

# Joint UNDP/World Bank Energy Sector Management Assistance Program

## Activity Completion Report

No. 093/88

**Country:** ZAMBIA

**Activity:** POWER SUBSECTOR EFFICIENCY STUDY

DECEMBER 1988

Energy Efficiency and Strategy Unit  
Industry and Energy Department

## ENERGY SECTOR MANAGEMENT ASSISTANCE PROGRAM

### PURPOSE

The Joint UNDP/World Bank Energy Sector Management Assistance Program (ESMAP) was started in 1983 as a companion to the Energy Assessment Program, established in 1980. The Assessment Program was designed to identify and analyze the most serious energy problems in developing countries. ESMAP was designed as a pre-investment facility, partly to assist in implementing the actions recommended in the Assessments. Today ESMAP carries out pre-investment activities in 45 countries and provides institutional and policy advice to developing country decision-makers. The Program aims to supplement, advance, and strengthen the impact of bilateral and multilateral resources already available for technical assistance in the energy sector. The reports produced under the ESMAP Program provide governments, donors, and potential investors with information needed to speed up project preparation and implementation. ESMAP activities fall into two major groupings:

- Energy Efficiency and Strategy, addressing the institutional, financial, and policy issues of the energy sector, including design of sector strategies, improving energy end-use, defining investment programs, and strengthening sector enterprises; and
- Household, Rural, and Renewable Energy, addressing the technical, economic, financial, institutional and policy issues affecting energy supply and demand, including energy from traditional and modern sources for use by rural and urban households and rural industries.

### FUNDING

The Program is a major international effort supported by the UNDP, the World Bank, and bilateral agencies in a number of countries including the Netherlands, Canada, Switzerland, Norway, Sweden, Italy, Australia, Denmark, France, Finland, the United Kingdom, Ireland, Japan, New Zealand, Iceland, and the USA.

### INQUIRIES

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**ZAMBIA**  
**POWER SUBSECTOR EFFICIENCY STUDY**  
**DECEMBER 1988**

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World Bank**

## FOREWORD

This report presents the findings of a mission 1/ conducted under the Joint UNDP/World Bank Energy Sector Management Assistance Program (ESMAP). The mission visited Zambia in February and March 1988. The objective of the mission was to make a study of the various problems facing the Zambia Electricity Supply Corporation Limited (ZESCO), Zambia's publicly owned electric utility, and define an economically feasible action program for ZESCO to guide its investment decisions and improve its operations.

The Government of Zambia requested the study following on a recommendation made by a previous ESMAP mission, fielded in December 1984, that a study be made to identify ways to improve the overall efficiency of the power subsector. 2/ The study was undertaken using financial assistance from the Swedish International Development Agency (SIDA).

The mission acknowledges with thanks the cordial cooperation of ZESCO's management and staff. Without this cooperation, it would have been impossible to develop the recommendations and action program outlined in this report.

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1/ The mission team comprised Messrs. W. Hay (Power Engineer), Team Leader; W. Pacheco (ESMAP), Power Engineer; G. von Bonsdorf (Consultant), Commercial Specialist; C. Lindwall (Consultant), Generation Engineer; and D. Sundén (Consultant), Transmission and Distribution Engineer.

2/ Zambia: "Energy Assessment Status Report", August 1985, Activity Completion Report No. 039/85.

Currency Equivalents

Currency Unit - Kwacha

1 Ngwee = .01 Kwacha

Official Exchange Rate

1 Kwacha = US\$0.13

8 Kwacha = US\$1 a/

Fiscal Year

April to March

Energy Measures

GWh	Gigawatt hour
kV	kilovolt
kVA	kilovolt ampere (1,000 volt-amperes)
kWh	kilowatt hour
MVA	Megavolt-ampere (1,000 kilovolt-amperes)
MW	Megawatt
MWh	Megawatt hour
V	volt

Acronyms

ESMAP	Joint UNDP/World Bank Energy Sector Management Assistance Program
FINNIDA	Finnish International Development Agency
IBRD	International Bank for Reconstruction and Development
MPTC	Ministry of Power, Transport and Communications
NORAD	Norwegian Agency for Development
SIDA	Swedish International Development Agency
SNEL	Société Nationale d'Electricité (Zaire)
UNDP	United Nations Development Program
VDU	video display unit
ZCCM	Zambia Consolidated Copper Mines Limited
ZESCO	Zambia Electricity Supply Corporation Limited
ZESA	Zimbabwe Electricity Supply Authority
ZIMCO	Zambia Industrial and Mining Corporation Limited
ZRA	Zambezi River Authority

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a/ Exchange rate at time of mission. Rate used in this report, unless otherwise noted.

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IBRD 20984R Zambia Electricity Supply Corporation Limited. Generation and Transmission Network. 1988

## SUMMARY

1. Zambia Electricity Supply Corporation Limited (ZESCO) has performed creditably during a period of severe economic difficulties for Zambia. The quality and reliability of electricity service have been maintained to high standards while the cost of energy to the consumers is low. Maintaining these high standards of quality and reliability is of crucial importance because of the critical dependence of Zambian industry in general, and the mining sector in particular, on reliable and low cost electric power. In addition, exports of power will assist ZESCO in achieving an adequate return on its investment in generating plant and contribute significantly to Zambia's foreign exchange income. Neighboring countries will need to be assured of the reliability of power supply from Zambia if exports are to increase. Generation and transmission infrastructure is sound and capable of satisfying the demands likely to be experienced up until the turn of the century. In the opinion of the mission the main problem areas which may jeopardize the traditional high standards are:

- (a) declining overall energy demand as a result of reduction in the amount of power exported and no corresponding increase in domestic consumption. ZESCO's income base is therefore severely restricted;
- (b) severe financial constraints experienced with availability of foreign exchange as well as local currency;
- (c) increasing difficulty in attracting and retaining competent professional staff; and
- (d) insufficient attention to some of the maintenance needs of generation, transmission and distribution equipment.

## Fundamental Causes of ZESCO's Problems

2. The following paragraphs deal with each of these problems in turn and outline their root causes.

### Reduced Demand

3. There are two major causes for decline in energy demand in Zambia. They are as follows:

- (a) Reduction in Exports. Zimbabwe is a major consumer of Zambian electric power and in the early 1980s purchased nearly 40% of the hydroelectric energy generated in Zambia. However, Zimbabwe has been systematically developing its own generating facilities based on thermal power stations burning indigenous

coal from the Hwange fields. As a result, the exports of power to Zimbabwe have been declining and in 1987 accounted for only about 13% of the energy generated by ZESCO. No alternative export market has developed to replace the lost sales to Zimbabwe.

- (b) Sluggish Domestic Demand. The reduction in exports to Zimbabwe has not been compensated for by increases in domestic demand. The economic recession has dampened industrial development and shortages of the materials needed for distribution line extensions have restricted ZESCO's ability to run power lines into areas previously without electricity. In addition, even where power lines do exist many households do not avail themselves of the service because of the relatively high initial deposit which ZESCO requires prior to connecting a new consumer to the system. Overall only about 12% of Zambian households are electrified and even in urban areas the percentage is below 30.

#### Financial Constraints

4. The financial constraints result from a number of factors. Zambia's foreign exchange resources are very limited and there are many crucial and competing demands for whatever is available. Local currency shortages are experienced because:

- (c) ZESCO's tariff levels are too low to allow adequate cash reserves for operation and maintenance after debt servicing has been attended to;
- (d) the procedure by which tariffs are adjusted is time consuming and does not provide the flexibility to quickly adjust tariffs to keep pace with inflation; and
- (e) low employee productivity and inadequate procedures in the meter reading and billing areas create billing delays and high levels of accounts receivable thereby exacerbating cash flow problems.

#### Shortage of Professional Staff

5. ZESCO's salaries are too low to be competitive with private enterprises and certain parastatal corporations in Zambia. The utility therefore is unable to attract competent professional staff in the numbers needed to guarantee efficient management of the organization in the future. ZESCO is not free to determine its own salary structures but is subjected to guidelines applied to most government-owned corporations.

### Deficient Maintenance

6. The problems listed in paragraphs 4 and 5 above have begun to be reflected in maintenance requirements not always being promptly attended to. Spares are often not available because the foreign exchange required is not forthcoming, the local currency is not readily available or the shortage of skilled manpower necessitates postponement of the work.

### Rationale for Action

7. An efficient and reliable power system is crucial to Zambia's economic survival. The copper industry on which Zambia depends for about 94% of its foreign exchange and 14% of its gross domestic product needs reliable low cost electricity for its survival. The same is true of most important industries in Zambia. Possibilities for increasing exports to neighboring countries will depend on continued reliability of the ZESCO system. The mission considers it important for quick action to be taken to reduce the impact of the problems discussed in paragraphs 4 and 5 above and prevent them from adversely affecting the reliability of public power supply.

### Recommendations

8. The following recommendations will contribute to better control of the deleterious effects:

#### Reduced Demand

9. Increased electricity consumption is urgently needed if ZESCO is to obtain an adequate return on the sunk investments in its generation and transmission infrastructure. These facilities now have capacity well in excess of maximum system demand. In the short run, ZESCO's best hope for stimulating demand is to promote electric power as an economic alternative to other energy sources in the industrial and commercial areas and to increase the number of agricultural and residential consumers. Energy substitution may be achieved, for instance, by installing electric boilers in industrial installations, replacing similar units now fuelled by oil. Such substitution would be accelerated if it were possible for ZESCO to assist the consumer in the purchase and installation of the electric equipment, recovering the investment in appropriately adjusted tariffs.

10. An important step towards increasing the number of agricultural and residential consumers is to reduce the cost and ease the affordability of new connections, thereby encouraging electricity use. It is therefore recommended that ZESCO:

- (f) engage consultants to develop technical designs and standards which will reduce the costs of distribution extensions, while maintaining economic levels of supply reliability. Draft Terms of Reference for these are included with this report (Annex 9);
- (g) include a capital recovery component in the tariffs so that the amount of the initial deposit can be reduced; and
- (h) consider instituting a system of credit for residential connections to permit affordability to new consumers.

The Government should:

- (a) examine the duties and taxes payable by ZESCO to confirm their appropriateness in the light of similar taxes paid by industry generally; and
- (b) review the need for other measures for reducing the impact of these duties and taxes on poorer households.

#### Financial Constraints

11. The mission recommends that the following actions be taken to reduce financial constraints:

- (i) ZESCO's tariffs should be indexed to certain objectively definable references, such as, for instance, the international exchange value of the Kwacha and the consumer price index. This would allow tariffs to be quickly and regularly adjusted to compensate for inflation. In addition, the tariff review procedure should be revised to provide prompter response to the management's requests for increases;
- (j) the procedures for meter reading and billing need to be revised to produce bills more promptly. A new program for computerized bill preparation is required. Annex 5 is a draft of Terms of Reference for the supply and installation of such a program;
- (k) bills for large industrial and commercial consumers should be prepared and hand delivered within three days of the meter having been read;
- (l) accounts receivable must be reduced by systematic disconnection of overdue accounts; and
- (m) meter readers need to be trained and their individual performances monitored to reduce the incidence of meter reading errors.

### Shortage of Professional Staff

12. ZESCO's salary and benefit levels, particularly those of professional employees, need to be raised to enable the organization to achieve its full complement of technical and managerial skills. The sophistication of equipment and operations in an electric utility is such that its efficient performance requires higher than average skill levels. The remuneration received by ZESCO's professional staff can therefore be justifiably higher than those of most other state-owned corporations.

### Maintenance Deficiencies

13. ZESCO's recurrent foreign exchange requirements are in excess of US\$15 million annually. It is desirable that a procedure be established whereby foreign exchange in this amount is routinely made available to ZESCO without the need for repeated applications and justifications to the central bank prior to each expenditure. Implementation of this suggestion would not relieve the utility of having to account to the central bank for its usage of foreign exchange. Tariff increases and improved cash flow, as recommended in paragraph 11, will enable the local costs of maintenance to become less problematic. Changes in the assignment of responsibilities within the organization to eliminate certain vacant positions and better reflect the shortage of competent managerial personnel will assist in more effective maintenance planning and execution.

### Proposed Investments

14. The mission has identified a number of investments that ZESCO should make in order to maintain the quality of its power system and increase the efficiency of electricity distribution. These are listed in Table 1.

15. The estimated cost of the proposed projects is approximately US\$20 million. About US\$14 million of this amount would require foreign exchange. The remaining US\$6 million reflects local currency costs.

16. Table 2 presents in schematic form the issues raised in this report, the mission's recommendations for resolving these issues, and the priority the mission has assigned to each.

### Report Layout

17. Further detailed analyses and discussion of the issues raised in this summary are presented in the following chapters and annexes of this report. Chapter I discusses the problems of declining demand, financial constraints, and the utility's need to attract and retain

competent professional staff, and recommends that policy decisions be taken to resolve these issues. Chapter II deals with commercial operations, including meter reading, billing, and collections. Recommendations made in this chapter are designed to increase the efficiency of these operations and thereby increase the utility's revenues. Chapter III deals with electricity generation and describes the maintenance needs of ZESCO's power stations. Implementation of the mission's recommendations for maintenance and/or rehabilitation should allow ZESCO to continue supplying electricity to meet expected demand until the end of the century. Chapter IV deals with electricity transmission and distribution, and recommends ways to improve them.

Table 1: SUMMARY OF INVESTMENTS RECOMMENDED FOR  
POWER EFFICIENCY IMPROVEMENTS

Item	Project	Priority	Estimated Cost		Ref/Para
			Foreign	Local	
			US\$	US\$	
1	Purchase and install new billing program	1	84,000	20,000	2.66-2.71, Annex 5.
2	Purchase of new meters and meter test equipment	2	308,000	-	2.57-2.58
3.	Generating station rehabilitation	1	2,716,000	1,833,000	Table 3.2
4.	Computer program for reservoir modelling	2	40,000	10,000	3.48
5.	Reopen Kafue Gorge Training Center (estimates are for capital expenditures, not operating costs)	3	60,000	15,000	3.51
6.	Undertake study to determine least-cost provision of firm power requirements of Northeastern system	3	150,000	50,000	3.52, Annex 7
7.	Distribution reinforcement and rehabilitation, Lusaka (does not include FINNIDA project)	1	3,300,000	1,400,000	Table 4.2
8.	Distribution reinforcement and rehabilitation, Copperbelt area	2	5,500,000	2,100,000	Table 4.3
9.	Study for reduction of distribution extension costs	1	105,000	17,000	4.47, Annex 9
Total			12,263,000	5,445,000	

Table 2: ZAMBIA : PROPOSED STRATEGY FOR EFFICIENCY IMPROVEMENT OF THE ELECTRIC POWER SUBSECTOR

Issues	Objectives	Recommendations	Study	Priority
<b>A. Institutional</b>				
(I) Difficulty in attracting professional staff.	Competent technical and managerial personnel.	Increase remuneration to levels similar to those prevailing in organizations able to recruit adequate numbers of professional staff (para 1.36, 1.37, 1.43).	Commission study to compare ZESCO/ZCCM salaries (Para 1.43).	1
(II) Organizational structure.	Most efficient use of scarce managerial resources.	Reassign responsibilities to reduce number of vacant positions (para 1.36). Place related disciplines under common divisional management (para 1.36, 1.40-1.42).	Ongoing organization and management study.	2
(III) Inadequate tariffs.	Financial independence and stability.	Shorten the approval procedure for tariff increases, adjust tariffs periodically to reflect changes in consumer price indices (paras 1.29-1.32, 1.39).	-	1
<b>B. Commercial Operations</b>				
(I) Bill production.	Produce bills more promptly, improve cash flow.	Purchase a new, sophisticated computer billing program (para 2.66-2.71 Annex 5). Hand deliver bills major consumers within 3 days of meter reading (para 2.73).	-	1
(II) Low productivity of meter readers.	More accurate billing, improve cash flow, reduce revenue losses.	Train meter readers, introduce productivity incentives (para 2.62).	-	1
(III) Unmetered consumption.	Account for all energy produced, reduce losses.	Investigate consumer connections, consider abolishing unmetered consumer category ("L" tariff) (para 2.52), and regularly inspect service connections (para 2.55).	-	1
(iv) Inadequate consumer data base.	Easy identification of consumer accounts. Reduce billing errors.	Revise system of account numbering (para 2.53). Identify each meter by a unique ZESCO number (para 2.54). Introduce new billing program (para 2.66-2.71).	-	2

Issues	Objectives	Recommendations	Study	Priority
(v) Reduce frequency of meter reading.	Reduce meter reading effort and increase inspections. (para. 2.60).	Read meters for residential and small commercial accounts once every two months. Continue monthly billing	-	2
(vi) Disconnection of overdue accounts.	Reduce accounts receivable.	Develop, publicize and rigidly enforce a policy of debt disconnection (para. 2.74).	-	2
<b>C. Generation</b>				
(I) Generating station rehabilitation.	Security of supply.	(a) Carry out maintenance work needed in all stations (para. 3.53-3.70, Table 3.2); (b) Monitor head loss, Kafue Gorge tunnel (para 3.57);	-	(a)1 (b)1
(II) Reservoir management.	Operation of power stations to optimize reservoir storage.	Purchase reservoir management computer program. Train staff in its use (para 3.48).	-	2
(III) Training of power station staff.	Develop high levels of operating and maintenance staff.	Reopen the Kafue Gorge Training Center (para. 3.51).	-	2
(IV) Firm capacity in Northeastern Region.	Reduce operating costs while maintaining security of supplies.	Undertake study to identify least-cost approach to providing firm power for the Northeastern region (para 3.52).	Annex 7	3
<b>D. Transmission and Distribution</b>				
(I) Reduce cost of distribution extensions.	Increase number of consumers.	Use more economic extension designs and construction methods (para. 4.47, Annex 8). Exempt ZESCO from import duties and sales tax (para 4.49).	Undertake design and construction study Annex 9).	1
(II) Capacity of Lusaka Distribution system.	Security of supply to Lusaka.	Rehabilitation and reinforce Lusaka distribution system (para 4.50, Table 4.2).	-	1
(III) Capacity of Copperbelt Distribution	Security of supply to the Copperbelt area.	Rehabilitate and reinforce the Copperbelt distribution system (para. 4.41-4.45, 4.53, Table 4.3).	-	2

## I. ADMINISTRATION

### Overview

1.1 Zambia Electricity Supply Corporation Limited (ZESCO), a publicly owned utility, is one of several subsidiaries of the Zambia Industrial and Mining Corporation (ZIMCO), a state-owned holding company. ZESCO is responsible for the commercial generation, transmission and distribution of electric power throughout the Republic of Zambia. The Ministry of Power, Transport and Communications (MPTC), which has oversight responsibility for Zambia's power sector, provides policy guidance to the utility and monitors its performance. The Minister appoints ZESCO's Board of Directors.

1.2 Electricity usage in Zambia increased rapidly in the 1960s and 1970s, resulting in heavy investments in generation and transmission to meet a rapidly increasing demand for electric power. This period of growth has been followed by relative stagnation of demand during the recession of the 1980s. ZESCO has been operating under tight financial constraints, particularly a shortage of foreign exchange. It has not been able to increase its customer base significantly, and has not always been able to maintain its infrastructure adequately. ZESCO's administration has also suffered because its levels of remuneration are not competitive with those in the private sector. It has had difficulty attracting and keeping competent, technically qualified professional staff.

1.3 This chapter will address in turn energy demand and growth, the financial constraints facing ZESCO, and the utility's organization and staffing situation. Recommendations for policy solutions to the above problems are given at the end of the chapter.

### Demand and Growth

1.4 ZESCO presently has an installed capacity of 1,608 MW on its main grid. This capacity exceeds peak demand by a wide margin. Peak domestic demand in 1987 was 912 MW. Exports to Zimbabwe now add between 100 and 250 MW to demand. However, these exports are expected to decrease with time.

1.5 ZESCO's generating and transmission infrastructure is basically sound. At the expected rate of increase in demand, major investment for the expansion of these systems will not be needed before the end of the century. The utility is in a position where it needs to stimulate demand in order to make use of its existing capacity and thus increase revenue.

1.6 Annex 2 gives the figures for energy generated and sales over the period 1980/81 to 1986/87. In each case the figures are presented

for the ZESCO financial year (April to March). Net Zambian consumption remained relatively constant between 1982 and 1985. In fact, the total energy consumed declined slightly between the 1981/82 and 1984/85 financial years. This was due to an economic recession following a weakening of the market for copper (Zambia's principal export). The recession affected all sectors of Zambian economic activity. Increases in demand returned in all sectors with the year 1986/87 and have continued through 1987/88.

#### Power Exports

1.7 Zambia's power exports are declining. This decline is unlikely to be reversed in the near future. ZESCO's main foreign customer, Zimbabwe, is increasingly relying on its own supplies. Other foreign customers are of minor importance, and are not likely to increase their imports of power in the near future.

1.8 Exports to Zimbabwe. For a number of years, Zimbabwe has purchased about 35% of the power generated in Zambia. However, Zimbabwe has been developing its own coal resources as a source of electric power and has begun to drastically reduce its imports from Zambia. During the period 1980/81 to 1987/88, exports to Zimbabwe have declined from a peak of 3,787 GWh in 1982/83 to 1,040 GWh in 1987/88. The amount of energy exported fluctuates depending primarily on the availability of the steam generating units in Zimbabwe. The agreement between the national electric utilities of the two countries is that each month the Zimbabwe Electric Supply Authority (ZESA) will provide ZESCO with a forecast of its power and energy requirements for the next six months. The projections for the first three months of each six-month period are firm. This means that ZESA will pay for its forecast power and energy requirements even if it consumes less than the anticipated amount.

1.9 Zambia exports a small amount of power to the Zimbabwean town of Chirundu, southeast of Lusaka. However, the Zambian and Zimbabwean grids are not interconnected at this point.

1.10 Exports to Zaire. Zambia's power system is interconnected with the Zairian system by a single 220 kV line at the northern border with Zaire. However, Zaire purchases a relatively small amount of power from ZESCO. The main purpose of the interconnection is to ensure security of supply to the copper mining areas of both countries by allowing the transfer of power in both directions.

1.11 The Zairian connection has been a problem for Zambia rather than an advantage. Erratic and sudden power demands from the Zairian side have threatened the stability of ZESCO's network in the Copperbelt. As a result, ZESCO has installed overcurrent relays which will separate the two systems if the transfer of power to Zaire exceeds 100 MW.

