transmission Interconnection Study summarized above, involved many of the same participants, and was described as the "Phase 2 study". The goal of this study was to determine whether such an interconnection could be financially justified. The primary objective was to calculate the wheeling charge that would be needed by a private operator of the facilities.

The study included the following elements:

- Summary of Phase 1 study
  - TANESCO projected capacity and energy import requirements.
  - ZESCO projected capacity and energy surplus.
  - Note of the benefits to ZESCO Northern and Luapula provinces through strengthening the transmission grid with the interconnection.
  - Recommendation: construct the interconnection from Pensulo to Mwakibete via Kasama.
- Summary of TANESCO existing and committed generation facilities
  - The benefits to TANESCO in reducing the risks of changes in load growth and the introduction of large hydro projects that have a long lead time.
- Summary of the interconnection co-operation agreements: Inter-Governmental (MOU), Inter-Utility MOU, General Agreement of Co-operation
- Description of the line route and environmental impact assessments
- Discussion of the transmission line design optimization and costing
  - Overall cost was estimated at 1998 US$152,880,000, apparently including no contingency, IDC, escalation, environmental costs, or development costs of IPP sponsor.

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- Description of the financial spreadsheet model, which calculated net present worth of the project using a range of assumptions.
  - Presentation of results for the various scenarios.
  - The conclusion that the project would be economically attractive at a price of about US$0.02 to 0.025 per kWh for transporting energy, assuming 85% load factor for the 200 MW line.
  - The recommendation that negotiations commence around a price of $0.025/kWh, with a delivered price for energy of around $0.045 - 0.05/kWh, inclusive of the cost the energy itself.
- The study's appendices contain a proposed power purchase agreement, draft request for pre-qualification for private investors, and the full text of the co-operation agreements, the environmental impact assessments for Zambia and for Tanzania, and the transmission line optimization details.
  - Overall cost was estimated at 1998 US$ 152,880,000, apparently including no contingency, IDC, escalation, environmental costs, or development costs of IPP sponsor.

Mkushi Electrification Scheme Project Design Report. Merz and McLellan, June 1988.

Summary

The primary objective of this study was to design a 33/11 kV system to serve much of the Mkushi farming block. It built upon a feasibility study done earlier which addressed many of the same issues, with reports issued in March 1983 (Phase 1) and April 1985 (Phase 2). The study addressed the design and cost of the system, not the sources of funding or the benefits. The 1988 study presents the following information:

- Description of the existing system in the area.
- The report was based on a load forecast taken from the 1983 Phase 1 report, rising to 11.9 MW six years after completion of the first stage of construction.
- Design criteria and design considerations for expanded system.
- Major elements of the expansion include a 330/33 kV Central substation that provides the main power supply for the new and existing loads, five (including Central) 33/11 kV substations supplied from Central, 11 kV distribution networks originating from each of the five new substations, and improvements to existing substations at Mkushi Farmers and Mkushi Boma (township). Estimated line lengths total 600 KM of 11 kV and 33 kV lines.
- Design of both a 33/11 kV system and an all 33 kV system.
- Design of and considerations relating to the 330/33 kV substation, the 33/11 kV substations, overhead distribution lines, system protection, and generally all of the new system.

- ZESCO infrastructure needed.
- Estimates of quantities and capital costs. Estimated cost of the entire expansion is $31 million in 1988 US.
- Schedule for construction, which would take about four years to complete.

Mkushi Electrification Scheme Review of Supply Options (Draft). Merz and McLellan, November 1993.

Summary

The 1988 study followed a 1987 undertaking by the Italian Government to provide a loan for the electrification and irrigation development of the Mkushi Block. However after the study was complete the Italian Government withdrew its commitment to provide the loan and the project did not develop. The 1993 study considered additional options for electrification, including supply from Serenje at 66 kV, supply from Lunsemfwa at 66 kV based on the existing Zambia Consolidated Copper Mines (ZCCM) hydro generation in that area, and direct supply from the 330 kV line as in the 1988 study. Some of the schemes envisioned using existing equipment to be recovered from elsewhere in the ZESCO system. The 1993 study presents the following information:

- The same load forecast that was used in the previous studies.
- The study notes a current maximum demand on the feeder circuit from Kapiri Mposhi of 50 amperes, corresponding to 2.9 MVA.
- Description of the existing system in the area.
- The design of the proposed 33/11 kV distribution system in the Mkushi area was based closely on the original 33/11 kV design from the 1988 study. The additional options differed primarily in the source of the power supply, that is the higher voltage transmission connection to the main system.
- The design of five options for electrification: a 66/33/11 kV scheme supplied from Serenje, a 66/11 kV scheme supplied from Serenje, a 66/33/11 kV scheme supplied from Lunsemfwa (Mita Hills Dam), a 66/11 kV scheme supplied from Lunsemfwa (Mita Hills Dam), and a 330/33/11 kV scheme supplied from the a new Central substation.
- Development in "Modules", or phases to make financing easier.
- Estimated capital costs for the five schemes ranging from US$30.6 million to 33.6 million. When the cost of losses is included, the schemes are all still close in overall cost. Scheme 1, the 66/33/11 kV supply from Serenje, is preferred on the basis of lowest overall capitalized cost. The 330/33/11 kV scheme is deemed technically superior.
- A six year program of development, construction, and expenditures is described.
- A financial evaluation indicated that project revenues based on ZESCO tariffs will fall far short of covering ZESCO's costs for the project (assuming ZESCO was the owner).

- An economic evaluation added the costs increased agricultural production to the costs of the electrification and compared these total costs to the benefits of increased agricultural production. The results indicated that costs substantially exceeded benefits. This was true even if the costs of electrification were zero.

3.1.4 Electricity Planning And Demand Forecasting

Zaire - Zambia Interconnection Reinforcement Study. SNEL, ZESCO, ESKOM, January 1997.

Summary

The general objective of this study was to identify the reinforcements needed to increase the capacity of the existing interconnection linking the Societe Nationale d'Electricite (SNEL) and ZESCO power system networks. The increased capacity could be used to export surplus power from the existing Inga hydro power plant in the (now) Democratic Republic of the Congo (DRC) to Zambia. About 1,000 MW of surplus was thought to exist in the DRC at the time of the study, with the largest stations being Inga 1 and 2. Additional development of the Congo river at Inga 3 could add 3,500 MW of generating capacity. Additional system studies would be required to identify what reinforcements to the ZESA, Botswana Power Corporation (BPC), and ESKOM systems would be required to permit export of the power to South Africa. (See summary below for information on these studies.) This study built upon a previous study completed by SNEL, ZESCO, and ESKOM in 1993, but with changes to many of the basic assumptions used in the earlier study.

More specific objectives were 1) to identify the reinforcements needed to utilize the full 500 MW existing capacity of the Inga - Kolwezi high voltage DC line, first on a non-firm (N - 0) basis, then on a firm (N - 1) basis, and 2) to determine what additional system strengthening would be required to uprate the Inga - Kolwezi line to its final design capacity of 1,000 MW, and to permit export of the 1,000 MW to Zambia first on a non-firm basis, then on a firm basis. The study included the following elements:

- Developing load forecasts for Zambia and the DRC.
- Agreeing on planning criteria to be used in the study.
- Establishing power system data bases for SNEL and ZESCO.
- Agreeing on generation patterns, power factors, and load factors.
- Creating computer files incorporating this information.
- Conducting load flow studies and dynamic modeling studies.
- Evaluating reinforcement alternatives at 220 kV and 330 kV.
- Calculating losses for the different cases.
- Assessing the environmental implications of the first phase of development.

The existing electrical connection runs from Inga to Kolwezi (high voltage DC), then at 220 kV AC through substations at Fungurume, Panda, Karavia, a T to Kasumbalesa, a T to Michelo, and finally to Luano. There are two circuits from Kolwezi to Karavia. and two from Kolwezi to Fungurume. The study indicated that the existing transfer capability was 310 MW.

The recommended program was presented in three phases, summarized below.

Phase 1: Second Karavia - Luano 220 kV line plus related equipment. This addresses the 500 MW N - 0 case.

Phase 2: Add third Karavia - Luano 220 kV line, and first Fungurume - Karavia 220 kV line, plus related equipment. Build for 330 kV but energize at 220 kV if Phase 3 is contemplated. This addresses the 500 MW N - 1 case.

Phase 3: Add uprating of Inga and Kolwezi converter stations to 1,000 MW; disconnect lines built for 330 kV in Phase 2 from 220 kV busbars and energize at 330 kV to create first Kolwezi - Luano 330 kV line; add second Kolwezi - Luano 330 kV line; add related equipment. This addresses the 1,000 MW N - 1 case.

Table 3-1 summarizes the increases in transfer capability, costs, and losses of the three phases. The costs are direct capital costs and do not include items such as interest during construction.

Table 3-1. Technical Parameters For SNEL - ZESCO Interconnection

Phase	Transfer Capability When Complete, MW	Added Transfer Capability, MW	Cost Of Phase, Million 1995 US$	Cost Of Phase, $/KW Added	Losses At Peak, MW	Added Losses At Peak, MW
Existing	310	N/A	N/A	N/A	122	N/A
1	430	120	19.7	164	156	34
2	465	35	77.2	2,206	154	-2
3	940	475	436.1	918	279	125

SNEL - ZESCO - ZESA - BPC - ESKOM Transfer Capability Study Progress Report. SAPP/SADC, 25 January - 9 February 1999, Lusaka

Summary

The objective of this study was to investigate possibilities of improving the transfer capability from SNEL through to ESKOM. The study had the following elements:

- Establishing data on the power systems of BPC, ZESCO, ZESA, SNEL, and ESKOM, including load forecasts and generation expansion and internal transmission strengthening programs.
- Establishing planning criteria.

- Conducting system analysis to determine transfer capability at the important interfaces and devising technical solutions to increase it.
- The study's key results were:
  - Replacing the current-voltage transformers and traps at Luano would increase transfer capability between SNEL and ZESCO by 60 MW, from 250 MW to 310 MW. The cost would be US$105,000.
  - Building a second 144km 220kV transmission line between Karavia (DRC) and Luano (Zambia), and installation of 2 x 72MVAr shunt capacitors at Karavia would increase transfer capability between SNEL and ZESCO to 500 MW, at a cost of US$ 17,417,000.
  - Installing a third 220/132kV transformer at Segoditshane will eliminate the 220/132 kV transformer overloading problem there and increase the transfer capability between South Africa and Zimbabwe from 250 MW to 700 MW. This will also improve the robustness of the BPC system and will greatly enhance its system stability. The estimated cost for this project is US$ 2,744,000.
  - Several other more expensive projects could increase the SNEL-ZESCO transfer capability to 1,000 MW and the ESKOM - ZESA transfer capability to 1,200 MW.

Zambia – Malawi Transmission Interconnection Options, Executive Summary. ESKOM, ZESCO, and TANESCO; November, 1996

Summary

This was in some sense a companion study to the Zambia – Tanzania 330 kV Transmission Interconnection Study summarized in the Subsection above, in that many of the same people from ESKOM and ZESCO worked on both studies, both studies shared the same general objectives, both were initiated following an offer during a Southern African Development Community (SADC) Energy Sector Technical and Administrative Unit (TAU) meeting in Arusha in 1994,by ESKOM to assist in an inter-utility planning study, and the similar Terms of Reference for both were developed based on discussions among ZESCO, ESKOM, TANESCO, and ESCOM the month following the Arusha meeting.

The objective of the study was to investigate the possible alternatives for interconnecting the power systems of Zambia and Malawi, and their impact. Because of its dependence on the hydro generation on the Shire river, ESCOM is at risk during periods of poor hydrology and from siltation. This risk would be reduced by having an interconnection with ZESCO. The study included the following elements:

- Developing power system data bases for both networks.
- Developing load forecasts for both systems.

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- Agreeing on the patterns for generation for the period when the interconnection would be operational, and power factors and load factors.
- Studying each system separately to identify the expected ZESCO surpluses and ESCOM shortages.
- Developing realistic capital cost estimates for the interconnection alternatives.
- Studying optimized interconnections between Pensulo in Zambia and Lilongwe B in Malawi at 132 kV, 220 kV, and 330 kV.
- Evaluating the impact of the interconnection on system losses in each system, and the dynamic stability of the interconnected system.
- Conducting a financial evaluation to determine the overall cost of the interconnection in US cents per kWh, considering its capital cost, the level of trading, the cost of losses, and the cost of energy sales. With all these costs included, for the different options the study shows a range of costs from 5 to 6.5 cents/kWh depending on the option and the scenario.

The study concludes that the 132 kV options should be considered only the availability of capital is a limiting constraint. Its estimated capital cost is 1996 US$ 22.3 million for a transfer capability of 67 MW. It has the lowest capital costs, but also the lowest transfer capability and the highest losses.

If trading up to 150 MW is desired, then the 220 kV option is recommended. Its capital cost is $53.0 million for a transfer capability of 169 MW.

For trading above 150 MW, the 330 kV option is recommended. Its capital cost is $90.6 million for a transfer capability of 243 MW.

Line optimization is recommended if the interconnection is committed in order to determine possible cost savings.

Twenty Year Power System Development Plan for Zambia. EKONO Energy; June 1996

Summary

This study includes an executive summary, a main report, and three volumes of appendices and drawings. It is a comprehensive planning study, including:

- A detailed demand forecast built up from forecasts of the sector-by-sector economic and demographic development of the country, and specific evaluations of the load of each mining division. Its low, base, and high demand growth scenarios correspond to average energy demand growth rates of 0.1%, 1.7%, and 3.4% from 1993 through 2014.
- Review of the energy sector and the resources available for power generation.
- Review of historical demand and power generation.
- Review of the potential for electricity trade with other countries.

- Description of the existing generation, transmission, and distribution systems.
- Description of potential future power generation sources. All the power plants are hydro plants. Of these, the most attractive are Itezhi-tezhi, Kafue Gorge Lower, and Batoka Gorge. It estimates energy costs for Kafue Gorge Lower and Batoka as virtually equal.
- The results of the generation planning exercises indicate that new resources are needed immediately in the base scenario, and that either Kafue Gorge Lower plus Itezhi-tezhi or Batoka alone could meet the system's needs over the planning horizon through 2014. Kafue Gorge Lower and Itezhi-tezhi are favored because Itezhi-tezhi's shorter construction time means that shortages in the early years could be avoided. In the high scenario, both Kafue Gorge Lower and Batoka are needed. In the low scenario, no new resources are needed.
- The study presents programs for the development of the transmission, sub-transmission, and distribution systems.

Feasibility Study Of The Development Of Hydroelectric Power In The Luapula And Northern Areas Of Zambia, Volume 4 of 6 - Load Forecast Report. Harza Engineering Company International, in association with Ekono Energy, March 2000

Summary

These volumes of the overall feasibility study present a detailed update of the demand forecast presented in the Twenty Year Power System Development Plan for Zambia, summarized above. Its low, base, and high demand growth scenarios correspond to average energy demand growth rates of 0.7%, 1.9%, and 3.1% from 1999 through 2020.

3.1.5 Southern African Power Pool

Southern African Power Pool Inter Utility Memorandum of Understanding. 8 December 1995

Summary

The objective of this document is to facilitate the establishment of the SAPP, which in turn has the objective of providing reliable and economical electric supply to the consumers of each SAPP Member. The purpose is to establish the basic principles under which the SAPP will operate. A Member is a signatory which is also an Electricity Supply Enterprise, which in turn is an entity which operates a Control Center around the clock, owns or controls generation and operates these units to meet some or all of its load, and which owns a transmission system which is or may be interconnected with its neighbors.

In summary the MOU delineates the management structure of the SAPP and some of the procedures to be followed. The MOU has the following key provisions:

- Membership is open to all SADC utilities and other non-SADC utilities empowered by their respective governments.

- Each Member shall at its own cost build, operate, and maintain its own transmission facilities.
- IPPs may participate in the Operating and Planning Sub-committees, but not in the Management of Executive Committees.
- An Operating Member is a Member which has its system interconnected internationally with at least one other Member and which is a signatory of the Agreement between Operating Members.
- The hierarchy of documents governing the pool is the Inter-Government MOU, the Inter-Utility MOU, the Agreement between Operating Members, and the Operating Guidelines.
- The management structure is as follows:
  - The Southern African Development Community Energy Ministers are responsible for policy matters which are normally under their control in terms of the national administrative and legislative mechanisms that regulate the relations between the Government and its respective power utility. The Executive Committee shall refer matters such as membership requests by non-SADC members and major policy issues to the SADC Energy Ministries.
  - The Executive Committee serves as the Board of the SAPP. It is composed of the Chief Executive Officers of only those Member Electricity Supply Enterprises who generate, wholesale, and retail power to end-use customers, but limited to one such Chief Executive Officer per country.
  - The SADC Technical And Administrative Unit of the Energy Sector provides secretarial and other services to the Executive Committee.
  - The Management Committee oversees the administration of the SAPP and the Sub-committees. It consists of a maximum of three representatives per Member.
  - The Operating Sub-committee addresses operating issues. Its duties are defined in the Agreement between Operating Members.
  - The Planning Sub-committee addresses planning issues.
  - The Environmental Sub-committee addresses environmental issues.
  - The Co-ordination Center reports to the Operating Sub-committee. Its duties are defined in the Agreement between Operating Members.

Southern African Power Pool Agreement Between Operating Members. 8 December 1995

Summary

The purpose of this document is to establish the basic principles and rules under which the interconnected potion of the SAPP will operate, so that all Operating Members can co-ordinate and co-operate in the operation of their systems to minimize costs while

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maintaining reliability, fully recover their costs, and share equitably in the resulting benefits. Its key provisions include:

- An IPP may become an Operating Member, but shall not be entitled to participate in the Management or Executive Committees.
- The specified rights and obligations of Operating Members are:
  1) To provide or receive Emergency Energy from other Operating Members, including wheeling if necessary, subject exclusively to technical limitations in terms of the Operating Guidelines.
  2) To operate as a control area using automatic generation control.
  3) To provide or receive transmission wheeling for capacity and energy transactions, where this is technically and economically feasible, subject to the conditions of Service Schedule I.
  4) To maintain at least a minimum level of generation reserves by complying with its Accredited Capacity Obligation...
  5) To exchange maintenance schedules.
  6) To disclose costs that are the basis for prices for some of the permitted transactions.
- Note that if an IPP becomes an Operating Member, it would appear to have the rights and obligations noted above, although how items 1, 2, 4, and possibly 5 would apply, if at all, is unclear.
- The document specifies the duties of the Operating Sub-committee, including establishing and updating the Operating Guidelines, co-ordinating maintenance schedules, and many others.
- It establishes the Co-ordination Center, whose functions are to monitor continuously the operation of the SAPP, transactions between Operating Members, time correction procedures, inadvertent power flows and returns, operating performance, and many others.
- It defines the Accredited Capacity Obligation, a key parameter in determining whether an Operating Member maintains an adequate level of reserves.
- It provides 13 Service Schedules covering various kinds of energy, banking, power, reserves, wheeling, and control area services transactions. They define the service, establish service conditions, and describe how the rates for the service will be established.
- It defines procedures and requirements for metering, settlements, arbitration, and related matters.

Southern African Power Pool Operating Guidelines. 14 August 1996.

Summary

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The objective of this document is to provide a set of guidelines to ensure that all the Operating Members of SAPP operate the interconnected Southern African network efficiently and effectively and that all Members participate equitable in the obligations and in the benefits resulting from the Pool. The emphasis is on operating each system in such a manner that it does not burden neighboring systems.

The clauses are divided into Operating Requirements, which are obligations, and Operating Recommendations, which are good operating practices which should be followed, taking into account system conditions and characteristics.

The guidelines are divided into six sections, some with appendices: System Control, system Security, Emergency Operations, Operating Personnel, Operations Planning, and Telecommunications. The individual clauses involve many issues that would or might affect the operation of an independent power project, either directly or indirectly. A few requirement areas are noted below:

- Automatic Generation Control.
- Voltage levels.
- Spinning reserve and operating reserve.
- Reactive power supply.
- Transmission operation.
- System monitoring.
- Maintenance coordination.
- Emergency operations.
- Telecommunications.

Southern African Power Pool Annual Report 1999; Annual Review Report. April 1997 - March 1999

Summary

This document first provides an overview of the SAPP, showing the members, the organization, the interconnections, and the members of the Executive Committee.

It then presents highlights of operations for the two years noted, including:

- Summary of energy transactions by Operating Member.
- Management Committee report.
- Operating Sub-committee report, noting among other things the establishment of the Co-ordination Center in Harare.
- Planning Sub-committee report, noting among other things that the interim wheeling rate of 7.5% was approved again, and that the DRC-Zambia 220 kV line, the Zambia-Tanzania 330 kV line, and the Mozambique-Malawi 220 kV lines would be presented to TAU for funding considerations.

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- Environmental Sub-committee report.
- Operational statistics, general statistics and planning data, and a map of the SAPP grid.

