No.

Republic of Zambia
Ministry of Energy and Water Development

The Study for Power System Development Master Plan in Zambia

Final Report

February 2010

JAPAN INTERNATIONAL COOPERATION AGENCY

Chubu Electric Power Co., Inc.

IDD
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Preface

In response to the request from the Government of the Republic of Zambia, the Government of Japan decided to conduct the "The Study for Power System Development Master Plan in Zambia" and entrusted the Study to the Japan International Cooperation Agency (JICA).

JICA sent a Study Team, led by Mr. Keiji SHIRAKI and organized by Chubu Electric Power Co., Inc. to Zambia five times from December 2008 to November 2009.

The Team held a series of discussions with officials from the Ministry of Energy and Water Development and conducted related field surveys. After returning to Japan, the Team conducted further studies and compiled the final results in this report.

I hope that the report will contribute to the development of power system facilities, stable power supply in Zambia, and the enhancement of amity between our two countries.

I would also like to express my sincere appreciation to the concerned officials for their close cooperation throughout the Study.

February 2010

Atsuo KURODA
Vice President
Japan International Cooperation Agency

February 2010

Atsuo KURODA
Vice President
Japan International Cooperation Agency
Tokyo, Japan

Letter of Transmittal

We are pleased to submit to you the final report for the "The Study for Power System Development Master Plan in Zambia".

The study was implemented by Chubu Electric Power Co., Inc. from November 2008 to February 2010 based on the contract with Japan International Cooperation Agency (JICA).

We formulated the countrywide power system development master plan, including the optimum generation development plan, the transmission and distribution plan and the interconnection plan with neighbor countries, for stable power supply in Zambia. The study was achieved with the cooperation of the Ministry of Energy and Water Development in Zambia, whilst transferring technology to them. In this study, we prepared not only the master plan but also recommendations on such broad issues as environmental and social considerations and private investment promotion.

We are convinced that the realization of the recommendations will lead to the acceleration of the power system development, which will surely contribute to the economic and social development in Zambia. We devoutly hope that the contents of this report can be reflected in the National Development Plan in Zambia and the master plan will be revised properly by the Ministry of Energy and Water Development.

Finally, we would like to express our sincere gratitude to JICA, the Ministry of Foreign Affairs and the Ministry of Economy, Trade and Industry for their advice and support. We also would like to express our deep gratitude to the Ministry of Energy and Water Development in Zambia, the Japanese Embassy in Zambia, the JICA Zambia Office and other concerned officials for the close cooperation and assistance through the study.

Keiji SHIRAKI
Team Leader
The Study for Power System Development Master Plan in Zambia

Table of Contents

Acronyms

ABWR	Advanced Boiling Water Reactor
AfDB	African Development Board
AfDF	African Development Fund
AGR	Advanced Gas Cooled Reactor
AIDS	Acquired Immune Deficiency Syndrome
AU	Africa Union
B/D	Basic Design (Study)
BIS	Business Information System
BOO	Build-Own-Operate
BOOT	Build-Own-Operate-Transfer
BOT	Build-Operate-Transfer
BPC	Botswana Power Corporation
BWR	Boiling Water Reactor
BSAC	British South African Company
BTU	British Thermal Unit
CAPCO	Central African Power Corporation
CEC	Copperbelt Energy Corporation
CEPCO	Chubu Electric Power Company, Inc.
CF	Capacity Factor
CFRD	Concrete Facing Rockfill Dam
CHP	Combined Heat and Power (Plant)
CIA	Central Intelligence Agency
C/P	Cooperation Partner(s)
C/P	Counterpart
CPC	Copperbelt Power Corporation
CPI	Consumer Price Index
CSO	Central Statistical Office
DBSA	Development Bank of South Africa
DD, D/D	Detailed Design (Study)
DfID	Department for International Development, UK
DOE	Department of Energy
DOPI	Department of Planning and Information
DRC	Democratic Republic of the Congo
DSM	Demand Side Management
EAPP	Eastern African Power Pool
ECZ	Environmental Council of Zambia
EIA	Environmental Impact Assessment

EIB	European Investment Bank
EIS	Environmental Impact Statement
EDM	Electricidade de Mocambique
ENE	Empresa Nacional de Electricidade
EPPCA	Environment Protection and Pollution Control Act
ERB	Energy Regulation Board
ESCOM	Electricity Supply Corporation of Malawi
ESKOM	ESKOM Enterprises
FPB	Federal Power Board
FNDP	Fifth National Development Plan
FPI	Framework and Package of Incentives (for Hydropower Generation and Transmission Development)
FS, F/S	Feasibility Study
FY	Fiscal Year
GCR	Gas Cooled Reactor
GDP	Gross Domestic Product
GIS	Geographic Information System
GNI	Gross National Income
GNP	Gross National Product
GRZ	Government of the Republic of Zambia
GSD	Geological Survey Department
GSJ	Geological Survey of Japan
GWh	Gigawatt hour
HFO	Heavy Fuel Oil
HIPC	Heavily Indebted Poor Country
HIV	Human Immunodeficiency Virus
HP	Heritage Party
HTGR	High Temperature Gas Cooled Reactor
HWR	Heavy Water Reactor
IAEA	International Atomic Energy Agency
ICB	International Competitive Bid
ICOMOS	International Council on Monuments and Sites
IDA	International Development Association
IAEA	International Atomic Energy Agency
IEA	International Energy Agency
IEE	Initial Environmental Examination
IFC	International Finance Corporation
IFS	International Financial Statistics

IMF	International Monetary Fund
IPP	Independent Power Producer
ITT	Itezhi-Tezhi
ITTPS	Itezhi-Tezhi Power Station
J	Joule
JBIC	Japan Bank for International Cooperation
JICA	Japan International Cooperation Agency
JV	Joint Venture
LCU	Local Currency Unit
LHPC	Lunsemfwa Hydropower Company
LWGR	Light Water cooled Graphite moderated Reactor
K	(Zambian) Kwacha
KCM	Konkola Copper Mines plc.
KGL	Kafue Gorge Lower (project)
KGPS	Kafue Gorge Power Station
KNBE	Kariba North Bank Extension (project)
KNBPS	Kariba North Bank Power Station
KPI	Key Performance Indicator
kWh	Kilowatt-hour
LEC	Lesotho Electricity Corporation
LFO	Light Fuel Oil
m.a.s.l	meter above sea level
MBO	Management Buy Out
MCL	Maamba Collieries Limited
MDG	Millennium Development Goals
MEWD	Ministry of Energy and Water Development
MFNP	Ministry of Finance and National Planning
MIGA	Multilateral Investment Guarantee Agency
MLGH	Ministry of Local Government and Housing
M/M	Minutes of Meeting
MMD	Movement for Multiparty Democracy
MMMD	Ministry of Mines and Minerals Development
MOTRACO	Mozambique Transmission Company
MP	Member of Parliament
MTENR	Ministry of Tourism, Environment and Natural Resources
MW	Megawatt
NEP	National Energy Policy
NES	National Energy Strategy

NCC	National Control Centre
NGO	Non Governmental Organization
NISIR	National Institute for Scientific and Industrial Research
ODA	Official Development Assistance
OPPPI	Office for Promoting Private Power Investment
p.a.	per annum
PAPs	Project Affected Persons
PB	Project Brief
PF	Patriotic Front
PLC	Public Limited Company
PPA	Power Purchase Agreement
PPP	Public-Private Partnership
PPP	Purchasing Power Parity
PRSP	Poverty Reduction Strategy Paper
PS, P/S	Power Station
PSRP	Public Service Reform Programme
PSS/E	Power System Simulator for Engineering
PV	Photovoltaic
PWR	Pressurized Water Reactor
RCC	Regional Control Centre
RCC	Roller Compacted Concrete (Dam)
RE	Renewable Energy
REA	Rural Electrification Authority
REF	Rural Electrification Fund
REMP	Rural Electrification Master Plan
SADC	Southern African Development Community
SAPP	Southern African Power Pool
SCADA	Supervisory Control and Data Acquisition System
SEA	Strategic Environmental Assessment
SEB	Swaziland Electricity Board
SIDA	Swedish International Development Cooperation Agency
SNEL	Societe Nationale d’Electricite
SPC	Special Purpose Company
SS, S/S	Substation
TANESCO	Tanzania Electricity Supply Company Ltd
TOE	Tonnes of Oil Equivalent
TWh	Terawatt-hour
UDA	United Democratic Alliance

UDI	Unilateral Declaration of Independence
ULP	United Liberal Party
UNDP	United Nations Development Program
UNIP	United National Independence Party
UNZA	University of Zambia
UPND	United Party for National Development
VAT	Value Added Tax
VFPS	Victoria Falls Power Station
WASP	Wien Automatic System Planning
WB	The World Bank
WEC	World Energy Council
WESTCOR	Western Power Corridor Company
Zam-En	Zambian Energy Corporation (Netherland) BV
ZCCM	Zambia Consolidated Copper Mines Limited
ZCCM-IH	ZCCM Investments Holdings plc
ZAWA	Zambia Wildlife Authority
ZDA	Zambia Development Agency
ZESA	Zimbabwe Electricity Supply Authority
ZESCO	ZESCO Limited
ZIC	Zambia Investment Centre
ZIMCO	Zambia Industrial and Mining Corporation Limited
ZMK	Zambia Kwacha
ZPA	Zambia Privatisation Agency
ZRA	Zambezi River Authority

List of Figures

List of Tables

Chapter 1 Introduction

1.1 Introduction

Due to the favorable tone of its economic development, the demand for electricity in the Republic of Zambia has been increasing at annual rates on the order of 3 - 4 percent in recent years. Toward the end of mitigating poverty, the Zambian government has posted the national targets of increasing the rural electrification rate, which is currently on the level of 2 percent, to 50 percent, and the urban electrification rate from a corresponding 48 to 90 percent, by 2030. It consequently faces the urgent task of further developing power sources to meet the growing demand for power and conditioning the transmission and distribution networks to raise the electrification rate nationwide.

Hydropower accounts for about 94 percent of Zambia's existing power source mix, and only about 30 percent of the estimated hydropower potential has been developed. For this reason, it would be advisable to formulate optimal generation plans that are centered around hydropower as the key national energy.

Zambia is located in the southern part of Africa, and is a major member of the Southern African Power Pool (SAPP), which is advocating the formation of a power pool that would enable power supply through intraregional interchange. It has already begun power interchange with neighboring countries, but a plan has not yet been determined for interchange with neighbors based on long-term demand forecasting and centered around Zambia. There is a need for the preparation of a more effective international power interchange plan grounded in the needs in neighboring countries.

To help stabilize the supply of power over the medium and long terms against this background, the government of Zambia requested the Japanese government to carry out a development study for preparation of a comprehensive master plan for power development.

In response to this request, the Japan International Cooperation Agency (JICA) executed a project formation study (i.e., "Project Formation Study for Power Development Planning in Zambia") in February and March 2008 in order to ascertain the detailed items involved in the request and confirm the appropriateness of master plan preparation. Through consultations with the concerned parties in Zambia and a field survey of the major hydropower facilities, the JICA confirmed the need for preparation of a master plan and concluded a Minutes of Meeting on the scope of the study proper with the Zambian side. Finally, it reached an agreement with the Zambian side with respect to the undertaking of “the Study for Power System Development Master Plan in Zambia” on the substance of a Scope of Work (attached in Annexure) in September 2008.

1.2 Objective

(a) The main objective of the Study is to formulate a blue print for the Power System Development Master Plan up to 2030 which shall be practical and comprehensive. The master plan will coordinate generation, transmission, and distribution expansion to ensure with confidence that all proposed capital investments are not ad hoc and are instead part of a long-term structured plan. It will ensure that network expansion is economically efficient and will provide a realistic framework for loss reduction. The study shall use the least cost analysis to compare various options available for the development of generation, transmission and distribution systems.

(b) The second objective of the Study is to conduct technical transfer through seminar and technical workshop for MEWD staff in modern power system planning techniques and tools.

1.3 Area Covered

The Study will cover the entire area of Zambia and its neighboring countries and take into account the demand and expansion programs in Southern African Power Pool (SAPP) and Eastern African Power Pool (EAPP).