1.12 The original agreement between ZESCO and Zaire's national electric utility, Société Nationale d'Electricité (SNEL) stipulated that

each utility could import up to 100 MW for as much as 30 minutes without having to pay for it, and could then replace the energy at some convenient time. ZESCO found that it was exporting large blocks of power at times of peak demand in the Copperbelt and having it returned, if at all, during off-peak periods. The new agreement has therefore removed the free emergency support and reduced the integration period for billing to five minutes in order to ensure that the high peak demands are captured.

1.13     Exports to Botswana. ZESCO supplies small amounts of energy to the Botswanan town of Kasane, near Zambia's southwestern border. The Zambian and Botswanan grids are not interconnected.

1.14     Export Prospects--Botswana and Malawi. Though Zambia may eventually be able to make significant exports of electric power to Botswana and Malawi, this is not likely to happen in the near future. Botswana's load center is remote from Zambia. The cost of constructing an interconnector is prohibitive. A tie-line is being built between Zimbabwe and Botswana for completion in 1990. As the Zambian and Zimbabwean grids are already interconnected at Kariba, the new line will provide an opportunity for Zambian exports to Botswana through Zimbabwe. The Canadian International Development Agency is funding this project to assist the interchange of power between the countries in the region. On completion of the line Zambia will be able to negotiate sales directly to Botswana, wheeling the power through Zimbabwe. It will also be possible for Zimbabwe independently to negotiate purchases from Zambia and sales to Botswana. Malawi wishes to remain independent in the provision of its firm electric energy, but would consider the purchase of secondary energy. The cost of the interconnection cannot now be economically justified for the supply of secondary energy alone.

#### The Domestic Situation

1.15     ZESCO's principal customer is the mining industry, which consumes about 70% of the energy the utility sells in Zambia. The mining industry has achieved maturity, and further increases in power demand or energy consumption from that sector are not likely to have a major effect on ZESCO's development plans. The utility also has a number of other industrial and commercial customers.

1.16     Of ZESCO's 115,000 customers, only 99,000 are residential consumers. This number represents about 12% of Zambia's households, given a population of 6.5 million and assuming an average household size of eight. Even in the greater Lusaka area, which has a population of about 800,000 and an estimated 100,000 homes, there are only about 26,000 residential connections. This means that only about 26% of the homes in Zambia's capital city are electrified.

1.17     One factor contributing to a low rate of residential electrification is remoteness of homes from existing distribution lines. This is an important factor in Zambia, but it does not explain why roughly 40% of all Zambian households with access to electricity are

why roughly 40% of all Zambian households with access to electricity are not connected to ZESCO's system.

1.18 The annual increase in residential connections is low and appears to be declining. Between financial years 1980/81 and 1987/88, the total number of ZESCO consumers moved from 93,000 to 115,000 if the figures are rounded off to the nearest thousand. The total annual increase in residential connections in the last eight years is therefore about 3%. This is less than the estimated population growth rate of 3.6%.

1.19 There are two primary reasons for the low rate of increase in residential connections. One is that ZESCO has been operating under financial constraints over the past eight years. It has lacked foreign exchange to purchase the materials needed to provide new connections. The second reason is that each new consumer must pay a high deposit to ZESCO in order to obtain service. The deposit reflects, in part, the relatively expensive construction standards employed in urban areas. It also reflects the fact that ZESCO must pay import duties and sales tax on the materials used in expanding its system. ZESCO reports that materials are now more readily available and that the rate of making new connections should increase in 1988.

#### Financial Constraints

1.20 ZESCO has been operating under tight financial constraints during the past few years. There are several reasons for this. First, as discussed in the preceding paragraphs, Zambia's economy has been suffering from recession. As a result of a decline in demand, ZESCO has lost revenue from unmade sales. Second, non-technical losses contribute to loss of revenue. Finally, ZESCO's tariff levels are too low to allow adequate cash reserves for operation and maintenance after debt servicing. 1/

1.21 Technical power losses and the tariff question are discussed in the following paragraphs. Non-technical losses are discussed in Chapter II.

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1/ The draft report "Zambia, Energy Sector Strategy, May 1988" prepared jointly by the Zambian Department of Energy and ESMAP indicates that average tariffs for supply to consumers other than those in the large industrial category are currently less than one-half of the long-run economic cost.

### Losses

1.22 The hydropower reserves currently available are in excess of ZESCO's needs. The incremental energy cost of technical losses is therefore very low. In addition, as no medium-term investment in new generating and transmission capacity is expected, the capacity cost of losses will be reflected primarily in investments in the distribution system. Though the overall cost of technical losses is relatively low, ZESCO can reduce expenditures by focussing attention on its distribution systems, where the technical losses as well as the cost of these losses are highest. Losses are fairly low for energy sold to the utility's two major customers, ZCCM and Zimbabwe. Calculations of power losses on ZESCO's transmission and distribution systems are provided in Annex 2.

1.23 A large portion of the energy sold by ZESCO is exported to Zimbabwe or sold in bulk to ZCCM. In 1987/88 these two categories of sale accounted for more than 70% of ZESCO's total production. The sales are made at transmission voltage levels (330 kV for exports to Zimbabwe and 220 kV for ZCCM sales). The losses experienced in transmitting the energy to the points of sale are very low. Losses in exports to Zimbabwe should be negligible as the distance involved is short. The losses on the 330 kV system within Zambia, as shown in Annex 2, amount to about 3-4% of the energy sent out to Zambia from the generating stations.

1.24 As a high percentage of total sales is made at the transmission voltages and therefore with relatively low losses, overall loss percentages on the ZESCO system should be low. Annex 2 shows overall losses to be 7.0% of net generation for the most recent statistics.

1.25 For the distribution system, losses vary widely from division to division and from year to year. Annex 2 shows that energy losses on the distribution systems supplied from the main grid in the 1987/88 financial year was 245.3 GWh, or approximately 12% of the energy input to the Distribution and Supply divisions. For Distribution and Supply--South, the losses were 15.4% of net energy input. For Distribution and Supply--North (Copperbelt Region), they were only 5.5%.

1.26 The variation of overall retail losses by financial year ranged from a high of 18.5% in the 1981/82 financial year to a low of 8.7% in 1984/85. The average level of losses is not unduly high by international utility standards. In the opinion of the mission the true loss levels are probably higher than indicated. The wide annual variation in the extent of losses is believed to indicate, among other things, the need for calibration of substation metering.

1.27 Mission calculations show technical losses in distribution lines, transformers and service drops as accounting for 9.6% of the energy supplied to the southern distribution system, whereas overall losses, as stated in paragraph 1.25, were 15.4%. On this basis, non-technical losses must have amounted to 5.8%. (For a discussion of non-technical losses, refer to Chapter II, paragraphs 2.33 to 2.50).

1.28 Losses on the Northeastern and isolated diesel systems together average about 18% of net generation.

Tariffs

1.29 Any tariff increases that ZESCO proposes must first be approved by its own Board of Directors, then by the Board of Directors of ZIMCO its parent company, the Prices and Income Commission and finally by the Minister of Power, Transport and Communications. The proposal for a tariff change has to pass through so many levels of review and approval that it may take months for a tariff increase to become effective.

1.30 Because of this delay in adjusting tariffs, once they become effective the economic situation may have already changed, and a new tariff adjustment is needed to accommodate to the change. This is the case at present. ZESCO's two most recent increases took place in August 1986 and January 1988. But the current high rate of inflation in Zambia and fluctuations in the international value of the Kwacha have prevented these increases from providing ZESCO with a stable profit margin. The unfavorable exchange rate has particularly affected ZESCO's financial picture as the servicing of foreign debts is a major item in the utility's operating expenses.

1.31 ZESCO is currently preparing an application for another increase in tariffs. The increase is unlikely to become effective before the end of the 1988 calendar year. The tariffs currently in effect are shown in Annex 3.

1.32 If ZESCO is to increase the rate of residential connections, as recommended in this report, this will probably require an injection of capital by the Zambian government. Despite the relatively low rate at which new consumers are connected to the system, the utility invests a significant percentage of its income in capital works and the purchase of fixed assets. In the financial year 1985/86 these items in the application of funds accounted for more than 28% of turnover and about 80% of operating profit. Preliminary figures for 1986/87 indicate investment of roughly the same percent of turnover and more than 60% of operating profit.

Administration

1.33 ZESCO's approximately 5100 employees are grouped in five operational divisions. Each of these divisions is headed by a divisional manager. The divisional managers report directly to the Managing Director, who is ZESCO's chief executive. An organogram of ZESCO's management structure, as it was at the time of the mission's visit, is provided in Annex 1. A description of each of the five ZESCO divisions, with the approximate number of employees in parentheses, is given below:

- (a) Distribution and Supply-South (2,000). This division is responsible for consumer services in Kabwe and the areas to the south. It is also responsible for the diesel stations within its territorial boundaries, but not for the major generating stations of Kafue Gorge, Kariba North and Victoria Falls. These are the responsibility of the Generation and Transmission Division;
- (b) Distribution and Supply-North (1,800). This division is responsible for consumer services in the areas generally north and east of, but not including, Kabwe. The Northeastern Region also falls within its jurisdiction. The division's responsibilities include hydroelectric and diesel generation, transmission and distribution at all voltages below 88 kV, metering, meter reading, distribution of bills and collections;
- (c) Generation and Transmission (800). This division is responsible for the Kafue Gorge, Kariba North and Victoria Falls generating stations and for all transmission lines and substations operating at 88 kV or higher voltages. In addition, the division maintains the 66 kV line between Victoria Falls and the Botswanan border town of Kasane;
- (d) Central Services (500). This division includes:
- Finance, which is responsible for accounting, data processing, bill preparation, budget development and insurance;
  - Engineering Services, responsible for system planning and formulation and implementation of projects. For the better coordination of generation planning, the hydrology section is also included in Engineering services;
  - Administration, including the Personnel Department;
  - Company Secretary, and Legal Department;
  - Internal Auditor.

1.34 A group of consultants has recently made a study of ZESCO's organization and management. Their report was under preparation at the time of the mission's visit. The consultants may recommend changes to ZESCO's present management structure. In that case, the organogram provided in Annex 1 of this report will no longer be valid. However, it is used as the basis for the observations in the following paragraphs.

1.35 Eight managers report directly to the Managing Director, but most of these have less than four immediate subordinates. Further down the organizational ladder, the span of management at any particular managerial level varies widely. In an extreme instance, the Senior

Operations Engineer in the Distribution and Supply Division--North has 14 immediate subordinates whose responsibilities cover a wide area of activities.

1.36 A notable feature of ZESCO's current staffing is that a large number of responsible positions are vacant. ZESCO is finding it difficult to attract competent Zambian professional personnel, and, to a lesser extent, to retain those already employed. The major cause of this problem appears to be the low salary structure prevailing at ZESCO when compared to private enterprise and certain other parastatal corporations. A major competitor in terms of salaries is Zambia Consolidated Copper Mines (ZCCM).

1.37 ZESCO's wage and salary structure is decided by the parent corporation, ZIMCO, which generally applies the same structure to all of its subsidiaries, with the exception of ZCCM. Recognizing that ZCCM needs managers with a higher level of technical and managerial skill than are needed for some of its other subsidiaries, ZIMCO permits a higher level of salaries for the copper mining group. However, high levels of technical and managerial skill are also indispensable to ZESCO's successful operation. Salary scales at ZCCM are much higher than those at ZESCO for comparable skills. ZESCO must compete for scarce Zambian personnel resources not only with ZCCM and local private enterprises but also with organizations in the wider geographical region.

### Recommendations

#### Demand Growth

1.38 To increase demand for electricity, ZESCO should increase its rate of residential connections. In order to do so, the utility needs easier access to the materials used to make the connections. Some of these materials are available locally, while others have to be purchased outside Zambia, using foreign exchange. ZESCO needs a source of both local and foreign currency to purchase the materials. As system expansion should bring about an increase in the utility's assets, the Government of Zambia, as sole owner, should consider making cash injections to assist in the cost of ZESCO's expansion. The government should also create a mechanism that would give ZESCO ready access to the foreign exchange it needs for its priority activities.

#### Financial Constraints

1.39 Tariffs. ZESCO and the Government should agree on a formula whereby tariffs would be regularly adjusted to reflect changes in the consumer price index, fluctuations in the international exchange rate of the Kwacha, Zambia's local currency and general inflation. The existing system for revising tariffs is too slow to keep pace with Zambia's high inflation rate, and does not take into consideration changes in the cost

of imported material related to changes in the international value of the Kwacha.

Administration

1.40 Management Structure. Responsibility for customer services is divided between the two distribution and supply divisions. The managers of both divisions report directly to the Managing Director. ZESCO should create a position with overall responsibility for customer service activities throughout Zambia. This would relieve the chief executive of being the only manager responsible for coordination of customer services.

1.41 All generating stations should fall within the jurisdiction of the Divisional Manager, Generation and Transmission. Under the present structure, the Divisional Manager, Distribution and Supply--North is responsible for all hydroelectric stations and diesel generating stations in the northeastern region while the Divisional Manager, Distribution and Supply--South is responsible for the diesel stations within the southern region but not for the large hydroelectric generating stations. The recommended redistribution of responsibilities should result in more efficient use of scarce specialized skills. It will also become more logical when the northeastern system is interconnected with the main grid (in mid-1989), as all hydroelectric stations will then be supplying a common network.

1.42 The report on the organization and management study recently undertaken by consultants to ZESCO is not yet available. However, it is understood that the recommendations concerning reassignment of responsibilities made in the preceding two paragraphs are not affected by any of the study's conclusions or recommendations. If the report, when received, does not deal specifically with the span of management, the mission recommends that the consultants be authorized to expand the scope of their assignment. They should be required to develop recommendations for redistribution of management responsibilities within ZESCO after evaluating the number of positions currently vacant and the personnel resources available to the utility in the short- to medium term.

1.43 Salaries. The problem of more competitive remuneration for ZESCO staff, in particular its professional personnel, needs urgent attention if ZESCO is to continue to fulfill its role in the Zambian economy without reverting to increased dependence on expatriate personnel. ZCCM is ZESCO's chief competitor for scarce personnel resources. As a first step in attempting to improve its competitiveness in this area ZESCO should commission a study to compare the remuneration of its managerial and technical staff with that received by ZCCM staff in comparable positions. ZESCO is probably the most critical element in the Zambian economy as ZCCM and all other export industries are dependent on ZESCO for continued operations. This fact should be reflected in the remuneration received by ZESCO staff relative to the other industries.

1.44 ZESCO is aware of the need for change, and has repeatedly made representation for wage and salary increases, but does not have the authority to resolve the problem on its own. However, ZESCO can contribute towards resolution of the problem by increasing the productivity of its staff. With about 5,000 employees and 115,000 consumers, the ratio of employees to consumers is relatively high by commonly accepted standards. The unfavorable relationship seems especially pronounced in the Distribution and Supply divisions.

1.45 Productivity may be increased by introducing standards of performance (e.g., number of meters read per manday, number of consumer applications processed per manday, etc.). This approach will allow ZESCO to identify those whose performance is substandard and reward those who surpass the standard. It also can be used to identify employees who could benefit from additional training. However, it will not be easily applicable to all staff categories and presents problems especially with managerial and professional staff.

### Conclusion

1.46 This chapter has focussed on some of the administrative problems facing ZESCO. Important among these are the limited availability of professional personnel and financial constraints that prevent the utility from taking necessary actions to improve its present position. The mission feels strongly that ZESCO must find ways to increase the salaries of professional employees so that it can continue to attract and keep a high caliber of technical and management personnel. At the same time, the utility must find ways to increase productivity. Actions must also be taken to improve cash flow. A necessary action is to adjust tariffs to take into account the current rate of inflation in Zambia and changes in the international value of the Kwacha. With an improved cash reserve, ZESCO will be in a better position to make the investments recommended elsewhere in this report, and to expand its services to meet the needs for electricity of a larger sector of Zambia's population.

## II. COMMERCIAL OPERATIONS

### Overview

2.1 The two divisions of ZESCO responsible for consumer services are Distribution and Supply--North and Distribution and Supply--South. Each division is responsible for consumer connections, metering, meter reading, bill dispatching and revenue collection within its geographical area. The division managers report directly to the General Manager.

2.2 The areas of jurisdiction of the Distribution and Supply divisions are shown on IBRD Map 20984 at the end of this report. The line between the northern and southern areas corresponds roughly to a line drawn in an east to west direction and passing through Kabwe. The town of Kabwe itself is administered by Distribution and Supply--South.

2.3 The Divisional Managers, Distribution and Supply, are responsible for the administration of all of ZESCO's technical and commercial operations within their respective areas, including the smaller hydroelectric stations and all isolated diesel generating installations, but excluding the Kafue Gorge, Kariba North and Victoria Falls power stations, transmission lines operating at 88 kV or higher, and the substations associated with these high voltage lines. These larger facilities and lines fall under the jurisdiction of the Generation and Transmission Division.

2.4 Each of the two Distribution and Supply divisions is subdivided into districts. The northern division has nine districts. The largest of these are Ndola and Kitwe, both in the Copperbelt area. The northern division's administrative offices are in Ndola. The southern division has eight districts. By far the largest of these is Lusaka, which encompasses the city of Lusaka and its environs. The southern division's administrative offices are in ZESCO's head office complex in Lusaka.

2.5 This chapter reviews the policies and procedures now in effect in ZESCO's commercial operations, drawing on observations made in the two Distribution and Supply divisions, and makes recommendations directed at improving their efficiency.

### Commercial Operations

2.6 The mission observed similar problems in both divisions. These include: long delays in issue of bills following meter readings; accounts receivable equivalent to several months of billing; and a relatively high level of non-technical losses due to an inadequate data base of consumer information and deficient meter reading and billing procedures.

Tariffs

2.7 Each of the two Distribution and Supply divisions purchases power in bulk from the Generation and Transmission Division at the same tariffs as apply to Zambia Consolidated Copper Mines (ZCCM). In this way, it is possible to evaluate separately the efficiency of the two divisions in controlling energy losses and collecting revenues.

2.8 The divisions distribute power to retail consumers at rates that are uniform throughout the country. Annex 3 reproduces the tariff structures and rates in effect in March 1988.

2.9 There are four basic tariff categories, "L", "E", "D" and "S". They are applied as follows:

- (a) the "L" tariff is applied to unmetered residential collections. The service lines are supposedly provided with current limiters;
- (b) the "E" category is for metered residential and commercial supplies of unrestricted single phase demand or less than 15 kVA 3-phase maximum demand;
- (c) the "D" category is for consumers receiving 3-phase supplies with maximum demands exceeding 15 kVA; and
- (d) the "S" category is a concessional rate for service to ZESCO employees exclusively.

2.10 Tariffs in the categories E3, E4, D1 and D2 are increased by 20% above the regular rates for consumers supplied from the isolated northeastern network. Virtually all of the power distributed in this region is produced from the small hydroelectric stations but some diesel generation may be necessary at times of unfavorable hydrological conditions. Energy supplied from isolated diesel stations is billed 150% above regular rates. In other words, the rates are higher by a factor of 2.5.

2.11 Annex 4 shows the number of consumers and billings by tariff category for the financial year 1987/88. ZESCO pays a 15% government tax on all billings. This tax is passed on to the consumer. If revenue is not collected from a consumer, ZESCO is still responsible for paying this tax.

Consumer Connections and Account Numbers

2.12 Applications for electricity supply are made to the ZESCO district office with responsibility for the area in which the premises are located. When an application is received, ZESCO makes an estimate of the cost of providing the electricity and requests a deposit from the consumer. Upon receipt of the deposit, the premises are inspected for

proper internal wiring. If the installation is satisfactory the meter is installed and the installer forwards the meter number to the accounting department.

2.13 The accounting department assigns an account number, called a "premises number" to the new service. The account number consists of 10 digits. It is developed in accordance with coding which includes information on the district and geographical location. A connection fee and deposit is required prior to the connection being made.

#### Metering

2.14 Supplies to all consumers, except those in the "L" tariff category, are supposed to be metered. However, because of a shortage of meters ZESCO occasionally provides some "E" consumers with direct connections. About 1,000 consumers in the "E" category are being billed on estimated consumption. These customers do not have current limiters installed as do the majority of "L" consumers. <sup>2/</sup> Meters installed for consumers in the "D" tariff category are equipped with current transformers.

2.15 The meters normally used are of the surface-mount type, usually with five digits on the register. There is a meter workshop in each of the Distribution and Supply divisions. All new meters are tested for accuracy in the workshop before installation. For both areas, an average of 300 new meters and about 60 to 100 older meters are tested per month. The law requires each meter to be tested at least once every 15 years but this law is now seldom complied with. Testing of used meters is done, as a rule, only if there is reason to suspect their accuracy. Though the test equipment is capable of testing 20 single-phase meters simultaneously, it is outdated and slow.

2.16 ZESCO does not assign company numbers to its meters. The manufacturer's serial number is used as identification in the meter records.

2.17 Although ZESCO regulations stipulate that the meters should be sealed, this is not now normally done because of scarcity of seals and sealing tools. Sealing of terminal boxes had been standard practice years ago but began to be neglected with time as fraud was not considered to be a serious problem.

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<sup>2/</sup> Because of financial constraints, ZESCO does not have current limiters in stock to use for new connections in the "L" category. Like the "E" consumers, new "L" consumers are being directly connected.

Meter Reading

2.18 Meters are normally read once a month. There are about 130 meter readers. Thirty-six of them are stationed in Lusaka and about 10 each in Ndola and Kitwe. In the isolated diesel systems the meter readers also have other functions. The meter reading cycles are so arranged that no meter should be read by the same person in two consecutive months.

2.19 For each route, the meters to be read by one person in one day are kept in a "meter book". Each sheet in these books contains information on the customer's address (if the premises are along numbered streets) the "premises number" (the identifying number unique to each account) and the serial number of the meter.

2.20 In most districts, the meter readers take the meter book with them along the route and enter the meter readings directly in the book. An exception is Lusaka. Here, the readers are given blank tear-out sheets on which they enter the meter reading, the serial number of the meter, the plot number where applicable, or any other information that may be used to identify the premises. Meter readers are expected to check each meter for correct installation and functioning.

2.21 The sheets in the meter books are arranged by numerical order of the premises numbers. Meter readers who take the books with them sometimes have difficulty in identifying accounts whose premise numbers are not in numerical sequence to the adjacent premises. This often occurs when a new service is provided between two existing services. In the case of Lusaka, the billing department may have problems identifying the correct account number from the information the meter reader has provided on his tear-out sheets.