3.1.6 Private Investment And Investment Incentives

Framework and Package of Incentives for Private Sector Participation in Hydropower Generation and Transmission Development. Government of the Republic of Zambia Ministry of Water and Energy Development; October, 1998

Summary

The purpose of this document is to provide a framework that spells out the concessions and incentives offered to attract private participation in the power industry. Its four main sections address a general framework, hydropower projects, transmission line projects, and institutional framework.

We note that at the time of this writing the provisions of this document had not yet been confirmed through legislation.

General Framework:

- Financing Arrangements - specifies requirements for financing
  - Limited recourse financing, meaning no sovereign guarantees.
  - Minimum 20% equity investment.
  - Various provisions to encourage development of a local corporate debt securities market.
- Fiscal Incentives - lists the various fiscal incentives which may be allowed.
  - Income tax holiday for 10 years from Commercial Operations Date.
  - No customs duties, value-added tax, or other surcharges for imports of plant and equipment for the projects covered by the framework.
  - Free repatriation of equity and dividends.
  - Exemption from income tax in Zambia for foreign lenders and investors of the project companies.
  - No requirement for participation of Zambian investors.
  - Various other related incentives.
- Security Package
  - Model implementation, power purchase, and transmission service agreements will be prepared to minimize the need for protracted negotiations between Government and project sponsors.

- The hydropower projects will be on a build-own-operate-transfer (BOOT) basis. Ownership will be transferred to the GRZ free of charge after 30 years of operation.
- Where appropriate, the GRZ shall guarantee the performance obligations of the utilities for the long term transmission service agreements.
- The implementation agreements for private projects shall provide for force majeure risks, changes in certain taxes, and convertibility of the Kwacha and remittability of dividends and equity.

Hydropower Projects:

- Procedures for Application and Processing of Proposals
  - OPPPI will be one-window operation for the development effort.
  - Sites will be allocated based on competitive bidding.
  - Fees required to register, apply, and when the bid is won.
- Tariff for Bulk Purchase of Power
  - Will be as per the offer of the successful bidder.
  - Power may be purchased by any entity, including ZESCO.
  - May include a nominal sum as the price of a royalty for the use of the water.
  - Payment will be made based on the actual energy and capacity sold during a month.
  - The hydropower plant will be given priority in load dispatch, and the investor will receive an assured amount each month to cover the costs of O&M, debt service, insurance, and return on equity.
  - The tariff will have four components: a) water charge; b) variable O&M; c) component subject to escalation (fixed O&M, insurance, administrative costs, return on equity, etc.); and d) a fixed component related primarily to debt service charges which will decline with the passage of time.
  - There will be provisions for escalation of components b and c.
  - Various assumptions that underlie the tariff are specified.
- Water Rights. This section summarizes the situation regarding water rights. Key provisions include:
  - Once a developer is an approved investor under the Investment Act, the granting of water rights will be automatic subject only to the relevant approvals from the Environmental Council and the ERB. Once an Investment Certificate is obtained, the developer is granted the automatic approval to acquire land.

- If a hydropower plants water rights are reduced by GRZ action, the developer will be compensated accordingly.

Transmission Line Projects:

- Concept
  - Build-own-maintain (BOM) approach.
  - Operation and loading of the line is the responsibility of the system operator (ZESCO).
- Choice of Transmission Projects
  - GRZ will prepare list of projects, to be offered as packages including lies and substations.
  - ZESCO will prepare minimum design and functional performance requirements for the projects.
  - Specifies experience requirements for lead promoters.
  - Land and acquisition of right of way will be provided free of charge by GRZ.
- Procedures for Application and Processing of Proposals
  - Fees required to register, apply, and when the bid is won.
- Transmission Service Charge
  - Monthly payment of service charges covering capital and maintenance costs.
  - Penalties for delays in commissioning, excessive outages, or excessive losses.
- Other Provisions
  - Developer must meet environmental standards in design and operation; GRZ will provide consent and approvals to cover environmental aspects and other regulatory requirements of right of way.
  - GRZ intends to allow open access including open access rules and transparent pricing.

Institutional Framework:

- OPPPI - the one-window operation
- Private Sector Infrastructure Development Fund - may be established with the assistance of the World Bank and others to provide up to 30% of the capital costs of the project.
- Feasibility Studies -GRZ will initiate preparation of studies for potential sites. Several concepts for undertaking and paying for future studies are presented.
- Issuance of a Separate Statutory Order - If required, the GRZ will issue such an order so that incentives and concessions given in various regulations and

directives are consolidated to facilitate understanding and implementation of the package of incentives.

Zambia Privatization Agency Progress Report No. 13. 1 July 1998 to 31 December 1998

Summary

This document contains nearly 150 pages of information on the activities of the ZPA. Most of it comprises summary data on each of the State owned enterprises which were privatized before 1 July 1998, including (typically) mode of sale, bidders and bid prices, purchaser, sale price, payment terms, reasons for selecting winning bidder, and background of purchaser. It provides a more detailed narrative and data for each of the privatizations concluded during the period of the Progress Report. 206 State owned enterprises had been privatized by 31 December 1998.

The Progress Report also provides:

- A summary of progress showing which enterprises were privatized each six month period starting with the second half of 1992.
- A summary of year by year, enterprise by enterprise privatization revenue, which by the end of 1998 totaled about 21 billion Kwacha, 312 million US$, and 13 million South African Rand.
- The ZPA Divestiture Sequence Plan
- The names and affiliations of the ZPA members
- A description of ZPA's organization and staffing
- Lists of individuals seconded to ZPA by donor agencies, consultants used as independent negotiating team members, and consulting and law firms contracted by ZPA or donor agencies to render various services to ZPA.

Zambia Privatization Agency Status Report as of 30 April 2000

Summary

This report provides shorter summaries (than Progress Report No. 13) of all the 239 privatizations through 30 April 200. Despite their brevity, they show statistics on labor force level, forced and volunteer redundancies, and employees retained.

It also provides very brief summary information on the status of the privatization process for the 5 enterprises for which negotiations are complete, the 9 enterprises ready for privatization or under negotiation, and the 26 enterprises under preparation.

3.1.7 ZESCO

ZESCO Statistics Yearbook of Electric Energy 1998-1999. Issued by the Statistics Section

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This document presents data on ZESCO and the Zambian electricity sector, in most cases monthly for the current year and yearly for the period from 1978/79 through 1998/99. The tables cover:

- Generation station capacity and type for ZESCO and for ZCCM.
- Length of high voltage transmission lines and distribution lines.
- Gross and net generation at the main hydro plants, the small hydro plants, and the diesel generators.
- Exports and imports from the DRC.
- Exports to ESKOM and BPC.
- Exports to Zimbabwe (ZESA)
- Low voltage exports to neighboring countries
- Bulk deliveries to Copperbelt Energy Corporation (CEC), formerly ZCCM (statistical, not sales), ZESCO North, and Lusaka and ZESCO South.
- ZESCO units net sent out plus net imports, and transmission losses.
- Gross bulk consumption in the main grid
- Chargeable main grid bulk sales summary
- ZESCO retail sales for ZESCO North and Lusaka and ZESCO South
- Retail sales for rural areas, including isolated systems.
- Number of customers and electricity consumption by district.
- Transmission, distribution, and system losses.

Government of the Republic of Zambia - ZESCO Performance Contract II, 1st April 2000 - 31 March 2003.

Summary

The recent document replaces the previous one, which was intended to cover the three year period starting April 1996. The Preamble to this current contract notes that only a modest number of the targets set in the previous version had been met, and in addition the envisaged Performance Contract Review Committee was never established and therefore there was no strict monitoring of compliance.

The stated purpose of the contract is to ensure the transformation of ZESCO into a financially sound, commercially viable, and efficient utility. The signatories are the Ministers of Energy and Water Development, and of Finance and Economic Development for the GRZ, and the Board Chairman for ZESCO.

ZESCO's short term general objectives are to improve financial viability, quality of supply, customer service management, and safety and health. Longer term general objectives address return on net assets, timeliness of collections, the quality of customer service, electrification, and training and development of personnel.

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Most of the document presents commitments on the part of ZESCO or the GRZ to do certain things or achieve certain goals. Some of the contract's provisions address issues in industry restructuring, tariff policy, risk management, safety and health management, provision of information, and management of the contract itself. Other provisions provide objectives in supply and customer service, operations management, interconnections, human resources management, management effectiveness, system, and finance. A sampling of the specific provisions includes:

On the part of the GRZ:

- To permit full commercial freedom to ZESCO in all areas subject to the provisions of relevant legislation, the contract itself, and ZESCO's Articles of Association.
- To decide on the preferred industry structure by 31 March 2001.
- To review the operations of the Rural Electrification Fund with a view to make it more effective and efficient.
- Agreement in principle on cost-based tariffs adequate to cover all necessary costs with minimum cross-subsidies.

On the part of the ZESCO:

- To extend service to 15,000 customers per year during the contract term.
- Develop a set of customer service metrics and associated performance targets.
- Maintain a generation plant availability average of 90%, excluding planned shutdowns arising from implementation of the power rehabilitation project (PRP).
- Achieve and maintain transmission average reliability of 95%.
- Reduce distribution system interruptions to1 per 100 customers per month.
- Achieve a customer to employee ration of 80.
- Complete the next revaluation of assets by 31 March 2002.
- Provide specified percentage contributions to the capital investment program.

Four appendices provide the assumptions for financial projections, financial performance objectives, detailed performance indicators and targets for a wide range of activities, and finally projected financial statements.

There is no indication of the consequences of achieving or failing to achieve the objectives, or keeping or failing to keep the commitments.

Project Agreement - Power Rehabilitation Project, 15 June 1998. CR.3042_ZA, between International Development Association and ZESCO.

Summary

This agreement obligates ZESCO to do certain things that would help maintain ZESCO's financial position, and presumably increase the likelihood that it would be able to repay

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the loan made available to ZESCO from the GRZ as a result of the loads from IDA to GRZ. The obligations include:

- Carry out the funded by the loan with due diligence and efficiency.
- Procure goods and services according to certain procedures.
- Meet certain requirements regarding insurance, use of goods and services, plans and schedules, records and reports, maintenance, and land acquisition.
- Provide information upon request to IDA.
- Meet certain requirements regarding accounts and disbursements.
- If ZESCO does not achieve the targets in its Performance Contract with the GRZ, it will prepare and carry out an action plan to achieve the targets.
- With respect to its overall management and operations, conduct its affairs in accordance with sound administrative and financial practices, and operate its plants and equipment and make all necessary repairs in accordance with sound engineering and financial practices.
- Submit audited financial statements to the IDA within six months after the end of each financial year.
- Earn an annual return on the average current value of its fixed assets of not less than 1% starting with the financial year commencing in 2001.
- Revalue its assets each year.
- Forecast whether it will meet the 1% return requirement during the next two years and, if it appears it would not, take all necessary measures including tariff changes in order to meet that requirement.
- Produce total revenues not less than an increasing requirement starting with the financial year commencing in 1997 and continuing through the financial years commencing in 2002 and thereafter.
- Forecast whether it will meet these revenue requirements during the next two years and, if it appears it would not, take all necessary measures including tariff changes in order to meet such requirements.
- From 1997 through 2000, and continuing thereafter, progressively reduce its average outstanding customer accounts to no more than 60 days.
- Take all steps within its control to reduce non-technical losses, including adding late payment charges and disconnecting customers with bills outstanding for more than 60 days.
- By July 1, 1998 establish separate accounting centers for its generation, transmission, and distribution centers and implement the agreed-to manpower rationalization plan.

Development Credit Agreement (Power Rehabilitation Project) between Republic of Zambia and International Development Association. Credit Number 3042-ZA, June 15, 1998

Most of the proceeds of the loan covered by this agreement was on-lent to ZESCO under the terms and conditions of the Project Agreement - Power Rehabilitation Project (PRP) summarized above. This Development Credit Agreement provides the terms and conditions of the loan between the GRZ and the IDA. The provisions are consistent to the extent necessary with those of the Project Agreement. They include:

- Description of the loan, interest rate, payment schedule, and scope of the Power Rehabilitation Project.
- GRZ to carry out its obligations with due diligence and efficiency.
- GRZ to cause ZESCO to implement the PRP with due diligence and efficiency, and in accordance with a to-be-adopted Project Implementation Plan.
- Various provisions providing protections regarding the administration, security of funds, insurance, record keeping, reporting, accounting, planning, competitive bidding (for PRP activities), and others.
- GRZ to implement a Hydropower Policy to encourage and facilitate private sector participation in major hydropower generation and transmission projects in Zambia.
- GRZ to develop an organizational framework and procedures for an effective one-window process to facilitate the implementation of the Hydropower Policy.
- GRZ to take various other steps to facilitate the implementation of the Hydropower Policy, including developing standard legal documentation, Request For Proposals packages, distributing of the policies and project proposals to prospective private sector investors, developing an enabling legal framework, and others.

Most of the provisions obligating ZESCO to do certain things are in the Project Agreement.

Zambia Power Rehabilitation Project - CR.3042_ZM, Supervision Mission (February 2000), Aide-Memoire. World Bank

Summary

This document summarizes the results of a World Bank mission that visited Zambia in February 2000. Most of the points made are related to the financial condition of ZESCO. Issues addressed include:

- The physical implementation aspect of the Power Rehabilitation Project (PRP) has progressed smoothly. However, without significant improvement in ZESCO's financial condition counterpart funding will be a problem, and delays in project implementation appear inevitable.

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- The Ministry of Finance and Economic Development agreed to provide the Bank information regarding how the debt from CEC/ZCCM to ZESCO would be cleared. The document includes a discussion of a recently completed debt for tax liability swap and the unpaid accounts of GRZ agencies.
- The Energy Regulation Board's rejection of ZESCO's application for a 15% retail tariff increase effective 1 October 1999 meant that the GRZ was in breach of commitments made in the Project Agreement.
- ZESCO would request a 24.6% tariff increase effective 1 April 2000.
- A review of ZESCO's financial situation, accounts receivable, and collection performance which indicated a deteriorating financial situation to such an extent that there has been a decline in the quality and reliability of service.
- ZESCO agreed to deliver to the Bank during the first week of March 2000 their audited financial statements for the year ending 31 March 1999.
- A summary of ZESCO's cost reduction measures.
- A discussion of problems with ZESCO's recently installed customer billing system. ZESCO agreed to address the problems through five specific commitments.
- A discussion of the problems associated with the financial operations of Kariba North Bank Company.
- A discussion of ZESCO's Performance Contract with the GRZ.
- A discussion of possible restructuring (re-allocation of resources) of the PRP to account for changed circumstances and to better achieve the development objectives.
- A discussion of the Bank's support for OPPPI.
- Three attachments present more detailed information on ZESCO's cost reduction measures, ZESCO's financial projections, and a Bank paper on tariff regulation that identified some problems with the system and suggested some improvements.

ZESCO Electricity Tariff Study Final Report. SwedPower, November, 1999

Summary

Although the report is dated November 1999, the discussion and references are to data primarily from 1995 and 1996, with the latest reference 1997.

The objectives of this study were to establish the long run marginal cost of supplying electricity, to recommend appropriate tariff structures reflecting costs of supply for the next 10 years for each customer category, taking into account socio-economic considerations, revenue requirements of the utility, ad the World Bank's financial covenants, and to recommend a transition period from existing tariffs to ensure satisfying the condition of appraising the Power Rehabilitation Project.

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The study relies on the 1996 EKONO Twenty Year Power System Development Plan for Zambia for some of its key inputs. It presents the following steps:

- Estimates of replacement cost of existing assets, accounting for remaining life.
- Estimates of average cost of supply based on those replacement costs, which were 6.4 US cents/kWh for 1995/96 data.
- Demand forecast.
- System expansion plans and investment costs.
- Calculation of long run marginal costs and long run total costs (including those associated with existing demand and assets). At the residential level (including both large and small residential consumers), the long run marginal costs were 13.17 US cents per kWh and the long run total costs were 12.86 cents/kWh.
- Calculation of basic long run marginal cost bulk supply tariff.
- Calculation of long run marginal cost and long run total cost-based customer class costs. The long run marginal cost-based costs were 21.55 cents/kWh for small residential consumers and about 12 cents/kWh for the largest demand, highest voltage consumers. The comparable long run total cost-based costs were 19.8 cents/kWh and about 10 cents/kWh.
- Comparisons of these tariff levels to the tariffs prevailing in February 1997, which averaged 3.4 cents/kWh.
- Suggested tariff system based on long run marginal cost, providing for some subsidies and reduced complexity.
- Proposed transitional tariffs to reach the suggested tariff levels in five years.
- Forecast of the financial performance of ZESCO assuming the transitional tariffs are implemented.

3.1.8 Relating to the Process of Selecting and Contracting With Private Investors

Request for Expressions of Interest in developing Kafue Gorge Lower. Zambia National Tender Board, January, 2000

Summary

This notice invites applications from eligible firms or consortia who are interested in pre-qualifying to undertake the Kafue Gorge Lower project on a build-own-operate-transfer (BOOT) basis. It describes the logistics of the pre-qualification process and provides a brief description of the project.

Company Pre-qualification Form (for submitting Expression of Interest for developing Kafue Gorge Lower). Zambia National Tender Board, January, 2000

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Summary

This document describes the objectives and logistics of the pre-qualification process, and briefly summarizes the scope of the Kafue Gorge Lower project. It specifies the information required by OPPPI on the technical, economic and financial, and legal capabilities of the applicant(s), and provides the methodology by which the EOIs will be evaluated.

Request for Expressions of Interest in developing Itezhi-tezhi. Zambia National Tender Board, May, 2000

Summary

This notice invites applications from eligible firms or consortia who are interested in pre-qualifying to undertake the Itezhi-tezhi project on a BOOT basis. It describes the logistics of the pre-qualification process and provides a brief description of the project.

Company Pre-qualification Form (for submitting Expression of Interest for developing Itezhi-tezhi). Zambia National Tender Board, May, 2000

Summary

Apart from the description of the project scope, this document is identical to the one for Kafue Gorge Lower described above. It describes the objectives and logistics of the pre-qualification process, and briefly summarizes the scope of the Itezhi-tezhi project, which includes the 220 KM 220 kV line from Itezhi-tezhi to Muzuma Substation.. It specifies the information required by OPPPI on the technical, economic and financial, and legal capabilities of the applicant(s), and provides the methodology by which the EOIs will be evaluated.

Standard Implementation Agreement. International Resources Group; July, 1997

Summary

The Implementation Agreement (IA) notes that it is only indicative and will require conformity to Zambian laws and the GRZ hydropower policy before application.

The IA provides the agreement between a private hydroelectric power generator (Company) and the GRZ regarding the development of the dam, plant, and related facilities (the Complex). It assumes that a Power Purchase Agreement (PPA) will be executed simultaneously between the Company and (tentatively) ZESCO, and a Water Use License will have been granted by the relevant Province. The IA's term will extend to the end of the term of the PPA, and at that point the facility will be transferred to the GRZ for one Kwacha.

The Company's primary responsibility is to design, insure, finance, acquire, construct, install, commission, own, operate, maintain, and transfer the Complex. It may use a Construction Contractor and an O&M Contractor to perform those services. The GRZ grants the Company the right to do all of the above.. The Company will take the necessary steps to undertake its responsibilities, including acquiring the site and applying for approvals, licenses, permits, etc. (Consents). The GRZ will assist the Company in

acquiring the site and obtaining the Consents and in general use its good offices to support the Company's performance of its obligations.

The provisions include:

- The GRZ will expeditiously grant applications of the Company for work permits, visas, and other permits if necessary for individuals involved in the project.
- The Company will provide adequate security personnel for the site.
- The GRZ will waive any applicable customs duties on machinery and equipment imported for the Complex.
- The Company has specified rights regarding foreign exchange and transfer of funds.
- The Company shall not be subject to taxation in Zambia on its income from energy payments (as defined in the PPA), and non-resident lenders shall not be subject to taxation regarding their income from interest on loans extended to the Company.
- If taxes are imposed, the power purchase price will be adjusted to recover the amount of such taxes.
- The GRZ shall execute and deliver to the Company the Guarantee, in which it irrevocably and unconditionally guarantees and promises to pay the Company any money owed but not paid to it by ZESCO.
- If ZESCO is restructured, the GRZ guarantees the performance of the succeeding entity.
- There are many protections against changes in law, nationalization, expropriation, and others.

The IA contains sections addressing various administrative and contractual issues such as definitions, liability, insurance, assignment and security, acquisitions and transfers of shares and assets, force majeure, termination, dispute resolution, notices, and miscellaneous provision. It includes four schedules providing a list of the Consents, compensation amounts in the event of termination, the form of the guarantee by which the GRZ guarantees the payments by ZESCO, and placeholder for the form of the Water License.

Some of the provisions of this draft of the IA are inconsistent with the provisions of the later Framework and Package of Incentives for Private Sector Participation in Hydropower Generation and Transmission Development.