1.4 Expected Key Outputs of Study

The expected key outputs of the Study shall include but not limited to the following:

(i) A detailed long-term demand forecast for Zambia at the power substation level with demand disaggregated between main consumer/customer groups;

(ii) A series of realistic least-cost long-term generation capacity expansion scenarios

(iii) A series of least-cost transmission expansion plans, matched to the generation expansion scenarios developed;

(iv) An assessment of the amount and timing of generation and transmission investments for each system development scenario;

(v) An estimate of distribution investment costs to meet demand growth;

(vi) A program of distribution loss reduction initiatives;

(vii) Institutional reform recommendations for MEWD / Electricity Industry to develop capacity to implement and revise the power system master plan as and when necessary;

The above outputs shall be achieved by using the least-cost analysis to compare various options for generation, transmission, and distribution through the following key activities to include;

(i) Assessing existing electricity demand and prepare a demand forecast, using both bottom-up (location-specific) data and top-down (macroeconomic) parameters;

(ii) Developing demand-side management options;

(iii) Assessing potential energy sources for generation development, and compare the likely development costs ;

(iv) Developing a series of least cost staged generation expansion plans

(v) Undertaking computer modeling of the country's current existing power system down to the power substation level, and analyze constraints;

(vi) Developing and conducting computer modeling of network expansion options to match the various generation expansion plans, and forecast demand growth;

(vii) Calculate annual investment requirements and investment net present values under each of the expansion plans and for a reasonable set of input cost assumptions;

(viii) Identify, analyze, and prepare cost estimates for options and opportunities for loss reduction, including projects forming part of the overall master plan and stand-alone projects;

(ix) Prepare a detailed transmission and distribution capital works program for the first 5 years of the master plan, including loss reduction subprojects;

1.5 Counterpart Team and Study Team

The counterpart organization of the Study shall be the Ministry of Energy and Water Development (MEWD) on behalf of the Government of Zambia.

The counterpart team and the study team are shown in Table 1.1.

Table 1.1 Counterpart Team and Study Team

No.	Assignment	Name	C/P	Title
1	Team Leader/ Power system development and Policy	Keiji SHIRAKI	Mr. Oscar S. Kalumiana	Director
2	Demand Forecast	Masayasu ISHIGURO	Mr. Alex Matale	Advisor
3	Sub Leader / Generation Development Planning / GIS Database	Hirokazu NAKANISHI	Mr. Arnold M. Simwaba Mr. Aggrey Siuluta	Sr. Electrification Officer Energy Informatics Officer
4	Hydro Power Planning 1 Hydro Power Planning 2	Yasuhiro KAWAKAMI Takashi AOKI	Mr. Patrick Mubanga	Sr. Power Sys. Dev. Officer
5	Interconnection Planning / Transmission Planning 1	Kazunori OHARA	Mr. William Sinkala	Electrification Officer
6	Interconnection Planning / Transmission Planning 2	Atsushi SUZUKI	Mr. Arnold M. Simwaba	Sr. Electrification Officer
7	Power System Planning	Yoshihide TAKEYAMA	Mr. Nkunsuwila Silomba	Electrification Officer
8	Environmental and Social Considerations	Kenzo IKEDA	Mrs. Langiwe Chandi	Sr. Energy Officer (Renewable Energy)
9	Economic and Financial Analysis / Private Investment Promotion Analysis	Takeshi KIKUKAWA	Mr. Lufunda Muzeya	Energy Economist
10	Distribution Planning	Tatsumi FUKUNAGA	Mr. Alex Matale	Advisor
11	Coordinator	Hiroyuki KONDO	Mr. Patrick Mubanga	Sr. Power Sys. Dev. Officer

1.6 Flow of Overall Study

The study will consist of five stages, as follows.

Stage 1 (Kick-off and basic study stage)

Key points

- Explanation and discussion of the inception report at the 1st seminar meeting
- Explanation and discussion of the inception report at the donor meeting
- Collection of basic information

Stage 2 (Power system development formulation I and neighboring country survey stage)

Key points

- Demand forecasting
- Preparation of the optimal generation plan
- Interviews with neighboring countries about power supply and demand, preparing the interconnecting plan (draft)

Stage 3 (Power system development formulation II and technology transfer stage)

Key points

- Explanation of the interim report at the 2nd seminar meeting
- Preparation of the transmission/ distribution plan (draft)
- Technology transfer by the workshop
- Case study
- Re-commissioning

Stage 4 (Power system development plan formulation III stage)

Key points

- Explanation and discussion of the power system development
- Counterpart training in Japan

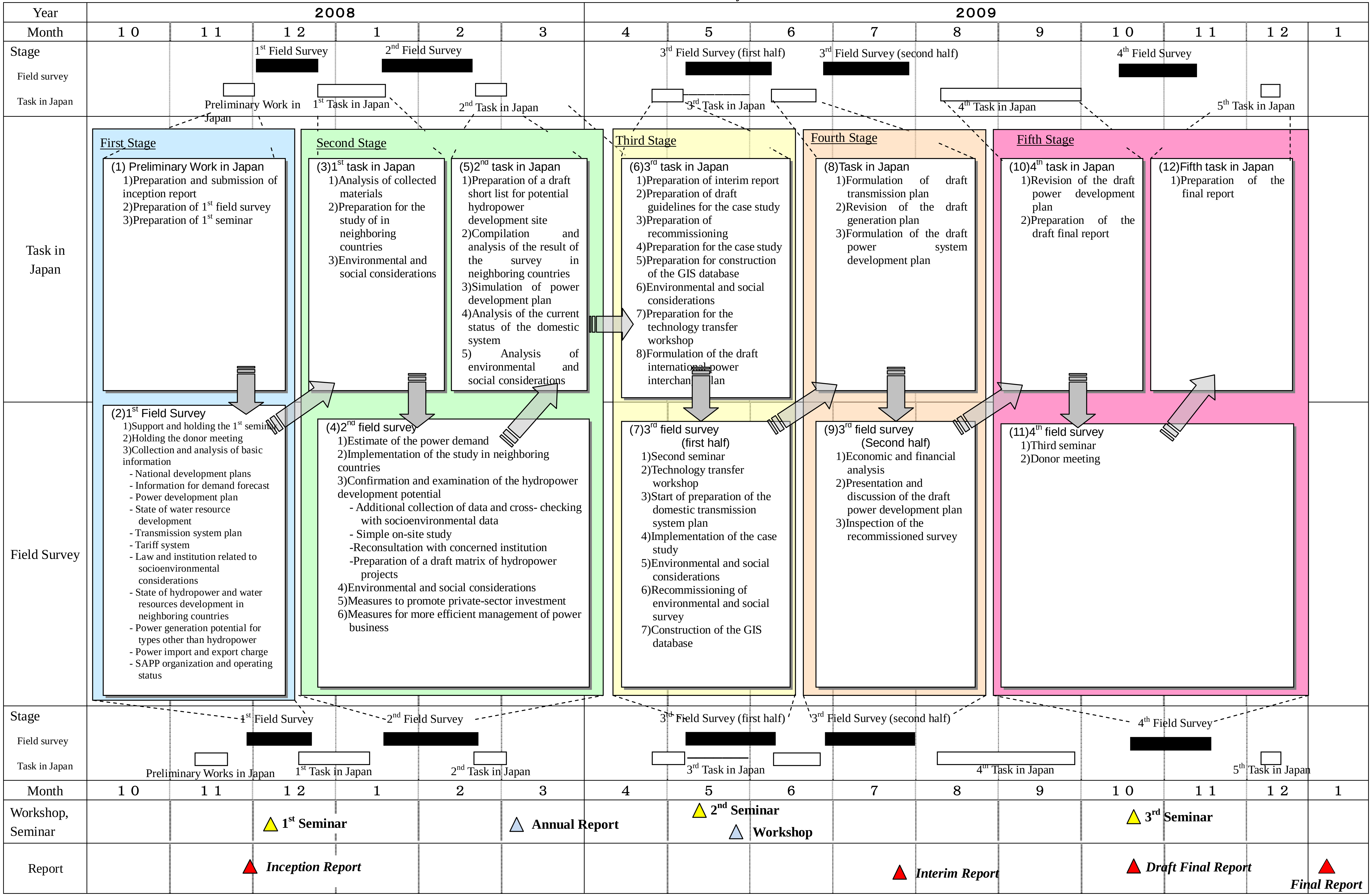
Stage 5 (Master plan authorization stage)

Key points

- Explanation and discussion of the draft final report at the 3rd seminar meeting
- Explanation and discussion of the draft final report at the donor meeting

The study flow is shown, as follows.

Table 1.2 Study flow



Chapter 2 General Information of Zambia

In this chapter, general information of Zambia such as history, geography, society, politics, economy etc. was described in Japanese edition, which was informative for strangers to Zambia and should be included in the final report of JICA study. However, most of the information here was unnecessary for Zambian people and has less importance to formulate the power system master plan. For this reason, the contents of this chapter were transferred to Appendix A by request from Zambian side.

Sections in this chapter show below for someone's reference.

Chapter 3 Energy Policies and Primary Energy Resources

In this chapter, energy policies and primary energy resources were described in Japanese edition, which should be included in the final report of JICA study. However, most of the information here was unnecessary for Zambian people and has less importance to formulate the power system master plan. For this reason, the contents of this chapter were transferred to Appendix B by request from Zambian side.

Sections in this chapter show below for someone's reference.

Chapter 4 Current status of power sector[1]

4.1 Power demand and supply

4.1.1 Existing generation facilities

The installed capacity of power generation facilities in Zambia totals about 1,860 MW. ZESCO owns the lion's share of this total at 1,744 MW, followed by the CEC at 90 MW and other private producers at 38 MW. The list of on-grid sources, i.e., sources connected to the "national grid", is confined to the three major ZESCO hydropower stations (Kariba North, Kafue Gorge, and Victoria Falls) and the Mulungushi and Lunsemfwa power stations owned and operated by the Lunsemfwa Hydropower Company (LHPC). All other power stations transmit and distribute power to specified areas through micro- or mini-grids.

Table 4.1 Principal Generation Facilities in Zambia

(Unit: kW)

Station	Installed Capacity	Available Capacity	Remarks
ZESCO			
Main Hydros	1,713,000	1,233,000	
Kariba North	660,000	510,000	
Kafue Gorge	945,000	615,000	
Victoria Falls	108,000	108,000	
Mini Hydros	23,750	19,750	
Lusiwasi	12,000	9,000	
Musonda Falls	5,000	5,000	
Chishimba Falls	6,000	5,000	
Lunzua River	750	750	
Diesel	7,285	6,545	
Mwinilunga	1,360	1,360	
Kabompo	1,160	1,160	
Zambezi	960	960	
Mufumbwe	400	400	
Luangwa	1,280	732	
Lukulu	512	320	
Chama	263	263	
Kaputa	550	550	
Chavuma	800	800	
Total ZESCO	1,744,035	1,259,295	
CEC	80,000	80,000	
Bancroft	20,000	20,000	Gas Turbine
Luano	40,000	40,000	Gas Turbine
Luanshya	10,000	10,000	Gas Turbine
Mufulira	10,000	10,000	Gas Turbine
Lunsemfwa	38,000	38,000	
Lunsemfwa	18,000	18,000	Hydro
Mulungushi	20,000	20,000	Hydro
Total	1,862,035	1,377,295	

(Source) Statistics Yearbook of Electric Energy 2007/08, ZESCO

[1] The history and organization of power industry in Zambia included in Japanese edition are transferred to Appendix C by request from Zambian side.

(1) ZESCO

i) Hydropower facilities

The major hydropower stations managed by ZESCO are Kariba North Bank (KNBPS), Kafue Gorge (KGPS), and Victoria Falls (VFPS). Taken together, these three sources account for about 98 percent of Zambia's entire installed generation capacity. Table 4.2 shows the hydropower facilities managed by ZESCO.

Table 4.2 Hydropower facilities managed by ZESCO (as of March 2008)

Power Station	Installed Capacity (MW)	Location
Kariba North Bank	660 (720)*	Zambezi River
Kafue Gorge	945 (990)*	Kafue River
Victoria Falls	108	Zambezi River
Sub Total	1,723	
Mini Hydropower Station		
Lusiwasi	12	Northern Province
Musonda Fall	5	Northern Province/ Luapula Province
Chishimba Fall	6	Northern Province
Lunzua River	0.75	Northern Province
Sub Total	23.75	
Total	1,746.75	

* Values after rehabilitation.