2.22 Foremen in the meter reading department are assigned to check the accuracy of meter reading. Each foreman supposedly rereads the meters in two or three books each month and compares the meter readings with those recorded in the book. Due to a shortage of personnel and of vehicles for transportation, this system of checking is not rigidly followed. If it were, it would allow the accuracy of each meter reader to be checked once every 12 to 18 months.

2.23 The productivity of the meter readers is relatively low. The Lusaka district has about 36 meter readers to read 30,000 accounts. If allowance is made for vacation and sick leave, as well as for the fact that some time will be spent on company activities other than meter reading, the average meter reader reads less than 50 meters per working day. This is a low average for a predominantly urban district. In fact, it is somewhat lower than the overall company-wide average.

### Bill Production and Dispatching

2.24 Calculation of consumer bills is now computerized for districts on the interconnected system, except Mongu and Kasama, a total of 13 districts. The computer is located in the head office in Lusaka. The Ndola office is equipped with a slave computer and five data entry stations with video display units (VDU) and printers. The slave computer communicates with the main computer in Lusaka over the public telephone lines.

2.25 In the Lusaka district, where tear-out sheets are used instead of meter books to record meter reading information (para. 2.19), the information is transferred to meter books in the meter reading office at the southern division's administrative offices, which are located within ZESCO's head office complex in Lusaka. The meter books are then forwarded to the data processing department in the same complex.

2.26 For the other 12 computerized districts, where the meter readings are entered directly in to the meter books, the books are not processed before being sent to the billing section, either in Lusaka for the southern division or Ndola for the northern. In the respective billing sections, the readings are key-punched and a printout of the entries is made. Each printout is checked only to ensure that the reading recorded corresponds to that in the meter book. During the data entry operations, the computer rejects many entries because of inconsistencies between the data and the account files stored in its data bank. For instance, if the meter number entered for a given premises does not correspond with the computer records, the computer rejects that entry.

2.27 The key-punched data is transferred to the computer section in Lusaka where the bills are computed automatically. If a meter has not been read, the computer program does not allow for an automatic estimation of consumption. If the monthly consumption varies from the previously calculated average by more than a fixed percentage (currently 50 percent) a caution message is printed against that account number to alert the district staff to the need for checking and, possibly, corrective action.

2.28 Bills are automatically printed after calculation. The bills for the northern division are printed in Ndola, and those for the southern division in Lusaka. The printed bills are then sent by vehicles to the responsible districts where they are manually inserted into envelopes, franked and mailed.

2.29 In Lusaka, bills are generally mailed about seven weeks after the meters are read. Because of delays in mail delivery, it may take another week before consumers receive their bills. Thus the delay between meter reading and the consumers' receipt of their bills is almost eight weeks. The time is divided roughly as follows: three weeks between the meter reading and receipt of the reading by the billing section; four weeks for data entry and validation, bill calculation and

printing, transmission to the districts, inserting into envelopes, franking, and depositing in the mail; and one week for mail delivery to the consumers. The shortest period is spent for computer calculation and printing of the bills. This operation takes only about one day.

#### Collections, Disconnections and ReconNECTIONS

2.30 The utility requires consumers to pay the amounts invoiced within 15 days of the date of issuance of their bill. Enforcement of this requirement is lax. At present, ZESCO's accounts receivable amount to about 130 days of billing. The worst offenders are certain government accounts and some smaller industrial operations. Major industrial consumers are generally prompt in their payments. There are no written guidelines as to when disconnections are to be effected, and the computer does not produce a disconnection list. Generally a consumer is not disconnected until four months after his bill is mailed, regardless of the amount invoiced.

2.31 Even after a consumer has been disconnected, he continues to be invoiced for the minimum charge and for government sales tax. Though the sales tax is theoretically collected from consumers, ZESCO must pay the tax on all invoiced amounts whether they are collected or not.

2.32 If a consumer pays his outstanding bills following disconnection, or negotiates a payment program with ZESCO, service will be restored following payment of a reconnection fee of 100 Kwacha. If the consumer does not ask to be reconnected, his contract is not normally terminated even after extended periods of disconnection unless he pays the amounts due and requests cessation of service. ZESCO continues to send out bills on which it pays sales tax to the government.

#### Non-technical Losses

2.33 It is estimated that non-technical losses account for about 3% of the energy sent out over the ZESCO system operating below 220 kV. <sup>3/</sup> For the 1987/88 financial year, a 3% energy loss would amount to a total loss of about 61 GWh, which converts to a financial loss of 6.1 million Kwacha at an average tariff of 10 Ngwee per kWh. There are two main classes of non-technical loss on the ZESCO system. One class encompasses the effects of deliberate attempts of consumers to defraud, by direct connections, meter tampering, etc. The other class results from operational deficiencies in the systems by which ZESCO accounts for and invoices energy consumption.

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3/ Loss estimates are given in Annex 2.

Consumer Fraud.

2.34 The incidence of consumer fraud appears to be increasing with the downturn in Zambia's economy. Shop checks of meters suspected of registering inaccurately have shown various methods of tampering with the meter. These include physically damaging it, disconnecting the voltage links, and increasing the friction on the disc bearings. In other instances meters have been, deliberately or unwittingly, subjected to overload, damaging the current coil and rendering subsequent readings inaccurate. Unauthorized direct connections to the low-voltage overhead lines is also becoming more frequent.

2.35 Residential consumers have accounted for most of the recorded cases of meter fraud. Attempts at fraud seem to be less common with commercial and industrial consumers. However, there have been instances in which one or two phases of the supply have been bypassed around the meter or the current transformer connections have been interfered with.

2.36 Although power theft is a criminal offence under Zambian law, ZESCO does not take legal action against offenders because of the difficulty in successfully pursuing litigation in the courts. Those who are discovered fraudulently diverting power are billed retroactively for the energy estimated to have been consumed but not metered.

Operational Deficiencies.

2.37 A number of operational deficiencies contribute to non-technical loss. These include: inadequate recording of electricity consumption; faulty assignment of account numbers and meter numbers; a faulty meter numbering system; and deficiencies in the computerized billing system. These will be discussed in the following paragraphs.

2.38 Inadequate Recording of Consumption. The unmetered "L" tariff category is an obvious source of revenue losses. Whenever consumption is estimated, the potential for error exists. Load limiters are ineffective in reducing the margin of error, but in any case financial constraints, particularly shortage of foreign exchange, have made it impossible for ZESCO to keep load limiters in stock. New "L" consumers are therefore being directly connected. However, even with load limiters installed it is a relatively simple exercise to defeat their intended effect. An instance was discovered in which an "L" consumer, supposedly limited to a maximum demand of 15 amperes, was drawing 60 amperes.

2.39 Similar problems exist in the "E" tariff category. Because of unavailability of single-phase meters, consumers are sometimes officially direct-connected to the system and are supposedly billed on estimated consumption. As the computerized billing system does not easily accommodate regular estimated billing, the effect is that such consumers are often not billed at all.

2.40 Faulty Assignment of Account and Meter Numbers. The system of allocation of account numbers for new consumers sometimes results in the same number being given to two premises. The computer will reject one of these when the master file is created. If there is no follow-up to regularize the rejected account, the consumer will continue to enjoy service without ever receiving a bill.

2.41 In principle, before an account number is assigned a meter is installed and the number and location entered into the computer's master file. This is not always done. Consequently, when the account number is allocated and entered into the master file the number is rejected if the meter information and the account number does not correspond with that already on file for the meter or if there is nothing on record for the meter.

2.42 A similar problem occurs when the meter at a given location is changed. This is usually done because the original developed defects. Subsequent meter readings record the new meter number. Unless the computer section has been informed of this new number and the records altered accordingly, the computer rejects the meter readings and does not prepare bills.

2.43 Faulty Meter Numbering System. There is no meter number unique to ZESCO. The manufacturers' serial numbers are used to identify the meters. As the meters on ZESCO's system come from several different manufacturers, it is not possible to develop a system of codification that would provide each meter with a distinctive number and at the same time allow the number to convey other information such as the meter range, number of phases, and multiplication factor.

2.44 Meter Reading Problems. Meter reading errors or omissions contribute significantly to revenue losses. It is estimated that in Lusaka on each billing cycle 5% to 10% of consumers are not billed because the meters have not been read. It is further estimated that each month 20% of meter readings (Lusaka) are incorrect because of errors on the part of the meter readers.

2.45 Many meters require a multiplication factor and/or a current transformer ratio. These are often wrongly recorded in the master file and result in incorrect invoicing.

2.46 Because of the system ZESCO uses of allocating "premises numbers" in the account numbers, meter readers often have difficulty locating accounts that are not in numerical sequence on the meter reading route. They also have problems with meter changes that are not indicated in the meter book. Both situations contribute to increasing the percentage of meters not read.

2.47 Due to a shortage of vehicles, meter readers are not able to read all meters in their assigned area each month.

2.48 The system used in the Lusaka District whereby the meter readings are first entered on a sheet, then transferred to the meter book and finally entered into the computer records creates the potential for errors at each stage of the process.

2.49 Faulty Billing System. The computer's billing program does not provide the range of features that are available in any reasonably powerful modern program. For instance, it does not allow the following:

- (a) easy cross-referencing between consumer names, account numbers, addresses, meter numbers, etc. Improved cross-referencing would reduce the time needed to properly match meter and account numbers when discrepancies exist;
- (b) automatic production of an estimated bill when no meter readings have been received for a given account in a billing cycle; and
- (c) automatic identification of accounts on which no payments have been made for the last 2 or 3 months.

2.50 Inactive accounts are not systematically removed from the billing register. About 40,000 accounts still show on the books as being in arrears although no transactions have been recorded for them for more than a year. 4/ No bills are prepared for these accounts. The presence of these accounts on the master file slows the overall billing process and complicates the coordination of meter numbers with the addresses or account numbers of active accounts.

#### Recommendations

##### General

2.51 ZESCO is about to acquire a new computer. Some bill preparation procedures will have to be changed to fit the new system. This is an ideal time for the utility to review the whole process of metering, meter reading, billing and collection with the objectives of reducing revenue losses, improving cash flow and enhancing customer satisfaction. The mission's recommendations for changes in the process are given in the following paragraphs.

##### Tariffs

2.52 The economics of metering all consumer connections (and abolishing the "L" tariff category) should be investigated. This may be

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4/ These inactive accounts are not included in the estimate of 115,000 consumers used elsewhere in this report (Chapter I, para. 1.16).

done by installing meters on a representative sample of "L" supplies and comparing the cost of the meters and meter reading with the benefits of increased revenue. An important advantage of metering all connections is that it will enable ZESCO to better account for all kilowatt hours distributed. This advantage is basic to control of losses but the benefits are not easily quantified.

#### Consumer Connections and Account Numbers

2.53 In order to avoid some of the problems experienced with the present system, ZESCO should introduce a new account numbering system. To allow for system expansion, each account number should contain at least six digits. The numbers used should relate to a unique service location in the consumer master file maintained on the computer. Using the number, all data considered important to the service would be entered in the master file at the time the account is established. The file would contain, for instance, the name and address of the registered consumer, the tariff category, the meter number, the geographical location of the account, the location of the transformer providing the supply, the account's payment history etc. Access to all the relevant information for the account could be obtained by entering any one of the items of information. The computer would establish the linkages. Records in any fields, except name and address, could be changed without affecting the others. <sup>5/</sup> The numbers allocated to adjoining premises need have no sequential relationship. Area rezoning or meter changes could be made without requiring assignment of a new account number or complicating meter reading. This new system of account numbering should be introduced along with the new billing program recommended in paragraph 2.66.

#### Metering

2.54 ZESCO should make it a priority to develop a system in which all meters are given a unique ZESCO number. By identifying each meter as ZESCO property, the utility should be able to reduce the incidence of meter thefts. An equally important advantage is that the system can be developed around ZESCO's own coding. This would allow each number to contain important information about the meter, such as rated amperage and number of phases. It would also make it easier to keep historical records for each meter.

2.55 Service connections and meters should be inspected at all points of supply. Experienced meter readers can be used for the

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<sup>5/</sup> The utility might want to limit alteration of some of the fields to specifically authorized persons.

inspections. 6/ The inspections should include multiplication ratios and current transformer connections where applicable. Meters and current transformers that are functioning satisfactorily should be sealed. The seals should be of a type that is difficult to break. The method used to seal them should make it possible to identify the person who performed the sealing. ZESCO should establish a task force for this program and give one individual the responsibility for planning and implementing it.

2.56 If a meter inspection program is begun (para. 2.55) and if all service is metered 7/, ZESCO will need to accelerate meter testing in order to have a larger supply of approved meters. ZESCO will need to acquire new test equipment in order to be able to test and approve meters at a faster rate. To further speed testing, the mission recommends that ZESCO discontinue the practice of testing all new meters and test a representative sample only, three from each box, for example. If all meters in the sample are found to be within acceptable limits of accuracy, the whole box can be accepted without further testing. If any meters in the sample are outside the accepted accuracy range, all the meters in the box should be tested.

2.57 ZESCO should introduce a regulation mandating that for all new connections meters are to be installed on building exteriors only. This regulation would have the effect of increasing the rate at which meters are read since the meter readers would not need to enter the buildings. It would also make it more difficult for consumers to bypass the meter and tamper with the meter or its connections, especially if these are sealed. With time all meters now installed indoors could be relocated outdoors, but ZESCO might have to bear some or all of the costs of the relocation.

2.58 The mission recommends that in installing meters for the current "L" consumers, ZESCO test plug-in type meters as an alternative to the surface-mounted design now used. As plug-in meters can be pole-mounted close to the roadway, they are easier and faster to read than the surface-mounted meters. Experience in other countries has shown that the plug-in meters are also more easily sealed and harder to bypass than the surface-mount type.

2.59 Implementation of the recommendations in paragraph 2.58 will require an investment of about US\$348,000. The estimated expenditures, which would be predominantly in foreign exchange, are as follows:

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- 6/ Enough meter readers should be available if ZESCO adopts the recommendation in paragraph 2.60 that meters be read once every two months instead of once a month.
  - 7/ It is suggested in paragraph 2.52 that ZESCO investigate the economics of metering all consumer connections.

	US\$
- 7,000 plug-in type single-phase meters for existing "L" services and direct-connected "E" services and for inventory reserves	140,000
- 200 plug-in single-phase meters for pilot testing	8,000
- 2 meter test benches, 1 for Lusaka, 1 for Ndola	160,000
Total	<u>308,000</u>

Meter Reading

2.60 Reducing the extent of errors in metering and meter reading will require more detailed meter inspections and further training of meter readers. In order to achieve these objectives without increasing the number of employees involved, it is recommended that the frequency of meter reading be reduced from monthly to once every two months for all consumers other than those in the "D" tariff category. If this recommendation were to be adopted it would still be possible to continue issuing monthly bills by calculating every other bill on the basis of estimated consumption.

2.61 The meter reading documents should be redesigned to minimize the transfer of sheets or books between departments. The pages in the meter book should contain only the account number, address and meter number of the service and should be arranged in the order in which the meters occur along the route. That way the meter reader would only have to check the meter number and write down the meter reading at each location. Space should be provided for him to make comments if, for instance, the number of the installed meter does not check with that in the book, or the meter appears to be malfunctioning, or he notices attempts at current diversion, etc. The book should have carbon inserts or other means of page duplication that allow copies to be made automatically. The originals could then be filed in the meter reading section for future reference, and the copies sent to the computer department. The computer department would not need to return the copies to the meter reading department. The system now in use in Lusaka in which readings are transferred from a sheet to the meter book and the book is sent to the computer department is time consuming and creates many opportunities for error.

2.62 The current high percentage of meter reading errors indicates that many of the meter readers lack the skills needed to carry out their duties effectively. Three steps should be taken to improve their skills. First, a manual of instructions should be developed to explain the entire process of meter reading, calculation and issuance of bills and revenue collection. This manual would be useful to all employees involved in ZESCO's commercial operations. Second, a training program should be developed for the meter readers. Third, a system should be

developed to test the readers both on their knowledge of the specifics of meter reading and on their meter reading performance.

2.63 The training and testing exercises can be used to find out the minimum standard of education the average new employee needs to have in order to become competent at his job. The training experience may show that ZESCO's existing compensation levels are not high enough to attract people with the minimum qualifications needed to become efficient meter readers. If so, the utility should adjust wages and salaries accordingly.

2.64 ZESCO should monitor the performance of individual meter readers. Those not meeting minimum standards of productivity and accuracy should be replaced. Incompetent meter reading can cause large losses of revenue. The utility should not tolerate incompetence in this critical area.

2.65 Meter reading performance can be monitored using the new billing program recommended in paragraph 2.66. With this program, it should be relatively easy to produce a monthly listing showing for each meter reader the numbers of:

- meters read;
- meters not read; and
- errors discovered in the readings.

#### Computer Billing Program

2.66 As ZESCO is purchasing a new computer, this is an ideal time to replace the utility's existing billing program with one providing a wider range of features. Rather than modify the program now in use to run on the new computer, it would be more expedient and cost effective to develop a better program. The mission recommends that ZESCO hire consultants who are specialists in the field to create an improved program. The consultants can be asked to modify programs already developed and in use elsewhere to comply with ZESCO's special requirements and characteristics. In this way ZESCO will be assured of having a program adapted to its needs. The program may, in fact, offer desirable features that ZESCO did not actually specify but that the consultants have found to be beneficial and that have already been proven in service.

2.67 The consultants should provide a competent person or persons to be present at ZESCO's offices during the installation and testing of the computer program to resolve any difficulties encountered in its operation and to train ZESCO's staff in its use and maintenance. This on-site support service should be continued for at least three months after the program begins to be regularly used for billing.

2.68 No attempt will be made to provide complete specifications for the new program in this report. However, it should include some features that deserve special mention. For all consumers, the program should

calculate and print bills monthly, although, with the exception of major consumers, meters will only be read once every two months. Bills produced in those months for which no readings are made should be calculated on the basis of the average consumption over the three previous meter readings. This estimation should be used also for accounts where the meters ought to have been read but no readings were obtained, resulting in two or more estimated bills consecutively.

2.69 The billing program should also be able to:

- (a) establish cross linkages between, as a minimum, account number, consumer name, service address and meter number. Entering any one of these items should provide information on the other items as well as access to information on tariff category, payment status, date of initial service, etc.;
- (b) prepare a printout of revenues outstanding, sorted by age, amounts, tariff categories, etc., as required;
- (c) prepare a daily list of accounts to be disconnected because of arrears in payments (see paragraph 2.74);
- (d) issue a printout of important data for management information on a routine basis, for instance, once a month. The information would include items such as energy and revenue billings, number of consumers by tariff category, collections, and accounts receivable; and
- (e) accommodate the introduction, at a later stage, of a transformer load management program. Such a program would indicate the loading of distribution transformers by establishing a relationship between that loading and the energy consumption recorded by meters energized from each transformer.

2.70 Estimated Cost of the Billing Program. Annex 5 gives draft Terms of Reference for services to develop, install and implement the recommended computer billing program. The total estimated cost for these services is US\$104,000. The cost of the actual program installed on ZESCO's computer is estimated at US\$40,000. An additional US\$64,000 would be needed for the services of support personnel, including travel and subsistence, during installation and initial operation of the program.

2.71 Benefits of the Program. The mission estimates that use of the proposed billing program, in conjunction with the other recommended changes to ZESCO's commercial operations, will reduce the period between meter reading and bill printing by at least five weeks. This in turn should improve ZESCO's cash flow by more than 16 million Kwacha at the present rate of billing. Alternatively, if a 16% rate of interest is

assumed, the savings will be 2.5 million Kwacha per annum, or US\$300,000 at the exchange rate prevailing at the time of the mission's visit. 8/

#### Other Billing Considerations

2.72 In order to increase revenues, ZESCO should consider introducing a surcharge on bills not paid within a certain period, for instance within one month of the date of mailing.

2.73 Bills for consumers in the "D3" tariff category should be calculated on the day after the meters are read, and hand-delivered the next day. This category encompasses consumers whose maximum demand exceeds 2,000 KVA. There are only 37 such accounts on the ZESCO system but together they account for more than 20% of total revenues. If collections from these accounts could be advanced by five weeks it would have the effect of increasing ZESCO's cash flow by the equivalent of seven days of billing or more than 3 million Kwacha in terms of current billing. This change should be introduced immediately. Until a better system is developed, the bills should be calculated manually if necessary.

#### Disconnections

2.74 ZESCO needs to develop, commit to writing and rigorously enforce unambiguous policies and procedures for the disconnection of consumers who are in arrears.

#### Conclusion

2.75 Relatively simple changes to ZESCO's procedures in the various areas of its commercial operations can bring tangible improvements in its cash flow. As indicated in this chapter, changes need to be made in several areas, including accounts receivable, billing, metering, and meter reading. However, the most significant benefits will be achieved by the introduction of a new computer billing program. The program should increase both the speed and accuracy of billing while providing an enhanced consumer data base. The imminent acquisition of a new computer provides an ideal opportunity for ZESCO to develop and implement a new billing program.

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8/ This was 8 Kwacha = US\$1. The mission visited Zambia in February and March 1988.

### III. GENERATION

#### Overview

3.1 This chapter describes ZESCO's power network, presents the mission's findings on the maintenance and rehabilitation needs of the generating stations, and gives recommendations to improve the efficiency and reliability of power generation in Zambia.

3.2 During its field trip in Zambia, the mission visited five power stations. These were: Kafue Gorge, Kariba North, Victoria Falls, Chisimba Falls and Musonda Falls. Because of their relative remoteness, it was not possible to visit the other generating stations on ZESCO's system in the time available to the mission.

3.3 The relative locations of the various power stations on the ZESCO system are shown on IBRD Map 20984 at the end of this report.

3.4 The mission concluded from its visits that ZESCO's generating plant is generally well maintained and operated. However, financial constraints, especially the limited availability of foreign exchange, have prevented the timely performance of several major maintenance tasks as well as a number of minor ones. In particular, the smaller stations on the northeastern system show signs of extended overhaul periods. In these stations, only the most urgent maintenance is being performed.

3.5 Completion of the maintenance and rehabilitation recommended in this chapter should enable ZESCO to keep its hydroelectric generating capacity at a level adequate to supply the country's needs until about the end of this century.