Standard Power Purchase Agreement. International Resources Group; July, 1997

Summary

The document (PPA) notes that it is only indicative and will require conformity to Zambian laws and the GRZ hydropower policy before application.

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The PPA provides the agreement between a private hydroelectric power generator (Company) and (tentatively) ZESCO for the sale and purchase of power from the facility (Complex). It assumes that an IA will be executed simultaneously between the Company and the GRZ, and a Water Use License will have been granted by the relevant Province. The PPA's term will extend for 30 years from the Commercial Operations Date of the Complex.

The Company's primary responsibility is to design, insure, finance, construct, complete, own, operate, maintain, and transfer the Complex. It may use a Construction Contractor and an O&M Contractor to perform those services The Company will take the necessary steps to undertake its responsibilities, including applying for approvals, licenses, permits, etc. (Consents).

The provisions include:

- The Company will sell exclusively to ZESCO, and ZESCO will buy the output of the plant.
- ZESCO will pay directly to the Province the Water Use Charge for the use of the water by the Company pursuant to the Water Use License.
- ZESCO will dispatch the plant, subject to various constraints.
- Requirements for providing information to each other.
- Establishment of an Operating Committee and development of operating procedures.
- ZESCO to supply energy to the Complex for testing and emergency at tariff rates.
- The Complex to be designed, engineered, financed, constructed, completed, and owned according to the Functional Specifications, sound engineering and construction practice, Prudent Electrical Practices, and Prudent Utility Practices.
- ZESCO can dispatch the Complex each day within a Company-declared amount of energy for the day.
- The Company must come within 3% of the directed dispatch level.
- The Complex may be operated using Automatic Generation Control.
- There are allowances for scheduled outages.
- There are provisions governing transmission facilities, interconnection, protection, metering, telecommunications, testing and capacity ratings, .
- There are procedures governing billing and payment, including the provision of letters of credit which can be accessed in the event of non-payment.
- The basic payment is determined by kWh generated (or declared available to be generated, but not dispatched) times an Energy Purchase Price, comprised of an Escalable Component, a Non-Escalable Component, and an O&M Costs

Component. Other payments apply in special circumstances. There is provision for revision of the components based on inflation and exchange rates.

- The Company to pay all lawful taxes, subject to the terms of the IA.

The PPA contains sections addressing various administrative and contractual issues such as definitions, termination, representations, warranties, and covenants, record keeping, security, insurance, liability and indemnification, force majeure, dispute resolution, assignment, notices, and other miscellaneous provision. It includes 8 schedules which address or provide places to address:

- Minimum functional specifications.
- Technical limits.
- Interconnection facilities and transmission facilities.
- Commissioning and testing
- Metering standards and testing.
- Tariff indexation and adjustments.
- Insurance.
- Form of Letter of Credit
- The table of contents refers to another two schedules, not provided, addressing construction reports and testing schedule.

Some of the provisions of this draft of the PPA are inconsistent with the provisions of the later Framework and Package of Incentives for Private Sector Participation in Hydropower Generation and Transmission Development.

As a commentary, we note that the provisions governing dispatch and energy payments appear to be designed for run-of-river plants. They would be difficult to adapt to plants controlled by substantial reservoirs, and are not at all suitable for Kafue Gorge Lower, which will be totally dependent on the discharge of water from Kafue Gorge Upper for its water over a period of hours, not days.

Standard Transmission Services Agreement. International Resources Group; July, 1997

Summary

This is an agreement for the development and use of transmission facilities between a private transmission developer and ZESCO, not an agreement for transmission service to be provided by ZESCO or someone else to a private hydro power developer.

The Transmission Services Agreement (TSA) notes that it is only indicative and will require conformity to Zambian laws and the GRZ transmission line policy before application.

The TSA provides the agreement between a private transmission line developer (Company) and ZESCO for the developer to build, own, and maintain transmission

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facilities (Installation), and for ZESCO to operate the facilities, use them to transmit power, and pay for their use. The TSA assumes that an IA will be executed simultaneously between the Company and the GRZ. The TSA's term will extend for 30 years from the Final Commercial Operations Date, with a possible extension for another five years.

The Company's primary responsibility is to design, insure, finance, acquire, construct, complete, test, commission, own, and maintain the transmission facilities. It may use a Construction Contractor and an O&M Contractor to perform those services The Company will take the necessary steps to undertake its responsibilities, including applying for approvals, licenses, permits, etc. (Consents).

The provisions include:

- ZESCO has the exclusive right to 100% of the capacity of the Installation. The Company will make the Installation available to ZESCO.
- The Installation to be designed, engineered, constructed, etc., in accordance with the Technical Specification and other requirements giving assurance of adequate quality.
- ZESCO will operate the Installation within the parameters of the Technical Specification and in accordance with Prudent Utility Practice, etc..
- The Company will maintain the Installation in accordance with Prudent Utility Practice, etc..
- Exchange of information such as drawings,
- Agreement on safety rules, schedule for scheduled outages,
- Requirements for tests, system control and data acquisition (SCADA) systems,
- Creation of a Co-ordination Committee to co-ordinate and monitor the performance of the parties' obligations under the TSA.
- Procedure for agreeing on the Accepted Route and dealing with changes to it.
- Dealing with the interface with the ZESCO system, and the outages necessary for construction of the Installation.
- Procedures for making new connections to the Installation.
- Procedures for making modifications to the Installation or ZESCO's assets.
- Procedures governing de-energizing.
- ZESCO will pay for its use of the Installation based on its availability, regardless of ZESCO's actual use of the Installation. Thus it could recover all of its costs, including return on equity, if the Installation maintained satisfactory availability, even if it were utilized very little. The basic payment includes Escalable and Non-escalable components, each multiplied by the fraction of time the relevant

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equipment was available during the period of interest, with allowance being made for scheduled outages.

- No mention is made of any special tax breaks for the project.

The TSA contains sections addressing various administrative and contractual issues such as definitions, billing and payment, liability and indemnification, force majeure, assignment and security, insurance, taxation, termination, governing law, dispute resolution, lenders' rights, , notices, record keeping, and other miscellaneous provision. It includes 13 schedules addressing or providing places to address:

- Definitions.
- Technical specifications and scope of works and scheduled commercial operations dates.
- Outage coordination procedures.
- Technical performance characteristics of the ZESCO system.
- The method of calculation and a table of tariffs for the transmission service charge.
- Notification of system incidents.
- Format of site responsibility schedule.
- SCADA systems.
- Pre-commissioning tests.
- Insurance.
- Dispute resolution procedures.
- Form of construction and commissioning program.
- Agreeing the accepted route.

Some of the provisions of this draft of the PPA are inconsistent with the provisions of the later Framework and Package of Incentives for Private Sector Participation in Hydropower Generation and Transmission Development.

3.1.9 General

Energy Statistics Bulletin 1974-1996. Government of the Republic of Zambia, Ministry of Energy and Water Development; March, 1998

Summary

This document almost 70 pages of tables and figures on the Zambian energy sector, covering the years 1974 - 1996 where data is available. 15 pages are devoted to the electricity sector, presenting information on the capacity of electricity generating plants in Zambia, their annual energy production, imports and exports, consumption by sector, and trends in electricity tariffs.

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Comparison of Electricity Prices in the Southern African Region. ZESCO Economics, Pricing, and Regulation Department, January 2000.

Summary

The report's objective is to compare Zambian tariffs to those in other countries in the region. It notes various factors affecting tariffs and inter-country tariff comparisons, such as changes in exchange rates, tariff structure, typical load factors, how recently tariffs were adjusted, taxes included in the tariffs, and the level of demand. The comparisons are presented in units of US cents per kWh.

It provides comparison of residential, commercial, and industrial tariffs at several levels of demand for the utilities in 12 regional countries. ZESCO's rates are lowest in three categories and among the lowest in all categories but the small use residential, where the rates are in the middle.

3.1.10 Documents Not Located

The Competition And Fair Trading Act. No. 18 of 1994

Summary

The 1996 Burns and McDonnell KGL Independent Power Project Report reviewed this document. The report makes the following points, among others.

The statute is designed to encourage competition in the economy by prohibiting anti-competitive trade practices, regulating monopolies and the concentration of economic power, protecting consumer welfare, and strengthening the efficiency of production and distribution of goods and services. It makes no specific reference to the power sector.

The functions of the Competition Commission provided for in the Act are to monitor, control, and prohibit acts or behavior which is likely to adversely affect competition and fair trading in Zambia, including (on its own initiative or at the request of any person) determining whether any enterprise is carrying on anti-competitive trade practices, including the abuse of a dominant position. The following acts could be indicative of such acts or behavior:

- Predatory behavior towards competition including use of court policy to eliminate competitors.
- Discriminatory pricing and discrimination in terms and conditions in the supply of services.

The ERB will regulate all power sector entities, including monopolies, and the Energy Regulation Act provides for cooperation between the ERB and the Competition Commission. If the ERB performs its functions as expected, and this cooperation is achieved, then there should be no problem.

Whatever Act removes currency restrictions.

Summary

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We understand that the Exchange Control Act, which restricted mobility of hard currency, was scrapped in 1994 and now there is no exchange for anyone (residents or non-residents) doing business control in Zambia. However, we have been unable to find documentation to substantiate this.

The Energy Act, 1995, if such an Act exists.

Summary

We understand that there may be an Energy Act which establishes the responsibilities of the Ministry of Energy and Water Development and the Department of Energy.

Taxes

Summary

We did not search for documents describing the laws, codes, etc., that describe and specify all taxes and similar charges for which an independent project may be liable. The Investment Act and the Framework and Package of Incentives for Private Sector Participation in Hydropower Generation and Transmission Development describe tax-related incentives, but do not describe the basic laws and other governing rules.

Merz and McLellan Feasibility Study March 1983 Phase 1 Report (established the model for agricultural development of the area and the forecast of electrical load). The April 1985 Phase 2 Report established the electrification scheme and irrigation and electrification activities, and addressed other issues.

Summary

The 1988 and 1993 Merz and McLellan studies addressing the Mkushi area refer to this earlier study and were the basis of some of the work in those later studies.

The SAPP Planning or Operating Sub-committee documents which specify the interim procedures regarding wheeling rates and conditions.

Summary

The SAPP Agreement Between Operating Members describes how wheeling rates are to be established. The methodology produces generally cost-based rates. However, we understand the following:

- That the SAPP operating members have been unable to agree on the implementation of these procedures, and are presently using an interim agreement on wheeling charges.
- That the SAPP operating members intend to continue to address this issue until a more permanent resolution can be obtained.
- That the interim charges are 7.5% of the value of the transaction if there is one wheeling utility for the transaction. The 7.5% is intended to cover the costs of losses, so there is no additional charge or requirement to return energy to account for losses.

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- That the interim charges are 10% of the value of the transaction if there is more than one wheeling utility for the transaction. The 10% is shared among the wheeling utilities. It too is intended to cover the costs of losses.
- That this approach for wheeling charges has been formalized in a document from (probably) the Operating Subcommittee.

Zambia: The Business Environment for Foreign Direct Investment in the Country's Infrastructure. Foreign Investment Advisory Service (a joint service of the IFC and World Bank); April, 1999

Summary

This is one of the documents recommended for review in the Terms of Reference for the Phase 2/3 Consultants.

4.1 *Issues*

The World Bank Terms of Reference for their project providing the next phase of Assistance to OPPPI indicate that projects selected for the preparation of model solicitation procedures should have a high priority, an available feasibility study, and be economically attractive. The four projects noted there as likely candidates are the Kafue Gorge Lower hydro project, the Itezhi-tezhi hydro project, the interconnection from Zambia to Tanzania, and grid expansion into the Mkushi farming area. That fact, taken with the lengthy history of all four, indicates a high priority. Section 3 summarizes one or more feasibility studies for each of them, and each feasibility study contains information on their economics. The two reports for Task 4 present our evaluation of the economic attractiveness of each project.

The documents reviewed address the issues noted above, and wide variety of other issues which may affect the attractiveness of projects to potential private investors.

4.2 *Feasibility Studies*

The most recent feasibility or feasibility type studies for each of the four projects of interest are the 1995 Harza study for Kafue Gorge Lower, the 1999 Harza study for Itezhi-tezhi, the 1995 -1998 ESKOM - ZESCO - TANESCO studies for the Zambia - Tanzania interconnection, and the 1993 Merz and McLellan study for grid extension into the Mkushi farming area.

The 1995 Harza study for Kafue Gorge Lower provided a detailed physical description of the project setting and the project itself, an environmental impact assessment, a construction schedule and cost estimate, and an economic and financial analysis.

- The physical descriptions are probably adequate for current purposes.
- The cost estimate is five years old and should be reviewed and revised.
- The economic and financial analyses did not evaluate the project with respect to the costs and required tariffs from the point of view of an independent power project.
- There was no analysis that dealt with the dependency of Kafue Gorge Lower on the operation of Kafue Gorge Upper.
- There was no analysis of the possible interactions (i.e., impact on each others' expected annual generation) of Kafue Gorge Upper, Kafue Gorge Lower, and Itezhi-tezhi.

The 1999 Harza study for Itezhi-tezhi provided a detailed physical description of the project setting and the project itself, an environmental impact assessment, a construction cost estimate, and an economic and financial analysis.

- The physical descriptions are probably adequate for current purposes.

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- The cost estimate is one year old and probably adequate for current purposes.
- The financial analyses did evaluate the project with respect to the costs and required tariffs from the point of view of an independent power project.
- There was no analysis of the possible interactions (i.e., impact on each others' expected annual generation) of Kafue Gorge Upper, Kafue Gorge Lower, and Itezhi-tezhi.

Taken together, the 1995 -1998 ESKOM - ZESCO - TANESCO studies for the Zambia - Tanzania interconnection provided a detailed description of the project and the line route, an environmental impact assessment, a construction cost estimate, and a financial analysis.

- The physical descriptions are probably adequate for current purposes.
- The cost estimate is two years old and probably adequate for current purposes.
- The financial analyses appeared to evaluate the project with respect to the costs and required tariffs from the point of view of an independent transmission project, but did not show the input values used for some of the key parameters.
- The results did not assess the desirability of the project from the point of view of the net benefits to Zambia or to Tanzania.

The 1993 Merz and McLellan study for grid extension into the Mkushi farming area, including references to earlier similar studies, provided a detailed physical description of the project, a construction cost estimate, and economic and financial analyses.

- The physical description is outdated and inadequate for current purposes.
- The load forecast is outdated and inadequate for current purposes.
- The cost estimate is outdated and inadequate for current purposes, and to develop a new estimate would require developing a new load forecast and system design, not just updating the unit cost parameters.

Bearing in mind that a private developer would want to review the key information and revise it to reflect current conditions, we conclude that the studies for the hydro projects appear to provide a sufficient starting point for such review and potential revision.

However, we believe that there is enough uncertainty in the level of expected generation at all three Kafue rive power plants, and their impact on each other, that additional study of that issue is necessary, to protect the interests of Zambia.

The transmission interconnection study does not address a key issue, namely whether the project would be economically attractive to Zambia or Tanzania or their electric utilities. However, this current project of assistance to OPPPI provides information on that point. The Mkushi grid extension study is outdated and would need to be extensively revised to form the basis for further activities.

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4.3 *Private Ownership*

There are provisions in several of the laws reviewed regarding private ownership, and many enterprises are privately owned and operated.

- The objective of the Privatization Act is to provide for the privatization and commercialization of State-owned enterprises.
- The Zambia Privatization Agency Status Report shows that 239 formerly State owned enterprises have been privatized as of 30 April 2000.
- The objective of the Framework and Package of Incentives for Private Sector Participation in Hydropower Generation and Transmission Development is to encourage private investment in the power sector.
- ZESCO is on the list of organizations to be privatized, with a study of privatization options just getting started. The National Energy Policy lists the immediate privatization of the distribution as one of its policy goals.
- The Energy Regulation Act provides that any person (i.e., including private foreign owners) may apply to the ERB for a license.

The existing legal framework and the actual participation of private owners in the economy in general and the power sector in particular should give some level of comfort to potential private investors regarding the climate for private ownership.

4.4 *Foreign Ownership*

There are provisions in several of the laws reviewed regarding private foreign ownership, and many enterprises are privately owned and operated by foreign individuals or firms.

- The Privatization Act provides that the shares in a State owned enterprise shall be sold to a citizen of Zambia or to a person who is not a citizen of Zambia.
- The Zambia Privatization Agency Progress Report shows that many of the firms privatized have been sold to foreign firms or their Zambian subsidiaries.
- The Zambia Privatization Agency Status Report shows that the ZCCM Power Division was sold to primarily foreign investors comprising the Copperbelt Energy Consortium. The CEC is the largest power sector organization after ZESCO.
- The Investment Act provides that any person (i.e., including foreigners) investing in a business enterprise may apply for an Investment Certificate. It also provides special protections for foreign investors regarding transferring dividends, principal, etc., out of Zambia in foreign currency.
- The Framework and Package of Incentives for Private Sector Participation in Hydropower Generation and Transmission Development has no requirement for participation of Zambian investors.

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- Exchange controls and other features that discourage foreign investment have been lifted.
- The Energy Regulation Act provides that any person (i.e., including private foreign owners) may apply to the ERB for a license.

The existing legal framework and the actual participation of foreign private owners in the economy in general and the power sector in particular should give some level of comfort to potential foreign private investors regarding the climate for foreign ownership.

4.5 *Electric Sector Regulation*

The Electricity Act provides for regulation of the generation, transmission, distribution, and supply of electricity. The Energy Regulation Act establishes the Energy Regulation Board (ERB) and defines ins functions and powers.

Together the Acts reasonably address many of the issues important to private investors. However, they also leave considerable discretion in the hands of the Minister, and several areas where authority is shared and/or ambiguous.

The World Bank Aide-Memoire discusses the ERB's handling of ZESCO's request for a 15% tariff increase in October 1999, which was rejected. However, the ERB has approved a 24.6% requested tariff increase effective 1 April 2000 despite public opposition.

Although not noted in any of the documents reviewed, it appears that the CEC feels it has been treated fairly by the ERB. However, the GRZ initially did not permit them to shut off service to a non-paying, non-GRZ customer, allowing a multi-million dollar debt to build up. Since then the shut off has been allowed, and implemented on a partial basis.

Good regulation is a combination of laws, institutions, practices, and the good intentions of the regulators and their staff. In Zambia the laws and institutions could be improved by removing some discretion from the hands of the Minister, but by and large the regulatory process has worked reasonably well so far. The interest of knowledgeable private parties in expanding their power sector activities is an encouraging sign regarding the regulatory climate.

4.6 *Incentives And Assistance*

- The Investment Act provides that the Zambia Investment Center will provide various services to investors, and also provides various tax-related incentives.
- The Framework and Package of Incentives for Private Sector Participation in Hydropower Generation and Transmission Development provides for various tax-related and other incentives. However, these incentives have not been confirmed through legislation.

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- The draft Power Purchase and Implementation Agreements provide that the GRZ and/or ZESCO will provide various services and other kinds of assistance to the private developer in the process of developing a hydro project.

The incentives and other assistance described in these documents will reduce the cost and risk of private development in a manner that a private developer could take into account in its cost proposal.

4.7 *Regional Trade*

The SNEL - ZESCO - ZESA - BPC - ESKOM Transfer Capability Study Progress Report provides information on the present transfer capability of some of the interconnections, and the estimated costs of increasing that capability. Among other things, it shows:

- Replacing the current-voltage transformers and traps at Luano would increase transfer capability between SNEL and ZESCO by 60 MW, from 250 MW to 310 MW. The cost would be US$105,000.
- Building a second 144 km 220 kV transmission line between Karavia (DRC) and Luano (Zambia), and installation of 2 x 72 MVAR shunt capacitors at Karavia would increase transfer capability between SNEL and ZESCO from 310 MW to 500 MW, at a cost of US$ 17,417,000.
- Installing a third 220/132 kV transformer at Segoditshane will eliminate the 220/132 kV transformer overloading problem there and increase the transfer capability between South Africa and Zimbabwe from 250 MW to 700 MW. This will also improve the robustness of the BPC system and will greatly enhance its system stability. The estimated cost for this project is US$ 2,744,000.

The SAPP Agreement Between Operating Members provides that:

- An IPP may become an Operating Member.
- An Operating Member has the right to receive Emergency Energy from other Operating Members, including wheeling if necessary, subject exclusively to technical limitations in terms of the Operating Guidelines, and to receive transmission wheeling for capacity and energy transactions, where this is technically and economically feasible.
- Although not noted in any of the documents reviewed, wheeling rates in SAPP have been an area of dispute. An interim procedure is being followed, and it is uncertain what the final formulas will contain or when they might me implemented.

The physical and administrative infrastructure for the developers of Kafue Gorge Lower and/or Itezhi-tezhi to engage in regional trade are reasonably in place. However, these arrangements have not been tested by actual successful private power trade.