(Source) ZESCO, Statistics Year Book of Electric Energy 2007/2008

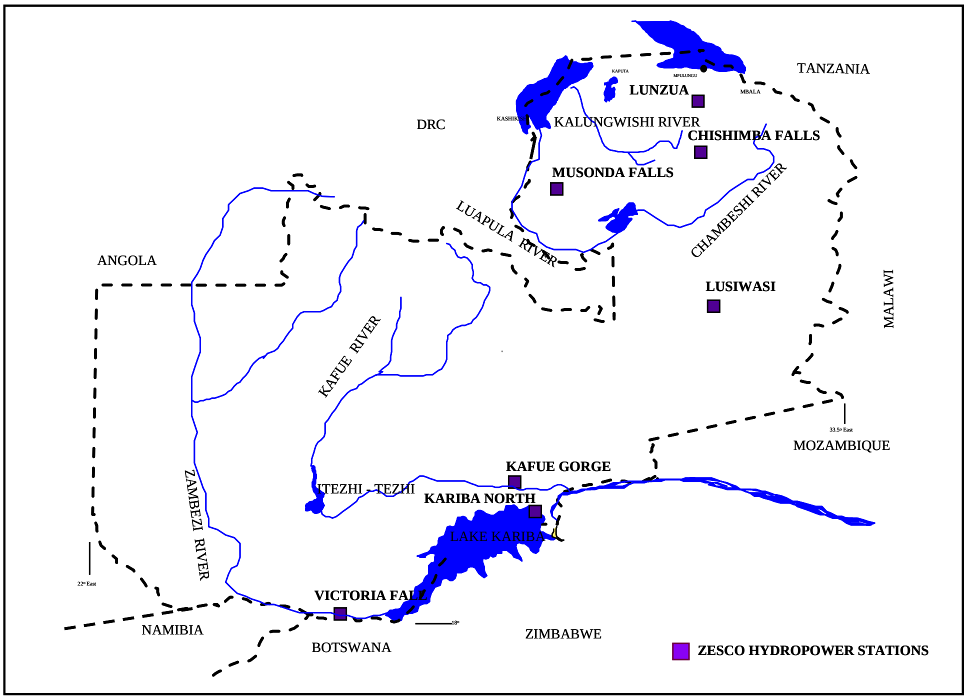


Figure 4.1 Location of the hydropower facilities managed by ZESCO

The generated output of the three major stations (KNBPS, KGPS, and VFPS) declined owing to the drought that lasted from 1995 to 1996, fire at the KGPS in 1989, and work for rehabilitation projects at these stations. Over fiscal years 1977 - 2007, it averaged about 8,400 GWh annually. Over fiscal years 1998 - 2001, before the start of rehabilitation projects, the output stayed on virtually the same level each year.

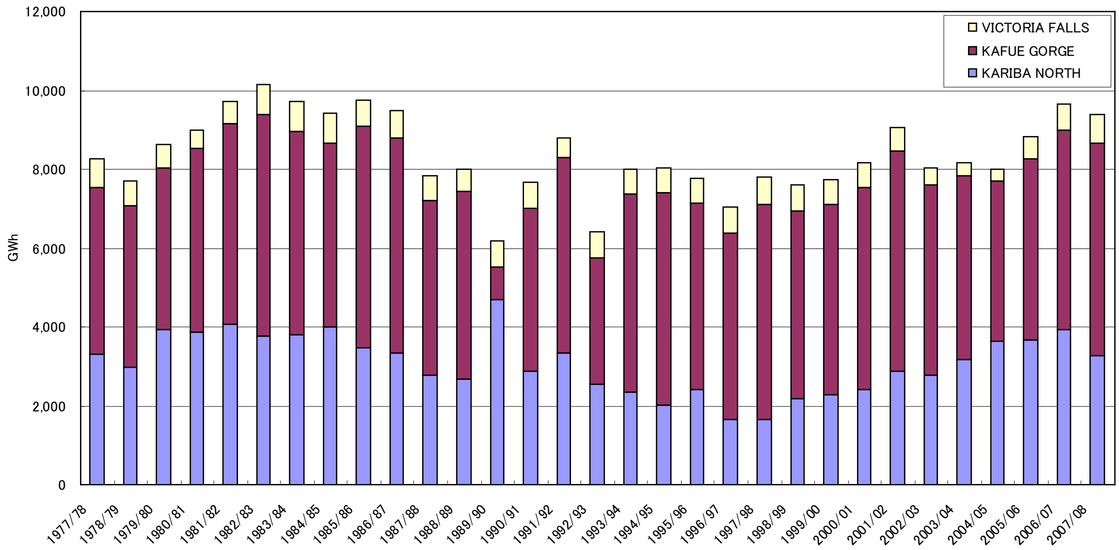


Figure 4.2 Yearly trend of generated output at the KNBPS, KGPS, and VFPS

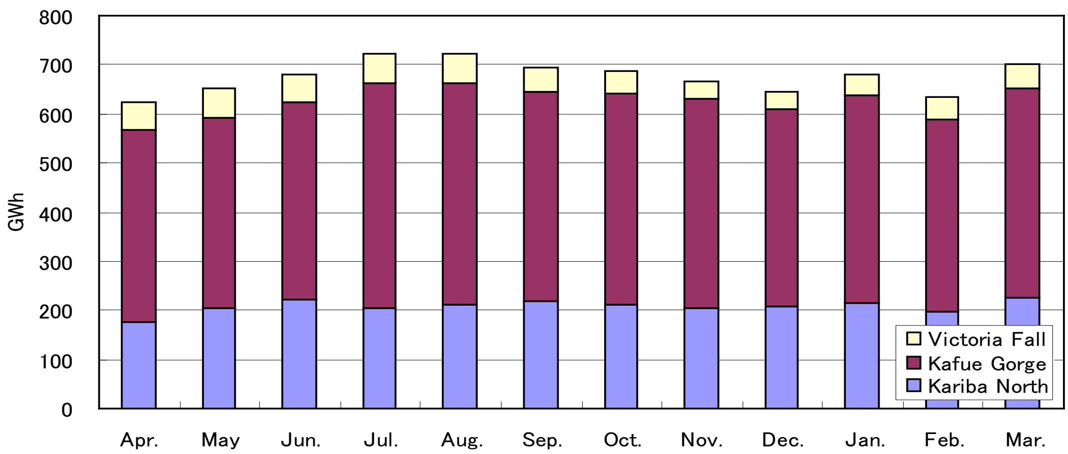


Figure 4.3 Monthly trend of generated output at the KNBPS, KGPS, and VFPS

(a) Kariba North Bank Power Station (KNBPS)

The KNBPS dam was constructed in the 1950s, in Kariba Gorge on the Zambezi River. It has a height of 128 meters and crest length of 617 meters, and forms a reservoir with a storage capacity of 185 billion cubic meters, making it one of the world's largest artificial lakes. The reservoir has an extended length of 280 kilometers and width of 32 kilometers at its widest point. The KNBPS was placed into operation in 1976. At that time, it was equipped with four units, each with an output of 150 MW, for a total capacity of 600 MW.

The Zambezi River flows over the national border with Zimbabwe, and an institution was therefore established to coordinate the interests of concerned countries in its development. With the enactment of the Zambezi River Authority Act in 1987, the Zambezi River Authority (ZRA) began to exercise jurisdiction over development of the river. It is engaged in dam management and maintenance, compilation of hydrological data, and survey of water quality and various other items. The ZRA also controls the amount of water use for power generation. Each year, it makes water allocations for such use and determines the allocations for the following year based on the results of analysis of hydrological data etc. Although ZESCO operates the power stations, the output is under the ceiling of water allocation by the ZRA.

The yearly trend shows that the generated output of the KNBPS was low in the 1990s. The operation has run-of-river control, and output basically depends on the dam water level. A look at the yearly trend of this level reveals that it was low in the 1990s. There were similarly many years in that decade when the flow of water from the Zambezi into Lake Kariba was low. Due to the large size of the reservoir, the station is not seriously affected by droughts in a single year, but continuation for several years has the effect of decreasing generated output unless the dam water level recovers.

As for the yearly operation pattern, the trend for the years 1998 - 2003, which were selected to exclude the influence of rehabilitation projects, indicates output on approximately the same level from year to year. The reservoir formed by the Kariba dam is operated in a manner to attain full supply level in July for use of the stored amount during the dry season. The water level declines until January, when storage starts again and continues until July. The operation may also be affected by factors such as facility deterioration since the start of operation in 1976. For this reason, a rehabilitation project was implemented from 2004 to 2009 in order to extend facility service life and increase capacity. This project expanded the capacity of each unit from 150 to 180 MW, and the combined capacity from 600 to 720 MW, for a total increase of 120 MW.

Figure 4.4 Kariba Dam (photo)

Table 4.3 Outline of the KNBPS

Name of the HP	Kariba North Bank
General information	
Installed capacity (MW)	720 (180 × 4 units)
Rated Discharge (m^3/s)	186.79
Rated head (m)	92
Plant factor (%) (in 2007/08)	73.5 (available capacity 510 MW)
Annual generation (GWh) (in 2007/08)	3,282
Technical information	
Dam type	Double Curvature Concrete Arch
Dam height and crest length (m)	Height 128 m, crest length 617 m
Dam Construction (year)	1958
Catchment area (km^2)	663,000
Area of the reservoir (km^2)	5,180
Total storage capacity (m^3)	185,000 million
Effective storage capacity (m^3)	64,740 million
Maximum supply level (m.a.s.l)	487.8
Minimum operating level (m.a.s.l)	474.8
Spillway Gate, discharge capacity	6 sluice gates, 9.14 x 8.84 6 × 1,574 m^3/s
Power house	L 130m,W 24m, H 45m
Type of turbine	Vertical Francis
Commercial operation date	#1: 5th May 1977 #2: 13th December 1976 #3: 24th August 1976 #4: 24th May 1976

(Source) ZESCO

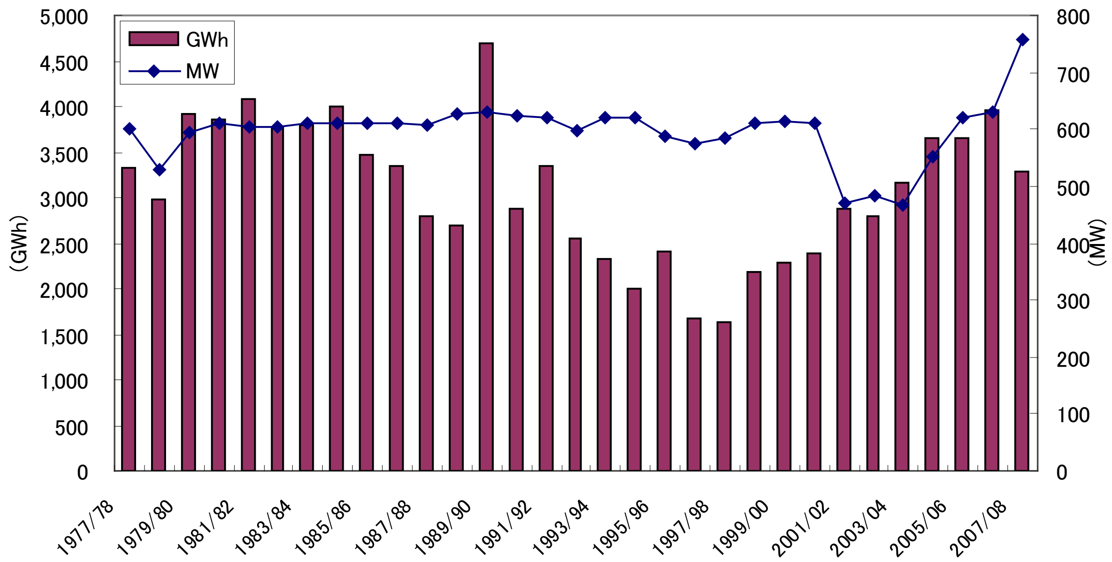


Figure 4.5 Yearly power generation at the KNBPS (actual, FY1977 - 2007)

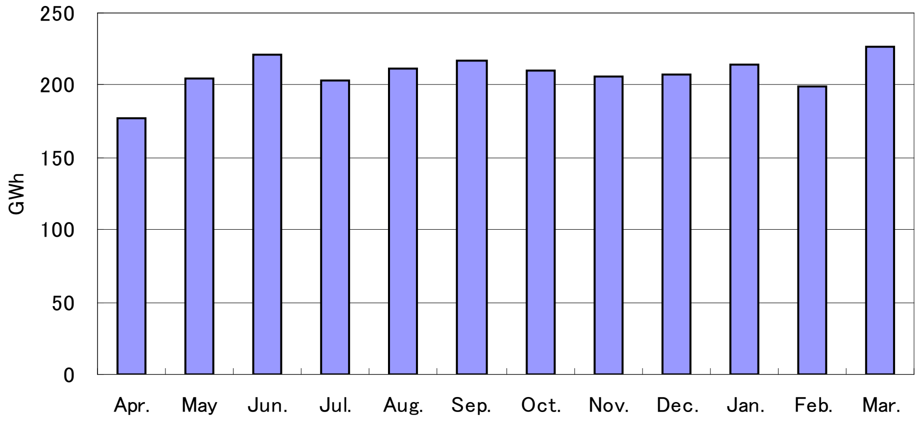


Figure 4.6 Monthly power generation at the KNBPS (1998 – 2002 average)