#### ZESCO's Power Network

3.6 ZESCO's power network consists of one large interconnected system, generally referred to as the main grid, a smaller interconnected system called the northeastern region, and a number of small, isolated systems served by diesel generating units. The main grid and the northeastern system are to be interconnected at Pensulo, near Serenje, during the course of 1988.

#### The Main Grid

3.7 The nominal generating capacity on the main grid is 1,608 MW from three major generating stations. Kafue Gorge on the Kafue River is rated at 900 MW, Kariba North on the Zambezi at 600 MW, and Victoria Falls, also on the Zambezi but upstream of Kariba, at 108 MW. Details of the equipment installed in these stations and their design parameters are provided in Annex 6.

3.8 There is a 330 kV interconnection between the Zambian and Zimbabwean networks at Kariba. There is also a 220 kV interconnection with the Zairian system at the border of Zaire with north-central Zambia. In addition, ZESCO's largest consumer, Zambia Consolidated Copper Mines Limited (ZCCM) owns a number of generating units which could, in theory, be connected to the main ZESCO grid. As these are never used to supply energy to the ZESCO system, they are not considered further in this Report.

3.9 The combined firm capacity of the generating stations on the main grid is estimated to be 9,575 GWh per annum. In this estimate the annual value attributed to the Kariba North station is 3,800 GWh, which is lower than the generally accepted figure of 5,000 GWh. The reduction has been made because recent hydrological and operational experience have indicated that the higher value may be too optimistic.

#### The Northeastern System

3.10 The capacity of the northeastern system is nominally just less than 27 MW. The four hydroelectric stations on this system are Lusiwasi (with an installed capacity of 12 MW), Chisimba Falls (6 MW), Mussonda Falls (5 MW), and Lunzua (0.75 MW). Detailed information on these installations is provided in Annex 6. Supply to the system is augmented by a number of diesel stations, together amounting to about 3 MW nameplate capacity. These are currently used only for emergency service. The estimate of aggregate firm capacities of the hydroelectric generating stations on the northeastern system is 105 GWh.

#### Isolated Systems

3.11 ZESCO operates seven very small independent systems which obtain power from diesel generators. The capacities of these systems range from 300 to 900 kW. The operating costs of these systems are very high because of high fuel costs, their remoteness from the more densely populated areas, and the diseconomies of scale.

#### Planned Maintenance and Rehabilitation

3.12 The installed generating capacity on the main grid (1,608 MW) is much greater than the peak demand, including exports. In 1987 the maximum demand on the Zambian interconnected system was 1,320 MW, including exports to Zimbabwe. This level is not likely to be exceeded for some time due to declining exports of power. Despite the overcapacity, ZESCO appreciates the importance of maintaining its power stations in first class condition. Towards this end a rehabilitation program is underway in the Kafue Gorge station with financial assistance from NORAD, the Norwegian Agency for Development. Funding is being sought for rehabilitation and operational improvements at the Victoria Falls installations.

### Firm Capacity

3.13 The following paragraphs give the mission's estimates for the firm capacity of the various stations on the main grid, and for the northeastern system. These have been tabulated and are presented in Table 3.1.

Table 3.1: ESTIMATED FIRM CAPACITIES OF  
ZESCO'S HYDROELECTRIC INSTALLATIONS

Installation	Installed Capacity		Firm Energy (GWh/annum)
	(MW)		
Kafue Gorge	900		5,000
Kariba North	600		3,800
Victoria Falls	108		775
Lusiwasi	12		50
Chisimba Falls	6		20
Musonda Falls	5		30
Lunzuia	1		5
Total	1,632		9,680

Source: ZESCO records and mission estimates.

### Kafue Gorge

3.14 The accepted value for the firm energy capability of the Kafue Gorge generating station is 5,200 GWh per annum. The average generation over the seven-year period 1981 to 1987 was 5,164 GWh per annum. Hydrological conditions have not been favorable during this period but the main storage reservoir at Itezhitezhi has always been maintained above the minimum operational level. The figure of 5,200 GWh per annum therefore seems to be a reasonable value. However, agricultural developments along the waterways have rights to abstract water for irrigation. These rights are not yet fully exercised. A prudent estimate of the firm energy potential of The Kafue Gorge station would be about 5,000 GWh.

### Kariba North

3.15 The Kariba North station is supplied with water from Lake Kariba. This reservoir is shared with the Kariba South station located in Zimbabwe on the opposite bank of the river and operated by the Zimbabwe Electricity Supply Authority (ZESA). The water flowing from the lake is intended to be shared equally between Zambia and Zimbabwe. The firm energy potential of the Kariba North station is therefore one-half

of the potential of Lake Kariba, which is generally stated to be 10,000 GWh per annum.

3.16 The records indicate that the reservoir reached the highest level so far attained in May 1981. The level was then 487.4 meters, or 1.6 meters below the maximum operating level of 489.0 meters. The average rainfall in the Zambezi catchment area has been much lower than normal since then, and the lake levels have declined more or less steadily, reaching 476.5 meters, or one meter above minimum operating level, in January 1987. The energy generated by both power stations as the lake level moved between the two extremes was about 43,000 GWh for an average of just over 7,000 GWh per annum.

3.17 Since neither maximum retention nor minimum operating level was reached during the period considered, the true firm capacity of Lake Kariba is probably somewhat higher than 7,000 GWh per annum, perhaps between 7,500 and 8,500 GWh. In any case it is substantially less than the 10,000 GWh per annum commonly assumed. In this report the firm energy of the lake will be taken to be 7,600 GWh per annum and that of the Kariba North station as one-half of the total, or 3,800 GWh per annum.

3.18 The bi-national Zambezi River Authority (ZRA) monitors the equitable distribution of the lake water to Zambia and Zimbabwe and also determines the rate of outflow from the lake. ZRA is currently based in Harare, but its headquarters are to be relocated to Lusaka within the next 12 months.

#### Victoria Falls

3.19 The Victoria Falls generating complex, a run-of-river installation, never utilizes the full river flows. The firm potential is therefore a function of the design characteristics. It is stated to be 775 GWh per annum. However, the output of the last four units installed at the site is limited to about 10 MW less than aggregate rated capacity because of tailrace limitations. Until remedial work is done on the tailrace structures, the available firm capacity will be about 90% of the stated figure.

#### Northeastern System

3.20 The Lusiwasi, Chisimba Falls, Musonda Falls and Lunzuza hydroelectric stations are all run-of-river installations with reservoirs allowing daily regulation. The combined firm capacity of these sites, as currently developed, is estimated to be 105 GWh.

#### Isolated Diesel Systems

3.21 The firm capacity of the isolated diesel systems was not calculated as no figures are available on which to develop reliable estimates. In any case, they are of no importance in the overall Zambian considerations.

Findings for the Stations Visited

3.22 The following paragraphs present the mission's findings for the Kafue Gorge, Kariba North, Victoria Falls, Chisimba Falls and Musonda Falls generating stations, which the mission inspected during its field visits in Zambia in February and March 1988.

Kafue Gorge

3.23 The first stage of this station (four units) was commissioned in 1972 and the second stage (two units) in 1976. Since then the station has operated with high availability, despite the financial constraints often experienced, especially shortage of foreign exchange. Problems developed with the stator laminations and rotor wedges of the first four alternators and with time all the turbines needed to be overhauled. Both of these maintenance aspects are now being attended to through assistance provided by NORAD. Overhaul of three turbines (Nos. 1, 2, and 5) has now been completed. No alternator has yet been completely repaired but the work on all turbines and alternators is scheduled for completion by the end of 1989.

3.24 Further maintenance work is needed on many of the auxiliary systems in the station. Funding for this work has not yet been finalized. At the time of the mission's visit only one air conditioning chiller was in operation, while two were not in serviceable condition. The chillers are needed principally for cooling the control room, busbar ducts and transformer rooms. All of these are located in the underground cavern which forms the power station proper. If the air is not cooled the temperatures quickly increase and some instrument and control circuits in the control room begin to malfunction. Under these conditions there is real potential for a total station shutdown. The situation is critical because the existing unit cannot be taken out of service for routine maintenance but is showing signs of developing problems. The units now out of operation cannot be serviced in Zambia. ZESCO has negotiated financial assistance from the Swedish International Development Agency (SIDA) for the purchase of a new unit at an estimated foreign exchange cost of US\$350,000. Many fan coil units employed to cool the air used for ventilation are also in need of replacement. Recent proposals indicate that the foreign exchange cost of these units will be US\$509,000.

3.25 Make-up for the chilled water circuit is taken from the domestic water supply from the village without any further treatment or additives to control corrosion or scaling. This is river water. It is filtered and chlorinated to make it suitable for domestic use, but not treated in any other way. The transformer oil coolers, the generator air coolers and the air conditioning chiller condensers are cooled by a once through system using river water. The water is shock chlorinated with concentrated sodium hypochlorite. The chlorination pumps are old and unreliable and need to be replaced.

3.26 The alternators generate at 17.5 kV. Nine 94 MVA single phase transformers increase the voltage to 330 kV. A tenth transformer is available in reserve. Each operating transformer is connected to two alternators. Spare windings were originally supplied with the transformers but winding faults have exhausted the supplies. Further transformer faults would therefore limit the output of the station.

3.27 The 330 kV unit transformer secondaries are connected to ten oil-filled cables, one for each energized transformer phase connection and one spare. These cables ascend through vertical shafts to the switchyard located on the surface about 500 meters above the power station. It was reported that a number of these cables have begun to bulge and cause concern for their reliability, although none has yet failed.

3.28 The individual penstocks to each of the six units are equipped with intake gates operated by hydraulic rams. There is oil leakage around the pistons in a number of these rams, with the result that the gates begin to close slowly. After closing to a certain point they return automatically to the fully open position. The oil pressurizing circuits were not designed for the frequent operation they must now undergo.

3.29 Raw water for the domestic supplies to the power station and the neighboring communities is taken from the main supply tunnel through one of the intermediate adits excavated during the initial construction of the station. Pipelines, pumps and valves are installed in the adit. Along a portion of the adit that the operating personnel must enter the rock is unstable and a number of rockfalls have occurred. Thus far no injuries to personnel have been reported, but there has been significant damage to equipment. Attempts have been made to improve the safety of the area but it remains a hazard.

3.30 Access roads to different areas of the generating complex are in need of repairs. In particular, the road from the station to the tailrace outlet is impassable due to rock slides. This condition would make emergency closure of the tailrace gates impossible.

3.31 There is a deep boom arrangement in front of the headrace intake to divert weeds and other flotsam carried by the stream to the spillway. At the time of the mission's visit, a densely compacted mat of weeds almost entirely covered the section of the reservoir that was visible from the dam. It was reported that these had accumulated since the previous day when a similar accumulation had been cleared by opening the spillway gates for a short period. Some of the weeds had passed through areas where sections of the deep boom were missing, and were floating in front of the headrace intake. If left unattended, these weeds will inevitably be sucked into the intake and will clog the trashracks. This has happened once before, and was so serious that the power station had to be shut down completely. The original equipment used for raking and cleaning the trashracks was not rugged enough for the

duty and a crane operated bucket is now being used instead. The process is very slow and not very effective. The problem is most serious at times of high flows such as existed during the mission's visit.

#### Kariba North

3.32 This station was found to be in excellent operating condition, with a high standard of housekeeping. Preventive maintenance programs appeared to be properly executed and no major maintenance problems were reported. Loose laminations in the alternator stators have caused a number of earth faults, but the problem is being overcome by tightening the laminations and applying an improved grade of insulating varnish. The units, each rated at 150 MW, are not normally operated between 60 and 110 MW except when the load is being increased or reduced as bubbles of air are observed in the tailrace at these loads. The concern is that the runners may be cavitating. However, no evidence of cavitation has been observed so far when the runners have been inspected. This constraint on loading has not significantly affected operation of the plant.

3.33 Although the station itself is in excellent condition, access roads and site roads within the project compound need to be repaired and better maintained.

#### Victoria Falls

3.34 "A" Station. This phase of the installation was commissioned in 1938. Most of the original equipment is still in service. Turbines and alternators need to be completely overhauled. The switchgear and control equipment should be replaced with more modern designs as spares for the existing apparatus are no longer available. The power cables, which run on the ground parallel to the penstocks, show signs of severe deterioration.

3.35 It is to be noted that this station, unlike the "B" and "C" stations, can be started without any external source of electricity. In fact, in an emergency, it can be first placed in service to provide the power needed to bring the other two stations into operation.

3.36 "B" Station. At some time in the recent past four of the six alternators in this station have been affected by stator earth faults. Two of these four affected alternators have already been rewound and rewinding is in progress on the other two. The insulation failures on the units are a consequence of the way in which they are connected to the system. The step-up transformers (11 to 33 kV) are installed between the alternators and the corresponding generator breaker. During switching, especially at the low loads experienced when a unit is taken out of service, the decay of the transformer's magnetic field causes voltage surges in the cables between the transformer and the generator. These surges may attain levels several times greater than the rated voltage and create resonant oscillations in the circuit, leading to failure of the insulation.

3.37     "C" Station. The maximum loading at which each unit in this station is being operated corresponds to 75% of rated output. This is due to a vibration problem. The civil works around the draft tubes vibrate excessively if the load limit is exceeded, although the vibration was not noticed on the generating units themselves. Considerable turbulence was observed in the tailraces even with the units operating well below the 75% limit. This problem is not experienced in the "B" station, which is of almost identical design.

3.38     It is reported that during construction of the "C" station, because of problems with high water levels, a decision was made to shorten the distance between the end of the draft tube and the crest of the tailrace discharge weir. As a consequence of this design change, the volume of water in the tailrace, and some of the stilling effect was lost. The resulting water turbulence probably contributes to the vibration problem around the draft tubes.

3.39     A previous inspection of the draft tubes revealed extensive damage due to a combination of cavitation, fatigue failures, and air voids in the supporting concrete. A diagnosis was made that the water was separating from the draft tube profile in the bends and that this condition was responsible for the shock waves in the tailrace. It was suggested that the submersion of the turbines be increased by raising the level of the water in the discharge weir. The tailrace arrangement in the "C" station is similar to that of the "B" station. However, the "C" turbines operate with a submergence of less than two meters, while the "B" turbines have a submergence of five meters.

3.40     The water intakes for the "A", "B", and "C" stations are all located some distance upstream of the falls. They consist of arrangements of booms to divert floating debris from the inlet canal, stoplog closures to allow safe maintenance of the system downstream of the intake, trash racks, and winch-operated radial gates behind the racks. All of this equipment needs to be rehabilitated or replaced as it is not operating as effectively as it should.

#### Chisimba Falls

3.41     The access road to the station, which is about four kilometers long, badly needs regrading and resurfacing. It is barely negotiable, even by a four-wheel drive vehicle. Two diversion weirs supply water to the powerhouse. There is a difference in elevation between them of about six meters. The upper weir diverts water into a steel-lined conduit about 1.8 kilometers long. A surge tower is located at the end of the conduit and two one-kilometer penstocks convey the water from that point to Units 5 to 8 inclusive. The lower weir supplies an open canal approximately 1.2 kilometers long. Two steel penstocks take water from the canal to Units 1 to 4 inclusive.

3.42     At the time of the mission's visit part of the open canal was under reconstruction as a section of about 50 meters had collapsed. The

collapse was probably caused by too-rapid drawdown of water from the canal. Leaks were observed through joints and cracks in other sections of the canal as well as on the steel-lined conduit.

3.43 The powerhouse building at the Chisimba Falls station needs routine repairs. No major maintenance problem was reported with the generating equipment. However, it has been several years since the machines were subjected to general overhaul, including internal inspection of turbines, conduit, surge tanks and penstocks.

#### Musonda Falls

3.44 A regulating dam about eight kilometers upstream of the station provides limited water storage for the station. The dam is leaking badly in a number of places and the leaks are gradually getting worse. The flow of water from the dam to the power station is controlled by manually operated gates. These must be adjusted three to four times a day, making close flow control difficult. The road between the dam and the station is in poor condition and is almost impassable in poor weather conditions. Near the power station itself, a second weir diverts some of the river flow to a canal. The water flow is controlled by gates located at the entrance to the canal. Five separate penstocks convey the water from the canal to the turbines.

3.45 The powerhouse building is in need of replastering and exterior finishing. Several panes of glass in the windows are broken or missing. The temperature inside the powerhouse was very high at the time of the mission's visit. No ventilation fans are installed. The generating equipment was all in operating condition, although several pipe connections and turbine casing joints were leaking. The generating units need maintenance. Unit 1 was reportedly overhauled recently, but preventive maintenance inspections are overdue on the other units.

#### Training Opportunities at the Kafue Gorge Station

3.46 ZESCO's power station staff currently receive only routine on-the-job training. No formal training program is currently being implemented. However, at the Kafue Gorge power station there is a training center that is closed because of a lack of resource personnel. The center was originally used to train ZESCO employees in the operation and maintenance of hydroelectric stations. Many of the staff initially selected for the Kafue Gorge station were successfully trained at the center. The center was closed in 1983. The buildings, including dormitories for the trainees, are still in good condition and could be readily restored to service.

### Recommendations

3.47 The recommendations that follow include some items on which ZESCO is already planning action. These items are identified as such, if known. They are included in this Report in order to provide a complete list of actions needed to correct the deficiencies observed in visits to ZESCO's generating stations. Recommendations for the Lusiwasi and Lunzua stations are based on discussions with ZESCO personnel familiar with them, as the mission did not visit these two installations.

#### Hydrology--Computer Modelling

3.48 The two major generating stations on the ZESCO system, Kafue Gorge and Kariba North, have large storage reservoirs fed from different catchment areas with different hydrological characteristics. Periods of low inflows to these reservoirs do not necessarily coincide. The interaction between the various factors influencing the optimum sharing of power generation between these two stations at any given time is too complex to be effectively evaluated manually. The mission recommends that ZESCO procure a computer program to assist in power scheduling and reservoir management decisions for these stations and train the staff in its hydrology division in the use of the program. The computer program will become increasingly useful as the Cahora Bassa station, downstream of both Kariba and Kafue, is restored to service, and as more and more of the national grids in Africa become interconnected.

#### Civil Works--Inspections

3.49 The mission supports the initiative undertaken by ZESCO to procure professional services for thorough inspection of the civil works of the Kafue Gorge, Kariba North and Victoria Falls generating complexes and of the Itezhitezhi dam. The utility should also consider including the civil works of the smaller hydroelectric plants in the inspection schedules.

#### Foreign Exchange

3.50 The limited availability of foreign exchange has been a major obstacle to ZESCO, making it difficult for the utility to carry out all needed maintenance tasks on its generating plant. The economy of Zambia depends heavily on reliable electric power. Delays in securing foreign funds needed for important maintenance can jeopardize this reliability. The chillers in the Kafue Gorge station provide an example in which the problem of access to foreign exchange has placed the operation of a station at risk. A system needs to be devised to provide ZESCO with ready and timely access to foreign exchange when critical needs develop. This can be done without changing the requirement that ZESCO account to the central bank for its foreign exchange expenditures.

### Training

3.51 The reopening of the Kafue Training Center is recommended. The center could be used for training not only ZESCO employees but also utility workers from neighbouring countries. As most of the infrastructure is already in place, the main funding needs would be to rehabilitate the laboratories and kitchen and for operational costs, including instructors' salaries. At least two of the instructors would probably be expatriates. It is estimated that operating costs would be about US\$300,000 a year, including US\$250,000 in foreign exchange and US\$50,000 in local currency. The initial investment required to reopen the institution would be about US\$250,000, including US\$200,000 in foreign exchange and US\$50,000 in local currency.

### Northeastern System--Study

3.52 When the Pensulo substation is energized, the northeastern system will be interconnected with the main grid. As the 330 kV line between Kabwe and Pensulo is single-circuit, the interconnection cannot be regarded as firm. The hydroelectric generating capacity in the northeastern system is already inadequate to satisfy peak demands under unfavorable hydrological conditions. The economics of the various alternatives of ensuring firm power, such as reinforcement of the tie-line, expansion of hydroelectric generating capacity, continued use of diesels, etc., should be evaluated in a study. The cost of such a study is estimated to be US\$200,000, including US\$150,000 in foreign exchange and US\$50,000 in local currency. Draft Terms of Reference for this study are provided in Annex 7 of this Report.

### Kafue Gorge

3.53 Air Conditioning System. The most critical problem in this station is that there is no operable spare chiller unit for the control room air conditioning system. ZESCO is arranging for the purchase of a new unit with assistance provided by SIDA. As the chillers cannot be rehabilitated in Zambia, the utility should also make arrangements to repair at least one of the unserviceable units so that a spare will always be available. In addition, ZESCO should:

- (a) purchase and install several new fan coil units;
- (b) treat the make up water for the chilled water system to prevent corrosion and scaling; and
- (c) purchase and install new liquid chlorine dosing pumps.

3.54 Electrical. Purchase two spare coils for the generator unit transformers. Investigate the cause of the deformation of the power cables. If necessary, purchase new cable to replace the affected lengths and provide spares.

3.55 Cylinder Gates. Purchase spares for the pistons and other components of the cylinder gates and their operating mechanisms and overhaul each unit.

3.56 Headrace Intake. Extend the deep boom before the intake by adding another section about 200 meters long. This should reduce build-up of weeds along each unit of length of the boom and lessen the chances of the weeds overtopping the boom. Modify the permanently installed trash rack cleaning equipment to make it functionally efficient. Replace the existing bucket with one of sturdier design.

3.57 Civil Works. The mission recommends that ZESCO continuously monitor the head loss in the tunnel and record it on the station log sheets to provide information on the condition of the tunnel.

3.58 Reinforce with structural concrete the weak section of the adit in which the domestic water supply lines are laid. This should be done to ensure the safety of personnel and equipment. The pipelines should be buried beneath a layer of sand at least one meter deep along the entire length of the adit.

3.59 Resurface the roadway between the station and the tailrace and protect it against rockfalls.

#### Kariba North

3.60 The mission has no recommendations to make concerning the operation and maintenance of the Kariba North station. As stated previously (para. 3.32) the station is in excellent operating condition.

#### Victoria Falls

3.61 Intake. Replace the existing boom at the intake with one of more substantial design, such as the one installed at Kafue Gorge. The boom should be at least 200 meters long and be installed more nearly parallel to the direction of river flow than the existing boom. Overhaul the stoplog closure, trash racks, radial gates and penstock gates, including the operating mechanisms. Replace the trash rack cleaning equipment with more effective devices. Repair the personnel elevator to the powerhouses.