A relatively low-cost solution could nearly triple the transfer capability to South Africa, by far the largest market.

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The Power Market report for Task 1 will address the economics of regional trade.

4.8 *Agreements Supporting The Solicitation Process*

The Implementation, Power Purchase, and Transmission Service Agreements provide an initial framework for developing a formal contractual relationship for the potential projects. They identify and present possible resolutions to many of the issues that must be addressed in a final document. As such, they should make it easier and quicker to come to agreement.

The PPA provisions regarding the dispatch and payment procedures for a private hydro plant are not suitable for Kafue Gorge Lower. The provisions are not well suited for a system involving operation of a river system to maximize the joint output of all plants in the river system, which seems desirable for the Kafue river system. In addition, they put all risk of poor hydrology on the developer.

All these issues will need to be addressed. For example, the TSA bases payments on the availability of the facilities, not on their use. An analogous approach for the hydro plants would put all risk of poor hydrology on the buyer. It will take careful consideration to develop a payment scheme that allocates risks and provides operational incentives that will encourage efficient operation from the point of view of all parties.

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Evaluation Of Grid Extension Into The Mkushi Farming Area

Final Report

Assistance To Zambia's Office For Promoting Private Power Investment
Task 4a: Evaluation Of Grid Extension Into The Mkushi Farming Area

Prepared under Contract for:
United States Agency for International Development
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Bechtel National, Inc. *July 2000*

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Acronyms And Abbreviations

GRZ	Government of the Republic of Zambia
GWh	Gigawatt-hour
km	Kilometer
kW	Kilowatt
kWh	Kilowatt-hour
kV	Kilovolt
MVA	Megavolt-ampere
MW	Megawatt
OPPPI	Office for Promoting Private Power Investment
US	United States
USAID	United States Agency for International Development
ZESCO	Zambia Electricity Supply Corporation
ZCCM	Zambia Consolidated Copper Mines

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Executive Summary

The Government of the Republic of Zambia (GRZ) has tentatively selected a first round of four projects for which model solicitation procedures for private development may be prepared. One of these projects is grid expansion into the Mkushi Farm Block, a commercial farming area in Central Province. The principal function of the grid expansion is to supply power for irrigation pumping during the dry season.

The United Kingdom consulting engineers Merz and McLellan conducted three studies which address grid expansion into the Mkushi area. They carried out the first Feasibility Study starting in 1982, with reports published in 1983 and 1985. Their Project Design Report was published in 1988. However, no development took place because funding for the project was withdrawn in 1989. In 1993 they conducted the third study, resulting in the report Review of Supply Options. It sought alternatives with an apparent focus on finding a lower cost solution.

Both the later studies relied to a considerable extent on the original 1983 - 1985 work. Considering possible changes in conditions due to the passage of time, the basic premises that were the foundation for earlier interest in proceeding with the project may no longer be valid. It therefore seems prudent to revisit the project analysis.

Accordingly, this work has two general objectives: to determine if it makes sense to try to offer the project for private investment at this time, and to recommend the best way to proceed with grid expansion into the Mkushi area.

Based on a review of the Merz and McLellan reports available to us and an investigation of current conditions, we conclude that the studies incorporated several technical and economic assumptions which are no longer valid. The studies also explicitly or implicitly assumed that ZESCO would be the owner and operator of the extended grid. However, our assignment is to study the issue of possible private (non-ZESCO) ownership of the grid extension. In addition, now it appears possible, even likely, that ZESCO will be unbundled and in some fashion privatized. Differences between current conditions and those assumed in the studies have important implications for an overall program of grid extension into the area. These differences could affect load forecasts, system performance and modeling, system design, project economics, and the roles of the private developer and ZESCO.

Based on the costs and loads in the earlier studies, we calculate that the annual costs (including return on equity) for the private developer would be $7.5 million, corresponding to a cost of delivered energy of $0.310/kWh. This is far above ZESCO's tariff rates and comparable to the cost of electrical energy from stand alone diesel generators. These costs seem so high as to be not viable. Aggressively changing some of the outdated assumptions to reduce the cost of delivered energy produced an energy cost of $0.076/kWh, which might approach viability for use for irrigation pumping.

At this time, several factors limit the prospects for development of grid extension into the Mkushi area as a stand-alone private project based on a competitive tendering process. Any one of them alone might preclude such development.

- The basic technical and economic information is badly outdated and could not be relied on to prepare a Request For Proposals or the proposals themselves.
- Even with updated information, it appears that the project would be either too costly to be attractive to the farmers, or generate too little revenue to be attractive to the developers, or both.
- The need for a separate independent development to coordinate and integrate with the existing ZESCO system has never been addressed.
- ZESCO's unresolved future structure and ownership complicate the issue of addressing important project requirements such as a supply of power, and create uncertainty and risk for potential investors.

Our analysis leads to the following recommendations:

Preparation of Model Solicitation Documents

Because of the project's high cost and other factors, we recommend that the Office for Promoting Private Power Investment not prepare model solicitation procedures for private development of grid extension into the Mkushi farming area at this time.

Grid Extension Into The Mkushi Area

The recommendation not to proceed with preparing model documents does not imply that grid extension cannot be accomplished in other ways, including with the participation of private investors, especially the farmers who will be the primary beneficiaries of the extension.

It appears likely that some form of financial support beyond that of the customers and the developer (whether ZESCO or private) will be necessary for the project to be an economic proposition for both the developer and the customers. We did not evaluate whether the Mkushi grid extension is the best use of the resources available in Zambia. However, if the GRZ decides that grid extension merits its support in comparison with competing priorities and wishes to pursue it, we recommend the following process for implementation. In essence this involves re-evaluating the issue, with any further grid extension to depend on the results.

The following represent barriers to development which could be addressed:

- Lack of information.
- Lack of funds.
- Lack of focus and commitment.
- Uncertainty regarding ZESCO's restructuring and privatization.

We believe that a committed and concentrated effort is necessary for grid extension to occur in the near future, and that a decision to proceed should not be made without recognizing and providing for the resources needed to undertake the effort. Assuming

this occurs, the process should include the following steps as described in more detail in Section 4:

- Establish the Mkushi grid extension project organization.
- Develop the basic information needed to provide a sound basis for taking the next steps in proceeding with development.
- Survey and inform the potential customers with respect to the key issues.
- Prepare grid extension designs and conduct evaluations based on the basic information gathered.
- Assuming the results of the evaluations were favorable, proceed with next steps leading to project development, including project definition, project financing plan, commitments and authorizations, and assuming successful completion of all these, project implementation.

1.1 *Background*

The United States Agency for International Development (USAID) has selected Bechtel/Nexant to assist Zambia's Office for Promoting Private Power Investment (OPPPI) in conducting Phase 1 of a three phase project leading to preparation of solicitation documents for private development of new hydropower plants and transmission lines. Phases 2 and 3 of the project will be funded from other sources and performed by other consultants. Phase 1 lays the foundation for the work of Phases 2 and 3 through market and economic analysis, project selection, and establishing schedules and resource needs for OPPPI.

The Phase 1 Project has eight Tasks requiring a total of eight deliverables. This report is the deliverable for Task 4a, Evaluation of Grid Expansion into the Mkushi Farming Area.

The Government of the Republic of Zambia has tentatively selected a first round of four projects for which model solicitation procedures for private development may be prepared. One of these projects is grid expansion into the Mkushi Farm Block, a commercial farming area in Central Province. The principal function of the grid expansion is to supply power for irrigation pumping during the dry season.

The United Kingdom consulting engineers Merz and McLellan conducted three studies which address grid expansion into the Mkushi area. They carried out the first Feasibility Study starting in 1982, with reports published in 1983 and 1985.

In 1987 the Italian Government undertook to provide a loan for both electrification and irrigation development of the Mkushi Farm Block. Merz and McLellan conducted a routing survey and detailed design of the electrification scheme in 1988, resulting in the Project Design Report. The primary objective of this study, which built upon the 1983 - 1985 Feasibility Study, was to design a 33/11 kV system to serve much of the Mkushi farming area. It. The 1988 Project Design Report presented the results of the work. It addressed the design and cost of the system, not the sources of funding or the benefits.

In 1989 contracts were awarded to two Italian firms, subject to financing being available. ZESCO funded substation site surveys and soils investigations. However, after that the Italian Government formally informed the Zambian authorities that it was withdrawing from its commitment to provide a loan for the project and the contracts with the Italian companies lapsed, with no development of the planned scheme having taken place.

In 1993 ZESCO instructed Merz and McLellan to review the options for bulk transmission of electricity to the Mkushi farming area. The 1993 Review of Supply Options study considered additional options for electrification, including supply from Serenje at 66 kV, supply from Lunsemfwa at 66 kV based on the existing Zambia Consolidated Copper Mines (ZCCM) hydro generation in that area, and direct supply from the 330 kV line as in the 1988 study. Some of the schemes envisioned dismantling and re-using conductor and other material from an existing transmission line elsewhere in the ZESCO system. Their scope also covered an assessment of an initial development that might be undertaken using in part other material available in ZESCO stores,

estimates of the overall net economic benefits of the project from ZESCO's point of view, and also from the point of view of Zambia as a whole.

1.2 *Objectives*

Both the later studies relied to a considerable extent on the original 1983 - 1985 work. Considering possible changes in conditions due to the passage of time, the basic premises that were the foundation for earlier interest in proceeding with the project may no longer be valid. It therefore seems prudent to revisit the project analysis.

Accordingly, we have two general objectives: to determine if it makes sense to try to offer the project for private investment at this time, and to recommend the best way to proceed with grid expansion into the Mkushi area.

1.3 *Approach*

Two key questions guided the approach we took to the evaluation. The first is related to the passage of time: have there been changes in the basic technical and economic information that might affect the project's desirability? The second is related to differences in motivation and requirements between potential private investors and the organizations who previously might have funded the project, such as donor-type agencies, the GRZ, or ZESCO.

Our approach involved several steps:

- Reviewing the Merz and McLellan 1988 Project Design Report and 1993 Review of Supply Options reports.
- Visiting the Mkushi area to investigate current conditions.
- Analyzing the feasibility of private investment to extend the grid into the area along the lines of the earlier studies.
- Developing a program for extending the grid into the Mkushi farming area.

1.4 *Organization Of This Report*

The remainder of this report is organized as follows:

- Section 2 summarizes the information presented in the earlier reports.
- Section 3 reviews the current situation.
- Section 4 presents our evaluation of the current situation.
- Section 5 provides our recommendations regarding whether or not to prepare model solicitation procedures for private development, and for grid expansion into the area.

2.1 *Overview*

The Merz and McLellan Feasibility Study produced two main reports. The March 1983 Phase 1 Report established the model for agricultural development of the area and the forecast of electrical load. The April 1985 Phase 2 Report established the electrification scheme and irrigation and electrification activities, examined alternative methods of providing bulk supplies of electricity, and recommended direct supply from the 330 kV line which traverses the area. It also included the results of a comprehensive study to identify the inputs to and therefore the costs of agricultural production. These reports were not available for our review. We did have copies of the reports from the later studies.

The key results of the 1988 Project Design Report address the following issues:

- Description and drawings of the existing system in the area.
- The report was based on a load forecast taken from the 1983 Phase 1 report, showing peak load rising to 11.9 MW (including the then-existing load) six years after completion of the first stage of construction.
- Design criteria and design considerations for expanded system.
- Description and drawings of the proposed grid extension.
- Design of both a 33/11 kV system and an all 33 kV system.
- Design of and considerations relating to the 330/33 kV substation, the 33/11 kV substations, overhead distribution lines, system protection, and generally all of the new system.
- ZESCO infrastructure needed.
- Estimates of quantities and capital costs.
- Schedule for construction, which would take about four years to complete.

The key results of the 1993 report Review of Supply Options address the following issues:

- The same load forecast that was used in the previous studies.
- The study notes a current maximum demand on the feeder circuit from Kapiri Mposhi of 50 amperes, corresponding to 2.9 MVA.
- Description of the existing system in the area.
- The design of the proposed 33/11 kV distribution system in the Mkushi area was based closely on the original 33/11 kV design from the 1988 study.
- The design of five options for electrification.
- Development in "Modules", or phases, to make financing easier.

- Estimated capital costs for the five schemes.
- A six year program of development, construction, and expenditures is described.
- A financial evaluation comparing the costs for the project to the revenues based on ZESCO tariffs, assuming ZESCO was the owner.
- An economic evaluation added the costs of increased agricultural production to the costs of the electrification and compared these total costs to the benefits of increased agricultural production.

2.2 *Proposed System Layout*

The 1988 Project Design Report offers two similar alternatives. The Terms of Reference specified a 330/33/11 kV system. For that system, the major elements of the expansion include a 330/33 kV Central substation that provides the main power supply for the new and existing loads, five (including Central) 33/11 kV substations supplied from Central at 33 kV, 11 kV distribution networks originating from each of the five new substations, and improvements to existing substations at Mkushi Farmers and Mkushi Boma (township). Some end-use loads would be served directly from the 33 kV lines, in cases where they are closer to the load than an 11 kV line. Estimated lengths total 600 KM of 11 kV and 33 kV lines. The system would serve about 200 farm consumers and a number of smaller loads in Mkushi Boma.

The consultants also proposed an all 33 kV system, which had the technical advantages of lower losses, better voltage profiles, and more potential for expansion. The line routes were essentially the same in either case.

The 1993 Review of Supply Options used the same basic layout within the Mkushi farming area. It sought alternatives with an apparent focus on finding a lower cost solution. The additional options differed primarily in the source of the power supply, that is the higher voltage transmission connection to the main system.

The five options were a 66/33/11 kV scheme supplied from Serenje, a 66/11 kV scheme supplied from Serenje, a 66/33/11 kV scheme supplied from Lunsemfwa (Mita Hills Dam, based on the existing ZCCM hydro generation in that area), a 66/11 kV scheme supplied from Lunsemfwa, and a 330/33/11 kV scheme supplied from the a new Central substation, quite similar to the basic design from the 1988 study.

In all cases the initial Module was strengthening and extending the existing 33 kV and 11 kV supply in the area. All options served the same group of consumers with the same assumed loads.

2.3 *Costs*

In the 1988 Project Design Report the estimated cost of the entire expansion was $31 million in 1988 US$. This included 10% for contingencies and 7.5% for engineering and site supervision, but did not include any amounts for items such as power losses, interest

during construction, land and right of ways, environmental mitigation, or the development costs of a private sponsor.

The 1993 Review of Supply Options provided estimated costs for each of the supply options, which ranged from $30.6 million to $33.6 million in 1993 US$. In all cases the cost estimates took into account the use of some existing equipment then lying in ZESCO's stores in Lusaka. Since ZESCO already owned the equipment, their cost was not included in the cost of the grid extension project. For the four 66 kV cases the cost estimates took into account the use of materials recovered from the Lusiwasi - Msoro No. 1 66 kV line, including the cost of dismantling. The estimates included spares and ZESCO costs such as housing for workers and vehicles. As in the earlier study, these estimates did not include any allowance for items such as power losses, interest during construction, land and right of ways, environmental mitigation, or the development costs of a private sponsor.

Based on 11.9 MW peak end use demand, the options had peak losses ranging from 0.92 MW to 1.43 MW. Based on yearly end use demand of 25.9 GWh, yearly energy losses ranged from 0.96 GWh to 1.49 GWh.

When the cost of these losses (based on the cost of generation required to supply them) is included, the schemes are all still close in overall cost. Scheme 1, the 66/33/11 kV supply from Serenje, has the lowest estimated capital cost and, despite the fact that its losses were highest, also the lowest equivalent capitalized cost when the cost of losses is included and is preferred on the basis of lowest overall capitalized cost.

The 330/33/11 kV scheme was deemed technically superior due to low losses, the highest availability, and highest capacity for expansion.

2.4 *Demand*

The 1993 study notes that a number of years have passed since the 1983 - 1985 Feasibility Study, and that some limited extension of the existing 33 kV system has taken place since then with a few more farms being provided a supply or increasing in supply. It states that the maximum demand on the circuit from Kapiri Mposhi is 50 amperes, corresponding to 2.9 MVA. The study concludes nevertheless that the model of projected development of agricultural activity and the load forecast derived from the Feasibility Study is probably still valid. Therefore the demand forecast from the Feasibility Study is used in the 1993 study, with the dates revised to reflect the earliest that the demand can be achieved, given the assumed schedule of grid expansion. Table 2-1 provides that forecast.[1] For system design purposes the report assumes that the power factor at the high voltage terminals of the distribution transformers is 0.8 lagging.

[1] *The early year peak loads of under 1 MW appear to be errors, since they appear inconsistent with the peak* of 2.9 MVA, and the 1993 study refers elsewhere to a peak of 2.3 MW at about 2.9 KVA.

Table 2-1. Demand Forecast

Farming Year	Energy Demand, GWh	Peak Demand, MW
1993/94	2.8	0.90
1994/95	2.9	0.92
1995/96	3.0	0.94
1996/97	6.2	2.9
1997/98	12.8	6.6
1998/99	17.5	8.7
1999/00	20.5	10.0
2000/01	23.3	11.0
2001/02	25.0	11.6
2002/03	25.9	11.9

2.5 *Overall Benefits*

The 1988 study presented cost estimates, but did not address the question of revenues or other benefits. The 1993 study presented results from the financial evaluation and the economic evaluation noted in Section 2.1.

The "financial" evaluation compared the costs of the preferred grid expansion to the revenues it would generate over an assumed life of 30 years. It calculated yearly values for all cost components, then added then together to produce total costs. The cost components were the capital costs of the preferred grid extension scheme, the long run marginal cost of generating the power delivered to customers, and associated losses, and the cost of operations and maintenance. The sum of the yearly costs over 30 years was $52.5 million.

It made assumptions on the size and profile of the individual loads which would comprise the incremental load associated with the grid expansion, then applied the appropriate then-current tariff schedules to determine resulting revenues each year. It also estimated the yearly revenues associated with connection charges, that is each customer's contribution to some parts of grid extension, related primarily to the cost of the line from the main feeder and transformation at the customer's site. The sum over the 30 year period of tariff revenues and connection charges was the total estimated revenue. The sum of tariff revenues for 30 years was about US$30.1 million in addition to the connection charges of $4.4 million.

The next step was to compare the total revenues to the total costs on a discounted basis, at discount rates of 0%, 5%, 10%, and 15%. Figure 2-1 presents the results. At the more realistic 10-15% discount rates the revenues cover less than 30% of the costs. The declining fraction of costs with discount rate reflects the fact that the large capital costs come even before operation, whereas the tariff revenues come over a period of years.

The financial evaluation notes that factors contributing to the revenue shortfall include the low assumed load factor of 25% in comparison to the system average load factor of 80%, and the low load density due to the widely spread geographical arrangements of the farms. It also evaluates several sensitivity cases with tariffs increased or costs reduced.

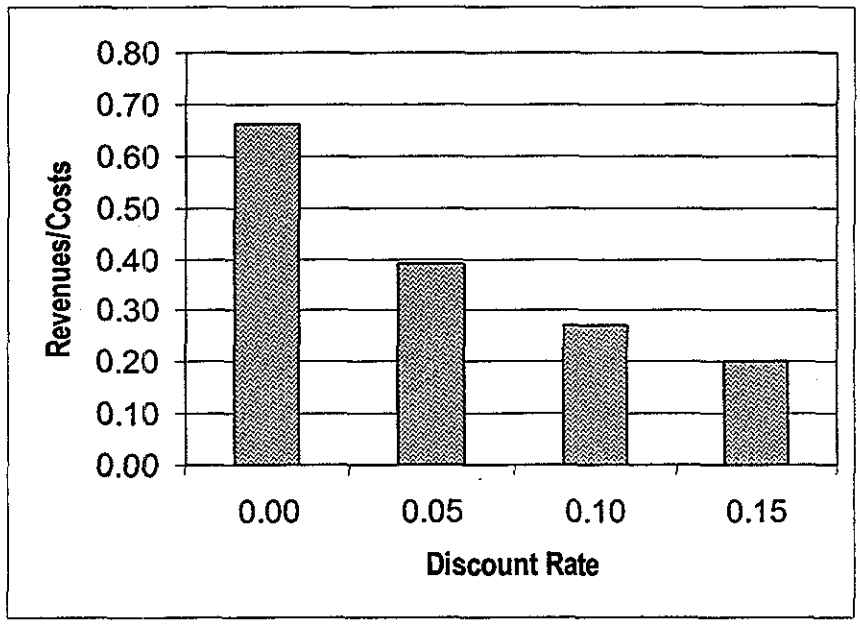

Figure 2-1. Project Revenues Divided By Project Costs

The "economic" evaluation represented an effort to capture a wider range of costs and benefits, which for convenience of reference we will call the "national" costs and benefits. In particular it accounted for electricity supply's role in the increased agricultural production due to an increased area available for growing crops, and to opportunities for double cropping. This in turn would result in increased exports and/or decreased imports. The availability of electricity would also result in the displacement of some imported petroleum products. The report notes that certain other benefits would be expected but were not quantified, including increased commercial activity, employment, and standards of living.