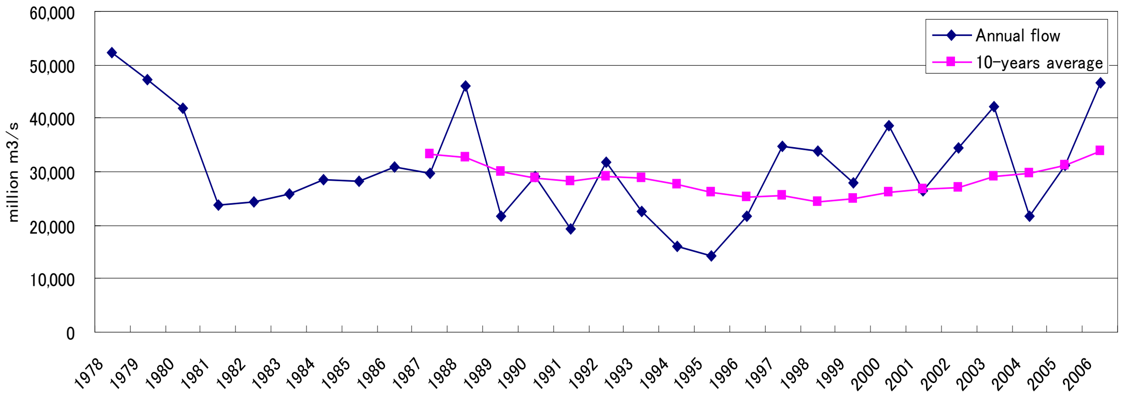


Figure 4.7 Annual flow of the Zambezi upstream (Victoria Falls water measurement station)

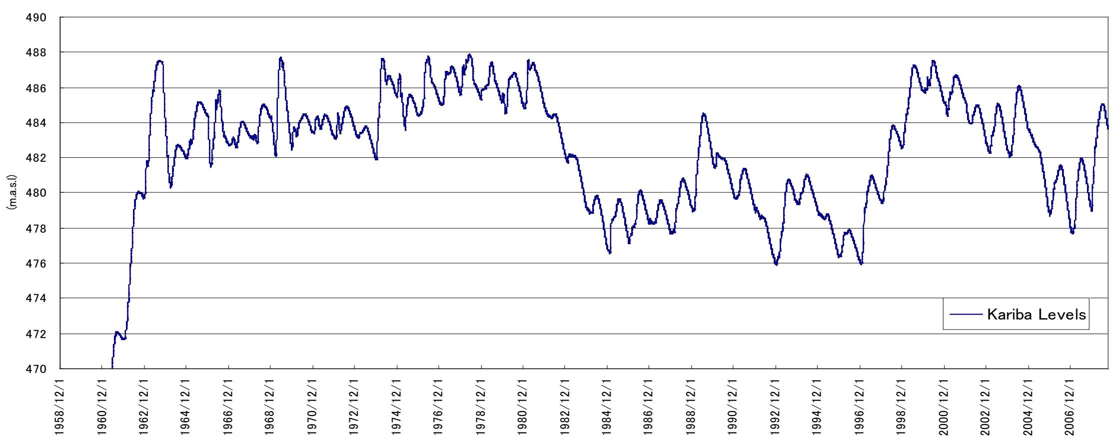


Figure 4.8 Yearly trend of dam water level in Kariba Dam

(b) Kafue Gorge Power Station (KGPS)

The KGPS lies on the Kafue River, which is a tributary of the Zambezi and the biggest river in Zambia after it. The Kafue is characterized by flat terrain upstream from the KGPS; the average grade is 0.0025 percent. The difference of elevation to the reservoir of the Itezhi Tezhi upstream is in the range of only 5 - 6 meters. For this reason, it takes about 90 days for discharge from the ITT reservoir to reach the Kafue Gorge reservoir. The ITT reservoir was constructed in 1978 and has a storage capacity of about 6 billion cubic meters. It levels the Kafue flow disparity between the rainy and dry seasons, and plays the role of supplying the KGPS. The flow-adjusting function of the ITT reservoir contributes to the supply of water for irrigation and drinking in the surrounding area as well as the KGPS operation.

Operation was commenced by KGPS Unit No.1 in 1971 and by three other units in 1972. As this was before development of the ITT reservoir, the station initially had four units with a capacity of 150 MW each, for a combined 600 MW. In 1978, upon the completion of the ITT reservoir, the remaining two units were placed into operation, and made the KGPS the biggest power station in Zambia. At this time, it was installed with six 150-MW units, for a combined capacity of 900 MW, and had an effective head of 387 meters, headrace tunnel length of 10 kilometers, and underground power house.

The trend of generated output reveals a substantial drop in 1989/90. This drop was caused by the outbreak of fire within the station. From actual data for the KNBPS in these years, it can be seen that the generated output is higher than in normal years and that the KNBPS compensated for the reduction at the KGPS. The figures for monthly average generated output also indicate coordination between the KNBPS and the KGPS to assure a certain combined output.

As the station has been operating since 1972, there have also been apprehensions about facility superannuation. In response, a rehabilitation project was implemented from 2004 to 2009 in order to lengthen facility service life and increase capacity. The project expanded the capacity of each unit from 150 MW to 165 MW and the total from 900 to 990 MW, up 90 MW.

Another notable facility feature is the shape of the water intake screen. The KGPS reservoir is sometimes covered with aquatic plants, depending on the season. The station is therefore installed with a flat screen in front of the intake as shown in Figure 4.9 to prevent the plants from coming near the intake aperture.

Figure 4.9 KGPS water intake screen (photo)

Figure 4.10 Kafue Gorge Dam (photo)

Table 4.4　　Outline of the KGPS

Name of HP	Kafue Gorge
General information	
Installed capacity (MW)	990 (165 x 6 units)
Rated Discharge (m^3/s)	46
Net head (m)	387
Plant factor (%) (in 2006/7)	76.6 (available capacity 750 MW)
Annual generation (GWh) (in 2006/7)	5,034
Technical information	
Dam type	Earth and Rock Fill
Dam height and crest length (m)	Height 50 m, crest length 375m
Dam Construction (year)	1968
Effective storage capacity (m^3)	800 million
Maximum supply level (m.a.s.l)	977.2
Minimum operating level (m.a.s.l)	975.4
Spillway Gate, discharge capacity	4 radial gates, 14 x 12 4,250 m^3/s
Headrace tunnel length (km)	10
Penstock	6 vertical penstocks Concrete lined in the upper 200m part, dia 3.3m Steal lining in the lower 170m part, dia 2.75m
Power house	Underground
Type of turbine	Vertical Francis
Tailrace tunnel (km)	1.4
Commercial operation date	#1: 1971 #2,3,4: 1972 #5,6: 1978

(Source) ZESCO

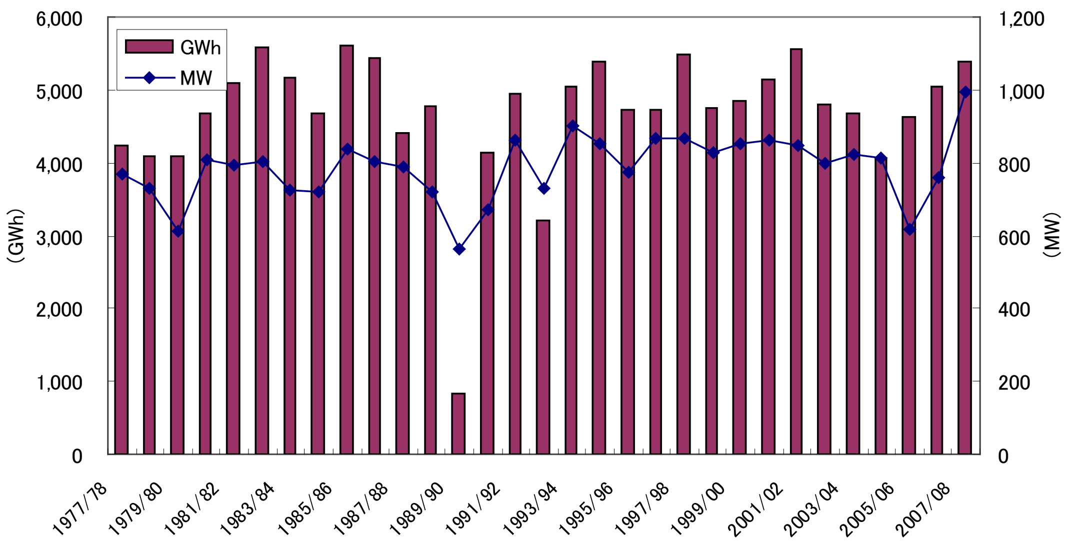


Figure 4.11　Yearly power generation at the KGPS (actual, FY1977 - 2007)

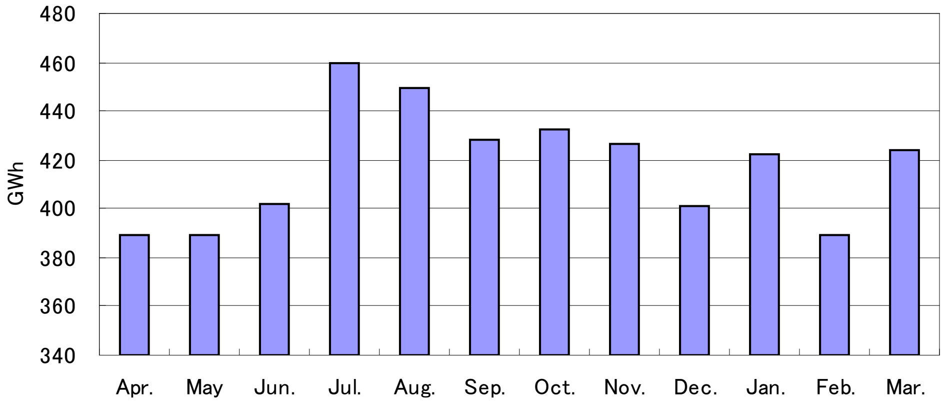


Figure 4.12 Monthly power generation at the KGPS (1998 – 2002 average)

(c) Victoria Falls Power Station (VFPS)

The VFPS lies on the main channel of the Zambezi on the border with Zimbabwe, in Livingstone, the former national capital. It is a run-of-river type of hydropower plant with a total capacity of 108 MW. It does not have a weir, and its intake is directly above Victoria Falls, a World Heritage site.

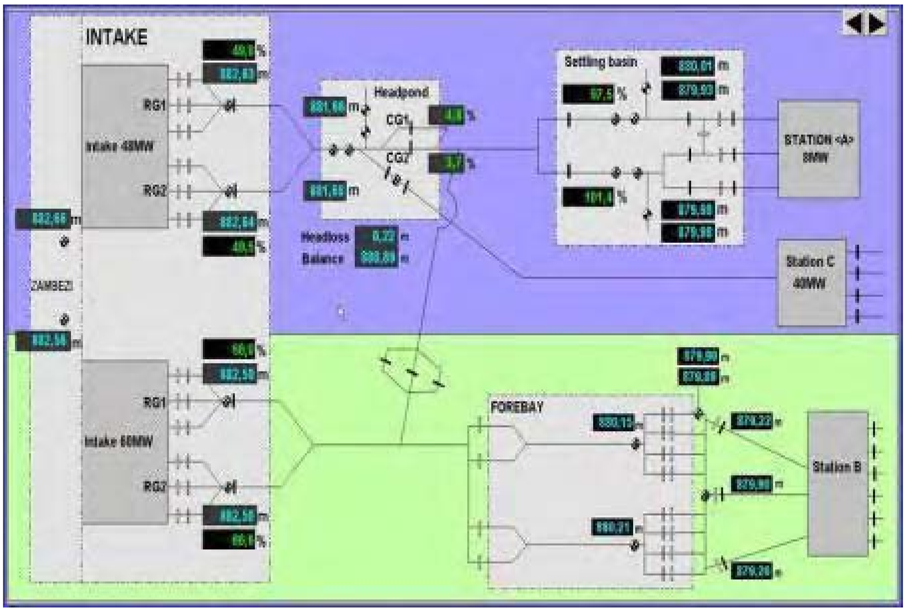
Development of Victoria Falls began in 1938, and the station had two units with a capacity of 1 MW each, for a total of 2 MW, when it went into operation. In 1956, the addition of two units with a capacity of 3 MW each raised the total to 8 MW. At this stage, the facility was known as Station A. There followed the development of Station B, which was installed with six 10-MW units for a total capacity of 60 MW, in 1968, and of Station C, which was installed with four 10-MW units for a total capacity of 40 MW, in 1972. Taken together, the three stations (A, B, and C) had a capacity of 108 MW.

Actual figures for the operation indicate that the generated output depends on the river flow because the station is of the run-of-river type. In fiscal 2007, the facility working rate was 77.5 percent as calculated on the basis of actual ZESCO statistics. Victoria Falls is a World Heritage site, and operation of the VFPS is under restrictions when the Zambezi flow rate is less than 400 cubic meters per second. Analysis of the duration curves obtained from flow data over the 30-year period 1978 - 2007 compiled by the Big Tree (Victoria Falls) observation station reveals that rates falling into this category 70 percent flow, that is 255 day flow (see Figure 4.17). In the months September - December, which correspond with the dry season, the flow rate falls below 400 cubic meters per second. The maximum rate of intake for generation is 117.2 cubic meters per second, and corresponding analysis of the duration curves yields a figure close to the minimum flow. While this would appear to show that the power station could constantly obtain the maximum intake throughout the year, there is no weir, and water can consequently only be taken from the flow along the left bank, where the intake is located.