3.62 "A" Station. Replace the switchgear and control equipment in the control room with equipment of contemporary design.

3.63 "B" Station. To reduce the risk of further generator winding failures, install surge arresters of the fast acting, metal oxide varistor type at each point of connection between a generator phase terminal and a cable. This is to be combined with phase to phase and phase to earth protection.

3.64     "C" Station. Reconstruct the tailrace basin to provide a greater stilling volume and increase submergence of the turbines to at least five meters. This will solve the vibration problem now being experienced at high loads with the units in this station and allow operation at rated capacity. The cost of this modification, including engineering designs, is estimated to be US\$1.6 million, including US\$400,000 in foreign exchange and US\$1.2 million in local currency. The benefit of the investment will be the recovery of about 10 MW of generating capacity. The flow of water through the station would not be increased beyond the amounts presently approved and for which the station was designed.

3.65     Although ZESCO currently has a surplus of generating capacity, investment in solving the problem of vibration in the "C" station and allowing the units there to operate at their design ratings can be justified as follows: the station is a run-of-river installation and any energy generated there will either require less generation at the Kafue Gorge or Kariba complexes or generation from those stations can be used to displace more expensive power elsewhere. The true value of incremental power from Lake Kariba is the marginal cost of power from the Hwange thermal station in Zimbabwe. However, Zambia cannot reasonably be expected to make an investment from which Zimbabwe is the primary beneficiary. Water in Lake Kariba is to be shared equally between the two countries. Therefore, the minimum value of power from this source should be the tariff at which ZESCO sells incremental energy to Zimbabwe, which is US\$0.006 per kilowatt hour. On this basis, and on the assumption that the increased capacity could be utilized at a capacity factor of 70%, the benefits from the investment would amount to US\$368,000 per annum. At a discount rate of 12% and a useful lifetime of 20 years for the investment the benefits equate to a present value of US\$2.75 million. Rehabilitation of the "C" station would also improve the reliability of power supply to West Zambia and of ZESCO exports to Botswana.

#### Chisimba Falls

3.66     The following actions should be taken at Chisimba Falls:

- make a general overhaul of all generating equipment;
- install circuit breakers with appropriate protective relaying on the high voltage side of all power transformers;
- install a second 3.3/0.4 kV auxiliary transformer for station service;
- maintain the powerhouse building as required;
- regrade and resurface the approach road to the station;
- repair the leaks in the culvert and conduit. Continued leakage may lead to a disastrous breakthrough of water; and

- coat the inner surfaces of the conduit and surge tank with a bituminous seal.

#### Musonda Falls

3.67 The following maintenance work should be undertaken at Musonda Falls:

- overhaul all generating equipment. Unit 1 was most recently done and so should be the last on a new schedule of overhauls;
- install circuit breakers on the two 3.3/33 kV transformers and on the Mwense 33 kV feeder;
- install ceiling fans to improve powerhouse ventilation;
- recondition the powerhouse building;
- regrade and resurface the road between the station and the dam;
- repair dam leaks. They will increase with time if not corrected;
- provide lifting devices to simplify the task of raising the stop gates;
- complete the installation of the footbridge across the dam in order to make the right side of the river more accessible; and
- investigate the feasibility of remotely controlling the flow of water from the dam to the power station.

#### Lusiwasi

3.68 The mission did not visit this station, but relied on a report ZESCO produced in January 1988 on the work needed in that station. Among the major recommendations are:

- implement a comprehensive preventive maintenance program;
- redesign and recommission the remote controls for the gates admitting water to the headrace canal to provide more reliable operation. This system is not currently operational;
- reduce the voltage on the direct current control circuits from 250 V to 220 V; and
- provide isolating devices and fuses for the station service transformers.

3.69 Discussions with other ZESCO staff indicated the need to install circuit breakers for the reactors on the 66 kV lines and to improve the condition of the access roads to the power station and the dam.

Lunzua

3.70 This station was also not visited. Reportedly all machines need complete overhauls and the conduits ought to be inspected. Various leaks in the station and at the air relief valves along the conduit need to be sealed.

Conclusion

3.71 The installed hydroelectric generating capacity in Zambia should be adequate to supply the country's needs until about the turn of the century. In general, with the exception of some smaller stations on the northeastern system, ZESCO's generating plant is well maintained and operated. However, funds must be made available to maintain the power stations in top operating condition. Financial constraints, especially the limited availability of foreign exchange, have prevented the smooth and timely implementation of certain maintenance plans. In the preceding paragraphs, the mission has made recommendations for actions which should improve the efficiency and reliability of Zambia's generating stations. These recommendations are summarized in Table 3.2, on the following page. Also included in the table are estimates of the costs for their implementation.

Table 3.2: HYDROELECTRIC STATIONS RECOMMENDED INVESTMENTS

Item	Project	Priority	Estimated Cost		Ref/Para
			Foreign	Local	
			US\$	US\$	
1	<u>Kafue Gorge</u> . Overhaul and/or replace liquid chillers, fan coil units	1	859,000	250,000	3.24, 3.53
2	<u>Kafue Gorge</u> . Provide spares for transformer coils, high voltage cable, cylinder gate operators, chlorination pumps and other auxiliaries	2	160,000	-	3.25-3.28 3.54-3.56
3	<u>Kafue Gorge</u> . Install additional deep boom section, rehabilitate trash rack cleaning equipment	2	112,000	16,000	3.31, 3.56
4	<u>Kafue Gorge</u> . Repair access roads, reinforce section of intermediate adit	2		35,000	3.29-3.30 3.58-3.59
5	<u>Victoria Falls "A" Station</u> . Replace switchgear and control equipment in control room	2	400,000	50,000	3.34, 3.62
6	<u>Victoria Falls "B" Station</u> . Install surge arresters for each generator phase connection	1	25,000	2,000	3.36, 3.63
7	<u>Victoria Falls "C" Station</u> . Reconstruct tailrace structure to enlarge stilling basin and increase submergence of turbines	1	400,000	1,200,000	3.37-3.39, 3.64
8	<u>Victoria Falls Intake</u> . Install new deep-boom overhaul gates, trash racks, trash rack cleaning equipment	2	120,000	30,000	3.40, 3.61
9	<u>Lusiwasi, Chisimba Falls, Musonda Falls, and Lunzuza</u> . Overhaul mechanical and electrical equipment, refurbish civil works including buildings, repair access roads	2	250,000	140,000	3.41-3.45 3.66-3.70
10	<u>Northeastern System</u> . Undertake study to determine least-cost solution to firm power and energy requirements	3	150,000	50,000	3.52 Annex 7
11	<u>Hydrology</u> . Acquire computer program for modelling reservoir management and power scheduling. Train ZESCO personnel in its use.	2	40,000	10,000	3.48
12	<u>Training</u> . Reopen the Kafue Gorge Training Center	2	200,000	50,000	3.46, 3.51
<u>Total:</u>			<u>2,716,000</u>	<u>1,833,000</u>	

#### IV. TRANSMISSION AND DISTRIBUTION

##### Overview

4.1 This chapter reviews the ability of the existing ZESCO transmission and distribution systems to provide Zambia with electricity service at a level of quality and reliability that can be economically justified. It considers likely expansion requirements and makes recommendations for investments in these systems which will better enable them to satisfy existing demands and the additional loads likely to be experienced in the medium term.

4.2 On the whole, ZESCO's transmission and distribution systems are well designed and the level of supply reliability is high. If they continue to be well maintained and operated, the systems should be able to provide sufficient electricity to respond to demands projected up to the end of this century. However, while the larger lines and substations are generally well maintained, some of the smaller lines and substations are suffering from poor maintenance. Distribution systems in some localities, particularly Lusaka, are overloaded. ZESCO is currently rehabilitating and reinforcing the Lusaka system, with funding in major part from the Finnish International Development Agency (FINNIDA). Other areas, such as Kitwe, also need attention.

4.3 As well as maintaining its transmission and distribution systems to a high level, and rehabilitating those that are overloaded, ZESCO needs to find ways to reduce the cost of customer connections in order to bring electricity to a wider cross-section of the population. Only about 12% of the households in Zambia are connected to the electrical distribution system. Even within Greater Lusaka the overall number of connections is less than 30% of the households. High connection charges are cited as the major factor inhibiting increases in the numbers of consumers in areas which are already served with distribution lines. In rural areas, there are other problems such as the distance of households from the distribution lines.

##### ZESCO's Transmission and Distribution Network

4.4 Like the generating facilities, ZESCO facilities for the transmission and distribution of power in Zambia may be classified into three major categories. These are: (a) the interconnected system; (b) the northeastern region; and (c) the isolated diesel systems. All three groupings are represented on IBRD Map 20984 at the end of this report.

4.5 The interconnected system, by far the largest of the three categories, consists of a 330 kV backbone extending from the major power stations of Kafue Gorge (900 MW) and Kariba North (600 MW) in the south,

through the Leopards Hill substation which supplies Lusaka, on to the mining areas in northcentral Zambia, known as "the Copperbelt". The Victoria Falls generating complex (108 MW) also forms part of the interconnected system via a 220 kV line which ties in with the 330 kV system at the Kafue West substation. The main grid is connected with the Zimbabwean power system by two 330 kV tielines at Kariba. ZESCO exports appreciable amounts of energy to Zimbabwe through these lines. The grid is also interconnected with the Zairian system via a 220 kV link in the north, providing another avenue for exports.

4.6 The northeastern region can be operated as a separate interconnected system, but local considerations often result in it being operated as two or more isolated systems. It obtains its power from five relatively small hydroelectric stations ranging in installed capacity from 12 to 0.75 MW and from a number of diesel generating units. The diesel units are operated only under emergency conditions or during periods of abnormally adverse hydrological conditions. A 330 kV transmission line has been constructed from the Kabwe substation on the main interconnected system to Pensulo. On completion of the 330/66 kV substation at Pensulo, planned for mid-1989, the northeastern region will be fully interconnected with the main grid.

4.7 ZESCO also operates seven small independent diesel-powered systems, whose capacities range from 300 to 900 kW. These isolated stations have high operating costs because the cost of fuel for the generating units is high, the stations are remote from the more densely populated areas, and they cannot benefit from economies of scale.

#### Load Centers

4.8 ZESCO's major load center is in northcentral Zambia, in the Copperbelt. Zambia Consolidated Copper Mines Limited (ZCCM) consumes almost 70% of the power that ZESCO sells in Zambia. ZCCM purchases the power in bulk from ZESCO at 220 kV. The mining group operates its own power system, which includes some generating plant in addition to transmission and distribution. However, ZCCM does not generate power for the ZESCO grid. The second largest load center is the city of Lusaka.

#### System Description

4.9 Seven voltage levels are currently used on the Zambian transmission and distribution systems. These are: 330, 220, 88, 66, 33, 11 and 0.4 kV. Primary distribution lines generally operate at 11 kV. Secondary lines operate at 0.4 kV three phase. However, some secondary circuits are fed from the 33 kV voltage level.

4.10 A transmission line now under construction between Lusiwasi and Chipata via Msoro, scheduled for completion in 1990, will operate at 132 kV, adding another voltage level to the seven listed above.

4.11 330 kV Lines. There are an estimated 1900 kilometers of 330 kV transmission lines currently in service on the ZESCO system. The central point of the main interconnected transmission system is the Leopards Hill substation. Four 330 kV transmission lines (two to each station) connect it directly to the two major generating stations, Kafue Gorge and Kariba North. A fifth incoming 330 kV line provides another connection to the Kafue Gorge and to the Victoria Falls stations through the Kafue West substation. From Leopards Hill three 330 kV lines run to Kabwe. From there, four 330 kV lines run to the Copperbelt, two to Kitwe and two to Luano. Only one line to Luano is currently energized as switchgear installation in the Luano substation is not yet complete. A 330 kV line has been constructed from Kabwe to Pensulo. This was energized but not transmitting power at the time of the mission's visit as the substation at Pensulo was awaiting completion, scheduled for July 1989.

4.12 220 kV Lines. The total length of 220 kV lines on the ZESCO system is 510 kilometers. A 220 kV transmission line emanates from the Victoria Falls substation and runs eastwards to Kafue Town, feeding a substation at Muzuma on the way. In the Kafue Town substation the voltage is first reduced to 88 kV then increased to 330 kV. A 330 kV line about 10 kilometers in length interconnects the Kafue Town and Kafue West substations, incorporating the Victoria Falls stations into the main grid.

4.13 Additional 220 kV lines include those in the Copperbelt between the Luano, Kitwe and Maposa substations. In addition a 220 kV line running from Luano into Zaire interconnects there with the system of the Zairian utility, Société Nationale d'Electricité (SNEL).

4.14 88 kV Lines. The total length of ZESCO's 88 kV lines is currently estimated to be 510 kilometers. A number of 88 kV lines emanate from the Leopards Hill, Kafue Town and Kabwe 330 kV substations. From Leopards Hill three 88 kV lines supply Lusaka and its environs. Single circuit 88 kV lines running in parallel with the 330 kV lines connect Leopards Hill to the Kafue Town and Kabwe substations. These 88 kV lines are energized but not normally loaded as ZESCO does not operate lines in parallel at different voltage levels (in these cases 330 and 88 kV) between two substations. Another 88 kV line from Leopards Hill runs southwards to the Zimbabwe border at Chirundu and supplies a small load in Zimbabwe but is not interconnected with the Zimbabwean system at that point.

4.15 88 kV lines from Kafue Town extend to Mumbwa through Nampundwe and to Mazabuka. From Kabwe an 88 kV supply extends to Mpongwe through Kapirimoshi. There is also an 88 kV extension from the Victoria Falls 220 kV system to the coal mining area at Maamba via the substation at Muzuma.

4.16 66 kV Lines. Approximately 3,100 kilometers of 66 kV lines are now in service on the ZESCO systems. These lines serve to connect larger load centers to the main grid. The line out of Victoria Falls going

westwards to Mongu and Kalabo deserves special mention as a branch from this line supplies certain areas of Botswana close to the border at Kasane. (The Mongu to Kalabo section is currently energized at 11 kV). The various power stations in the northeastern region are also interconnected at 66 kV. This network will be interconnected with the main grid on commissioning of the substation at Pensulo. Construction of the 330 kV line between Kabwe and Pensulo has already been completed.

4.17 33 kV Lines. 33 kV lines are used primarily as trunk lines supplying load centers from substations which are themselves fed from lines operating at higher voltages. The 33 kV voltage level is used extensively in Lusaka to interconnect substations from which 11 kV feeders emanate. It is also the supply voltage for a fairly large number of industrial consumers.

4.18 11 kV and 0.4 kV Lines. The general primary distribution voltage level is 11 kV with 0.4 kV as the three-phase secondary voltage. There are, however, a number of instances in which secondary lines are supplied from the 33 kV system.

#### System Characteristics

4.19 Power Factor. The ZESCO system operates with an average power factor of about 95%, rising to above 96% at times of system peak. The increase with the peak is attributed to the effect of incandescent lighting. The very high average power factor is primarily due to the fact that ZESCO's major consumer, ZCCM, carries out reactive compensation on its own system. The ZCCM system is equipped with synchronous condensers and capacitors. In addition, power factor correction is done at many of the load centers. Other major consumers also exercise power factor control. The long stretches of lightly loaded transmission line in certain areas contribute as well to the high power factor. The Lusaka power factor at peak is generally about 85%, which is lower than generally accepted as being the economic optimum.

4.20 Power Losses. Annex 2 presents the losses calculated from ZESCO's annual reports. The overall level of losses is very low because of the very high percentage of total distributed energy that is sold to ZCCM at 220 kV immediately after transformation from 330 kV. For the financial year 1987/88 total losses on the retail system amounted to 15.4% in the south and 5.5% in the Copperbelt, for an overall average of 12.2%. The reliability of these loss values is suspect, as they fluctuate widely from year to year and because they appear low in view of the acknowledged relatively high level of nontechnical losses. Inaccurate instrumentation is believed to contribute to errors in the records from which the losses in Annex 2 are calculated. The mission observed a number of instances in the Leopards Hill and other Lusaka substations in which the values indicated by instruments measuring power inflows did not correspond with those indicating outflows. These observations apply to indicating instruments and are not necessarily true of the integrating instruments used to generate energy consumption records. Nevertheless,

they demonstrate that substation instruments are not being regularly calibrated and therefore the accuracy of all instruments, indicating as well as integrating, is suspect.

4.21 The mission's calculations for the Lusaka system indicate that technical losses amounted to 9.6% of the energy fed into the system in the financial year 1985/86. The technical losses were calculated to be distributed as shown in Table 4.1.

Table 4.1: LUSAKA DISTRIBUTION SYSTEM LOSSES  
(1985/86)

Peak Demand : 118 MW.	Energy Input 588.1 GWh			
	Losses at Peak (MW)	% of Peak Demand	Annual Energy Losses (MWh)	% of Energy Input
88 kV subtransmission lines and 88/33 kV transformers	4.0	3.4	16550	2.8
33/11 kV transformers:				
No local losses	0.3	0.3	3040	0.5
Local Losses	0.3	0.3	820	0.1
33 kV lines	2.2	1.9	6500	1.1
11 kV lines	4.4	3.7	12200	2.1
11/0.4 kV transformers:				
No local losses	0.6	0.5	4820	0.8
Local losses	1.1	0.9	3120	0.6
Secondary lines and service drops	<u>5.1</u>	<u>4.3</u>	<u>9380</u>	<u>1.6</u>
Total Technical Losses	18.0	15.3	56,430	

Source: Mission calculations.

4.22 These calculations are approximate only as the information required for more accurate calculations was not immediately available. Single-line diagrams are incomplete. The energy consumption of the entire Lusaka system is metered at the Leopards Hill substation only. The loading of individual feeders is checked annually but the probability is that these checks will not coincide with the absolute peak demand on each feeder. Work is now in progress installing transducers which will provide remote indication of feeder loadings in the Regional Control Center. Once this work is completed, the information flow will be greatly improved.

4.23 Because it has excess capacity in generating and transmission plant and its source of energy is hydropower, ZESCO has had no great financial incentive to reduce technical losses. The greatest benefit that would now result from technical loss reduction measures would be the deferment of investment in distribution in the medium term. However, ZESCO's design standards do not currently evaluate cost of losses in the design of distribution systems.

#### Transmission Expansion

4.24 The capacity of the main transmission system (330 kV and 220 kV lines and substations) is adequate to satisfy the projected power demand up to the year 1998 even under the most optimistic forecasts now considered. Load flow calculations were made for the main 220/330 kV grid under the following assumptions:

- (a) no change in the existing 220/330 kV grid except that the fourth Kabwe/Copperbelt line will be in service;
- (b) no significant load on the Kabwe - Pensulo line;
- (c) no exports to Zaire during periods of maximum Zambian demand;
- (d) the maximum current on each 330 kV conductor is 600 amperes;
- (e) the maximum conductor temperature rise is 50°C above ambient; and
- (f) the voltage at all busbars is maintained above 90% of nominal.

4.25 The studies show that, at the loads forecast for 1998, the 330 kV lines between Leopards Hill and Kabwe will be operating at their maximum rated capacity. If the load growth turns out to be more rapid than that assumed in the forecast it may be necessary to install additional transmission capacity between Leopards Hill and Kabwe or, alternatively, between Kafue West and Kabwe. This could conceivably be done via a new substation located to the west of Lusaka.

4.26 The cost of energy from the isolated diesel systems is very much higher than from the main grid or from the northeastern region. It is therefore desirable that these systems be interconnected whenever economically feasible. However, the mission's calculations show that the distances over which transmission lines would have to be run are so great and the demands in the areas now supplied by the diesel stations so relatively low, even under the most favorable assumptions of increases in demand, that it will be uneconomic to integrate any of these isolated systems into the interconnected system before the turn of the century.

### Distribution Expansion

4.27 The Zambian distribution systems in major urban centers consist of both overhead lines and underground cables operating at primary voltage levels of 33 and 11 kV. The secondary phase-to-phase voltage is 0.4 kV. In urban areas, distribution transformers rated at 300 kVA or above are pad mounted. Feeder pillars are used for the low voltage distribution. Transformers of less than 300 kVA are pole mounted. In rural areas, overhead distribution systems are used. In all of Zambia about 25% of the total length of distribution lines is run underground and 75% overhead. Although 98% of all consumer connections are single phase, the low voltage network is almost all three phase.

4.28 Annex 8 presents an assessment of ZESCO's investments in the distribution system. The existing relatively high standard of construction results in investments averaging US\$4,500 per consumer connection, including the underground cables and distribution transformers. In rural areas with overhead lines and pole mounted transformers the cost per consumer is US\$1,730. These rather high rural costs result from the fact that the consumers are sparsely distributed, and the number of connections per kilometer of lines is correspondingly low. Also, the average house is located an appreciable distance from the lines along the roadway, making fairly long service drops necessary.

4.29 A contributory factor to the high cost of distribution service is the fact that ZESCO pays import duty and sales tax on all foreign material used in its construction projects, except those which will serve government ventures. Rural electrification extensions are sometimes exempted, but specific application must first be made. Duties and taxes increase the cost of imported material by about 30 to 60% of the landed cost. Farmers are not required to pay these duties and taxes. The financial cost of extensions to farms is therefore much lower if the farmer, and not ZESCO, undertakes responsibility for construction of the line.

### Lusaka Subtransmission System

4.30 Lusaka is important in any consideration of distribution expansion as it already constitutes more than 25% of ZESCO's total consumer base and its greater urban areas offer the best prospects for significant increase in the number of residential consumers. The supply system to consumers in Lusaka is currently overloaded below the 330 kV level and requires major investments in the near future. The firm capacities of the 330/88 kV transformers now installed in the Leopards Hill substation and of the three 88 kV subtransmission lines supplying Lusaka are lower than the current maximum demand of the city and its surrounding areas. Sections of the 33 kV distribution ring main inside the city are also overloaded. There are only two injection points for that system, the Coventry Street and Waterworks substations, but the area to be supplied and the total load continue to grow.

4.31 A number of studies by ZESCO's own Engineering Services Division and by external consultants,<sup>9/</sup> have investigated the question of the optimum reinforcement and expansion of the Lusaka distribution system. The later studies support the establishment of a 132 kV injection point on the perimeter of the city and the gradual extension of the 132 kV system to replace the 88 kV ring. Implementation of the first phase of this proposal will begin in mid-1988, with funding provided by FINNIDA. The mission supports the project, but wishes to emphasize the need for additional investigations such as load flow calculations, short circuit studies, etc., for each of the various stages of implementation.