However, the economic evaluation also accounted for a wider range of costs. It includes the costs (besides electrification) associated with increased agricultural production. The total costs include the costs of electrification and ongoing supply of electricity, the costs of irrigation development, the costs of land clearance, and the other costs of agricultural

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production such as labor, seed, fertilizer, machinery, vehicles, buildings, and so on. The sum of the yearly costs over the assumed 30 year life was $406.9 million.

The evaluation based the benefits on the impact of the calculated increased production in reducing imports of wheat and maize, in increasing exports of tobacco, and in reducing imports of private generating plant, diesel fuel, paraffin, and bottled gas. The sum of the yearly benefits over the assumed 30 year life was $306.3 million.

Yearly benefits and costs were discounted at 0%, 5%, 10% and 15%. and the present values compared. Figure 2-2 presents the results. As with the project costs and revenues, the revenues decline as a fraction of costs as the discount rate increases. At the more realistic 10-15% discount rates the revenues cover less than 60% of the costs.

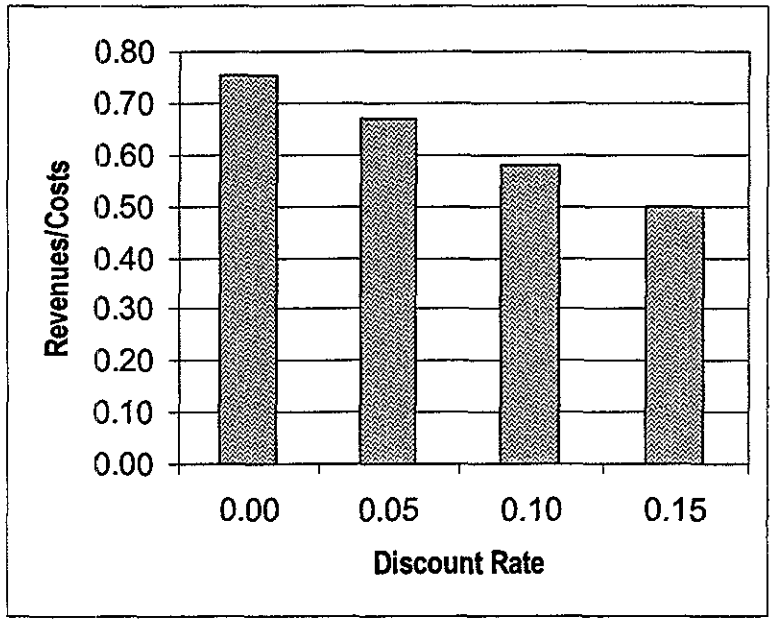

Figure 2-2. National Revenues Divided By National Costs

The economic evaluation considered several sensitivity cases, with adjustments to costs and values. However, the report noted that "it is possible that by careful selection of a number of changes to input variables in the analysis, and by the optimization of crops to be grown, that an acceptable return from the project could be identified. This however would be creating a rather artificial case which it would be unsound to build on."

The study's results showed the project was clearly uneconomic both from the point of view of the project's costs and revenues and from a broader national perspective on costs and revenues, with several caveats:

- The value of the crops may be understated by its assumptions, especially regarding the benefits that the availability of irrigation would provide.
- There will be social and other benefits which were not quantified.

- Higher tariffs would increase the overall return from the electrification scheme to a more acceptable level.

The next section investigates the changes that have occurred since these studies were performed.

3.1 *Overview*

In order to investigate the current situation, two representatives from OPPPI and one from Bechtel/Nexant visited the Kapiri Mposhi substation, the ZESCO office in Kapiri Mposhi, and the Mkushi farming area on Tuesday, 18 April 2000. ZESCO's Area Manager for Kapiri led us on our survey of the area, and provided useful background on the history and current conditions there.

We observed the physical layout of the substation and readings on the voltages and currents in the two lines into the Mkushi area. We visited one large farm which had electricity supply from the grid, and one large farm which did not.

Most of the information presented below is the product of the visit. Issues associated with ZESCO's potential reorganization and privatization also are relevant.

3.2 *Existing System*

In the Merz and McLellan studies there was only one 33 kV line from Kapiri Mposhi into the Mkushi farming area. It extended as it does now from the substation to a tee, where it branched. One branch went from the tee to Farmers substation and finally to Mkushi Boma substation. A second branch went from the tee to a mine which had shut down since the line was built. This line section now normally operates open.

However, on our visit we observed that there is now a second line. It was built about three years ago from Kapiri Mposhi to and past the mine to serve a group of farmers, the farthest of which is about 130 kilometers from the substation. There is presently no connection between the two lines, but ZESCO would like to connect them somewhere to improve reliability (in the event of certain outages, service could be provided to more customers with the connection).

The line serves about 20 or so farmer customers clustered at the far end, along some individual connections along its length.

ZESCO's policy is that it will provide grid extensions if the customer contributes half of the capital cost of the extension. The contributing customers do not get ownership rights or rates reduced form standard tariff levels as a result, but they do get an electricity supply. Especially when long distances are involved, the costs per customer are reduced if several customers agree to share the costs of the extension. In the area beyond the mine that group of customers had agreed to jointly support the grid extension into their area. As a group they covered 50% the total costs of the extension, including the 130 km of 33 kV line.

3.3 *Demand*

At the time we visited the Kapiri Mposhi substation the instruments indicated a flow of about 25 amperes on the line to Mkushi Boma. The records for the day before showed a

peak flow of 50 amperes on that line. There was very little flow on the line the mine on either day, which serves primarily irrigation load. Because of the season, no irrigation pumping was necessary.

Because of problems with instruments and recording, historical written records unfortunately are either unreliable or unavailable. However, the staff at the substation recalled that the maximum loads on the circuits during the peak of the irrigation season were about 120 amperes on the circuit to Mkushi Boma and 90 amperes on the newer circuit. At 0.80 power factor this would correspond to about 6.9 MW on the Mkushi Boma circuit and 5.1 MW on the newer circuit, for a total of 12.0 MW

Even at those flows voltages were reported as being within limits, and that there have been no customer complaints regarding poor voltage control.

The farmer who did have electricity supply from ZESCO discussed his plans for a considerable expansion of his pumping and electrical load, primarily to serve center pivot irrigation systems. He had already installed the substantial foundation upon which one of the new transformers would rest. He indicated that his load after the expansion would be about 3 MVA.

He was aware that ZESCO charges included a component for reactive power, but did not realize that he could substantially reduce the amount of reactive power by providing compensation at his loads, which were primarily pumping. The ZESCO representative advised him of this possibility, and that the cost of the compensation would probably be much less than the savings in charges from reduced reactive power use.

The farmer without electricity supply from ZESCO indicated that he was "desperate" to get electricity. It would be extremely valuable to them, primarily for pumping. Their diesel generation is quite expensive. The ZESCO representative encouraged him to contact his neighbors to see if they would be interested in a joint program of grid extension, to reduce the per customer costs of the extension.

3.4 *ZESCO Reorganization And Privatization*

ZESCO is among the state-owned enterprises listed on the GRZ Cabinet-approved Divestiture Sequence Plan. Through 30 April 2000 239 formerly state-owned enterprises had been privatized, with only about 40 remaining, ZESCO among them.

At the request of the GRZ, the Zambia Privatization Agency recently has embarked on a process of developing and evaluating options for private sector participation in ZESCO. Several options for the reorganization, restructuring, unbundling, and privatization of ZESCO will be developed and evaluated.

ZESCO currently owns, operates, and maintains the existing grid in the Mkushi farming area. It handles all administrative and billing matters related to power supply through the Mkushi distribution grid, and using facilities outside the Mkushi area also generates and transmits to the substation at Kapiri Mposhi the energy delivered ultimately delivered to Mkushi area customers.

3.5 *Implications For Grid Expansion*

3.5.1 Technical And Economic Issues

The Merz and McLellan studies incorporated several technical and economic assumptions which are no longer valid:

- That only a single line existed into the area. In fact there are now two 33 kV lines.
- That the load on the line was limited to 50 amperes. In fact the line carries as much as 120 amperes.
- The maximum load served by the single line was shown variously to be 0.90 MW and 2.3 MW, all on the segment to Mkushi Boma. The study indicated that 2.3 MW would cause voltages outside limits. In fact the line to Mkushi Boma alone may carry 6.9 MW today, with no observed or reported voltage problems.
- That the farming area beyond the mine did not have an electricity supply. In fact a substantial development has taken place.
- That the maximum load in the Mkushi farming area, including Mkushi Boma, would be 11.9 MW. The current maximum load on the two existing lines serving only a relatively small part of the overall area considered in the study may be 12.0 MW.
- That irrigated agricultural development was not cost-effective from the viewpoint of the farmers, when the costs of agricultural production were included with the costs of electricity. In fact there has been considerable load growth related to irrigation in the area.
- That customer contributions would be a relatively small fraction of the overall cost of grid extension. The group of customers at the end of the new line paid half the cost of the entire line.

Differences between current conditions and those assumed in the studies have important implications for an overall program of grid extension into the area.

First, the forecast of 11.9 MW maximum demand and 25.9 GWh per year in the Mkushi area may be well below what a current forecast would predict. This raises the question of whether the design proposed in the studies would be adequate to serve the loads associated with a revised forecast, and if not what design would be necessary.

Second, the existence of an already-developed area within the general area studied would affect both the design and cost of the overall grid extension into the area, and the load served by the new facilities.

Third, higher loads would affect the economics of development. Undoubtedly there would be some economies of scale in serving a higher level of demand. This raises the question of what the economics of grid extension would be from the point of view of ZESCO, a private developer, the farmers, and possibly other interested parties.

Fourth, the modeling in the 1993 study indicated that a flow of even 50 amperes on the 33 kV line from Kapiri Mposhi to Mkushi Boma produced predicted voltages outside design parameters, unless extensive power factor correction measures were to be taken. Since the existing line to Mkushi Boma carries current flows well above 50 amperes without such measure having been taken, this raises the question of whether the modeling used too conservative an approach. Alternatively the higher flows may cause existing operating parameters to fall outside reasonable limits such that those conditions should be addressed.

Fifth, the fact that irrigated farmland has expanded and the likelihood that the overall economics have changed raises the question of whether the conclusions of the economic and financial evaluations of the 1993 study would be different given the new circumstances.

Sixth, customer capital contributions exceeding those assumed in the study would also affect the economics of development, at least from the point of view of a private developer.

3.5.2 Issues Related To Non-ZESCO Ownership And ZESCO Privatization

The Merz and McLellan studies explicitly or implicitly assumed that ZESCO would be the owner and operator of the extended grid. However, our assignment is to study the issue of possible private (non-ZESCO) ownership of the grid extension. In addition, now it appears possible, even likely, that ZESCO will be unbundled and in some fashion privatized. These circumstances have important implications for an overall program of grid extension into the area, some of which we note below.

First, what will the role of the private developer be? Will the project be in effect a very small distribution company, a financing agency for what amounts to a ZESCO project, or have some other role?

Second, how will changes to ZESCO's structure and ownership affect whatever arrangements are developed between ZESCO and the private developer? For example, how can the private developer be assured that whatever rights and obligations it has under a contract with ZESCO will be honored, or even be capable of being honored, by successor organizations?

Third, how will interfaces between the existing ZESCO distribution system and the new grid extension be handled? This may involve exchange of technical information, shared services such as maintenance, purchase of facilities, metering, and many others.

Fourth, assuming it has the role of a small distribution company, how will the private developer obtain power, energy, and transmission services, and at what prices?

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4.1 *Private Investment In Grid Extension*

Private investors consider a number of issues in deciding how and where to make their investments, with the foundation for any project being a sound economic basis. A wide variety of other issues come up, many of which can be viewed as representing different kinds of risks and uncertainties the project may face. Furthermore, we are addressing a narrower and more demanding question: should OPPPI proceed with creating and issuing documents seeking private investment through a competitive tender process.

Section 4.1.1 presents potential costs and revenues associated with the grid extension based primarily on the information in the 1993 study. Section 4.1.2 shows what the impact on the economics would be if many of the uncertainties were resolved in a manner which reduced the delivered cost of electrical energy. Section 4.1.3 assesses the potential for private investment given the economics and uncertainties, and Section 4.1.4 provides a discussion and our conclusions.

4.1.1 Costs And Revenues

The 1993 Review of Supply Options preferred scheme had an installed capital cost of $30.6 million in 1993 US$. The overall cost of delivered power would include additional items, some related directly to the grid extension, some not. Table 4-1 shows the calculation of costs and revenues based on the preferred scheme, and using the same loads as the 1993 study. The values reflect the costs that would apply if the project were developed by a private developer. We do not include any payments from the private developer to ZESCO, although the loads and revenues are based in part on the use of existing ZESCO distribution facilities in the area.

We add escalation from 1993 to the year 2000 to the study's estimate for the preferred scheme, basing the amount on the change in the US Gross Domestic Product Implicit Price Deflator index between those years. The estimate for interest during construction assumes a two year construction period, because each module will take about two years to construct before revenues begin to come in. The entry for development costs of private sponsor accounts for the costs such as developer's fee, owner's engineer, additional environmental studies, legal services, loan facility fee, and loan commitment fee. We calculated the annualization factor on a constant dollar basis based on a 30 year life, 15 year loan, 70/30 debt/equity ratio, 5% real interest rate on debt, 15% real rate of return on equity, 15% income tax rate to reflect possible investment incentives, and 0.5% to account for property tax, insurance, and any other similar charges. The annual operations and maintenance cost is 1.5% of the total installed capital cost. The general and administrative cost covers business related costs such as billing, customer service, supervision and management, and all other administrative costs associated with running a small electric distribution company.

The annual costs (including return on equity) for the private developer would be $7.5 million, corresponding to a cost of delivered energy of $0.310/kWh. This is far above

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ZESCO's tariff rates and comparable to the cost of electrical energy from stand alone diesel generators. The capital cost of the grid extension alone mounts to nearly $3,700/KW, before the cost of generation and transmission. This is of course the primary reason for the high total cost.

An independent private developer presumably would be regulated by the Energy Regulation Board and would be entitled to recover its costs. However, these costs seem so high as to be not viable. For example, relatively little irrigation is powered by diesel generation, so it appears to be uneconomic from the point of view of most farmers, who would be unlikely to be willing to pay that much for grid-based electric service. Furthermore the existence of much lower ZESCO rates would make the approval of full cost-based rates more difficult.

Table 4-1 presents data on revenues, assuming that the rates charged would be the same as ZESCO tariffs today.

Table 4-1. Mkushi Grid Expansion Costs And Revenues

Costs are in 2000 US$ unless otherwise noted	
Equipment and installation, million 1993 US$	30.6
Escalation to 2000, million US$	4.2
Interest during construction, million US$	1.7
Development costs of private sponsor, million US$	7.3
Total installed cost, million US$	43.8
Peak load served, MW	11.9
Total installed cost, $/KW	3,680
Annualization factor	0.126
Annual costs, million US$	
Interest, return, depreciation, taxes, insurance	5.5
Operation and maintenance	0.7
General and administrative	1.3
Total annual cost of grid extension, million US$	7.5
Annual energy received including losses, GWH	27.4
Cost of received energy (generation and	0.020
Cost of received energy, million US$	0.5
Annual energy delivered, GWH	25.9
Total cost of energy delivered, million 2000 US$	8.0
Total cost of energy delivered, US$/KWH	0.310
Annual revenues, million US$, at US$/KWH:	
0.04	1.0
0.06	1.6
0.08	2.1

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ZESCO's tariff schedules include components for maximum demand in KVA, energy, and fixed monthly charges, which vary among customer classes. Within a customer class the average cost per kWh depends on power factor, load factor, and level of demand. Today residential and commercial customers with typical usage patterns pay in the range $0.04 - 0.06/kWh. Large customers with high load factors may pay under $0.03/kWh on average, but at low load factors the average could be over $0.08/kWh. The farming area demand is likely to be at relatively low load factor compared to industrial customers because most of it will be for agricultural pumping. Accordingly we calculated revenues based on a range of average tariff levels. Even at $0.08/kWh the revenues fall far short of the costs, naturally enough since the costs average $0.310/kWh.

4.1.2 Unresolved Issues

Section 3 notes several areas where the current situation varies significantly from the assumptions used in the Merz and McLellan studies, and where changed assumptions might change the economics. In this section we will change some of those assumptions to study the effect of the changes, and to see if the conclusions would be affected. The objective is not to predict what the assumptions should be, but rather to see what the impact would be if there were significant changes. The changed assumptions are:

- Peak demand triples, from 11.9 MW to 35.7 MW.
- Annual energy demand quadruples, from 25.9 GWh to 103.6 GWh. Energy losses also quadruple.
- Despite the far greater demand, capital costs increase by only 50%, accounting for possible changes in design criteria and actual design, the grid extension already in place, and economies of scale in building for the larger demand.
- We assume "Donor funding" covers most of the capital investment In concept this could be from international agencies, the GRZ, ZESCO, or anyone else.
- We assume that the customers provide capital contributions amounting to 50% of the private developers gross capital costs.

Table 4-2 shows the resulting costs and revenues.

Even with what we would characterize as very aggressive assumptions with respect to reducing the unit costs of delivered energy, the delivered cost is $0.076/kWh. In fact the net cost to the customer would be much greater than that, considering the assumed level of customer capital contributions.

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Table 4-2. Mkushi Grid Expansion Costs And Revenues With Changed Assumptions

Costs are in 2000 US$ unless otherwise noted	
Equipment and installation, million 1993 US$	45.9
Escalation to 2000, million US$	6.2
Interest during construction, million US$	2.6
Donor funding	30.0
Development costs of private sponsor, million US$	4.9
Gross total installed cost, million US$	29.7
Customer capital contribution, million US$	14.8
Net total installed cost, million US$	14.8
Peak load served, MW	35.7
Total installed cost, $/KW	831
Annualization factor	0.126
Annual costs, million US$	
Interest, return, depreciation, taxes, insurance	3.7
Operation and maintenance	0.7
General and administrative	1.3
Total annual cost of grid extension, million US$	5.7
Annual energy received including losses, GWH	109.6
Cost of received energy (generation and transmission), US$/KWH	0.020
Cost of received energy, million US$	2.2
Annual energy delivered, GWH	103.6
Total cost of energy delivered, million 2000 US$	7.9
Total cost of energy delivered, US$/KWH	0.076
Annual revenues, million US$, at US$/KWH:	
0.04	4.1
0.06	6.2
0.08	8.3

4.1.3 Prospects For Private Investment

At this time, several factors limit the prospects for development of grid extension into the Mkushi area as a stand-alone private project based on a competitive tendering process. Any one of them alone might preclude such development.

- The basic technical and economic information is badly outdated and could not be relied on to prepare a Request For Proposals or the proposals themselves.

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- Even with updated information, it appears that the project would be either too costly to be attractive to the farmers, or generate too little revenue to be attractive to the developers, or both.
- The need for a separate independent development to coordinate and integrate with the existing ZESCO system has never been addressed.
- ZESCO's unresolved future structure and ownership complicate the issue of addressing important project requirements such as a supply of power, and create uncertainty and risk for potential investors.

4.1.4 Discussion and Conclusions

For the reasons noted in Section 4.1.3 we conclude that development of grid extension into the Mkushi area as a stand-alone private project based on a competitive tendering process is not likely to be successful at this time.

A fundamental issue is that extending electrical grids into rural areas is often not economic. The actual costs are too high to be fully borne by the limited number of customers and small amount of load. Inability of customers to afford to pay for even low levels of service is often a problem as well, although that appears not to be the critical factor here. Many of the commercial farms already have domestic electricity from diesel generators. What they need is lower cost power to make irrigation pumping economically viable..

Nevertheless grid extension (or at least provision of some sort of electrical service) into rural areas is a common occurrence. Different motivations and circumstances may contribute:

- Rural customers may form cooperatives or otherwise join together to encourage and even finance and build the needed facilities. Jointly they have access to economies of scale and enhanced credibility as customers.
- Governments may support such development as a matter of policy, by imposing grid extension requirements on utilities, providing low-cost financing, building the electrical systems themselves, or other means. Zambia's Rural Electrification Fund might be used for this purpose.
- The construction of new generating plants and/or transmission lines to other areas may in effect bring the grid closer to some customers, making it less costly to extend service to them.
- Electric companies may extend their grids as a strategic move, in anticipation of load growth, either for long-term profitability or for competitive reasons.
- The electric company, whether publicly or privately owned, may devote a fraction of its resources to this activity as a matter of policy.
- The growth of actual or potential load in an area may eventually make grid extension economic on conventional terms.

- When rural customers are charged the same as any other customers with similar demand, the "uneconomic" costs of grid extension are rolled in with the lower costs of service to (say) urban customers. In effect those customers subsidize the rural customers to some extent. For example, this is the case with ZESCO service to the isolated communities whose power comes from diesel generators.