As the operation dates from 1938, there have been apprehensions about superannuation. In response, a rehabilitation project aimed at renovating facilities and lengthening the service life was implemented from 2003 to 2005.

Table 4.5 Outline of the VFPS

	Station A	Station B	Station C
Year of Commission	1938: 2 MW (1×2 MW) 1956: 6 MW (2×3 MW)	1968	1972
Installed Capacity (MW)	8 MW	60 MW (6 × 10 MW)	40 MW (4 × 10 MW)
Intake	No intake weir Left bank just upstream of the Victoria Falls		
Maximum Water discharge (m^3/s)	10.5	106.7	
Gross head (m)	105.77	112.77	
Power Station	Surface	Underground	Surface



(Source) ZESCO

Figure 4.13 Overall VFPS system

(Source) ZESCO

Figure 4.14 VFPS area (photo)

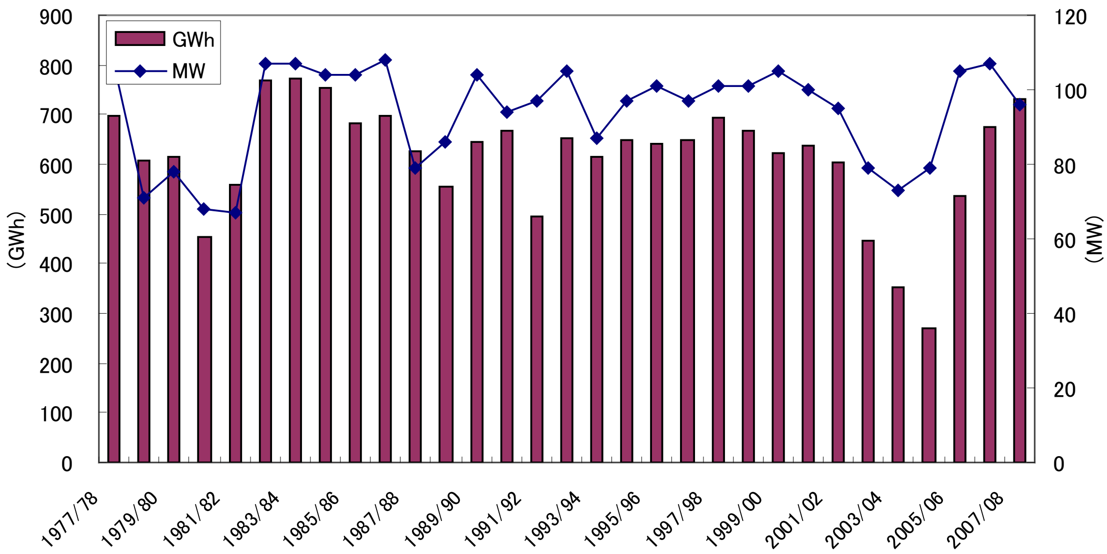


Figure 4.15 Yearly power generation at the VFPS (actual, FY1977 - 2007)

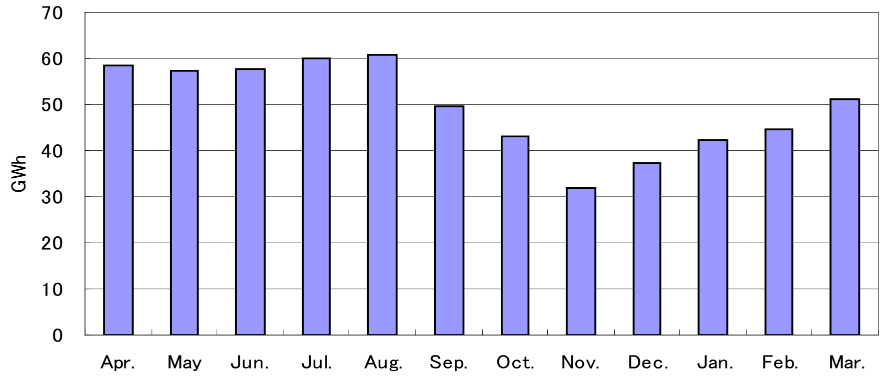


Figure 4.16 Monthly power generation at the VFPS (actual average, 1998 - 2002)

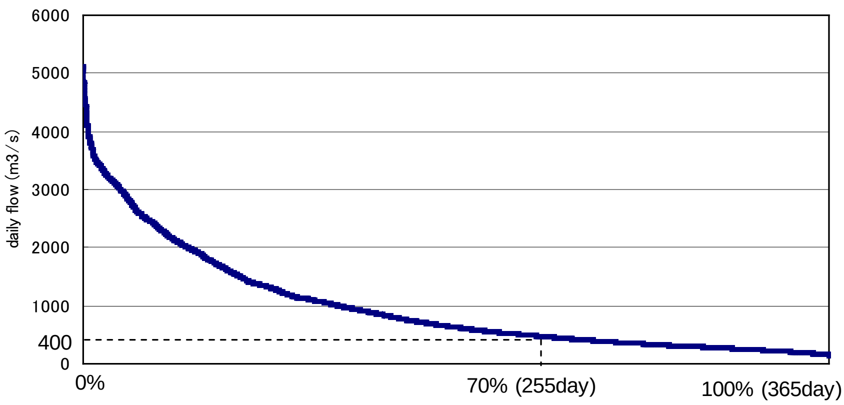


Figure 4.17 Duration curve at the VFPS site

Table 4.6 River flow at the VFPS site (Big Tree observation station)

	Oct.	Nov.	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	max	min	ave
1978/79	550.55	601.71	835.10	1,071.70	1,523.85	2,469.46	4,132.12	3,885.23	2,252.68	1,246.49	763.81	568.30	4,132.12	550.55	1,658.42
1979/80	428.20	488.02	795.29	1,224.13	2,426.83	2,615.39	3,077.00	2,754.82	1,959.41	1,037.46	668.43	502.17	3,077.00	428.20	1,498.09
1980/81	384.68	423.44	591.86	843.60	1,176.43	1,902.23	3,100.19	3,210.79	2,093.58	1,055.32	651.66	479.81	3,210.79	384.68	1,326.13
1981/82	348.11	319.59	423.80	558.29	765.51	957.71	1,423.79	1,579.44	1,157.10	659.54	482.13	373.16	1,579.44	319.59	754.01
1982/83	317.29	364.57	598.32	842.39	1,033.94	1,227.45	1,381.16	1,331.15	902.59	549.26	420.28	331.49	1,381.16	317.29	774.99
1983/84	260.64	297.19	422.29	633.04	867.75	1,273.47	2,049.55	1,766.23	1,033.37	514.53	377.52	293.56	2,049.55	260.64	815.76
1984/85	241.84	279.17	405.63	619.52	962.58	1,170.32	1,762.20	2,153.66	1,660.37	757.19	467.10	339.63	2,153.66	241.84	901.60
1985/86	256.29	247.49	314.31	489.27	698.90	1,018.57	1,760.80	2,683.44	1,691.02	768.08	471.81	353.27	2,683.44	247.49	896.11
1986/87	317.15	446.56	684.45	876.82	1,054.90	1,472.11	2,235.42	1,965.80	1,278.23	643.88	467.22	354.36	2,235.42	317.15	983.08
1987/88	290.29	270.33	404.14	531.66	835.09	1,311.90	1,940.60	2,388.34	1,675.52	795.70	479.74	360.48	2,388.34	270.33	940.32
1988/89	283.98	300.50	454.62	672.60	1,108.78	2,795.89	3,272.67	3,590.39	2,571.99	1,379.35	650.46	432.24	3,590.39	283.98	1,459.46
1989/90	332.24	298.66	302.04	538.97	864.49	1,003.67	1,164.17	1,194.06	1,167.40	615.55	415.72	300.94	1,194.06	298.66	683.16
1990/91	253.35	236.56	324.11	553.36	930.41	2,065.06	2,295.37	2,003.50	1,231.50	539.36	379.09	288.35	2,295.37	236.56	925.00
1991/92	224.56	276.81	466.02	652.77	814.71	1,014.49	1,101.69	1,048.19	712.93	444.47	332.67	251.84	1,101.69	224.56	611.76
1992/93	184.93	213.17	292.84	461.99	741.87	1,236.97	2,411.44	3,122.88	1,886.87	801.13	420.11	287.78	3,122.88	184.93	1,005.16
1993/94	219.92	211.79	350.82	538.85	926.21	1,540.15	2,040.09	1,299.46	542.09	361.64	291.19	220.17	2,040.09	211.79	711.86
1994/95	163.96	164.36	230.16	361.88	507.94	773.39	1,408.22	1,253.30	508.10	317.45	245.27	178.11	1,408.22	163.96	509.35
1995/96	126.09	133.47	239.80	387.79	536.49	695.12	913.75	1,013.22	547.12	335.81	256.26	186.08	1,013.22	126.09	447.58
1996/97	130.39	132.84	223.35	420.59	767.71	1,012.81	1,456.18	1,723.84	1,266.26	528.11	326.79	233.47	1,723.84	130.39	685.20
1997/98	168.03	159.74	239.33	516.49	857.17	2,110.46	3,170.68	2,826.72	1,690.58	727.00	438.12	304.08	3,170.68	159.74	1,100.70
1998/99	212.35	181.03	295.68	540.88	854.75	1,867.01	2,644.55	3,024.32	1,815.93	736.02	421.25	282.70	3,024.32	181.03	1,073.04
1999/00	203.14	196.34	276.44	456.28	638.48	974.19	2,665.20	2,431.60	1,513.26	638.63	368.68	261.12	2,665.20	196.34	885.28
2000/01	171.67	145.21	278.23	569.54	919.29	2,325.08	3,074.11	3,287.84	2,112.01	974.83	507.49	351.52	3,287.84	145.21	1,226.40
2001/02	239.08	246.13	424.22	561.34	717.83	1,053.96	1,706.71	1,940.91	1,634.16	812.40	431.95	296.61	1,940.91	239.08	838.77
2002/03	226.86	202.70	282.83	501.87	831.01	1,300.96	2,226.46	3,422.10	2,211.60	1,092.60	521.07	337.67	3,422.10	202.70	1,096.48
2003/04	230.41	208.74	298.55	558.43	908.48	2,107.00	4,051.29	3,535.83	2,227.32	1,080.18	522.95	343.84	4,051.29	208.74	1,339.42
2004/05	241.84	216.41	334.51	502.47	775.33	1,142.96	1,378.68	1,384.15	1,122.58	558.89	371.63	275.59	1,384.15	216.41	692.09
2005/06	177.66	165.59	308.93	560.82	921.02	1,327.20	2,375.63	2,482.70	1,898.12	903.61	449.66	295.84	2,482.70	165.59	988.90
2006/07	228.05	248.17	395.75	702.00	2,016.28	4,279.80	3,360.58	2,761.50	1,829.41	946.07	549.76	385.14	4,279.80	228.05	1,475.21
ave.	255.64	264.70	396.32	612.05	964.97	1,587.75	2,261.39	2,312.60	1,523.90	752.43	453.44	326.53	2,312.60	255.64	975.98

(d) Mini-hydropower stations

In addition to the large-scale stations KNBPS, KGPS, and VFPS, ZESCO manages mini-hydropower stations at four locations, i.e., Lunzua, Chishimba Falls, Musonda Falls, and Lusiwasi, with respective capacities of 0.75, 6, 5, and 12 MW. Taken together, the four generated about 60 GWh in the year 2007/08. This total was less than 1 percent as high as that of 9,403 GWh for the three stations KNBPS, KGPS, and VFPS in the same year. As shown in Figure 4.18, because the stations are of the run-of-river type, the generated output tends to be lower in the third quarter, which corresponds with the dry season.