4.32 The advantage of using the 132 kV operating voltage is that for a given conductor size the carrying capacity of a line is more than double its capacity when operated at 88 kV. It has been determined that the existing 88 kV line structures can be modified for 132 kV operation for a relatively modest investment if compared to the cost of constructing an entirely new line. A further consideration is that 132 kV is an international standard voltage, which 88 kV is not. Equipment bought for 88 kV, such as switchgear or breakers, is most often designed for operation at 132 kV or above. ZESCO therefore pays the 132 kV price without obtaining the benefits of increased power carrying capacity which would come with the higher voltage operation.

4.33 The frequency of faults on the 88 kV system is high, causing approximately ten line trips each year. Construction of the new 132 kV subtransmission line and rehabilitation of the existing 88 kV lines to operate at 132 kV will improve the reliability of supply to Lusaka. The distribution system should then be well endowed to accommodate increased demands until the end of the present century. Although Lusaka will still be dependent on the single 330 kV substation at Leopards Hill for its supply, the reliability of the 330 kV supply to Leopards Hill is very high. The construction of a new separate 330 kV substation, such as that proposed for Lusaka West, cannot be economically justified on the basis of reliability or load demand.

4.34 The first 132 kV line and substation will not be constructed and commissioned for another two years at least. Until then, if the breaker controlling the bank of two 330/88 kV transformers, (one each of 90 MVA and 60 MVA), were to trip, the remaining 90 MVA transformer would not be capable of satisfying the city's peak demand. ZESCO plans to

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<sup>9/</sup> Reference studies were: (a) "Report on the Short Term Reinforcement of the Power Distribution System of Lusaka" by Engineering Services Division, ZESCO, Oct. 1987; (b) "Lusaka Power Distribution Project Prefeasibility Report" by FINNIDA, Finland, Sept. 1987; (c) "Lusaka Power Distribution Project" by IVO International, Finland, Dec. 1986; (d) "Power System Master Plan for Zambia" by Ekono, Finland, May 1985; and (e) "Lusaka 33 kV and 11 kV Reticulation Study" by Zambia Engineering Services Ltd., England, July 1982.

install a second 60 MVA, 330/88 kV transformer in parallel with the 90 MVA unit which now stands alone. This is considered not only as an increase in the firm capacity of supply to Lusaka but also as insurance against unexpectedly steep rises in the Lusaka demand and/or delays in the upgrading of the subtransmission system to 132 kV. However, in view of the intention to upgrade the supply to Lusaka from 88 to 132 kV, new investment in 330/88 kV transformers should be avoided wherever reasonably possible. It may be more economic to purchase and install separate breakers and switchgear for the 90 and 60 MVA units now operated in parallel. This would have the effect of increasing the firm transformer capacity to 150 MVA and would not involve the purchase of any equipment which is likely to become redundant in the short to medium term.

#### Lusaka Distribution System

4.35 The present distribution system in Lusaka consists of a 33 kV grid comprising a mixture of underground cables and overhead lines interconnecting nine substations that supply the 11 kV system. The 33 kV system is operated as a closed ring with a number of radial spurs feeding smaller 33/11 kV substations. Major substations have two transformers, each with a rated capacity greater than the peak demand on the substation. The exception to this pattern is the Dublin Road substation, where peak load is 94% greater than the capacity of a single transformer. The breakers must be sectionalized to relieve the load on the 11 kV feeders from Dublin Road whenever one of the transformers trips.

4.36 The 33 kV feeders are equipped with differential-type relays for short circuit, earth fault and overcurrent protection. These relays need frequent maintenance and adjustments to avoid spurious trips on the 33 kV system. Extensions of the 33 kV ring in future will increase the complexity of operation and make greater demands on the attention of the maintenance personnel.

4.37 The 11 kV system comprises an underground ring network and overhead lines with about 2200 transformers supplying approximately 32,000 consumers through the 400 V system.

4.38 The physical condition of most of the 33/11 kV substations is poor. Spares, particularly breaker spares, are unavailable. Following a fire in February 1985, the Coventry Street substation was restored to service after only essential repairs had been made. Since then further repairs have been undertaken and new 11 kV switchgear installed, but the station is still unreliable and urgently needs further rehabilitation. New 33 kV switchgear should be purchased and installed.

4.39 The poor condition of the substations is not due to age alone. They have also been neglected and vandalized. Many instruments indicate inaccurately or are completely nonfunctional. The locks on most doors to switchgear rooms and the latches for the windows are either broken or missing. Many furnishings or items of equipment, such as

bulbs, switches, electrical outlets, telephones and construction material have been stolen.

4.40 Table 4.2 is a listing of the short term reinforcement needed on the Lusaka distribution system. This table includes the projects developed by FINNIDA and ZESCO's Engineering Services Division as well as recommendations of the mission.

Table 4.2: COMPONENTS AND COSTS OF THE LUSAKA DISTRIBUTION PROJECT

Components	Cost (US\$ million)
<b>A. FINNIDA Phase I:</b>	
1. Establishment of a new Roma 132/33 kV, 2x40 MVA, and 33/11 kV, 2x10 MVA substation including 27.2 km 132 kV transmission line, Leopards Hill-Roma	5.1
2. Establishment of a new 132/33 kV, 2x40 MVA and 33/11 kV, 2x20 MVA substation at Coventry and 330/132 kV, 2x125 MVA extension at Leopards Hill including uprating 28.5 km of existing 88 kV Leopards Hill-Coventry line to 132 kV.	11.4
3. Load transfer, rehabilitation and reinforcement of 33/11 kV substations at Chelston, Dublin and University including 33 kV connections to Roma	3.0
4. Extensions, reinforcement and rehabilitation of 11 kV distribution system in Lusaka.	3.1
5. Engineering and supervision for Phase I above Subtotal	<u>2.6</u> <u>25.2</u>
<b>B. Other Projects:</b>	
6. Add 88/33 kV, 30 MVA transformer at Chongwe substation	1.6
7. Add 330/88 kV, 60 MVA transformer at Leopards Hill substation	1.0
8. Replace 33 kV switchgear at Coventry St. substation	0.5
9. Change feed point of Chisamba load to Chongwe substation	0.6
10. Add 88/33 kV, 30/45 MVA transformer at Waterworks substation Subtotal	<u>1.0</u> <u>4.7</u>
Total	29.9

Sources: FINNIDA, ZESCO, Mission.

### Kitwe and Ndola Distribution Systems

4.41 The predominant voltage used in the Northern Division for supply to the major load centers is 66 kV. The 66 kV systems are operated radially, although sometimes alternative lines effectively form open ring circuits. The relatively high capacity of the subtransmission and distribution systems and the fact that the load growth projected for most of these areas is lower than that for the southern areas means that only minor reinforcements are required in the north by the end of this century.

4.42 The type of switchgear used in Ndola and other Copperbelt substations is no longer in production, and spares cannot be obtained. This problem is especially acute because of the large number of faults that occur in these substations.

4.43 The industrial and residential areas of Ndola have been experiencing increases in load demand higher than the average for the northern system. Investments are needed to reinforce the underground ring main in the industrial area and to provide additional distribution transformers to satisfy the growing residential demand.

4.44 The reliability of supply to the town of Kitwe is jeopardized as there is only one bulk supply point for most of the industrial and residential areas. The resulting lack of operational flexibility in the distribution system has caused prolonged outages when faults occur on one or more feeders. ZESCO plans to improve the security of supply to Kitwe by the establishment of another substation to provide an additional energy injection point for the 11 kV system.

4.45 In Ndola and Kitwe poor communication facilities affect both the operational reliability of the stations and the efficiency with which system faults are detected and corrected. The average duration of outages is thereby increased. The telephone and radio communication systems should be improved.

### Recommendations

4.46 ZESCO's priority must be to increase the number of economic consumer connections and thereby increase the system power demand and energy consumption. Considerable investment has been made in generating and transmission facilities. These are now underused although the percentage of Zambian citizens enjoying the benefits of electricity is very low. An EAP household energy survey which is now underway in Zambia will provide indications of the ability and willingness of potential consumers to pay for electricity services. The major factors restricting more widespread electrification are:

- (a) technical standards of design for the distribution system are higher than needed to provide good-quality service;
- (b) connection costs, and the deposits required from consumers, are too high;
- (c) ZESCO operates under severe financial constraints, in local and foreign currency, and;
- (d) the material required for distribution extensions is not readily available.

4.47 The high investment now required to supply the average consumer from the distribution system is, in part, a result of the technical standards to which ZESCO'S distribution systems are designed. Annex 8 shows that even without modifying the existing design standards, the average cost of serving a consumer on the distribution system would be halved if only overhead line construction were used. Even this lower figure could be reduced by a further 50% if low construction costs were made an objective of distribution system design. The mission recommends that ZESCO engage consultants to review the design standards and prepare modifications that will lower the cost of consumer connections while providing an economic level of reliability. Draft Terms of Reference for this study are included with this report in Annex 9. The estimated total cost is US\$122,000, of which US\$105,000 would be in foreign exchange and US\$17,000 in local currency.

4.48 The contribution required from a new consumer before electricity supply is provided can be reduced not only by lower-cost line construction but also by including an appropriate contribution to the capital investment in the electricity tariffs. The existing tariffs do not now specifically include such a contribution. It is also recommended that ZESCO consider instituting a system of credit for residential connections to permit affordability by a larger number of new consumers.

4.49 Another major factor in ZESCO's high distribution investment costs is that the utility is required to pay duties and taxes on imported material, thereby increasing their landed cost substantially. This requirement by the Government makes it difficult for ZESCO to achieve the Government objective of increasing the percentage of electrified households. The Government is recommended to verify the appropriateness of the tax levels in the light of similar taxes paid by industry generally, and to review the need for other measures for reducing the impact of these duties and taxes on poorer households. More widespread electrification would increase the quality of life of Zambia's citizens and reduce the rate of deforestation, since fewer households would then have to rely on wood as the fuel for domestic cooking.

4.50 The Lusaka distribution system is being well provided for by ZESCO, with assistance from FINNIDA. Completion of this project is necessary before the number of consumers in the Lusaka area can be

significantly increased. However, the mission recommends that thorough load system analyses (load flow studies, short circuit calculations, etc.,) be carried out before implementation of the project becomes too far advanced. The establishment of a second 330/132 kV substation, such as the much discussed Lusaka West substation, is not considered a priority in the medium term. The economics of the Lusaka West substation should be re-examined when the capacity of the 330 kV supply to Lusaka must be increased.

4.51 It is expected that existing substations, including buildings and fittings, will be properly renovated during the rehabilitation and reinforcement project. The substations should be better secured against unauthorized entry.

4.52 Despite the relatively low power factor on the Lusaka system, installation of capacitors for power factor correction is not recommended. The rehabilitated system will provide adequate voltage regulation and low energy losses. However, following the rehabilitation ZESCO should closely monitor the power factor of the Lusaka system and frequently evaluate the costs and benefits of power factor correction.

4.53 The mission's recommendations for the Copperbelt area, and their estimated costs, are itemized in Table 4.3.

Table 4.3: COMPONENTS AND COSTS OF THE NORTHERN SYSTEM PROJECTS

Components	Cost (US\$ million)
1. Replacement of obsolete HV and MV switchgear at Ndola and Kitwe	2.6
2. Replacement of obsolete HV and MV switchgear elsewhere in the Copperbelt	3.8
3. Replacement of underground cable at Ndola industrial area	0.6
4. Reinforcement of existing substation in Ndola industrial areas	0.1
5. Improvement of telephone and radio communication	0.5
Total	7.6

Source: ZESCO Northern Division.

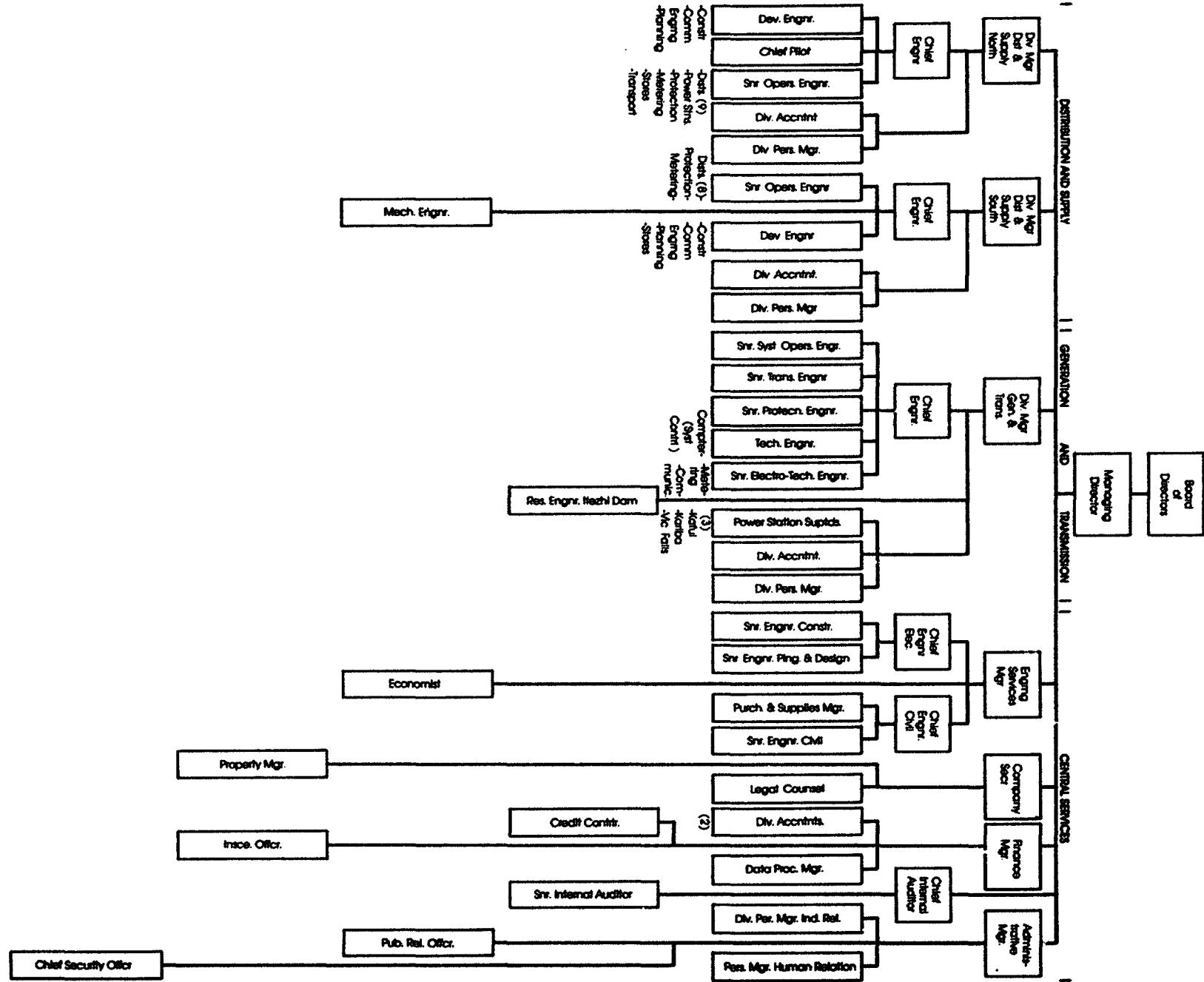
#### Conclusion

4.54 ZESCO's transmission and distribution systems are well designed and, in the main, adequate to supply existing needs. The level of supply reliability is high and expansion to serve future demands should also pose no serious problems. The transmission system has ample reserve to accommodate demands projected for the turn of the century. The 330 kV lines and substations are very well maintained. Stations operating at

lower voltage generally need improved maintenance. The distribution systems in certain specific localities, particularly in Lusaka, are overloaded. Lusaka's needs are being addressed by ZESCO and FINNIDA, but there are other areas, such as Kitwe, which need attention.

4.55 The main thrust in the area of transmission and distribution should be reducing the costs of serving new consumers to a level which will make electricity available to a much wider cross section of the population. This objective will require ZESCO to review its technical designs and its tariffs and the government to provide relief from import duties and sales taxes on the material required for system expansion.

**ZAMBIA ELECTRICITY SUPPLY CORPORATION LIMITED**  
**Organization Chart**



ZAMBIA ELECTRICITY SUPPLY CORPORATION

GENERATION AND SALES DATA. 1980 TO 1987.

		MAIN GRID							
		1980/81	1981/82	1982/83	1983/84	1984/85	1985/86	1986/87	1987/88
<b>NET GENERATION</b>	(GWh)								
Kafue Gorge		4669.2	5082.0	5586.1	5151.6	4676.9	5594.3	5436.5	4407.4
Kariba North		3856.6	4072.3	3779.3	3788.0	3995.7	3475.2	3335.9	2782.8
Victoria Falls		452.4	556.0	768.3	769.2	755.6	679.5	697.4	623.5
Total		8978.2	9710.3	10133.7	9708.8	9428.2	9749.0	9469.8	7813.7
<b>EXPORTS</b>	(GWh)								
		3156.6	3531.0	3792.2	3311.6	3038.4	3409.6	2756.2	1036.2
<b>ZAMBIAN BULK SALES</b>	(GWh)								
ZCCM		4026.2	4190.1	4257.2	4292.6	4249.3	4137.8	4465.3	4459.0
ZESCO South		931.6	1073.4	1173.3	1216.9	1211.3	1221.3	1287.6	1361.2
ZESCO North		576.4	587.2	601.9	605.6	611.3	636.2	653.6	655.8
Total		5534.2	5850.7	6032.4	6115.1	6071.9	5995.1	6406.5	6476.0
<b>HIGH VOLTAGE LOSSES</b>									
GWh		287.4	328.6	309.1	282.1	317.9	344.3	307.1	301.5
%		3.2	3.4	3.1	2.9	3.4	3.5	3.2	3.9
<b>RETAIL SALES</b>	(GWh)								
ZESCO South		781.4	815.6	1032.4	1044.4	1089.0	1057.3	1097.1	1152.1
ZESCO North		571.2	537.1	549.6	569.1	575.3	567.3	627.8	619.6
Total		1352.6	1352.7	1582.0	1613.5	1664.3	1624.6	1724.9	1771.7
<b>RETAIL LOSSES</b>									
ZESCO South (GWh)		150.2	257.8	140.9	172.5	122.3	184.0	190.5	209.1
%		16.1	24.0	12.0	14.2	10.1	13.4	14.8	15.4
ZESCO North (GWh)		5.2	50.1	52.3	36.5	36.0	68.9	25.8	36.2
%		0.9	8.5	8.7	6.0	5.9	10.8	3.9	5.5
Total (GWh)		155.4	307.9	193.2	209.0	158.3	232.9	216.3	245.3
%		10.3	18.5	10.9	11.5	8.7	12.5	11.1	12.2
<b>OVERALL LOSSES</b>									
GWh		442.8	638.5	502.3	491.1	476.2	577.2	523.4	546.8
%		4.9	6.6	5.0	5.1	5.1	5.9	5.5	7.0

Source: ZESCO. Finance Dept.

Data Applicable for Supply from Main Grid Only.

ZAMBIA ELECTRICITY SUPPLY CORPORATION LIMITED

Electricity Tariffs

In accordance with Section 12 of the Electricity Act, Chapter 811 of the Laws of Zambia, notice is hereby given that from 1st January 1988 fixed, maximum demand and energy charges will be as given below. The bills based on the new charges should therefore be received by consumers in February 1988.

ENERGY TARIFFS L AND E

Tariff-L	A	B	C	D	E	F	G	H	I	J	K	L
Load Limiter Rating: Amperes	1	1.5	2	2.5	3	5	6	7	7.5	10	12.5	15
Monthly Charges:	4.6	5.4	6.3	6.5	7.7	11.1	14.8	16.1	17.5	21.7	25.9	29.4
<u>Tariff E1 - Restricted to 5 Amperes single phase:</u>												
	Fixed monthly charges:											2.50 Kwacha
		Unit charge:										7.00 Ngwee
<u>Tariff E2 - Restricted to 15 Amperes single phase:</u>												4.90 Kwacha
		Fixed, monthly charge:										7.00 Ngwee
<u>Tariff E3 - Domestic Only: Unrestricted single phase and up to 15 kVA three phase:</u>												15.00 Kwacha
		Fixed monthly charge:										7.00 Kwacha
<u>Tariff E3H (hydro)</u>												1/-
<u>Tariff E3D (diesel)</u>												2/-
<u>Tariff E4 - Commercial Only: Unrestricted single phase and upto 15 kVA three phase:</u>												71.50 Kwacha
		Fixed monthly charge:										10.14 Ngwee
<u>Tariff E4H (hydro)</u>												1/-
<u>Tariff E4D (diesel)</u>												2/-

MAXIMUM DEMAND TARIFF D

<u>Tariff D1 - Maximum Demand less than 300 kVA:</u>	Fixed monthly charge	91.00 Kwacha
	M.D. Charge per kVA per month:	15.43 Kwacha
	Unit charge:	6.89 Ngwee
<u>Tariff D1H (hydro)</u>		1/-
<u>Tariff D1D (diesel)</u>		2/-
<u>Tariff D2 - Maximum Demand from 300 to 2000 kVA:</u>	Fixed monthly charge:	1,722.50 Kwacha
	M.D. charge per kVA per month:	13.81 Kwacha
	Unit charge:	5.33 Ngwee
<u>Tariff D2H (hydro)</u>		1/-
<u>Tariff D2D (diesel)</u>		2/-
<u>Tariff D3 - Maximum Demand over 2000 kVA:</u>	Fixed monthly charge:	17,225.00 Kwacha
	M.D. charge per kVA per month:	11.80 Kwacha
	Unit charge:	3.51 Ngwee
<u>Tariff S1 - ZESCO Staff:</u>	Fixed monthly charge	0
	Unit charge	1.5 Ngwee

Surcharges on isolated networks: Tariffs E3, E4, and D will attract surcharges as follows:

- 1/ (a) The 20% surcharge on isolated networks fed from hydroelectric sources.  
2/ (b) The 150% surcharge on isolated networks fed from diesel power stations.