With respect to grid extension, the Mkushi farming area has many advantages: a 330 kV line runs through it, there is demonstrated demand potential, viable commercial farms exist with the means to pay for power, there is demonstrated willingness to pay part of the costs of development, and there is the economic incentive of potential profits from increased agricultural production through irrigation pumping.

At the start of this subsection we concluded that development of grid extension into the Mkushi area as a stand-alone private project based on a competitive tendering process is not likely to be successful at this time. We would like to emphasize that this conclusion does not imply that grid extension cannot be accomplished in other ways, including with the participation of private investors, especially the farmers who will be the primary beneficiaries of the extension.

In fact, based on its advantages, grid extension into the Mkushi farming area seems likely. One question is whether it would be better done in an organized and comprehensive manner than the ad hoc approach that has prevailed to date. The following subsection discusses some of the issues that would need to be addressed to support grid extension.

4.2 *Proceeding With Grid Extension*

Grid extension into the Mkushi area has been considered since at least 1982, yet the accomplishments to date have been modest. It appears that initial interest was lifted by the prospect of donor funds, and with their withdrawal the project has not been seriously advocated. It also appears that the following represent barriers to development:

- Lack of information.
- Lack of funds.
- Lack of focus and commitment.
- Uncertainty regarding ZESCO's restructuring and privatization.

The activities we suggest below would address some of these barriers. We believe that a committed and concentrated effort is necessary for grid extension to occur in the near future, and that a decision to proceed should not be made without recognizing and providing for the resources needed to undertake the effort.

If the GRZ decides that grid extension merits its support in comparison with competing priorities and wishes to pursue it, we recommend the following process for implementation.

ZESCO Restructuring

The activities relating to ZESCO restructuring and privatization program will be outside the scope of the Mkushi grid extension project. However, the results of that work will be important to the Mkushi project. We suggest that the Project Manager closely monitor that project and incorporate any interim results as soon as they are known.

4.2.1 Organization

The activities discussed below need to be organized, led, and conducted in an integrated manner. We suggest a project team lead by a full-time project manager, with the commitment of the GRZ and ZESCO to support the team's activities and provide the team the necessary authority to accomplish its tasks. Its capabilities should include electric system design, economics, and finance, which could be provided by seconded staff or consultants. Establishing a project office in or near the Mkushi area should be considered.

The activities above would be organized in phases, with decision to proceed to the next phase depending on the results.

4.2.2 Basic Information

The basic technical and economic information is badly outdated. Developing the following information would provide a sound basis for taking the next steps in proceeding with development.

- Current power and energy loads in the area and their recent rate of growth.
- Forecast of future energy and peak demand if the grid were to be extended.
- Drawings and other data that would define the existing system, its condition, and its performance.

4.2.3 Market Research And Marketing

Both the forecast level of demand and the willingness for the farmers to contribute to the grid extension will be critical factors. Every significant farm in the area should be surveyed and informed with respect the key issues affecting project success:

- Increasing the level of knowledge of presently non-grid-connected farms regarding the costs and benefits of electricity supply.
- Informing them of the technical factors involved in developing grid-powered irrigation systems.
- Assisting them in forming groups to share the costs of grid extension.
- Determining the degree to which they would be willing to use their own funds to assist in paying for grid extension.
- Discussing with them the demand they would be likely to create if the project proceeded.
- Developing load forecasts consistent with the above discussions.

4.2.4 Design And Evaluation

Based on the information developed above, assess the situation and as appropriate undertake the next steps:

- Establish design criteria.
- Develop concepts for potential extension alternatives (voltages, arrangements, etc.).
- Prepare preliminary designs for the alternatives.
- Prepare rough cost estimates for the preliminary designs.
- Prepare detailed design for a preferred alternative and develop detailed cost estimate.
- Conduct economic evaluations to address issues such as the cost of delivered energy, the prices farmers could pay for power for irrigation and other purposes, and the need for capital or other subsidies to support development.

4.2.5 Project Implementation

Assuming the results of the evaluations were favorable, the next steps would lead to project development. These would involve:

- Project definition, including final design and cost estimates and project organizational structure.
- Project financing plan, which may include components of donor funds, private capital, GRZ support, and ZESCO in-kind support.
- Commitments and authorizations: obtaining customer commitments, obtaining agreement and commitments from the GRZ and ZESCO, and obtaining commitments for the financing plan.
- If these activities were successfully completed project implementation would follow.

5.1 *Preparation of Model Solicitation Documents*

In Sections 4.1.3 and 4.1.4 we noted several factors which limit the prospects for development of grid extension into the Mkushi area as a stand-alone private project based on a competitive tendering process and concluded such an approach is not likely to be successful at this time.

Consistent with that evaluation and conclusion, we recommend that OPPPI not prepare model solicitation procedures for private development of grid extension into the Mkushi farming area at this time.

5.2 *Grid Extension Into The Mkushi Area*

We also emphasized that the above-mentioned conclusion does not imply that grid extension is not viable in other circumstances, including with the participation of private investors, and noted that in fact, based on its advantages, grid extension into the Mkushi farming area seems likely.

It also appears likely that some form of financial support beyond that of the customers and the developer (whether ZESCO or private) will be necessary for the project to be an economic proposition for both the developer and the customers. We did not evaluate whether the Mkushi grid extension is the best use of the resources available in Zambia. However, if the GRZ decides that grid extension merits its support in comparison with competing priorities and wishes to pursue it, we recommend the following process for implementation. In essence, this involves re-evaluating the issue, with any further grid extension depending on the results.

We believe that a committed and concentrated effort is necessary for grid extension to occur in the near future, and that a decision to proceed should not be made without recognizing and providing for the resources needed to undertake the effort. Assuming this occurs, the process should include the following steps as described in more detail in Section 4:

- Establish the Mkushi grid extension project organization.
- Develop the basic information needed to provide a sound basis for taking the next steps in proceeding with development.
- Survey and inform the potential customers with respect to the key issues.
- Prepare grid extension designs and conduct evaluations based on the basic information gathered.
- Assuming the results of the evaluations were favorable, proceed with next steps leading to project development, including project definition, project financing plan, commitments and authorizations, and assuming successful completion of all these, project implementation.

Schedule And Resources Needed

Final Report

Assistance To Zambia's Office For Promoting Private Power Investment
Task 5: Schedule
Task 6: Resources Needed

Prepared under Contract for:
United States Agency for International Development
LAG-I-00-98-00006-00

Bechtel National, Inc. *July 2000*

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Project Summary Report

Final Report

Assistance To Zambia's Office For Promoting Private Power Investment
Task 7: Project Summary Report

Prepared under Contract for:
United States Agency for International Development
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Bechtel National, Inc. *July 2000*

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Acronyms And Abbreviations

ERB	Energy Regulation Board
GRZ	Government of the Republic of Zambia
GWh	Gigawatt-hour
MW	Megawatt
OPPPI	Office for Promoting Private Power Investment
US	United States
USAID	United States Agency for International Development
ZESCO	Zambia Electricity Supply Corporation

Executive Summary

The United States Agency for International Development has selected Bechtel/Nexant to assist Zambia's Office For Promoting Private Power Investment (OPPPI) in conducting Phase 1 of a three phase project leading to preparation of solicitation documents for private development of new hydropower plants and transmission lines. Phases 2 and 3 of the project will be funded from other sources and performed by other consultants.

The objectives for the parts of the Bechtel/Nexant project covered by this report (Tasks 5 and 6) are to:

- Evaluate and make recommendations regarding OPPPI's organization, and its short- and long-term needs for human resources development.
- Identify and discuss the studies and preparatory work needed for later phases of the project, and the resources needed to conduct them.
- Develop a target schedule leading up to project implementation for the projects for which solicitation documents will be prepared.

We conclude that OPPPI presently lacks many of the logistical and basic office resources which would help it operate more effectively, especially when the process of preparing solicitation documents get underway in earnest. OPPPI would need additional staff if all three projects were to go forward at the same time, and we discuss its training needs in ten areas such as finance, contracts, project management, and others. We understand that most of the logistical and basic office resources, and some of the training, will be provided as part of the Phase 2/3 Consultants Terms of Reference. For those items not covered by those Terms of Reference, we recommend that they should be sought from other sources.

The separate report Evaluation of Projects, which coves the work of other Tasks which are part of this assistance, concludes that the Zambia - Tanzania Interconnection and the Kafue Gorge Lower and Itezhi-tezhi hydro projects are each economic as a stand-alone project. However, there is some uncertainty regarding the hydro projects' output. There is also a possibility that the hydro projects reduce each others' value, and the impact may be more serious for Itezhi-tezhi.

We recommend that this issue be investigated more completely and include the following work:

1) Conduct plant output studies. We recommend that this work be performed by international consultants expert in this area under the direction of OPPPI. Funding for these consultants would have to be obtained from other sources, because OPPPI does not have the funds available to hire them.

2) Establish approach to river management. We recommend that OPPPI's role be as leader of the effort to institute a joint management approach. Obtaining other key inputs would require the commitment the Government of the Republic of Zambia, ZESCO, and the Zambezi River Authority to provide support through the active participation of their representatives in the process, including the drafting of legal documents creating an organization perhaps akin to the Zambezi River Authority.

3) Develop consistent contractual provisions regarding dispatch, river management, and payment. OPPPI's role would be as provider of technical inputs and project leadership. The Government of the Republic of Zambia (GRZ) would provide key inputs regarding its preferences. The Phase 2/3 Consultant's role will be to create the provisions that implement preferences in those areas. It will be important for OPPPI to have the commitment of the GRZ either to participate actively in this process, or to defer to the judgement of OPPPI in establishing the preferences.

Among other things, the results of this investigation would provide guidance regarding whether Itezhi-tezhi should be pursued as well as Kafue Gorge Lower. Pending the completion of such an investigation, this report presents the schedule, which assumes that the process of preparing solicitation documents for the Zambia - Tanzania interconnection and Kafue Gorge Lower will be started in the near future. Work on Itezhi-tezhi may also be initiated in the near future, but a final decision to proceed through implementation will not be made until the studies are complete.

Based on the individual activities necessary through project implementation and their dependencies, we created a schedule for the development of the two projects. The schedule shows start of construction in February 2003 for the Zambia - Tanzania interconnection and in March 2003 for Kafue Gorge Lower. Considering their estimated construction times, these construction start dates would produce commercial operation in 2005 for the interconnection and in 2008 for Kafue Gorge Lower.

This schedule assumes that certain decisions and actions will be made relatively quickly by the GRZ. We recognize that this will require agreement among officials that may be difficult or time-consuming to achieve. Since these decisions are on the critical path of project development, delay will delay project implementation and commercial operation on a month for month basis. In particular, we emphasize the need to define a buyer for the services to be provided by the developer.

Section 1 Introduction

1.1 *Background*

The United States Agency for International Development (USAID) has selected Bechtel/Nexant to assist Zambia's Office For Promoting Private Power Investment (OPPPI) in conducting Phase 1 of a three phase project leading to preparation of solicitation documents for private development of new hydropower plants and transmission lines. Phases 2 and 3 of the project will be funded from other sources and performed by other consultants (the Phase 2/3 Consultants, for convenience of reference). Phase 1 lays the foundation for the work of Phases 2 and 3 through market and economic analysis, project selection, and establishing schedules and resource needs for OPPPI.

The Phase 1 Project has eight Tasks requiring a total of eight deliverables. This report provides the deliverables covering Task 5, Schedule, and Task 6, Resources Needed.

1.2 *Objectives*

The objectives for the parts of the Bechtel/Nexant project covered by this report are to:

- Evaluate and make recommendations regarding OPPPI's organization, and its short- and long-term needs for human resources development.
- Identify and discuss the studies and preparatory work needed for later phases of the project, and the resources needed to conduct them.
- Develop a target schedule leading up to project implementation for the projects for which solicitation documents will be prepared. The time necessary to conduct the studies and other preparatory work needed for Phases 2 and 3 naturally affects the schedule.

1.3 *Approach*

Working hand in hand with OPPPI over several months provided insights regarding their organizational and human resources needs. The work of the other tasks provided guidance regarding what are the key questions and issues that need to be answered or addressed. The studies and preparatory work are designed to resolve these matters.

We outlined all the individual activities necessary through project implementation and estimated the time necessary to complete them. We determined which tasks relied on the results of other tasks, then developed schedules consistent with these relationships.

1.4 *Organization Of This Report*

The remainder of this report is organized as follows:

- Section 2 identifies and discusses the key questions and issues, the studies and other activities needed to address them, and the associated resources needed.

- Section 3 provides the schedule for developing the two projects.
- Appendix A provides a list of the documents which may be included in the Request For Proposals.

2.1 *Key Questions And Issues*

OPPPI must have the basic physical and human resources needed to perform its responsibilities effectively, both in the short term to deal with the projects currently under consideration and in the longer term to deal with possible future projects. It must also have the resources needed to undertake any special studies needed to support the development of the current group of potential projects. We discuss these two categories of resources in the two sub-sections below.

2.1.1 Basic Physical And Human Resources

2.1.1.1 Logistical And Basic Office Resources

OPPPI presently lacks many of the logistical and basic office resources which would help it operate more effectively, especially when the process of preparing solicitation documents get underway in earnest. These resources include:

- Vehicle for OPPPI's use (there are none now).
- Telephone lines and telephones for all staff (none now).
- High speed internet connection and service (none now).
- Cell phone (none now).
- Fax line and machine (none now).
- Copy machine (none now).
- Computers for each staff member (there are three now, five are needed).
- Printer (none now).
- Electronic overhead projector and screen (none now).
- Overhead projector for transparencies (none now).
- Basic office machines, such as punches and document assemblers, and supplies such as paper, binders, etc. (few now).

2.1.1.2 Basic Skills Needed

OPPPI has limited resources - only four professional staff - and although the staff all have background in hydropower development, none has experience in private power projects. The skills necessary for effective implementation of private power investment include:

- Technical and economic
  - To understand the physical and economic setting and requirements for the potential projects
  - To conduct technical and economic analysis of various aspects of the projects

- To assess the technical capabilities of the bidders
- To develop terms of reference for and oversee feasibility studies

- Power system planning and operations
  - To assess and evaluate the domestic and regional market potential for electricity sales.
  - To understand and assess the planning need for potential power projects
  - To understand and assess the operational needs of the system.
  - To understand and quantify the costs and capabilities of new facilities, and their impact on value.
- Project management
  - To manage, from the point of view of the Government of the Republic of Zambia (GRZ), the process of project development through financial closure. This includes management of activities such as those described in all the other bullets (technical and economic, power system planning and operations, etc.), which may be done by teams within OPPPI or by outside specialists.
- Procurement process
  - To develop effective pre-qualification documents
  - To review and evaluate expressions of interest
  - To review and evaluate proposals
  - To negotiate contracts and other agreements with potential developers
- Legal and regulatory
  - To draft necessary changes to legislation
  - To review and modify contract terms to reflect the Zambian legal environment and to provide legal advice and protections
  - To understand regulatory principles and processes, how they influence private power development, and what must be done to support the project development process
- Policy
  - To understand the GRZ's objectives and advise on policies and policy changes that would be effective in meeting those objectives
  - To assess the impact of policy options to assist legislative and policy makers
- Finance
  - To understand the principles of project finance
  - To understand cost of capital concepts and capital markets

- To understand financial modeling concepts
- To evaluate the financial capabilities of bidders
- To develop financial models and conduct financial analysis of bids

- Contracts
  - To develop contract terms consistent with the GRZ's objectives and with the specific circumstances of the project
  - To create clear, easily managed contracts that represent a meeting of the minds
  - To understand independent power producer concepts and contracts
- Risk assessment
  - To identify the key risk factors
  - To analyze the impact of the risk factors
  - To develop measures to mitigate the risks, or to achieve an acceptable level of risk consistent with the GRZ's objectives
- Privatization (i.e., of existing state-owned power system assets)
  - To understand the objectives of privatization and the details of the privatization process
  - To understand the implications of power system privatization on OPPPI's private power development projects
- Social and environmental
  - To understand the full range of social impacts and different approaches to mitigating them
  - To understand the full range of environmental impacts and different approaches to mitigating them

2.1.2 Project Specific Activities - Energy Production Results

Several studies have produced estimates of the expected annual output from Kafue Gorge Upper, Kafue Gorge Lower, and Itezhi-tezhi. Table 2-1 provides a summary of those estimates. In all of the studies the plants' output was calculated over many years with widely varying hydrology.

The 1995 Harza Kafue Gorge Lower Hydroelectric Project Feasibility Report presented a range of values for the output of both Kafue Gorge Lower and Kafue Gorge Upper. For each plant the range depended on the approach taken for determining the releases from Itezhi-tezhi. Up to a point, releasing more water except when constrained increases average yearly generation over a sequence of hydrologic years. However, it reduces the yearly generation during the driest years, presumably because the reservoir is drawn down more at the start of those years.

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The 1999 Harza Feasibility Study of the Itezhi-tezhi Hydroelectric Project developed an approach to river management that maximized output in the worst year of the sequence of years. The average values were based on using that approach every year.

The 1996 EKONO Twenty Year Power System Development Plan for Zambia presented an estimate of average annual generation for Kafue Gorge Lower of 3,480 GWH/year. The study did not describe what approach to river management was used.

The 1993 Shawinigan Engineering Itezhi-tezhi/Kafue Gorge Operating Procedure was intended to maximize the amount of generation during the worst year of the sequence of years, similar in that respect to the 1999 Harza study. The study provided no estimate of average annual energy generation.

The OPPPI internal studies were based on the Valoragua model, which has as an objective to minimize the overall cost of generation in a power system. Table 2-1 does not display it, but the results showed that either of the potential new plants had a significant effect on generation (up to 2,000 GWh/year change in average generation) at Kafue Gorge Upper. The impact due to a new plant could be positive or negative depending on which other plants were assumed to be operational when it was added. It also showed substantial changes in generation in Zambezi river plants, including Kariba, due to the operation of plants on the Kafue river. Some of the results seem improbable, but no source of error has been identified.

The actual historical energy production values from Kafue Gorge Upper came from ZESCO's Statistics Yearbook of Electric Energy 1998-1999.

Table 2-1. Estimates Of Hydro Plant Output

	Output, GWh/year		
	Kafue Gorge Upper	Kafue Gorge Lower	Itezhi-tezhi
1995 Harza Kafue Gorge Lower Hydroelectric Project Feasibility Report			
Annual generation (results over a range of river management approach)			
Minimum	1,146 to 3,213	487 to 1,434	N/A
Average	5,195 to 6,497	2,681 to 3,180	N/A
Maximum	7,284 to 7,708	4,295 to 4,430	N/A

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Table 2-1 (continued). Estimates Of Hydro Plant Output

	Annual Output, GWh/year		
	Kafue Gorge Upper	Kafue Gorge Lower	Itezhi-tezhi
1999 Harza Feasibility Study of the Itezhi-tezhi Hydroelectric Project			
Annual generation (river management approach that produces highest minimum)			
Minimum	2,970	N/A	292
Average	5,904	N/A	642
1996 EKONO Twenty Year Power System Development Plan for Zambia			
Annual generation			
Average	N/A	3,480	N/A
1993 Shawinigan Engineering Itezhi-tezhi/Kafue Gorge Operating Procedure			
Annual generation (river management approach that produces highest minimum)			
Minimum	3,767	N/A	N/A
OPPPI Internal Studies			
Annual generation (depends on which plant are assumed built)			
Average	4,713 to 7,193	3,303 to 3,711	519 to 643
Actual generation from Kafue Gorge Upper, 1980-1988, 1990-1998 (excludes 1989, when plant was shut down due to fire)			
Minimum	3,210	N/A	N/A
Average	4,873	N/A	N/A
Maximum	5,594	N/A	N/A

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These results illustrate the following points:

- The average output from the new plants is uncertain within a range of at least 20%.
- The average output of the potential new plants and Kafue Gorge Upper will depend on the policies and procedures used for the management of all the Kafue river reservoirs and power plants.
- The new plants may have a significant impact on each other and Kafue Gorge Upper.
- Annual output will vary over a wide range depending on hydrology.

These results have important implications for the project.

- The amount of energy generated depends on hydrology and river management practices.
- The value of the plants to Zambia depends on the amount of energy generated, so understanding how much energy is expected and how to maximize that amount is critical to the process of negotiating an agreement and developing the projects.
- Maximizing the amount of energy generated by the three plants jointly is likely to require some form of central control of the releases from all of the dams and reservoirs on the Kafue river.
- Optimal river management practices may depend on which (or both) new plant is built.
- The variation in annual output can be reduced through river management practices, but possibly with a reduction in average annual output.
- The value of the plants to potential developers, and the prices they demand, are likely to depend on their expectations regarding the amount of energy generated as well as the contractual terms relating payments to energy generation.