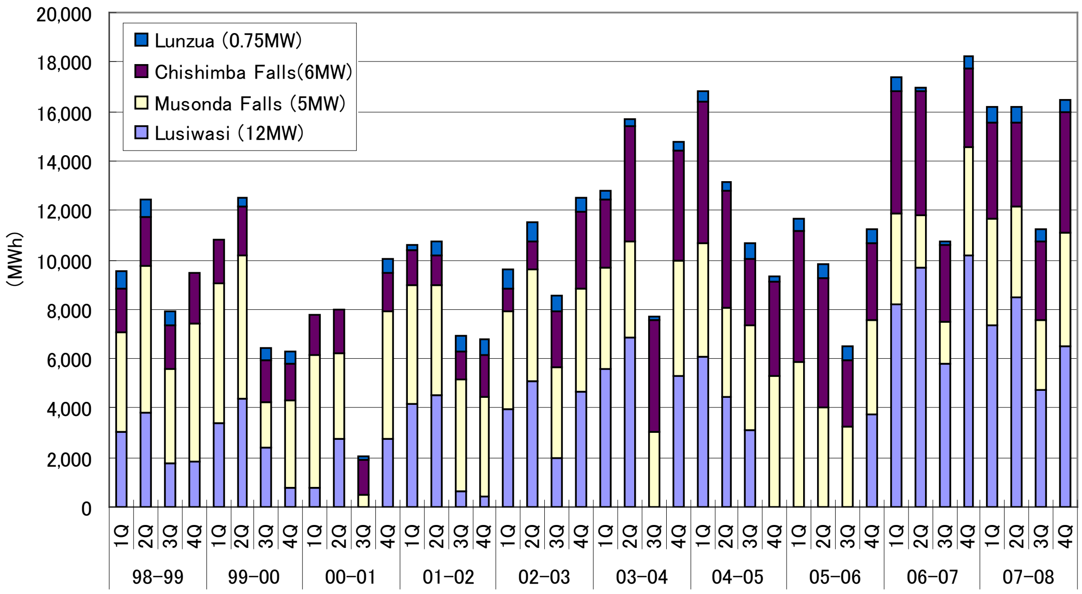


Figure 4.18 Actual generated output at the mini-hydropower stations

ii) Other generation facilities

As shown in Table 4.1, ZESCO has some diesel generation sets to supply off-grid area, besides the hydropower facilities mentioned above. These diesel generators are set mainly in the North-Western Province where the national grid is not expanded. While some diesel generators were abolished with the expansion of transmission lines, others were replaced in the area where grid expansion was not planned. Table 4.7 shows the operational status of these diesel generation facilities.

Table 4.7 Operational Status of Diesel Generation Facilities

	Station	Province	Capacity (kW)	Generation 2006 (MWh)	Generation 2006 CF	Generation 2007 (MWh)	Generation 2007 CF
1	Kaputa	Northern	550	1,167	24.2%	1,007	20.9%
2	Chama	Eastern	263	836	36.3%	840	36.5%
3	Luangwa	Lusaka	1,280	783	7.0%	1,128	10.1%
4	Mwinilunga	North-western	1,360	2,469	20.7%	2,169	18.2%
5	Kabompo	North-western	1,160	2,759	27.2%	2,078	20.4%
6	Zambezi	North-western	960	2,201	26.2%	2,159	25.7%
7	Chavuma	North-western	800	701	10.0%	597	8.5%
8	Mufumbwe	North-western	400	1,036	29.6%	705	20.1%
9	Lukulu	Western	512	1,109	24.7%	1,050	23.4%
	Total		7,285	13,061	20.5%	11,733	18.4%

(Source) ZESCO annual report

(2) Private sector

i) Hydropower facilities

As of March 31, 2008, Zambia had one private hydropower company: Lunsemfwa Hydropower Company (LHPC). LHPC owned two hydropower stations and was selling power to ZESCO. Located at Lunsemfwa and Mulungushi, the two stations had respective capacities of 18 and 20 MW, for a total of 38 MW. LHPC stated that it had plans to increase these capacities by 6 and 8.5 MW, respectively.

In fiscal 2007/08, the generated output of these stations came to a combined 286 GWh, or only about 3 percent as high as the corresponding output of 9,403 GWh for the KNBPS, KGPS, and VFPS. The monthly trend indicates a lower output in the third quarter under the influence of the dry season as the stations are of the run-of-river type. The output tended to be lowest in November.

LHPC is also planning to develop additional hydropower sources in the vicinity of existing ones (see Clause 6.4.1).

Table 4.8 Private hydropower facilities (as of 31 March 2008)

Power Station	Installed Capacity (MW)	Location	Ownership
Lunsemfwa	18	Central Province	LHPC
Mulungushi	20	Central Province	LHPC
Total	38		

(Source) ZESCO, Statistics Year Book of Electric Energy 2007/2008

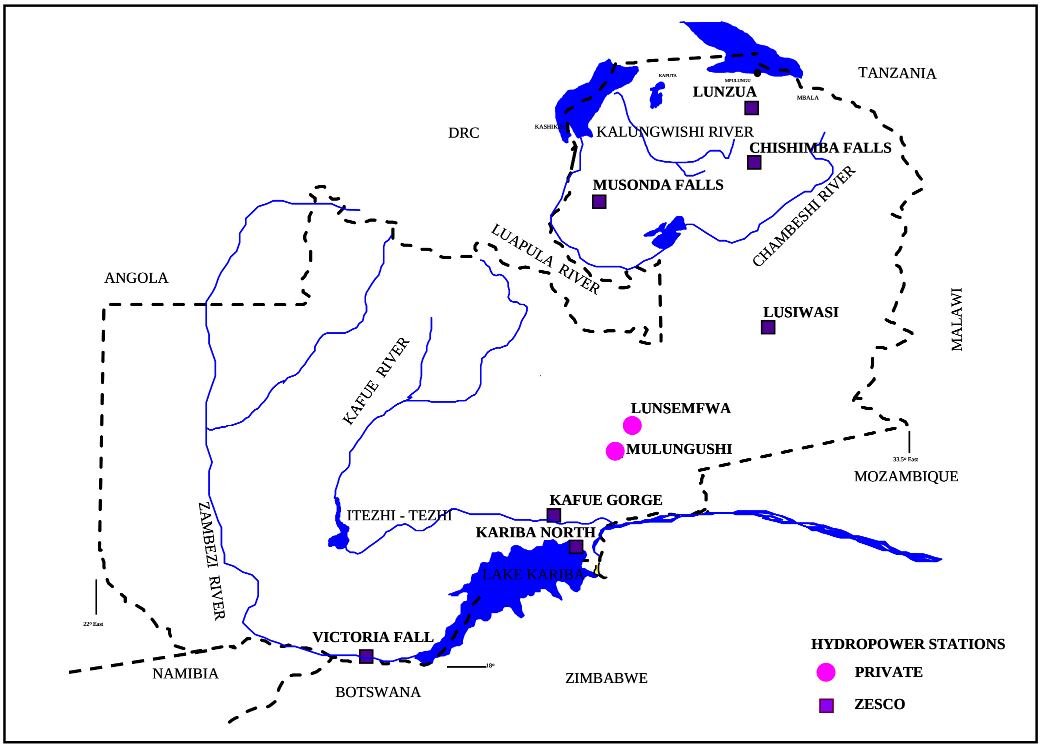


Figure 4.19 Map of private hydropower facility sites

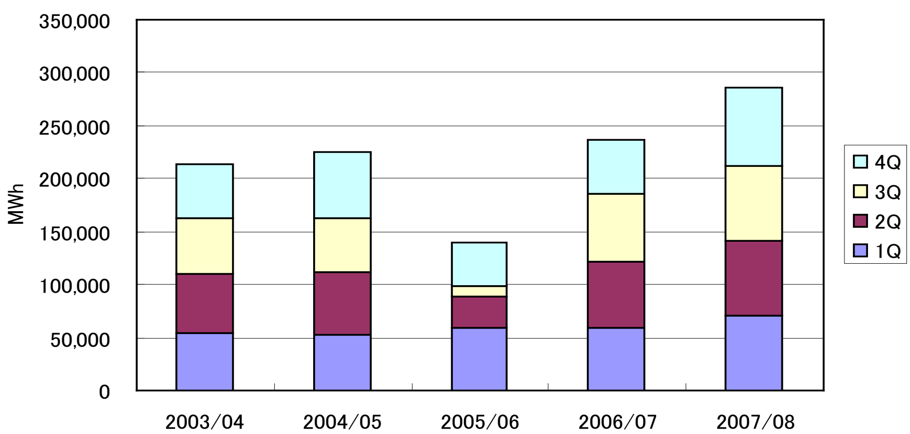


Figure 4.20 Generated output of private hydropower facilities (FY2003 - 2007)

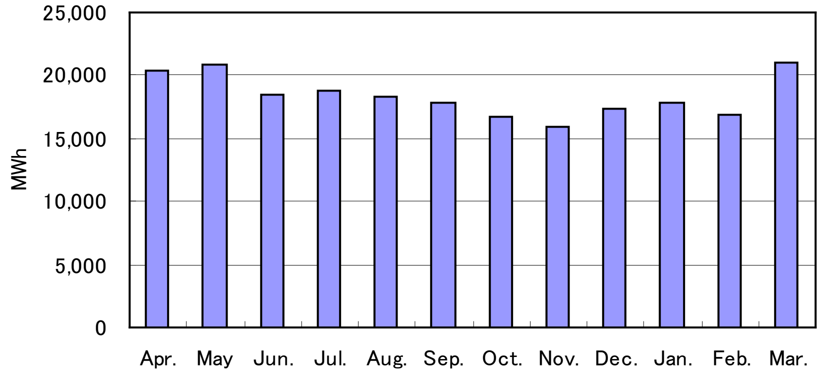


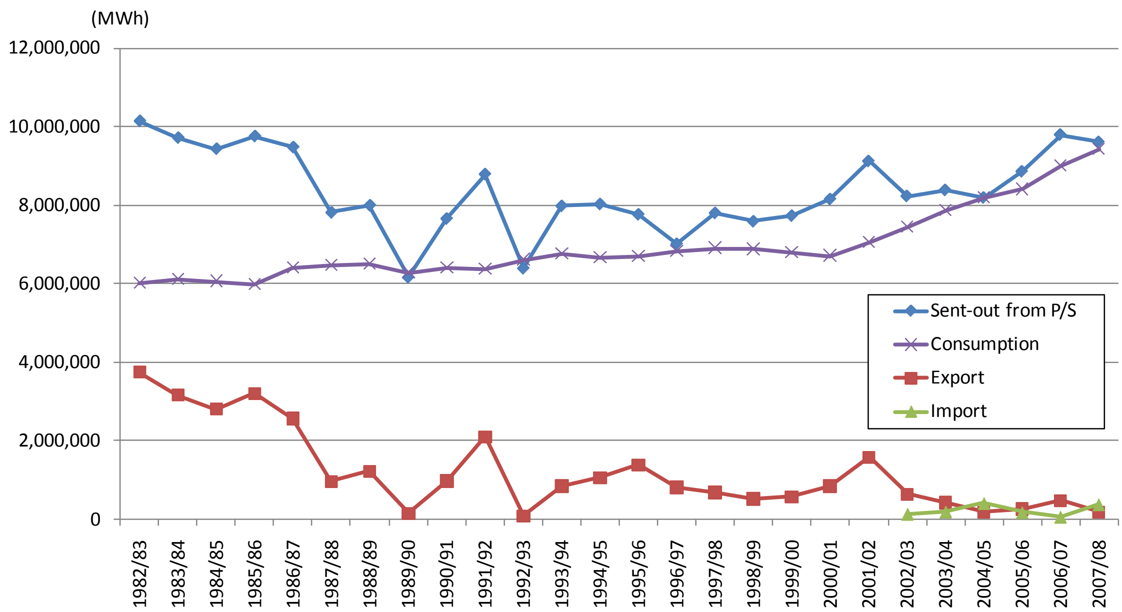
Figure 4.21 Monthly output of private hydropower facilities(average, 2003 - 2007)

ii) Other Generation Facilities

CEC has four gas turbine generators with total capacity of 80 MW. However, CEC's main business is to sell electricity purchased from ZESCO under long-term Bulk Supply Agreement to mining companies by using its own transmission and distribution facilities, so that these generation facilities are recognized as emergency generators when power supply from ZESCO is disrupted.

4.1.2 Demand and supply situation

As seen in the previous section, installation of new generation facilities has long been stagnant, so that energy export is decreasing due to growth of domestic power demand. Additionally, drought and rehabilitation of existing facilities are making matters even worse to import energy in recent years. Figure 4.22 indicates the trend of power balance for 25 years between FY 1983/84 and FY 2007/08. Power consumption has been steadily increasing, especially after 2000 while power generation by hydropower ranges approximately from 6 to 10 TWh p.a. despite the fluctuation induced by river flow or rehabilitation of facilities. As a result, power import started from FY 2002 and import exceeded export in FY 2004 and 2007 as around 4 tera-watt-hour of energy was exported a quarterly century before.



Note) Fiscal Year (FY): April to March

Figure 4.22 Trend of power demand and Supply (FY 1982 – 2007)

4.1.3 Sector-wise demand structure

Electricity demand in Zambia has been increasing at the annual rate of 3 – 4 %, mainly owing to mining sector and agricultural sector.

The largest power purchaser in the whole sale level is Copperbelt Energy Corporation supplying energy to the mines in Copperbelt, whose share (44 %) is larger than any distribution divisions of ZESCO. Power demand in Zambia heavily depends on demand of mining industry and is subject to be affected by fluctuation of their consumption.

Among distribution of ZESCO, the Lusaka distribution division is the largest. In terms of end use, residential use (service) accounts for the lion's share while the manufacturing sector share is just 17 %.