Security Deposits:

(a) Restricted supply (maximum 5 Amperes)	30.00 Kwacha
(b) Restricted supply (over 5 Amperes)	50.00 Kwacha
(c) Unrestricted Domestic	200.00 Kwacha
(d) Other consumers (excluding M.D. consumers)	500.00 Kwacha

Reconnection Charge: 100.00 Kwacha

Meter Testing Charges: 30.00 Kwacha

Inspection Installation Charges:

(a) Residential Houses	50.00 Kwacha
(b) Commercial and Industrial Premises	90.00 Kwacha

Government Sales Tax: 15 Per Cent

ZAMBIA ELECTRICITY SUPPLY CORPORATION LIMITED

Consumers per Tariff Category

Financial Year 1987/88

TAR	Number of Consumers	kWh '000s Units	Revenue K '000s	kWh per Consumer	Revenue per Consumer	K per kWh
LA	1,824	2,460	307	1,350	170	0.12
LB	159	74	10	450	60	0.14
LD	108	74	8	700	70	0.11
LF	4,418	3,215	588	750	130	0.18
LI	368	788	77	2,150	210	0.10
LL	50	215	17	4,300	340	0.08
<b>Subtotal</b>	<b>6,927</b>	<b>6,826</b>	<b>1,007</b>	<b>1,000</b>	<b>150</b>	<b>0.15</b>
E1	2,918	2,545	269	900	90	0.11
E2	16,066	31,810	3,479	2,000	220	0.11
E3	68,396	393,578	38,506	5,750	560	0.10
E3H <u>a/</u>	4,798	20,110	2,709	4,200	560	0.13
E3D <u>b/</u>	293	783	263	2,650	900	0.34
E4	9,542	79,590	13,171	8,350	1,380	0.17
E4H <u>a/</u>	1,529	10,122	2,341	6,600	1,530	0.23
E4D <u>b/</u>	132	524	346	3,950	2,620	0.66
<b>Subtotal</b>	<b>103,674</b>	<b>539,062</b>	<b>62,084</b>	<b>5,200</b>	<b>600</b>	<b>0.12</b>
D1	2,272	241,897	30,728	106,450	13,540	0.13
D1H <u>a/</u>	242	27,843	4,471	115,050	18,480	0.16
D1D <u>b/</u>	26	3,045	1,159	117,100	44,580	0.38
D2	222	260,561	26,624	1,173,700	119,930	0.10
D2H <u>a/</u>	22	20,571	3,258	935,650	148,090	0.16
D3	37	602,925	38,420	16,295,250	1,038,380	0.06
<b>Subtotal</b>	<b>2,821</b>	<b>1,157,442</b>	<b>104,660</b>	<b>410,300</b>	<b>37,100</b>	<b>0.09</b>
S1 <u>c/</u>	1,535	7,740	101	5,050	70	0.01
<b>Total</b>	<b>114,957</b>	<b>1,710,470</b>	<b>166,852</b>			

a/ Consumers supplied from the isolated hydro system.

b/ Consumers supplied from the isolated diesel systems.

c/ ZESCO staff

Source: ZESCO.

## TERMS OF REFERENCE

### ELECTRIC UTILITY BILLING SOFTWARE

#### Introduction

Zambia Electricity Supply Corporation Limited (ZESCO), the national electric utility of the Republic of Zambia, is soliciting proposals from data processing consultants for the development, installation, and implementation of software to address a wide range of functions of the Consumer Services Department. The functions involved include, but are not limited to:

- consumer billing
- receivables reporting
- statistical reporting
- consumer file maintenance
- meter inventory

#### Scope of Work

The firm chosen to undertake the work, hereinafter referred to as the "Consultant", will be required to undertake the work in four phases as follows:

- (1) program development;
- (2) program installation and testing;
- (3) personnel training and program shakedown; and
- (4) program support.

Phases (1) and (4) will be executed primarily in the Consultant's home offices while phases (2) and (3) will be undertaken in ZESCO's offices.

#### Program Development

The Program must be developed for use on ZESCO's DEC VAX 8250 and Microvax II computers and support data inputs from a maximum of 40 separate terminals. Its minimum requirements in each of the functional areas will be as listed below.

- Consumer billing:
- printing of meter reading sheets
  - interactive meter reading entry and editing
  - calculation of estimated readings
  - support of multiple account types, consumer groups, and tariff rates
  - automatic bill calculation and printing

- on-line updating of consumer master and historical data
- step-by-step controlled processing
- mid-period meter change processing
- final bill processing independent of meter reading cycle
- identification of consumption on suspended accounts
- detailed statistical and control reports, including:
  - (a) consumption proofs;
  - (b) billing register reports; and
  - (c) automatic generation of meter maintenance work orders.

**Receivables:**

- recording and processing of cash receipts from multiple locations
- recording receipts and refunds of deposits
- security controlled on-line cash receipts processing
- identification of cash and check transactions
- receipt printing
- automatic updating of consumer balance
- detailed end-of-day processing and reporting, including:
  - (a) cashier summaries with transaction listings; and
  - (b) bank deposit summary listing.

**Statistical:**

- monthly sales and revenues summaries
- aged trial balance and debtors analysis reports
- consumer disconnection listings
- detailed consumption analysis reports

**File maintenance:**

- security-controlled on-line consumer masterfile and rate file maintenance
- controlled file reorganization to disregard obsolete records
- multi-copy file back-up and recovery

**Meter Inventory:**

- meter masterfile maintenance and reporting
- interactive meter change facility
- automatic interface to the billing subsystem

The program must include an on-line account inquiry facility which is capable of displaying the masterfile account and status information together with the last 24 account transactions and consumptions. The search facility must allow the user to identify and display the record of a particular consumer from a minimal amount of information such as: name, address, account number or meter number. Preparation of a duplicate bill must be possible on user request.

#### Program Installation and Testing

The Consultant will send a competent staff member to Zambia to install and test the program on ZESCO's computer. ZESCO's staff will work along with the Consultant during this phase of the work and will be trained in the program's characteristics and operation. Normal billing processes must not be disrupted by any of these activities. After the program has demonstrated its satisfactory performance by a minimum of one complete cycle of error-free bill preparation for the entire consumer listing, it will be adopted as the regular billing program.

#### Personnel Training and Observation of Program Functioning

Some training of ZESCO's employees will take place in the installation and testing phase of the Project. Nevertheless the Consultant will be required to keep personnel on-site after the program has begun regular operations to train a larger number of ZESCO staff and to ensure that the software is properly understood and operated. The Consultant's representative will also scrutinize the functioning of the program and make such modifications as may be necessary to ensure its complete compliance with ZESCO requirements. This period will be a minimum of three months or until such time as the program's performance is acceptable. If problems with the program require the Consultant to extend the stay of his representative beyond three months, the cost of that extension will be borne entirely by the Consultant.

#### Program Support

The Consultant will provide free telephone assistance to resolve problems encountered in the application of the software for a period of 12 months after the departure of his representative from Zambia following program installation and observation. If requested by ZESCO, and within seven days of such request, the Consultant will send a representative to Zambia to assist in any problems which cannot be resolved by telephone. Unless it can be unequivocally demonstrated that the problem resulted from defective software development or installation, the direct cost of the representative's visit to Zambia as well as his time charges will be borne by ZESCO. The man-hour rates of service representatives will be as stated by the Consultant in his proposal.

Program Documentation

The Consultant will submit six copies of manuals providing source listing and detailing the structure of the program, including instructions on its operations and maintenance.

Hardware

The provision of hardware is not included in the Consultant's scope of work.

ZESCO's Responsibilities

ZESCO will provide:

- (a) data concerning hardware, consumer base, consumer groupings, tariff rates, and all other information relevant to the satisfactory development and implementation of the project;
- (b) office accommodation, clerical and secretarial support, and telecommunication facilities for the Consultant's staff while working on the project in Zambia;
- (c) access to all equipment and locations relevant to the project, provided always that the Consultant shall give a minimum of one-day's notice when requiring access to the computer or other equipment involved in the preparation and distribution of consumer bills and that priority will be given to the execution of billing operations. However, ZESCO will not unnecessarily delay the project and will make all reasonable efforts to expedite compliance with the Consultant's requests; and
- (d) a two-person project team of competent data processing personnel to work full-time with the Consultant during his work in Zambia.

Guidelines for the Proposal

The Proposal should provide for implementation of the project as described in the Scope of Work. It should provide details of the following:

- (a) previous experience in similar projects undertaken within the last five years, giving the name of the organization for which the work was performed and, for each organization, the name and title of a person who could be consulted for reference;

- (b) curricula vitae of staff who will be assigned important responsibilities for the project in the Consultant's offices as well as in the field, stating the intended role of each individual. During execution of the Project, involvement of persons other than those named for specific tasks in the proposal will require ZESCO's prior approval;
- (c) a work plan and project schedule, in weeks, indicating the location in which each aspect of the work is to be performed and the personnel to be assigned;
- (d) a statement of man-hour rates for services to be provided subsequent to installation and observed satisfactory operation of the program; and
- (e) a proposed schedule of payments which links progress payments to clearly defined and objectively identifiable performance targets.

The Consultant's cost and fees proposal is to be included with the rest of the Proposal in a separately sealed envelope. The cost elements, which are firm, are to be clearly indicated and the factors which can affect variable costs are to be stated along with a statement as to the effect which these factors can have on the relevant costs.

#### Timing

Proposals for performance of the work are to be submitted in sealed envelopes to ZESCO's head office: Great East Road, Lusaka, Zambia, not later than (\_\_\_\_\_), 1989. Envelopes are to be addressed to the Managing Director and are to be conspicuously marked "Proposal for Billing Software".

ZESCO will complete evaluation of the proposals on or before (\_\_\_\_\_), 1989 and will begin negotiations with the firm which submitted the most highly evaluated proposal. If mutually satisfactory terms and conditions cannot be agreed on within four calendar weeks, ZESCO may proceed to negotiate with other firms. ZESCO may, at its sole discretion, reject any or all of the proposals received.

The date of contract-signing will be considered as the starting date of the project and will be used as the milestone by which the progress of the project will be measured.

#### Form of Contract

The contract to be awarded to the successful firm will be based on the International Model Form of Agreement Between Client and Consulting Engineer, Number IGRA 1979 P.I., produced and issued by the International Federation of Consulting Engineers (FIDIC).

Inquiries

Firms requiring clarifications of the contents of this document or any further relevant information may write to or telephone the:

Manager, Data Processing  
ZESCO; Zambia Electricity Supply Corporation, Ltd.  
Great East Road  
P.O. Box 30040  
Lusaka  
Zambia

Telex: 40150 ZESCO ZA  
Telephone: 1-213-177, (Country code 260)

**ZAMBIA ELECTRICITY SUPPLY CORPORATION**

**Hydroelectric Generating Stations**

Station	River	Units	Year	Make	Each Turbine			Each Alternator		
					Speed (RPM)	Flow (CM/S)	Head (M)	Make	Rating (MW)	Voltage (kV)
Kafue Gorge - Phase 1 - Phase 2	Kafue	1 - 4	1972	Kvaerner	375	44	390	Alsthom	150	17.5
	"	5 - 6	1977	Kvaerner	375	44	390	Alsthom	150	17.5
Kariba North	Zambezi	1 - 4	1977	Voest-Alpine	136.4	190	93	Rade-Koncar	150	18
Victoria Falls - A1 A2 B C	Zambezi	1 - 2	1950	English Electric	1000	1.2	100	English Electric	1	3.3
	"	3 - 4	1950	English Electric	750	3.5	100	English Electric	3	3.3
	"	1 - 6	1968	Voith	500	12	100	Siemens	10	11
	"	1 - 4	1972	Voith	500	12	100	Siemens	10	11
Lusiwasi	Lusiwasi	1 - 4	1970/75	Bell	1000	0.71	500	Bruce-Peebles	0.3	3.3
Chisimba Falls - Phase 1 - Phase 2 - Phase 3	Lwonde	1 - 3	1960	Gillkes	1000	0.5	75	Bruce-Peebles	0.3	3.3
	"	4	1968	Gillkes	1000	0.5	73	Bruce-Peebles	0.3	3.3
	"	5 - 8	1973	Gillkes	1000	1.8	79	Parson-Peebles	1.2	3.3
Musonda Falls	Luapula	1 - 5	1960/85	Armfields	600	3.5	33	English Electric	1	3.3
Lunzuia	Lunzuia	1 - 3	1960	Gillkes	1000	0.25	130	Bruce-Peebles	0.25	3.3

**TERMS OF REFERENCE  
NORTHEASTERN SYSTEM. FIRM POWER STUDY**

**Introduction**

Zambia Electricity Supply Corporation Limited (ZESCO) is inviting proposals from qualified consulting engineering firms to undertake a study to determine the most economic means of ensuring the firm power and energy requirements of the Zambian Northeastern Power System. The Northeastern Power System supplies northeastern Zambia with electricity, and until mid-1989 was independent of the main grid. A 330 kV transmission line was constructed from the Kabwe substation on the main system to Pensulo and, after installation and commissioning of appropriate terminal facilities at both ends of the lines the two systems were interconnected. (See the attached map, "Zambia Electricity Supply Corporation, Generation and Transmission Network", IBRD No. 20984).

The northeastern system has four hydroelectric generating stations with an aggregate installed capacity of 23,750 kW, and five diesel stations which together are rated at 3,200 kW. As the peak system demand is about 12 MW, the hydroelectric stations are capable of satisfying the maximum demand under normal hydrological conditions. However, at times of low river flows it sometimes becomes necessary to run the diesel generating units to meet the peak demands.

The interconnection of the Northeastern System with the main grid should make the diesels redundant. However the interconnection is by a single-circuit line, and therefore cannot be regarded as firm power. Availability of firm power to meet peak demands in the Northeastern System under all conditions may be ensured by one of the following alternatives:

- (a) continued operation of the diesels;
- (b) increasing the firm hydroelectric generating capacity; and
- (c) construction of an additional interconnection to the main grid.

The study is required to evaluate the economics of these alternatives and to choose the least-cost option.

**Scope of Work**

The firm selected to execute the study, hereinafter called "The Consultant", will be required to:

- (a) Estimate the economic value of power and energy to the Northeastern Region.

- (b) Assess the probability of the line interconnecting the Northeastern System to the main grid being out of service during periods in which existing hydroelectric generation will be unable to satisfy peak demands in the northeast. In this assessment the Consultant will not only review the operating history of the line during its relatively short service life but will also evaluate the performance of similar lines elsewhere in Zambia.
- (c) Calculate the cost of supplying the shortfall in firm energy from :
  - (i) diesel generation;
  - (ii) increasing the hydroelectric generating capacity; and
  - (iii) reinforcing the interconnection to the main grid.

The calculations are to be based on the Consultant's best estimates of the likely rate of increase in demand in the Northeastern Region.

#### Reports

At the conclusion of the study the Consultant shall submit to ZESCO six copies of a draft report recording the Consultant's activities, findings, conclusions and recommendations. The report must indicate the sources of all important data used in the report. Where the data were the result of the Consultant's calculations, the calculations are to be included in the report.

The report shall be written in the English language and the metric system of units is to be used exclusively.

Within six weeks of receipt of the draft report ZESCO will inform the Consultant of its comments. The final report, which will reflect ZESCO's comments, is to be completed within a further four weeks. Fifteen copies of the final report are to be submitted to ZESCO.

The Consultant will not make copies of the report, in whole or in part, available to third parties without the consent in writing of ZESCO.

#### ZESCO's Responsibilities

The Consultant will be fully responsible for the execution and timely completion of the study. However, the development of his work plan and the generation of estimates of cost for his services, are to be based on the following items being provided by ZESCO:

- (a) drawings, cost data and all other relevant information which may be in ZESCO's possession or to which ZESCO may have unrestricted access;

- (b) access to any ZESCO owned locations and installations relevant to the study;
- (c) off-road transportation where required;
- (d) office accommodation, clerical and secretarial support and telecommunication facilities for the Consultant's staff while working in Zambia; and
- (e) a competent engineer to work full-time with the Consultant during his activities in Zambia.

Guidelines for the Proposal

Each firm desirous of undertaking the study must submit a proposal which will include:

- (a) a work plan and schedule of activities in weeks, (bar chart), developed in accordance with these Terms of Reference;
- (b) a description of the methodology to be followed in determining the least cost source of firm power to the Northeastern Region;
- (c) if the firm is not Zambian, indication as to which aspects of the work will be performed in the Consultant's offices and which in Zambia;
- (d) information as to the nature of the firm and a list of similar tasks previously undertaken in developing countries. The list must include the name and addresses of the organizations for which the work was undertaken and the names and titles of persons within those organizations who can be consulted as references;
- (e) curricula vitae of staff who will be assigned important responsibilities for the study in the Consultant's offices as well as in the field, stating the intended role of each individual. During execution of the study, involvement of persons other than those named for the specific tasks in the proposal will require prior ZESCO approval; and
- (f) a proposed schedule of payments which links progress payments to clearly defined and objectively identifiable performance targets.

The firm submitting the proposal is to include the submission for costs and fees along with the rest of the proposal but in a separate sealed envelope. The cost elements which are firm are to be clearly indicated and the factors which may affect the variable costs are to be identified along with a statement as to the effect which these factors can have on the relevant costs.

Timing

Proposals for performance of the study are to be submitted in sealed envelopes to ZESCO's head office in Great East Road, Lusaka, Zambia not later than , 1989. Envelopes are to be addressed to the Managing Director and are to be conspicuously marked "Proposal for Firm Power Study. Northeastern Region".

ZESCO will complete initial evaluation of the proposals on or before , 1989, and will begin negotiation with the firm which submitted the most highly evaluated proposal. If mutually satisfactory terms and conditions cannot be agreed within four calendar weeks, ZESCO may proceed to negotiate with other firms. ZESCO may at its sole discretion reject any or all of the proposals received.

The date of contract signing will be considered the start of the project and will be used as the milestone by which progress of the project will be measured.

Form of Contract

The contract to be awarded to the successful firm will be based on the International Model Form of Agreement Between Client and Consulting Engineer, Number IGRA 1979 P.I., produced by the International Federation of Consulting Engineers (FIDIC).

Enquiries

Firms requiring clarification of the contents of this document or any further relevant information may write to or telephone the:

Manager, Engineering Services,  
Zambia Electricity Supply Corporation Ltd.,  
P.O. Box 30040,  
Lusaka,  
Zambia.

Telex: 40150 ZESCO ZA  
Telephone: 1 213 177 (Country code 260)

**INVESTMENT IN THE LUSAKA DISTRIBUTION SYSTEM**

Data received from ZESCO indicate that the replacement cost of the Lusaka distribution system at prevailing equipment and material prices and labor rates would be as shown in Table 1.

**Table 1: REPLACEMENT COST OF THE LUSAKA DISTRIBUTION SYSTEM**

Component	Quantity	Unit Cost	Total Cost
		(US\$)	(US\$)
<b><u>33 KV</u></b>			
Underground Cables	32.5 km	125,000	4,062,500
Overhead Lines	100 km	12,500	1,250,000
Subtotal a/			5,312,500
<b><u>11 KV</u></b>			
Underground Cables	231 km	100,000	23,100,000
Overhead Lines	1046 km	10,000	10,460,000
Transformers, 88/11 and 33/11 KV	15 each	1,875,000	28,125,000
Distribution transformers, 11/0.4 KV	2200 each	10,120	22,264,000
Subtotal			83,949,000
<b><u>Low Voltage</u></b>			
Underground Cables	760 km	37,500	28,500,000
Overhead Lines	1710 km	5,250	8,977,500
Underground Service Drops	1935 km	6,250	12,093,750
Overhead Service Drops	298 km	4,000	1,192,000
Meters	32,000	100	3,200,000
Subtotal			53,963,250
Total			143,224,750

a/ The cost of the 88/33 KV transformers is not included.

Source: ZESCO, Mission

The number of consumers in Lusaka is about 32,000. The average investment in distribution is therefore US\$4,500 per consumer served. This average investment would be lower if the distribution lines were exclusively run overhead. Table 2 on page 2 calculates what the present value of the Lusaka distribution system would be with the same system configuration and units costs but with all lines overhead.

Table 2: INVESTMENT IN LUSAKA DISTRIBUTION SYSTEM IF ALL LINES WERE RUN OVERHEAD

Component	Quantity	Unit Cost (US\$)	Total Cost (US\$)
<b>33kV</b>			
Lines	132.5 km	12,500	1,656,250
Subtotal			1,656,250
<b>11 kV</b>			
Lines	1277 km	10,000	12,770
Transformers, 88/11 and 33/11 kV	15 each	1,875,000	28,125,000
Distribution transformers (pole-mounted)	2200 each	8,000 <u>a/</u>	17,600,000
Subtotal			45,737,770
<b>Low Voltage</b>			
Lines	2470 km	5,250	12,967,500
Service drops	2233 km	4,000	8,932,000
Meters	32,000 each	100	3,200,000
Subtotal			25,099,500
Total			72,993,520

a/ The average cost per transformer is lower than before because they are all pole-mounted.

The average cost per consumer now becomes US\$2,300 instead of US\$4,500. However, there is potential for even further reductions. If only one primary distribution voltage were used, the total cost of the 33/11 kV transformers would be avoided and the total length of distribution line reduced. Table 3 develops costs for the Lusaka system if it were supplied entirely with overhead lines and a primary voltage of 33 kV. All transformers are pole-mounted.

Table 3: INVESTMENT IN LUSAKA SYSTEM WITH 33 KV AS ONLY PRIMARY VOLTAGE - ALL LINES AND TRANSFORMERS OVERHEAD

Component	Quantity	Unit Cost	Total Cost
		US\$	US\$
Overhead Lines	1277 km	12,500	15,962,500
Pole-mounted Transformers	2200 each	11,000	24,200,000
Low-voltage lines	2470 km	5,250	12,967,500
Service drops	2233 km	4,000	8,932,000
Total			62,062,000

The average cost is now reduced to US\$1,940 per consumer served. However, the calculations are based on the cost of 33 kV lines with all conductor sizes being the same as that used on existing trunk lines. In practice, the conductor size for each spur line would be chosen in accordance with the demand it is intended to satisfy. The overall costs would therefore be lower.

Investment in distribution can be reduced even further. The costs in Table 3 were developed for a primary voltage of 33 kV. This is not necessarily the optimum voltage which only cost/benefit analyses can determine. Lines supplying residential consumers with low average demands could be run in two- or one-phase configurations in both primary and secondary. The mission confidently expects that the cost of supplying the average consumer can be reduced to US\$1,200 or less if the distribution systems were to be designed for low investment costs while maintaining economic levels of reliability.