2.2 *Recommended Studies And Other Activities*

The following activities would address these issues. The activities involve areas of overlap and depend on each other, and therefore should be conducted in close coordination.

2.2.1 Basic Physical And Human Resources

2.2.1.1 Logistical And Basic Office Resources

We recommend that these basic resources be obtained.

2.2.1.2 Basic Skills Needed

We recommend that the basic skills needed be maintained, developed, or acquired.

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2.2.2 Project Specific Activities - Related To Energy Production Results

2.2.2.1 Plant Output Studies

Reducing the uncertainty in plant output will make a new plant more valuable to both Zambia and potential developers. We are aware of no comprehensive study involving the operation of all three Kafue river plants. Accordingly we recommend that OPPPI undertake a comprehensive study of plant output, which would involve at least the following steps:

- Develop a model for the Kafue river system that calculates the output of each plant based on technical factors, hydrological inputs, and different assumptions for rules governing river management procedures.
- Determine whether it is necessary to include the Zambezi river plants in the model, and if so incorporate them.
- Validate the model based on actual historical results for Kafue Gorge Upper.
- Develop a range of river management practices designed to maximize joint output (i.e., of all plants being studied for a particular case) at different levels of risk (e.g., average, worst year, etc.), and use the model to estimate annual output for each plant over a full range of hydrological conditions.
- Tabulate results at least for cases involving all combinations of one, two, and three of the Kafue river plants.
- Evaluate the impact of the plants on each other.
- Evaluate the risks associated with differences in output due to hydrology.

2.2.2.2 Approach To River Management

From Zambia's point of view a reasonable objective would be to maximize the generation from its set of hydro plants within the framework of the hydrologic risks it believes appropriate to take. This is likely to result in each plant generating less than if it tried to maximize its own generation. It would be difficult to achieve this overall maximization if each plant were able to control releases without consideration of the impact on the other plants. Furthermore, the plants taken together are rated at 1,620 MW, about 40% more than Zambia's 1999 peak demand. It will be mandatory to manage the electrical dispatch of the plants in order to control frequency and cover swings in daily loads, which will affect their water releases in any event.

We recommend that OPPPI develop an approach for the joint operation of the dams and power plants on the Kafue river, which would be consistent with the goal of maximizing joint output. The approach would have to take into account the following factors, among others:

- The results of the plant output studies.
- The primary role of the ZESCO's system dispatch (or its successor in this function) in controlling the short-term operation of the plants.

- The need to integrate the control of the water and control of the electrical generation.
- The willingness and ability of the GRZ to accept different kinds of risk.

The approach would involve some form of central direction, and would include some or all of the following:

- Description of how the direction of operation would be achieved.
- Specification of the approach describing how the system will be operated.
- The legal, administrative, procedural, and other arrangements to create such an organization.
- A Joint Operations Group consisting of the interested parties, including the power purchasers, to exchange information and as a forum for discussion.
- Mechanisms for the sharing of costs and benefits.
- Very close coordination of the operations of Kafue Gorge Upper and Kafue Gorge Lower.
- Possible extension to the plants on the Zambezi.

2.2.2.3 Contractual Provisions

Developing a Power Purchase Agreement is part of the scope of the Phase 2/3 Consultants. However, we believe that their role with respect to the issues below should be to advise the GRZ and implement its informed decisions.

The draft Standard Power Purchase Agreement developed by International Resources Group in 1997 provides for all of the payment to depend on the amount of energy generated, or offered to be generated, at prices to be determined at contract signing. This puts the risks associated with hydrology and the management of the river system on the developer, and the risks associated with demand growth and other market factors on the buyer. (The particular mechanism proposed was not suitable for Kafue Gorge Lower because its operation is so closely tied to the releases from Kafue Gorge Upper.)

There are many other approaches. For example, another approach would be to have all of the payment be fixed each month and not dependent on the amount of energy generated, with prices determined at contract signing. Requirements for high plant availability and efficiency would encourage the developer to maximize the energy it generated with the available water. Such an approach would greatly simplify dealing with the issues of electric dispatch and joint operation of several plants on the same river, and would remove the risk of hydrology from the developer, presumably enabling it to offer better prices. However, both that risk and the market factor risks would then fall on the buyer.

Almost any mix of capacity and energy payments is possible, and also any mix of prices fixed at contract signing and prices that depend on market conditions. Which would be preferable depends on what the parties want to achieve with the provisions related to the payment scheme.

We recommend that OPPPI develop an approach for the structure of the payment scheme (energy and capacity components, how to encourage availability and efficiency, the allocation of risks, etc.). This would involve at least the following activities:

- Develop several alternatives such as nearly all capacity payment, nearly all energy payment, etc..
- Assure that the terms recognize the joint operation of the river system and the electrical dispatch procedures.
- Analyze the alternatives in the context of the risks such as hydrology and demand growth.
- Discuss with GRZ officials and other interested parties, and select a preferred approach with their concurrence.
- Coordinate with the Phase 2/3 Consultants, who should participate in the work within the framework of their Terms of Reference, throughout the course of the work.

2.3 *Resources Needed*

2.3.1 Basic Physical And Human Resources

2.3.1.1 Logistical And Basic Office Resources

We understand that most of the needed resources will be provided as part of the Phase 2/3 Consultants' Terms of Reference. We recommend that the needed resources not included in those Terms of Reference be sought from other sources.

2.3.1.2 Basic Skills Needed

OPPPI's resource needs depend on the overall level of effort involved in OPPPI's work as well as the particular skills required to perform the necessary functions. At this point it is difficult to say with confidence what the future level of effort will be. For example, if ZESCO, a candidate for restructuring and privatization, is privatized wholly or in part, some of the future private power investment will likely be handled by the successor(s) to ZESCO. If ZESCO remains primarily state-owned, then OPPPI's role in future private participation in the power sector will be more significant.

Furthermore, the current projects under consideration appear to be the most attractive of the known possibilities, and if constructed would represent a large expansion of the power system in Zambia. Depending on load growth and other factors, it might be many years before additional investment would be needed, at least in generation.

In the near term the level of effort is likely to be higher and the options for dealing with it are limited due to the limited time available. Based on Bechtel/Nexant staff's experience in working extensively with India's Investment Promotion Cell in the Ministry of Power, whose functions were nearly identical with OPPPI's (though on a larger scale), we find it likely that the current level of OPPPI staff would be overwhelmed if all three projects

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were to go forward at the same time. Under such a scenario we estimate that at least a doubling of staff (i.e., to a manager plus three senior staff, as today, plus another three senior or junior staff) would be called for.

A larger staff would provide a number of benefits in addition to providing more people to do the work. With more people, there would be more opportunity for project teams to be formed and/or for functional specialization to be developed, thereby enhancing the effectiveness of OPPPI in carrying out its mission. Training would be easier to manage, since not all staff would have to attend each training session, and the office could continue to function normally during training. There would be more depth, as more people brought and developed skills, and more opportunity for cross-fertilization of ideas. OPPPI would be less affected by loss of individual staff members as they are promoted or transfer to new jobs in other organizations. It would be feasible to establish project-specific teams of less than all OPPPI staff to manage each project.

Options for obtaining the skills necessary for performing the necessary functions include one or more of the following:

1) Use of existing staff skills
2) Hiring new staff
3) Training of existing and possible new staff
4) Temporary assignment of other GRZ and/or ZESCO staff to OPPPI for specialized tasks
5) Use of outside consultants for specialized tasks

Recognizing that it may be difficult to gain authorization to hire new staff, and also the uncertainty in the number of projects that will be undertaken immediately, we recommend that in the near term the focus be on acquiring the skills needed beyond those of the existing staff through items 4 and 5, and using the presence of non-OPPPI personnel as one of the mechanisms for the training noted in item 3. If more staff is authorized, the need for outside support will be reduced accordingly.

In particular, if any one of the projects now under consideration goes forward there will be a need for legal assistance, which must come from items 4 or 5. This will cover areas such as drafting changes to legislation, for example to turn the incentives noted in the Framework and Package of Incentives for Private Sector Participation in Hydropower Generation and Transmission Development into law, and to review and modify contract terms in any Power Purchase Agreement drafted.

In any case an elaborate organizational structure is not necessary. The main role of staff members is likely to be as generalists and project managers, for example as for the activities discussed in Section 2.3.3 below. The necessary skills will vary depending on the particular project under consideration, and on the stage of the project.

We recommend the following:

- Functional specialization. The amount desirable will depend on the level of OPPPI staff authorized - the more people, the more specialization.

- Project team approach to the work. With only four professionals available today, each team would include all or nearly all of them. If staff is increased, then teams of three or four could be formed around each project.

Assuming no increase in current staff, we suggest the degree of specialization noted in Table 2-2. We assume that all professional staff have technical or economic backgrounds and will not need much training in those areas. More staff would imply more opportunity for specialization.

In most areas the training activities for the OPPPI staff should focus on developing an introductory knowledge (where it does not now exist) and corresponding skills in the areas they will be dealing with. They should develop an understanding of the basic concepts and vocabulary, and the main issues.

In order to become proficient in the areas noted in Table 2-2, we recommend a comprehensive training program, which would cover all the areas. Based on our previous experience, ideally training in each subject area would involve about one week dedicated to the subject, away from the office. Assuming that the courses will be taught by international experts, we suggest that courses be given back-to-back over two weeks, which will minimize costs. These can be a combination of two, three, and five day modules depending on the topic. The estimated cost per two week session, for the instruction, development of training materials, and instructors' expenses, but not including the cost of the venue or the costs of the participants, is US$60,000 - 70,000. Allowing for five such sessions to cover ten subjects (all but technical and economic) produces a total cost of about $300,000 - 350,000 for the training.

Table 2-2. Functional Specialization

Area	Manager	Staff A	Staff B	Staff C
Technical and economic	X	X	X	X
Power system planning and operations		X	X	
Project management	X	X	X	X
Procurement process	X		X	
Legal and regulatory	X	X		X
Policy	X	X	X	X
Finance	X	X	X	X
Contracts	X	X		
Risk assessment		X		X
Privatization			X	X
Social and environmental			X	X

Although the objective of the training would be to provide the OPPPI staff the knowledge they need, and the focus should be on those individuals, any of these areas would provide information valuable to others active in the Zambian power sector. This would include people from ZESCO, the Energy Regulation Board (ERB), the Ministry of Industry and Water Development, and others. We suggest that representatives from these organizations be invited to any training that is offered. Increasing the overall level of understanding of these issues within Zambia will be beneficial to the country, even if the individuals never work for OPPPI.

Each course would provide an overview of the subject area and address in more detail the issues most likely to be relevant and important for OPPPI, such as those noted as sub-bullets in Section 2.1.1.2. Each course would cover one week (of a two week session) and be held away from OPPPI's offices. A two week session would be delivered each quarter, so that the five sessions could be completed within about one year.

Perhaps the most pressing need is to develop a better understanding of finance, project finance, and financial analysis. This will be critical in evaluating bids and understanding the economics of a project from the viewpoint of both the private developer and the buyer. This understanding will be crucial in negotiating the best contract possible for Zambia within the framework of what is acceptable to the private developer. We suggest that this course be given first.

We understand that the Phase 2/3 Consultants will have some training responsibilities, and will have expertise in many of the areas above. If their scope permits, they may be able to provide some of this training. If not, we recommend that funds or other resources be sought to provide the support for these training activities.

2.3.2 Project Specific Activities - Related To Energy Production Results

2.3.2.1 Plant Output Studies

Some capability exists within OPPPI to undertake this work, and some exists at ZESCO that might be made available to OPPPI, but there are reasons to seek assistance from outside experts. These are specialized technical studies that involve the use of detailed models. They are time-consuming to learn to use and even more so to develop, and the OPPPI staff are unlikely to be able to devote full time to such studies for 12 weeks or so at the start of the project. In addition there it will be important to have the best tools available for long term use as conditions in the river change, disputes arise that involve these issues, and so on. These can be more effectively developed by specialists.

Therefore we recommend that this work be performed by international consultants expert in this area under the direction of OPPPI. It will be important that OPPPI and eventually the organization responsible for Kafue river management become fully familiar with the concepts, procedures, and programs used in the analysis.

Funding for these consultants would have to be obtained from other sources, because OPPPI does not have the funds available to hire them.

The Phase 2/3 Consultants should coordinate with this effort as much as possible, so that they will understand the implications of plant output in the context of the Power Purchase Agreement.

2.3.2.2 *Approach To River Management*

OPPPI's role here would be as leader of the effort to institute a joint management approach. In order to perform effectively the OPPPI staff person assigned to this area would need to be extremely knowledgeable regarding the results of the plant output studies and other technical matters. Other key inputs would be provided by the representatives from the GRZ, ZESCO, and the Zambezi River Authority regarding their views in this area.

This would require the commitment of those organizations to provide such support through active participation in the process.

In addition legal documents creating an organization perhaps akin to the Zambezi River Authority would probably have to be created. This could be done by the GRZ or outside local legal assistance, but not by OPPPI.

The Phase 2/3 Consultants should coordinate with this effort as much as possible, so that they will understand the implications of river management on the provisions of the Power Purchase Agreement.

2.3.2.3 *Contractual Terms*

Once again the role of OPPPI would be as provider of technical inputs and project leadership. The GRZ would provide key inputs regarding its preferences. The Phase 2/3 Consultants will have special expertise in developing contractual provisions, but the focus of this activity will be on assuring that such provisions properly reflect the objectives of the GRZ and its willingness and ability to deal will different kinds of risk. The Phase 2/3 Consultant's role will be to create the provisions that implement preferences in those areas.

It will be important for OPPPI to have the commitment of the GRZ either to participate actively in this process, or to defer to the judgement of OPPPI in establishing the preferences.

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3.1 *Identify All Activities Necessary Through Project Implementation*

The Evaluation of Projects report recommends that OPPPI initiate the process of developing solicitation documents for the Zambia - Tanzania interconnection, Kafue Gorge Lower, and Itezhi-tezhi, but notes that for Itezhi-tezhi the decision should be reviewed upon the completion of certain hydro operations modeling studies. Since there is more uncertainty regarding Itezhi-tezhi we present a schedule that assumes that just the interconnection and Kafue Gorge Lower will be pursued. If the modeling results confirm that Itezhi-tezhi is economically beneficial, it can be added. Its schedule would look much like that for Kafue Gorge Lower.

The first step in establishing a schedule for the joint development of the Kafue Gorge Lower hydro plant and the Zambia - Tanzania interconnection is to identify all the activities necessary through project implementation. We have grouped these activities into five categories.

3.1.1 Assemble Necessary Documents

These are documents that will be included in the Request For Proposals for the projects, or at least be made available to the potential bidders. The objective is to provide as complete a set of information as possible to permit each bidder to make a fully informed proposal.

Most of the documents identified as important in this regard have been identified and collected. They include feasibility studies, laws, policies, and many others. Appendix A provides a list of these, which is very similar to the list of documents reviewed in Task 3. Appendix A also lists six documents which might be useful for this purpose but have not yet been collected.

3.1.2 Government Decisions/Actions

Some of the issues that must be dealt with in the Request For Proposals requires or would benefit from a decision or other action on the part of the GRZ. The list below presents many of the key decisions, showing some which must be decided and others where a decision would help, but where a default exists in the absence of a decision.

Must Decide (There is no default position)

Who will be the buyer(s) for the output from Kafue Gorge Lower?

Who will be the buyer(s) for the transmission services provided by the Zambia - Tanzania interconnection?

A Power Purchase/Sales Agreement between Zambia and Tanzania must be established to support the transmission service agreement for the interconnection.

Should Decide

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Define and translate into legislation all tax and other incentives, if any are to be provided (such as those in the Framework and Package of Incentives for Private Sector Participation in Hydropower Generation and Transmission Development): import duties, property taxes, income taxes, water usage fees, VAT, etc. (Default is business as usual)

Will the GRZ guarantee payments of ZESCO or another Zambian buyer? (Default is no)

Will ZESCO (or the GRZ in general) be part owner as well as possibly buyer or part buyer? (Default is no)

What fraction of output, if any, is to be reserved for Zambia, on what schedule? (Default is none)

How much risk of hydrology it is willing to take? (Default is leave it up to OPPPI)

How much risk of demand growth it is willing to take? (Default is leave it up to OPPPI)

What consideration, if any, should be given to operators of Zambezi river plants? (Default is none)

Are there any requirements for Zambian content? (Default is none)

3.1.3 Preparatory Activities

These are the activities discussed in Section 2. They apply only to the hydro plants.

- Conduct plant output studies.
- Establish approach to river management.
- Develop consistent contractual provisions regarding dispatch, river management, and payment .

3.1.4 Phase 2/3 Activities

These are the activities to be performed by the Phase 2/3 Consultants, as defined in the Terms of Reference for their work.

3.1.5 Project Implementation

These are the steps starting with establishing the short list for the potential bidders and continuing through to the start of construction. It is assumed that the Phase 2/3 Consultants will have developed a near-final Request For Proposal. The steps include:

- Revise Solicitation Documents (especially for interconnection)
- Expressions Of Interest Process (only for interconnection process)
- Establish Short List (only for interconnection process)
- Review And Approve Request For Proposals
- Issue Request For Proposals
- Prepare Proposals

- Evaluate Proposals
- Select Concessionaire
- Negotiate Agreement
- Financial Closure
- Final Design
- Licensing, Pre-construction
- Start Construction

3.2 *Determine Dependencies*

Some of the activities rely on the output of other activities. We identified these dependencies and used them to produce an overall schedule.

3.3 *Develop Schedule*

Based on the activities and dependencies we created a schedule for the joint development of the two projects. Figures 3-1 presents the schedule for Kafue Gorge Lower and Figure 3-2 the schedule for the Zambia - Tanzania interconnection. For convenience in presentation we show separate schedules for each project. However, the two schedules are subsets of a single overall schedule. For example, the Phase 2/3 Activities take place at the same time on both figures. The same is true for the activity in which the GRZ would establish legislation to implement the incentives in the Framework and Package of Incentives, and so on.

The figures show the dependencies as well as the schedule. The schedules do not show the entire construction period, but for reference we note that the Kafue Gorge Lower feasibility study estimated construction periods of 53 and 59 months, depending on dam type selection. The study of the Zambia - Tanzania interconnection presented information from which one can infer a construction period of about two years.

3.4 *Discussion*

The schedules show start of construction in February 2003 for the Zambia - Tanzania interconnection and in March 2003 for Kafue Gorge Lower. These start dates would produce commercial operation in 2005 for the interconnection and in 2008 for Kafue Gorge Lower.

It seems reasonable that most of the activities can be completed within the time indicated on the schedule. One category merits special discussion. Decisions or actions by the GRZ will require agreement among officials that may be difficult or time-consuming to achieve. The allotted times seem reasonable from the point of view of the tasks themselves, but building consensus and allocating scarce resources to the effort (for

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example) of developing legislation may take much longer than the times indicated. We view this category of activity as the area of greatest uncertainty. Since these decisions are on the critical path of project development, delay will delay project implementation and commercial operation on a month for month basis.

We also must emphasize the need to define a buyer for the services to be provided by the developer. It is highly unlikely that a developer would be willing to undertake any of these projects as a "merchant" facility, that is to rely on sales to as yet undefined parties at as yet unspecified prices to provide the revenues needed to support the project. In addition, the developer will need to believe that the buyer can credibly meet its financial obligations. This may require GRZ guarantees as well as a definition of a buyer (such as ZESCO).

We have allowed only 12 weeks to negotiate an agreement. This is enough time if no major issues require resolution and the parties start out in basic agreement. Especially for the first project, negotiation may result in uncovering issues that take time to analyze and resolve, or at least for the parties to become accepting of the risks involved. As with decisions or actions by the GRZ which require agreement among officials, these negotiations require parties coming to agreement, and this may in fact take longer that the schedule shows.