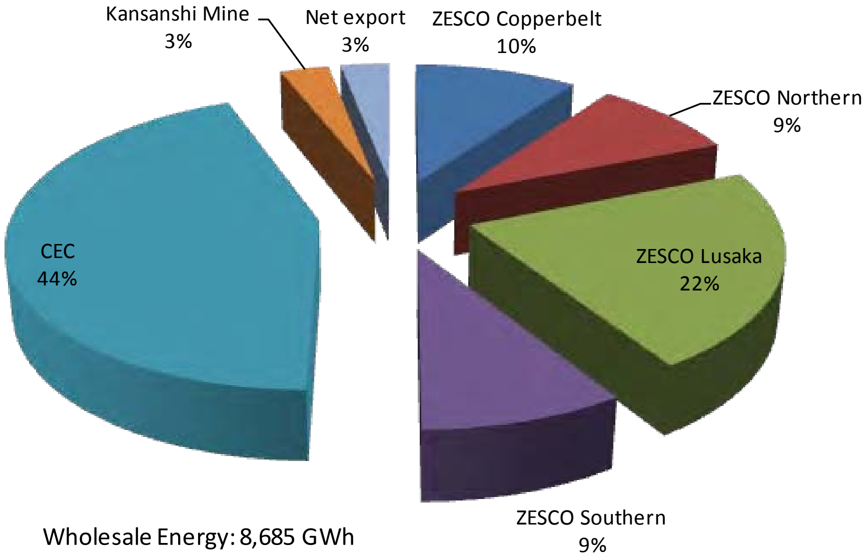


Figure 4.23 Power wholesale of ZESCO

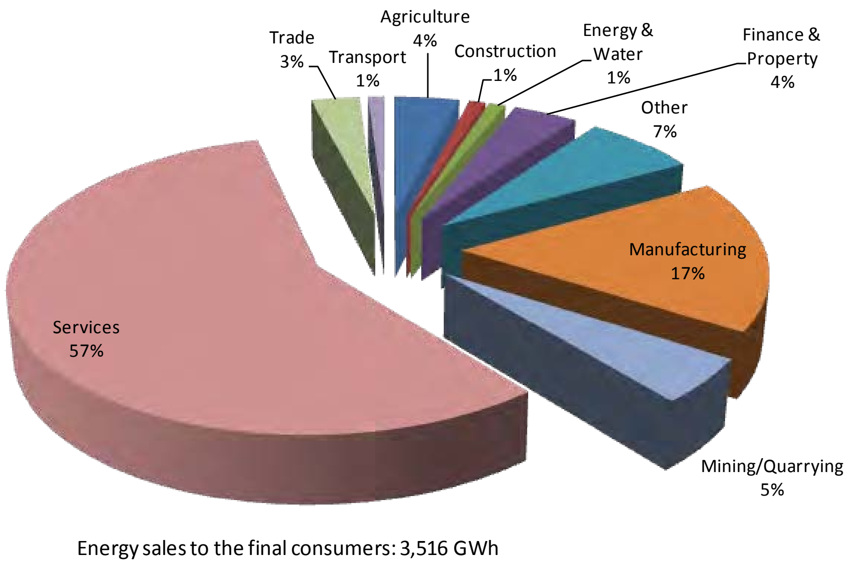


Figure 4.24 Final power consumption of ZESCO

Structurally, future demand growth will depend on mining company demand. Copper ore production may be affected by international market conditions. If the market price declines, Zambia could lose its competitive edge. Power demand could then also decline, a trend which has historical precedence. Thus, power demand in the mining sector is strongly affected by copper price on the international market and by price volatility.

Future increases in electrification ratios also are important factors. By 2030, the Zambian government plans to increase the electrification ratio from the current 3.1% to 50% in rural areas, 48% to 90% in urban areas, and to reach the nationwide target ratio of 60% by 2030. These increases will be additionally piled up in future demand; but the increases will be determined by restriction in actual supply rather than by potential demand.

4.1.4 Recent power demand from SCADA data

The National Control Centre of ZESCO has a SCADA system that monitors and controls the Zambian domestic supply-demand balance and can operate interconnections. The SCADA system stores various data series for about two years. Then, we looked these data to see the trend of Zambian demand.

(1) Load duration curve

The important records named 'System Total Load[2]' represent to be deducted sum of the value of interconnections from total gross output are stocked by SCADA. These records represent gross total demand including losses (transmission and distribution losses) from another point of view.

Figure 4.25 shows the load duration curves in CY2007 and 2008.

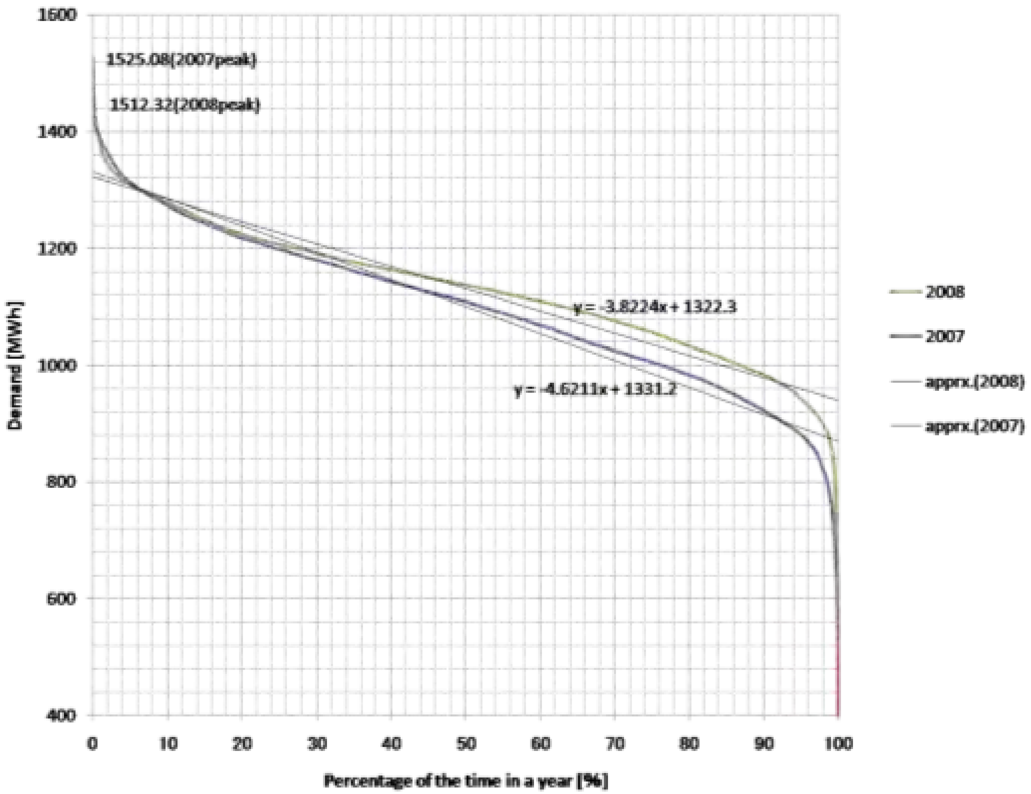


Figure 4.25 Load duration curves in 2007, 2008

Comparing 2007's and 2008's, it is clear that conditions around the peak points are similar but those of other points, especially in the light load period, is increased. This shows that an

2 This value can be given by following equation;
'System Total Load' = 'Vicrtia Falls PS Total GenP(MWh) '+'Kafue Gorge PS Total GenP(MWh) '+
'Kariba North Bank PS Total GenP(MWh) '+'Lusiwasi PS Total GenP(MWh) ' +
'Intetrchange toward Zimbabwe'+'Intetrchange toward DRC'+'Intetrchange toward Namibia'+
'Intetrchange toward Botsuwana'

original power demand in Zambia has been activated, and it is surmisable that there was a bottom raising of the power consumption atmosphere in Zambia overall, and that there was the continuation of a steady power demand by Zambian copper industry influenced with the price of international copper that is growing up of a right shoulder until July, 2008.

Thus, the overall rising of the running electric energy as for year with load factor improvement is a desirable tendency on electrical power supplier's financial affairs.

(2) Daily load curve

Following figure shows daily load curves. These show the date and value of peak power demand in 2007 and 2008, off-peak demand (Sunday) in 2007 and 2008, Easter Sunday in 2007 and 2008 respectively[3].

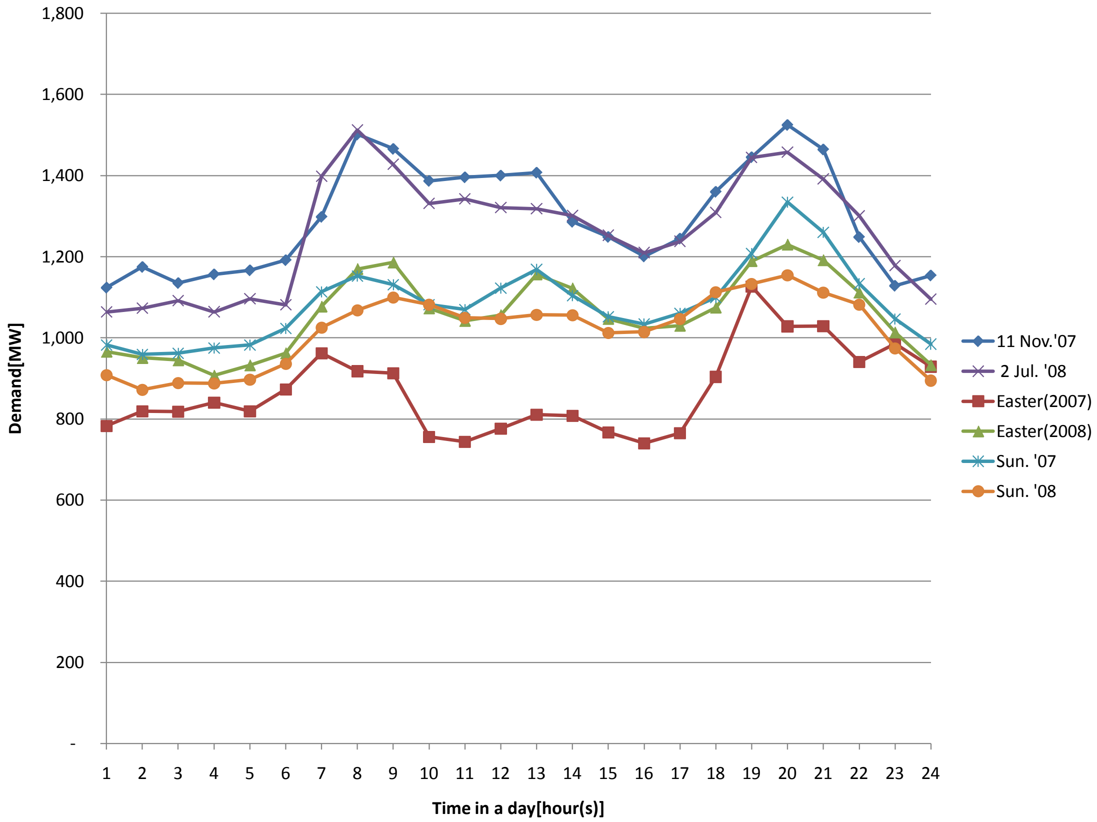


Figure 4.26 Daily load curves

This shows that the power demand has two peaks (morning and evening) and those of normal Sunday and Easter Sunday have three summits (morning, evening and afternoon). Thus, it is clear that residential consumption is the main determinant of the occurrence of peak demand.

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[3] Frequently we compare the several daily curves in order to confirm characteristic between nationalitiy and the shape of demands.

Major curve,

Minor curve-1 : We select Sunday when the people don't work on.

Minor curve-2 : We select the day of holiday when the people tend to take rests whole day on.

(3) Weekly averaged demand

Following figure shows transition of weekly averaged demand in 2007 and 2008.