**TERMS OF REFERENCE  
DISTRIBUTION SYSTEM DESIGN STUDY**

**Introduction**

Zambia Electricity Supply Corporation Limited (ZESCO) is inviting proposals from qualified consulting engineering firms to undertake a study of alternative distribution system designs suitable for application in Zambia and to recommend a set of design and construction standards appropriate to serving the various groups of consumer demands.

The objective of the study is to arrive at conclusions as to how the cost of extending the distribution system and of connecting new consumers to the system may be reduced while maintaining an economic level of supply reliability.

ZESCO is the publicly owned electric utility of the Republic of Zambia and is charged with the responsibility of providing electricity throughout the republic to as wide a cross section of the population as can be economically justified. At present the overwhelming majority of energy sales (in excess of 80%) are made to industrial and commercial enterprises, while less than 15% of the households nationwide are electrified. Even in urban areas the overall percentage of houses electrified is less than 30%. These percentages have remained relatively stable over several years.

It is an objective of the Government of Zambia and of ZESCO that a larger percentage of the population should enjoy the benefits of electricity usage. In addition, greater availability of electricity in the households would reduce the extent of deforestation now being experienced as a result of widespread use of wood and charcoal for domestic cooking. One of the obstacles to more widespread electrification is the relatively high cost of providing service at the distribution level. It is believed that this cost may be reduced by utilizing different design standards and construction techniques for different types of loads without reducing the reliability and quality of service below the economic optimum.

**Scope of Work**

The firm selected to undertake the study, hereinafter called "The Consultant", will be required to:

- (a) review ZESCO's operating system, the areas of the country served and those not served as well as the nature of existing and potential loads;
- (b) determine the economic value of energy supplied to industrial, commercial and residential consumers and the investment which can be economically justified in satisfying incremental demands

in each of these categories. It is recognized that such determinations cannot be precise, that the economic value of energy will vary among consumers of the same category and that most often the same extension will supply different categories of consumers. Nevertheless, the Consultant should assemble and consider the facts objectively and judiciously arrive at conclusions;

- (c) review alternative design standards and determine the most economic approach for supplies to at least seven different categories of service, namely: (i) large industrial and commercial; (ii) medium industrial and commercial; (iii) small commercial and medium to high income urban residential; (iv) low income urban residential; (v) agricultural; (vi) middle to high income rural; (vii) low income rural;

The alternative designs considered should include but not be limited to undergrounding, bare overhead conductor, aerial bundled cable, pad-mounted versus pole-mounted transformers, small distribution transformers and short secondary lines versus larger transformers and longer secondary lines, etc. In arriving at recommendations, consideration must be given to safety of personnel and property, initial investment costs, operating and maintenance costs, losses, resistance to climatological conditions and, where appropriate, resistance to vegetation, wildlife and termites.

The recommendations must include the selection of appropriate primary voltages and conductor sizes.

- (d) review the current construction techniques, including crew sizes and skill composition, work methods, degree of mechanization, etc. Make suggestions as to means by which construction costs may be reduced;
- (e) investigate the feasibility of reducing the consumer deposit required before connecting a new consumer by incorporating a capital recovery component in the tariffs;
- (f) select and prioritize for electrification at least 12 townships currently without power supply. The aggregate potential for new consumers should be in excess of 15,000 consumers. Formulate, without detail design, the technical basis on which electricity service should be extended to these townships, (e.g., off-take from the existing system, primary line voltages, number of phases, conductor material and size, etc.). Develop estimates for the cost of the extensions to each of these townships; and
- (g) provide ZESCO with copies and unrestricted right to usage of any computer software developed specifically for the project.

Reports

At the conclusion of the study the Consultant shall submit to ZESCO six copies of a draft report recording the Consultant's activities, findings, conclusions and recommendations. The report must indicate the sources of all important data used in the report. Where the data were the result of the Consultant's calculations, copies of the calculations are to be included in the report.

The report shall be written in the English language and the metric system of units shall be employed exclusively.

Within six weeks of receipt of the draft report ZESCO will inform the Consultant of its comments. Fifteen copies of the final report, which will reflect ZESCO's comments, shall be submitted within four weeks of receipt of the comments.

The Consultant will not make copies, in whole or in part, available to third parties without the consent in writing of ZESCO.

ZESCO Responsibilities

The Consultant will be fully responsible for the execution and timely completion of the study. However, the development of his work plan and the generation of estimates of cost for his services, are to be based on the following items being provided by ZESCO:

- (a) drawings, cost data and all other relevant information which may be in ZESCO's possession or to which ZESCO may have unrestricted access;
- (b) access to any ZESCO owned locations and installations relevant to the study;
- (c) off-road transportation where required;
- (d) office accommodation, clerical and secretarial support and telecommunication facilities for the Consultant's staff while working in Zambia; and
- (e) a three-person project team of competent technical staff to work full time with the Consultant during his activities in Zambia.

Guidelines for the Proposal

Each firm desirous of undertaking the study must submit a proposal which will include:

- (a) a work plan and schedule of activities in weeks (bar chart) developed in accordance with these Terms of Reference;

- (b) a description of the methodology to be followed in determining the most economic design standards and construction techniques;
- (c) if the firm is not Zambian, indication as to which aspects of the work will be performed in the Consultant's offices and which in Zambia;
- (d) information as to the nature of the firm and a list of similar tasks previously undertaken in developing countries. The list must include the name and addresses of the organizations for whom the work was undertaken and the names and titles of persons within those organizations who can be consulted as references;
- (e) curricula vitae of staff who will be assigned important responsibilities for the study in the Consultant's offices as well as in the field, stating the intended role of each individual. During execution of the study, involvement of persons other than those named for the specific tasks in the proposal will require prior ZESCO approval; and
- (f) a proposed schedule of payments which links progress payments to clearly defined and objectively identifiable performance targets.

The firm submitting the proposal is to include the submission for costs and fees along with the rest of the proposal but in a separate sealed envelope. Those cost elements that are firm are to be clearly indicated and the factors which may affect the variable costs are to be identified along with a statement as to the effect which these factors can have on the relevant costs.

#### Timing

Proposals for performance of the study are to be submitted in sealed envelopes to ZESCO's head office in Great East Road, Lusaka, Zambia not later than , 1989. Envelopes are to be addressed to the Managing Director and are to be conspicuously marked "Proposal for Distribution Study".

ZESCO will complete initial evaluation on or before , 1989, and will begin negotiation with the firm which submitted the most highly evaluated proposal. If mutually satisfactory terms and conditions cannot be agreed within four calendar weeks, ZESCO may proceed to negotiate with other firms. ZESCO may at its sole discretion reject any or all of the proposals received.

The date of contract signing will be considered the start of the project and will be used as the milestone by which progress of the project will be measured.

Form of Contract

The contract to be awarded to the successful firm will be based on the International Model Form of Agreement Between Client and Consulting Engineer, Number IGRA 1979 P.I., produced by the International Federation of Consulting Engineers (FIDIC).

Enquiries

Firms requiring clarification of the contents of this document or any further relevant information may write to or telephone the:

Manager, Engineering Services,  
Zambia Electricity Supply Corporation Ltd.  
P.O. Box 30040  
Lusaka,  
Zambia.

Telex: 40150 ZESCO ZA  
Telephone: 1 213 177 (Country code 260).

ENERGY SECTOR MANAGEMENT ASSISTANCE PROGRAM

Activities Completed

Country	Project	Date	Number
<b>Energy Efficiency and Strategy</b>			
Africa Regional Participants	Reports - Regional Power Seminar on Reducing Electric System Losses in Africa	8/88	087/88
Bangladesh	Power System Efficiency Study	2/85	031/85
Botswana	Pump Electrification Prefeasibility Study	1/86	047/86
	Review of Electricity Service Connection Policy	7/87	071/87
	Tuli Block Farms Electrification Prefeasibility Study	7/87	072/87
Burkina Faso	Technical Assistance Program	3/86	052/86
Burundi	Presentation of Energy Projects for the Fourth Five-Year Plan (1983-1987)	5/85	036/85
	Review of Petroleum Import and Distribution Arrangements	1/84	012/84
Costa Rica	Recommended Technical Assistance Projects	11/84	027/84
Ethiopia	Power System Efficiency Study	10/85	045/85
The Gambia	Petroleum Supply Management Assistance	4/85	035/85
Ghana	Energy Rationalization in the Industrial Sector of Ghana	6/88	084/88
Guinea-Bissau	Recommended Technical Assistance Projects in the Electric Power Sector	4/85	033/85
Indonesia	Energy Efficiency Improvement in the Brick, Tile and Lime Industries on Java	4/87	067/87
	Power Generation Efficiency Study	2/86	050/86
	Diesel Generation Efficiency Improvement Study	12/88	095/88
Jamaica	Petroleum Procurement, Refining, and Distribution	11/86	061/86
Kenya	Power System Efficiency Report	3/84	014/84
Liberia	Power System Efficiency Study	12/87	081/87
Madagascar	Recommended Technical Assistance Projects	6/85	038/85
Malaysia	Power System Efficiency Study	12/87	075/87
Mauritius	Sabah Power System Efficiency Study	3/87	068/87
Panama	Power System Efficiency Study	5/87	070/87
Papua New Guinea	Power System Loss Reduction Study	6/83	004/83
	Energy Sector Institutional Review: Proposals for Strengthening the Department of Minerals and Energy	10/84	023/84
	Power Tariff Study	10/84	024/84
Senegal	Assistance Given for Preparation of Documents for Energy Sector Donors' Meeting	4/86	056/86
Seychelles	Electric Power System Efficiency Study	8/84	021/84
Sri Lanka	Power System Loss Reduction Study	7/83	007/83
Syria	Electric Power Efficiency Study	9/88	089/88
Sudan	Power System Efficiency Study	6/84	018/84
	Management Assistance to the Ministry of Energy and Mining	5/83	003/83

ENERGY SECTOR MANAGEMENT ASSISTANCE PROGRAM  
Activities Completed

Country	Project	Date	Number
<b>Energy Efficiency and Strategy (Continued)</b>			
Togo	Power System Efficiency Study	12/87	078/87
Uganda	Energy Efficiency in Tobacco Curing Industry	2/86	049/86
	Institutional Strengthening in the Energy Sector	1/85	029/85
Zambia	Power System Efficiency Study	12/88	092/88
	Energy Sector Institutional Review	11/86	060/86
	Energy Sector Strategy	12/88	094/88
Zimbabwe	Power System Efficiency Study	12/88	093/88
	Power Sector Management Assistance Project: Background, Objectives, and Work Plan	4/85	034/85
	Power System Loss Reduction Study	6/83	005/83
<b>Household, Rural, and Renewable Energy</b>			
Burundi	Peat Utilization Project	11/85	046/85
	Improved Charcoal Cookstove Strategy	9/85	042/85
Côte d'Ivoire	Improved Biomass Utilization--Pilot Projects Using Agro-Industrial Residues	4/87	069/87
Ethiopia	Agricultural Residue Briquetting: Pilot Project	12/86	062/86
	Bagasse Study	12/86	063/86
The Gambia	Solar Water Heating Retrofit Project	2/85	030/85
	Solar Photovoltaic Applications	3/85	032/85
Global	Proceedings of the ESMAP Eastern & Southern Africa Household Energy Planning Seminar	6/88	085/88
India	Opportunities for Commercialization of Non-Conventional Energy Systems	11/88	091/88
Jamaica	FIDCO Sawmill Residues Utilization Study	9/88	088/88
	Charcoal Production Project	9/88	090/88
Kenya	Solar Water Heating Study	2/87	066/87
	Urban Woodfuel Development	10/87	076/87
Malawi	Technical Assistance to Improve the Efficiency of Fuelwood Use in the Tobacco Industry	11/83	009/83
Mauritius	Bagasse Power Potential	10/87	077/87
Niger	Household Energy Conservation and Substitution	12/87	082/87
	Improved Stoves Project	12/87	080/87
Peru	Proposal for a Stove Dissemination Program in the Sierra	2/87	064/87
Rwanda	Improved Charcoal Cookstove Strategy	8/86	059/86
	Improved Charcoal Production Techniques	2/87	065/87
Senegal	Industrial Energy Conservation Project	6/85	037/85
Sri Lanka	Industrial Energy Conservation: Feasibility Studies for Selected Industries	3/86	054/86
Sudan	Wood Energy/Forestry Project	4/88	073/88
Tanzania	Woodfuel/Forestry Project	8/88	086/88
Thailand	Accelerated Dissemination of Improved Stoves and Charcoal Kilns	9/87	079/87
	Rural Energy Issues and Options	9/85	044/85
	Northeast Region Village Forestry and Woodfuel Pre-Investment Study	2/88	083/88
Togo	Wood Recovery in the Nangbeto Lake	4/86	055/86
Uganda	Fuelwood/Forestry Feasibility Study	3/86	053/86

## ZAMBIA

**ZAMBIA ELECTRICITY SUPPLY CORPORATION  
GENERATION AND TRANSMISSION NETWORK  
1988**

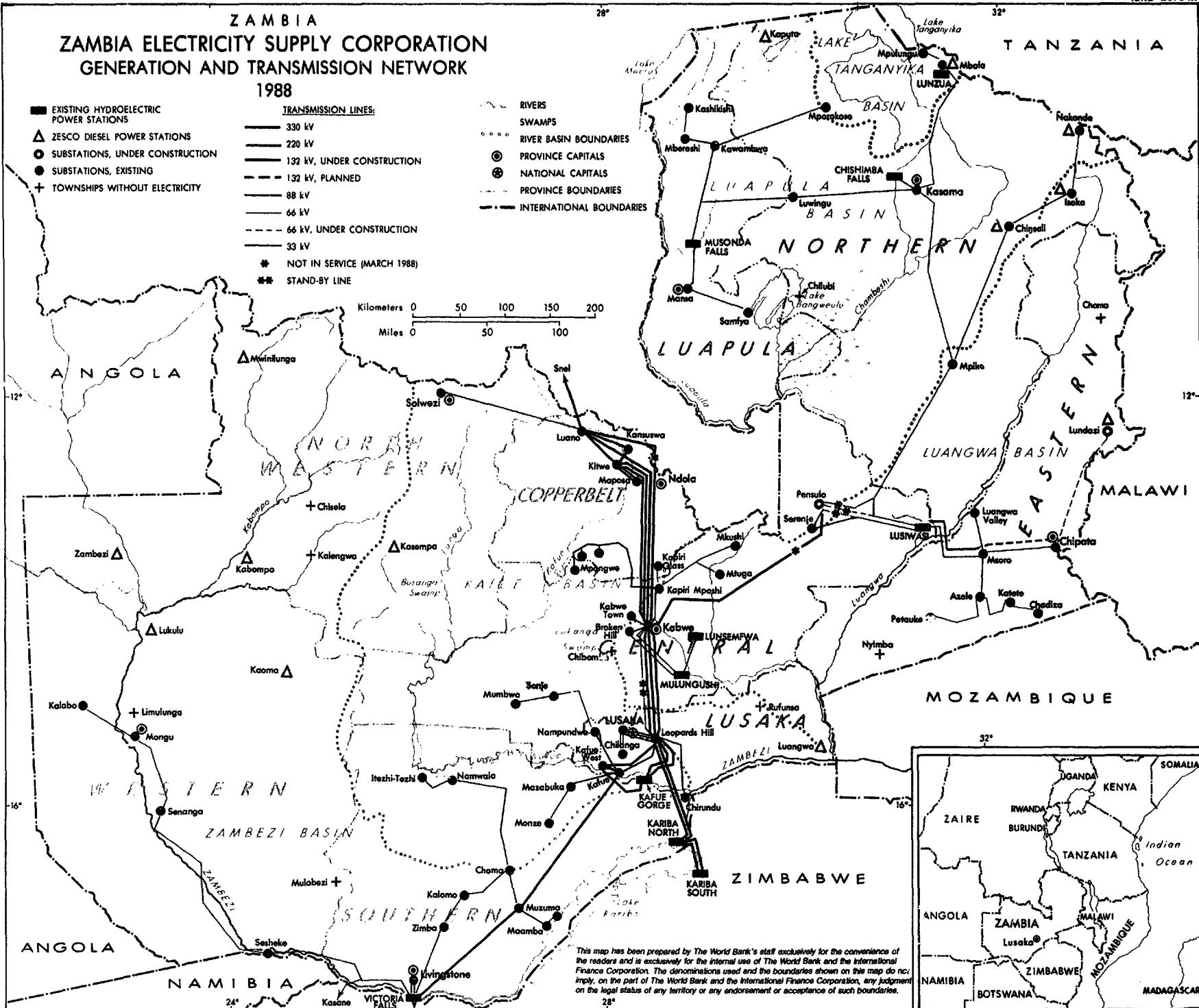
- EXISTING HYDROELECTRIC POWER STATIONS
- △ ZESCO DIESEL POWER STATIONS
- SUBSTATIONS, UNDER CONSTRUCTION
- SUBSTATIONS, EXISTING
- + TOWNSHIPS WITHOUT ELECTRICITY

**TRANSMISSION LINES:**

- 330 KV
- 220 KV
- 132 KV, UNDER CONSTRUCTION
- - - 132 KV, PLANNED
- 88 KV
- 66 KV
- - - 66 KV, UNDER CONSTRUCTION
- 33 KV
- \* NOT IN SERVICE (MARCH 1988)
- \*\* STAND-BY LINE

- RIVERS
- SWAMPS
- RIVER BASIN BOUNDARIES
- (●) PROVINCE CAPITALS
- (◎) NATIONAL CAPITALS
- PROVINCE BOUNDARIES
- - - INTERNATIONAL BOUNDARIES

Kilometers 0 50 100 150 200  
Miles 0 50 100



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ZAMBIA

# ZAMBIA ELECTRICITY SUPPLY CORPORATION GENERATION AND TRANSMISSION NETWORK

1988

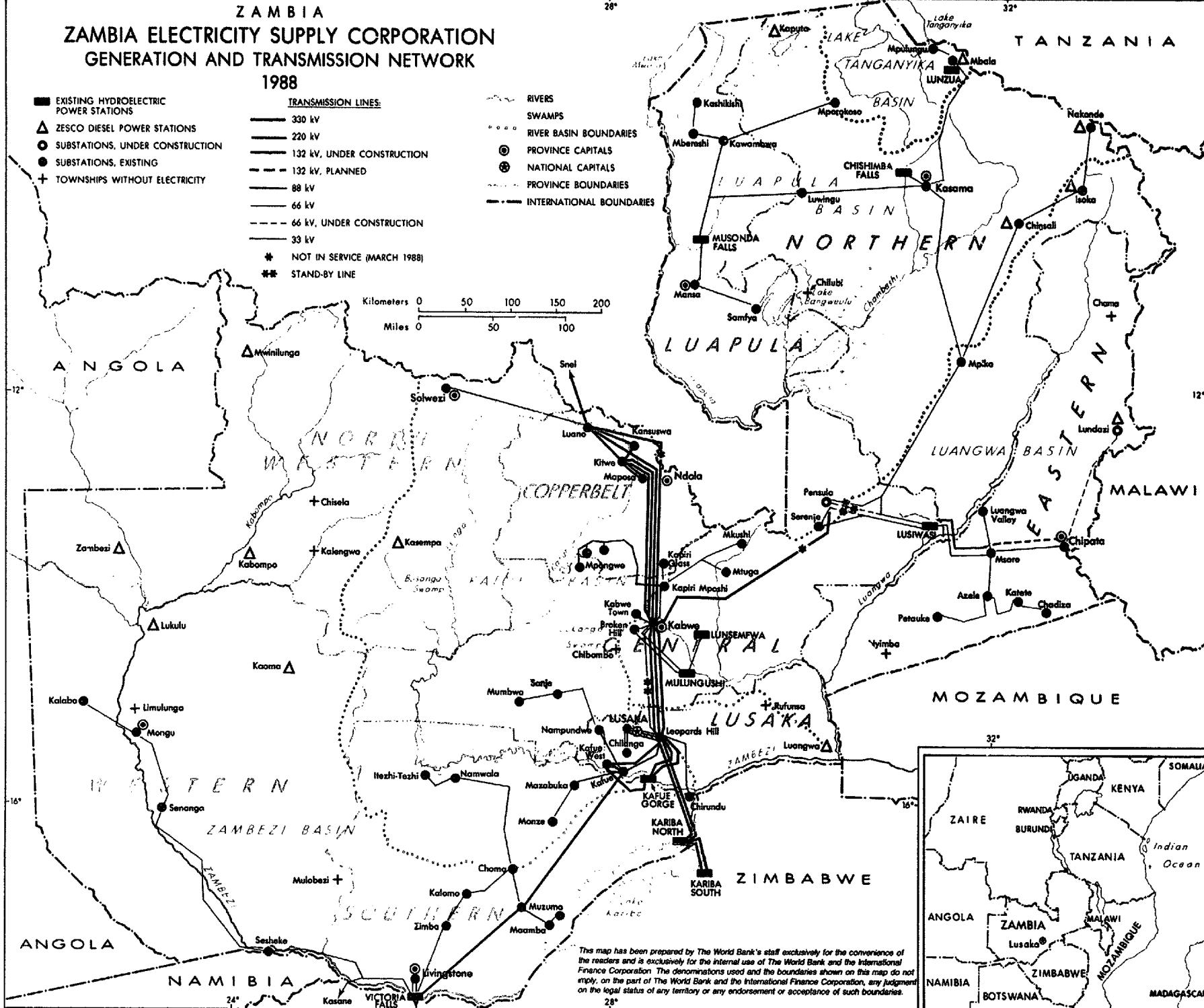
- EXISTING HYDROELECTRIC POWER STATIONS
- △ ZESCO DIESEL POWER STATIONS
- SUBSTATIONS, UNDER CONSTRUCTION
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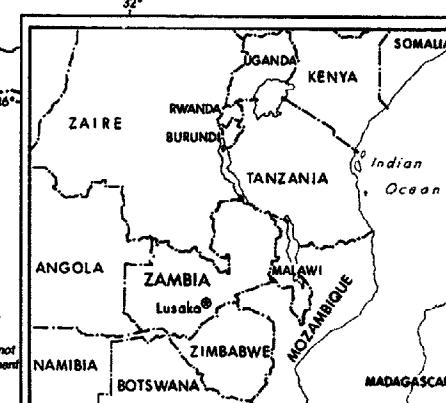
- RIVERS
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NOVEMBER 1988