Table 3-1. Schedule For Kafue Gorge Lower

ID	Task Name	Duration
1	**Assemble Necessary Documents**	**42d**
2	Catalog Current Library	1w
3	Collect Missing Documents	4w
4	**Preparatory Activities**	**120d**
5	Hydrologic Studies	24w
6	River Management Approach	24w
7	Structure For Payments	24w
8	**Government Decisions/Actions**	**180d**
9	Determine Buyer	24w
10	Define ZESCO Role	24w
11	Legislation For FPI	24w
12	Define Acceptable Risks	12w
13	**Phase 2/3 Activities**	**215d**
14	Complete Detailed Wrok Plan	2w
15	Develop Solicitation Strategy	2w
16	Assess Alternative Structures	3w
17	Detailed Financial Analysis	4w
18	Legal/Regulatory Changes	3w
19	Prepare Phase 2 Report	3w
20	Prepare Solicitation Documents	13w
21	Draft Legal Documents	8w
22	Prepare Phase 3 Report	5w
23	**Project Implementation**	**727d**
24	Establish Short List	1w
25	Review And Approve RFP	4w
26	Issue RFP	1w
27	Prepare Proposals	12w
28	Evaluate Proposals	4w
29	Select Concessionaire	2w
30	Negotiate Agreement	12w
31	Financial Closure	24w
32	Final Design	78w
33	Licensing, Preconstruction	78w
34	Start Construction	1w

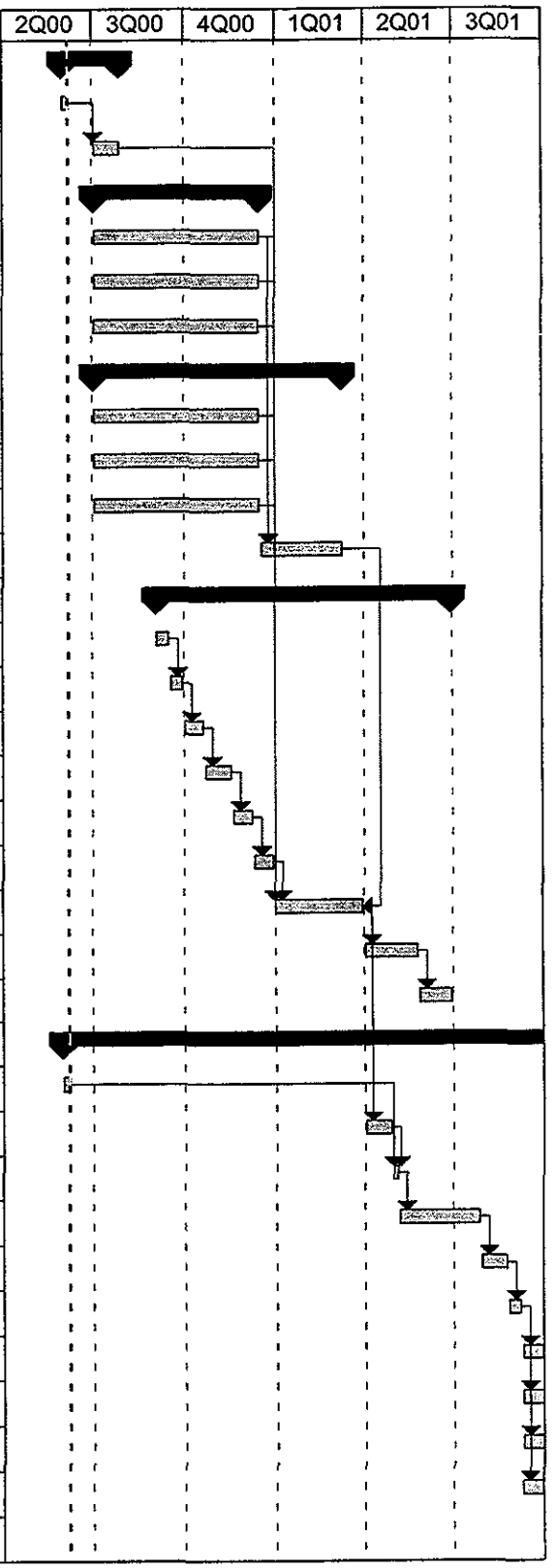

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Table 3-1 (continued). Schedule For Kafue Gorge Lower

ID	Task Name	Duration
1	**Assemble Necessary Documents**	**42d**
2	Catalog Current Library	1w
3	Collect Missing Documents	4w
4	**Preparatory Activities**	**120d**
5	Hydrologic Studies	24w
6	River Management Approach	24w
7	Structure For Payments	24w
8	**Government Decisions/Actions**	**180d**
9	Determine Buyer	24w
10	Define ZESCO Role	24w
11	Legislation For FPI	24w
12	Define Acceptable Risks	12w
13	**Phase 2/3 Activities**	**215d**
14	Complete Detailed Wrok Plan	2w
15	Develop Solicitation Strategy	2w
16	Assess Alternative Structures	3w
17	Detailed Financial Analysis	4w
18	Legal/Regulatory Changes	3w
19	Prepare Phase 2 Report	3w
20	Prepare Solicitation Documents	13w
21	Draft Legal Documents	8w
22	Prepare Phase 3 Report	5w
23	**Project Implementation**	**727d**
24	Establish Short List	1w
25	Review And Approve RFP	4w
26	Issue RFP	1w
27	Prepare Proposals	12w
28	Evaluate Proposals	4w
29	Select Concessionaire	2w
30	Negotiate Agreement	12w
31	Financial Closure	24w
32	Final Design	78w
33	Licensing, Preconstruction	78w
34	Start Construction	1w

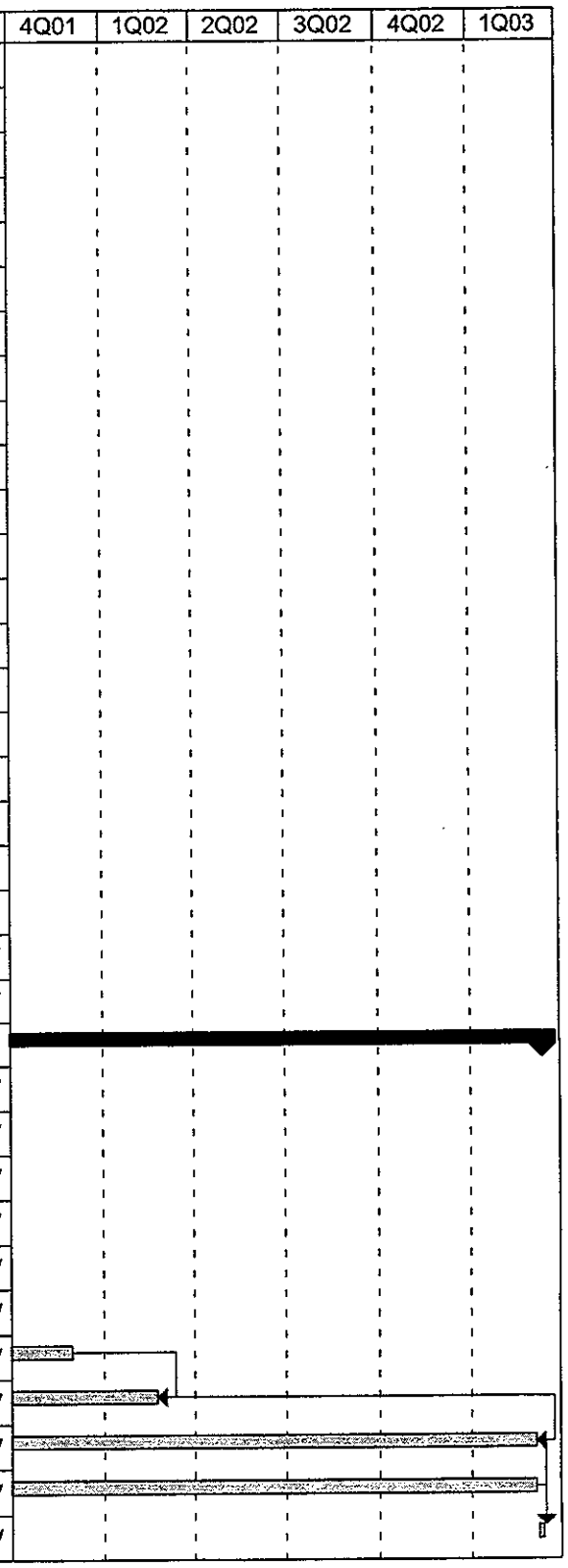

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Table 3-2. Schedule For Zambia - Tanzania Interconnection

ID	Task Name	Duration
1	**Assemble Necessary Documents**	**42d**
2	Catalog Current Library	1w
3	Collect Missing Documents	4w
4	**Government Decisions/Actions**	**260d**
5	Negotiate PPA With Tanzania	52w
6	Determine Transmission Seivices Buyer	24w
7	Define ZESCO Role	24w
8	Legislation For FPI	24w
9	**Phase 2/3 Activities**	**215d**
10	Complete Detailed Work Plan	2w
11	Adaptations Of BOM Model	5w
12	Financial Analysis	4w
13	Legal/Regulatory Changes	3w
14	Prepare Phase 2 Report	3w
15	Prepare Solicitation Documents	13w
16	Draft Legal Documents	8w
17	Prepare Phase 3 Report	5w
18	**Project Implementation**	**435d**
19	Revise Solicitation Documents	8w
20	Expressions Of Interest Process	14w
21	Establish Short List	1w
22	Review And Approve RFP	4w
23	Issue RFP	1w
24	Prepare Proposals	12w
25	Evaluate Proposals	4w
26	Select Concessionaire	2w
27	Negotiate Agreement	12w
28	Financial Closure	24w
29	Final Design	52w
30	Licensing, Preconstruction	52w
31	Start Construction	1w

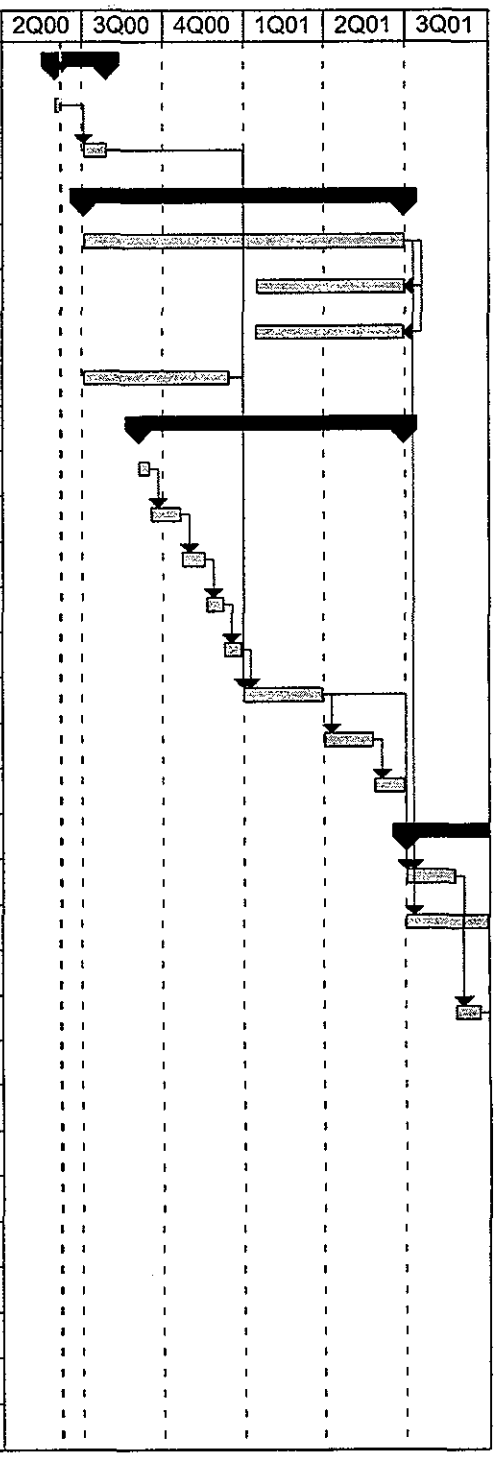

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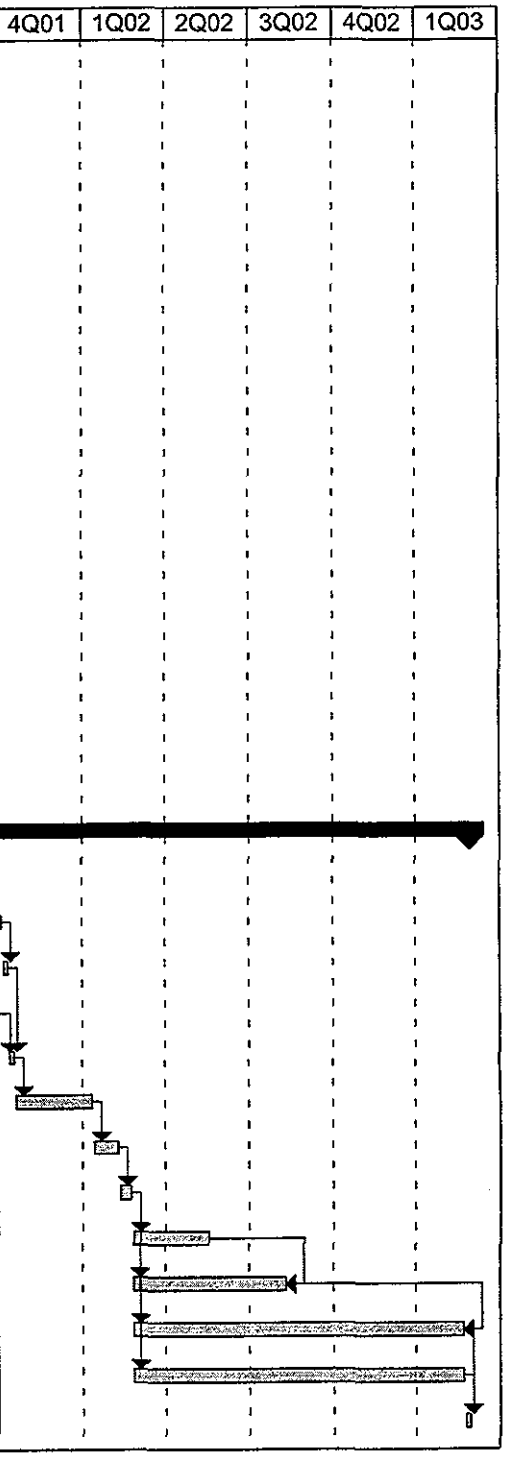
Table 3-2 (continued). Schedule For Zambia - Tanzania Interconnection

ID	Task Name	Duration
1	**Assemble Necessary Documents**	**42d**
2	Catalog Current Library	1w
3	Collect Missing Documents	4w
4	**Government Decisions/Actions**	**260d**
5	Negotiate PPA With Tanzania	52w
6	Determine Transmission Seivices Buyer	24w
7	Define ZESCO Role	24w
8	Legislation For FPI	24w
9	**Phase 2/3 Activities**	**215d**
10	Complete Detailed Work Plan	2w
11	Adaptations Of BOM Model	5w
12	Financial Analysis	4w
13	Legal/Regulatory Changes	3w
14	Prepare Phase 2 Report	3w
15	Prepare Solicitation Documents	13w
16	Draft Legal Documents	8w
17	Prepare Phase 3 Report	5w
18	**Project Implementation**	**435d**
19	Revise Solicitation Documents	8w
20	Expressions Of Interest Process	14w
21	Establish Short List	1w
22	Review And Approve RFP	4w
23	Issue RFP	1w
24	Prepare Proposals	12w
25	Evaluate Proposals	4w
26	Select Concessionaire	2w
27	Negotiate Agreement	12w
28	Financial Closure	24w
29	Final Design	52w
30	Licensing, Preconstruction	52w
31	Start Construction	1w



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A.1 *Available Documents By Category*

Documents which may be included in one or more of the Request For Proposals are listed below, in nine categories. Documents which may be needed but which have not yet been collected are listed in Section A.2.

A.1.1 Laws

The Energy Regulation Act. 28 April 1995

The Electricity Act. 28 April 1995

The Investment Act, 1993. 8 September, 1993

The Privatization Act, 1992. 4 July, 1992

Zambezi River Authority Act, No. 17 of 1987, including Agreement between Governments of Zambia and Zimbabwe for the joint development and utilization of the water of the Zambezi River. July 1987

The Water Act, Cap 198 (re-numbered from Cap 312)

The Environmental Protection and Pollution Control Act. No. 12 of 1990

A.1.2 Policies

National Energy Policy. Government of the Republic of Zambia Ministry of Energy and Water Development; May 1994

National Water Policy. Government of the Republic of Zambia Ministry of Energy and Water Development; November 1994

A.1.3 Feasibility Studies And General Information Relating To The Projects Of Interest

KGL Independent Power Project. Burns and McDonnell, The Dahlgreen Group, KcKenna and Company Report 96-417-4

Kafue Gorge Lower Hydroelectric Project Feasibility Report. Harza Engineering and Rankin Engineering; May, 1995

Kafue Gorge (refers to Upper) Hydroelectric Power Project - Project Report (one volume) and Project Report on Main Storage Reservoir (another volume). SWECO; April 1967 and April 1968.

Feasibility Study of the Itezhi-tezhi Hydroelectric Project. Harza Engineering and Rankin Engineering; April, 1999

Itezhi-tezhi/Kafue Gorge Operating Procedure. SADC AAA.3.4; Hydrological Assistance Project – Phase 2; Shawinigan Engineering; January,1993

Zambia – Tanzania 330 kV Transmission Interconnection Study. ESKOM, ZESCO, and TANESCO; September, 1995

Zambia – Tanzania 330 kV Transmission Interconnection Financial Justification Investigation. ESKOM, ZESCO, and TANESCO; April 1998

Mkushi Electrification Scheme Project Design Report. Merz and McLellan, June 1988.

Mkushi Electrification Scheme Review of Supply Options (Draft). Merz and McLellan, November 1993.

A.1.4 Electricity Planning And Demand Forecasting

Zaire - Zambia Interconnection Reinforcement Study. SNEL, ZESCO, ESKOM, January 1997.

SNEL - ZESCO - ZESA - BPC - ESKOM Transfer Capability Study Progress Report. SAPP/SADC, 25 January - 9 February 1999, Lusaka

Zambia – Malawi Transmission Interconnection Options, Executive Summary. ESKOM, ZESCO, and TANESCO; November, 1996

Twenty Year Power System Development Plan for Zambia. EKONO Energy; June 1996

Feasibility Study Of The Development Of Hydroelectric Power In The Luapula And Northern Areas Of Zambia, Volume 4 of 6 - Load Forecast Report. Harza Engineering Company International, in association with Ekono Energy, March 2000

A.1.5 Southern African Power Pool

Southern African Power Pool Inter Utility Memorandum of Understanding. 8 December 1995

Southern African Power Pool Agreement Between Operating Members. 8 December 1995

Southern African Power Pool Operating Guidelines. 14 August 1996.

Southern African Power Pool Annual Report 1999; Annual Review Report. April 1997 - March 1999

A.1.6 Private Investment And Investment Incentives

Framework and Package of Incentives for Private Sector Participation in Hydropower Generation and Transmission Development. Government of the Republic of Zambia Ministry of Water and Energy Development; October, 1998

Zambia Privatization Agency Progress Report No. 13. 1 July 1998 to 31 December 1998

Zambia Privatization Agency Status Report as of 30 April 2000

A.1.7 ZESCO

ZESCO Statistics Yearbook of Electric Energy 1998-1999. Issued by the Statistics Section

Government of the Republic of Zambia - ZESCO Performance Contract II, 1st April 2000 - 31 March 2003.

Project Agreement - Power Rehabilitation Project, 15 June 1998. CR.3042_ZA, between International Development Association and ZESCO.

Development Credit Agreement (Power Rehabilitation Project) between Republic of Zambia and International Development Association. Credit Number 3042-ZA, June 15, 1998

Zambia Power Rehabilitation Project - CR.3042_ZM, Supervision Mission (February 2000), Aide-Memoire. World Bank

ZESCO Electricity Tariff Study Final Report. SwedPower, November, 1999

A.1.8 Relating To The Process Of Selecting And Contracting With Private Investors

Request for Expressions of Interest in developing Kafue Gorge Lower. Zambia National Tender Board, January, 2000

Company Pre-qualification Form (for submitting Expression of Interest for developing Kafue Gorge Lower). Zambia National Tender Board, January, 2000

Request for Expressions of Interest in developing Itezhi-tezhi. Zambia National Tender Board, May, 2000

Company Pre-qualification Form (for submitting Expression of Interest for developing Itezhi-tezhi). Zambia National Tender Board, May, 2000

Standard Implementation Agreement. International Resources Group; July, 1997

Standard Power Purchase Agreement. International Resources Group; July, 1997

Standard Transmission Services Agreement. International Resources Group; July, 1997

A.1.9 General

Energy Statistics Bulletin 1974-1996. Government of the Republic of Zambia, Ministry of Energy and Water Development; March, 1998

Comparison of Electricity Prices in the Southern African Region. ZESCO Economics, Pricing, and Regulation Department, January 2000.

A.2 *Documents Needing To Be Collected*

The Competition And Fair Trading Act. No. 18 of 1994

Whatever Act removes currency restrictions.

The Energy Act, 1995, if such an Act exists.

Documents describing the laws, codes, etc., that describe and specify all taxes and similar charges for which an independent project may be liable

Merz and McLellan Feasibility Study March 1983 Phase 1 Report (established the model for agricultural development of the Mkushi area and the forecast of electrical load). The April 1985 Phase 2 Report established the electrification scheme and irrigation and electrification activities, and addressed other issues.

The SAPP Planning or Operating Sub-committee documents which specify the interim procedures regarding wheeling rates and conditions.

Zambia: The Business Environment for Foreign Direct Investment in the Country's Infrastructure. Foreign Investment Advisory Service (a joint service of the IFC and World Bank); April, 1999