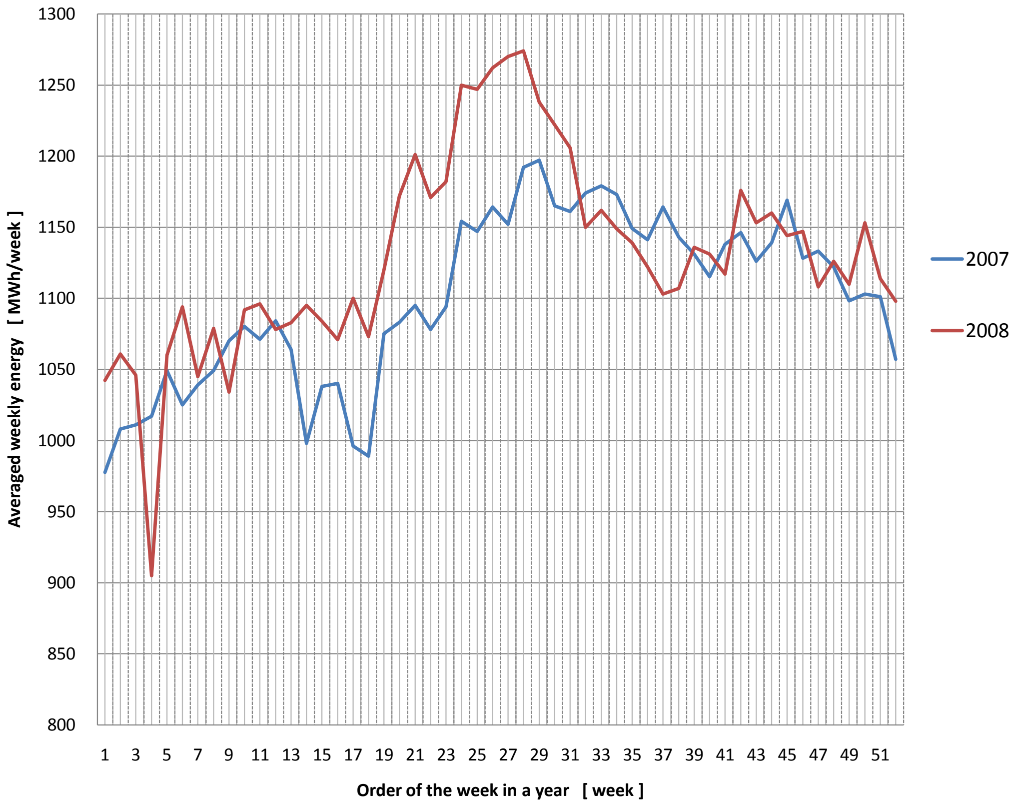


Figure 4.27 Transition of weekly averaged demand in 2007 and 2008

Recent power demand in Zambia tended to rise gradually until July (27^{th}-31^{st} week) when the peak power was generated, getting depressed was not shown afterwards, and to be going to connect the power next year. As a result, the tendency is seen from 2007 to 2008 In this case, however, after July, 2008, the tendency in recent years cannot be found. It is guessed that this is because industrial demand for the electric power is controlled by the production adjustment of copper by dramatic slowdown of copper price since July, 2008.

(4) Quarterly load duration curves

Figure 4.28 shows the load duration curve for each quarter of calendar 2007, and Figure 4.29, that for each quarter of calendar 2008.

The quarterly load duration curves trace the same line. The differences of the maximum and minimum levels in each time period in each quarter are also of a similar magnitude. These results indicate that power consumption in Zambia does not vary greatly across the seasons (rainy and dry) seasons. The cause may be due to the following factors:

A. The residential power demand tends to remain basically constant regardless of the change of seasons (rainy versus dry).

B. The electrification rate is low, and seasonal demand fluctuation has little influence on demand.

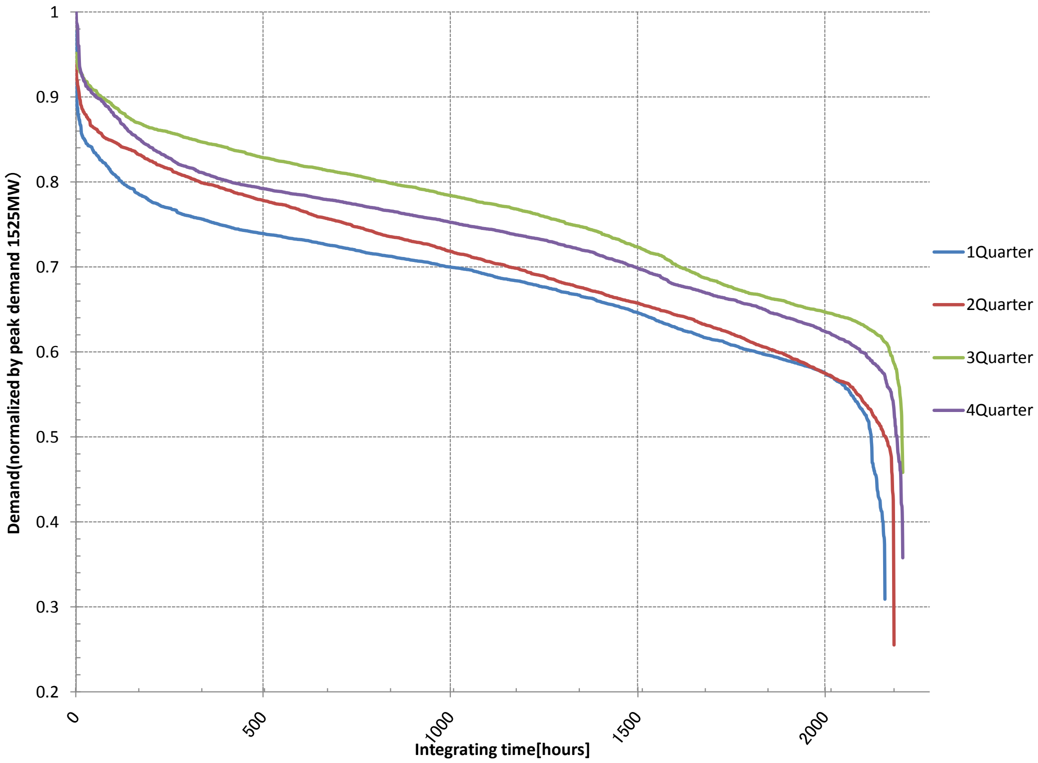


Figure 4.28 Quarterly load duration curves in 2007

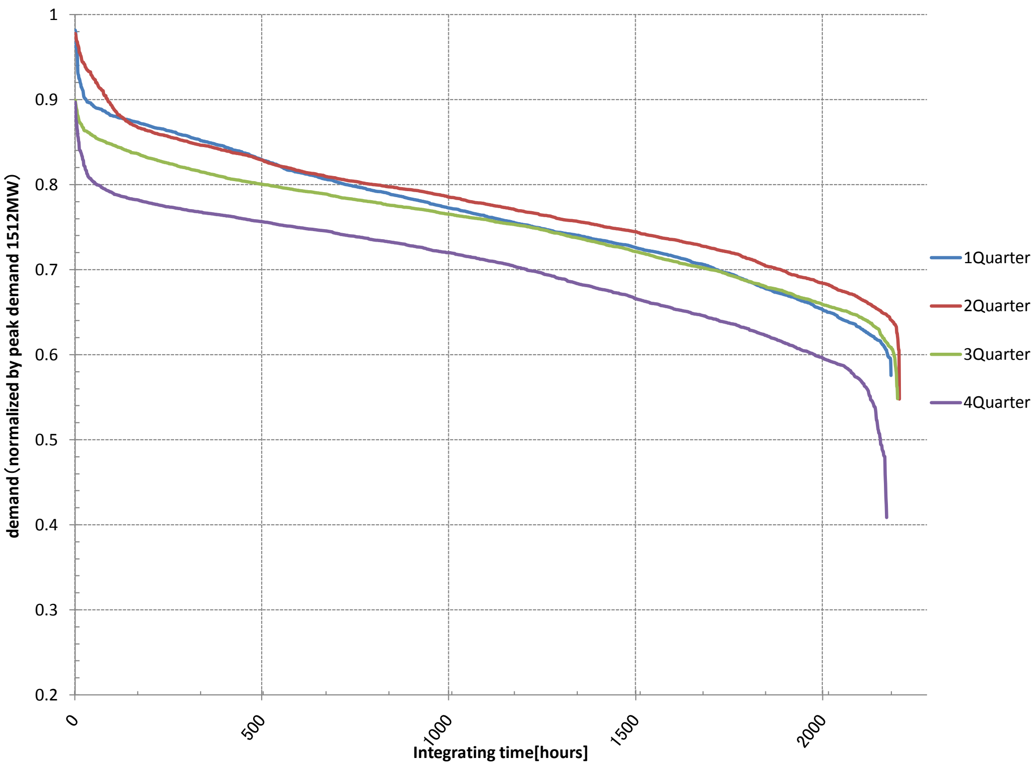


Figure 4.29 Quarterly load duration curves in 2008

(5) Time-period loads in load duration curves

Application of three time periods (peak, daytime, and nighttime, the latter two being off-peak periods) to the daily load curves shown in Figure 4.26 yields the following data.

A. Peak load time period: 6 - 9 AM and 7 - 10 PM, six hours total

B. Daytime load time period: 9 AM - 7 PM, ten hours total

C. Nighttime load time period: 11 PM - 6 AM, eight hours total

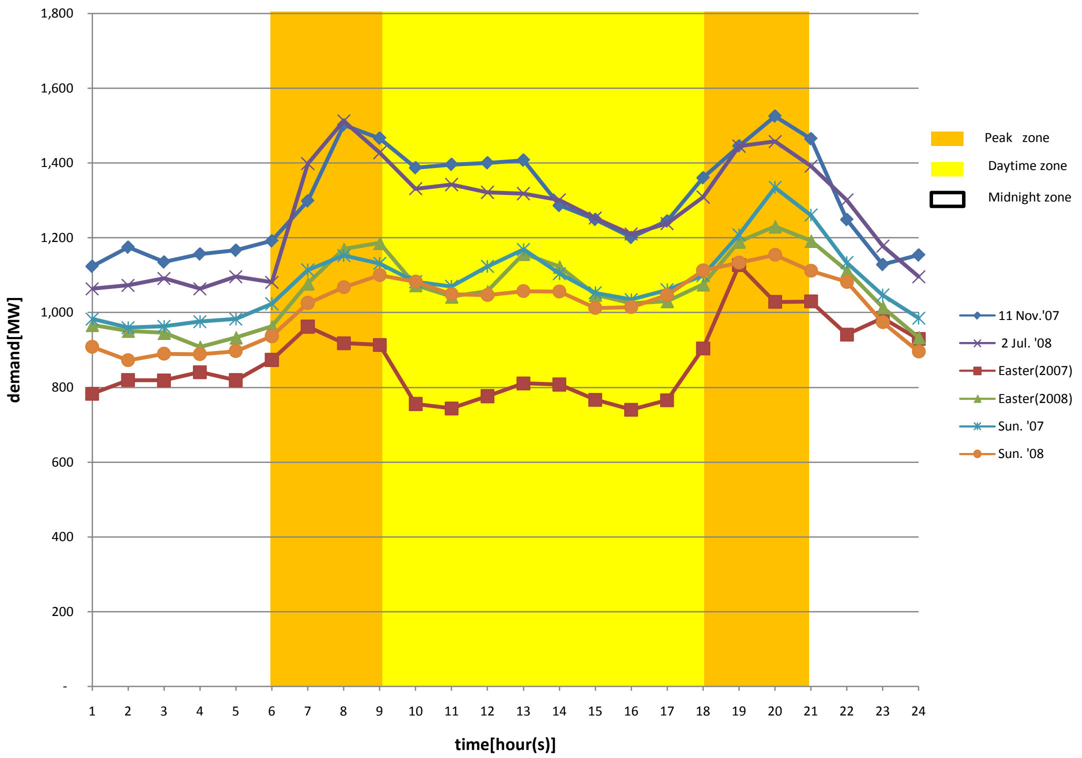


Figure 4.30 Definition of peak, daytime, and nighttime load time periods

This sheds certain light on the position occupied by each time period in the load duration curve. The degree of clarity regarding this position is also a barometer of the electrification rate and extent of economic activities. The position of each time period should become even clearer along with future demand increase.

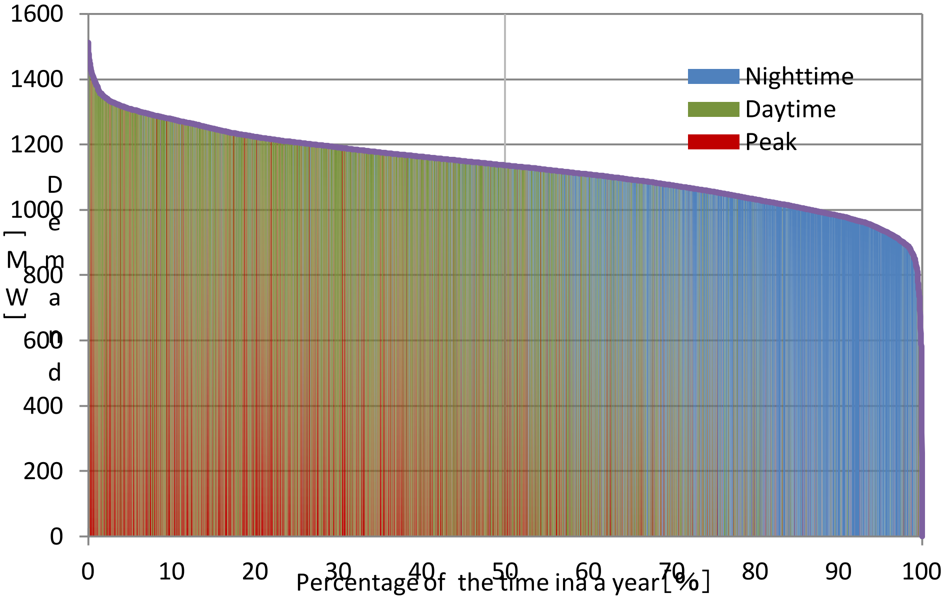


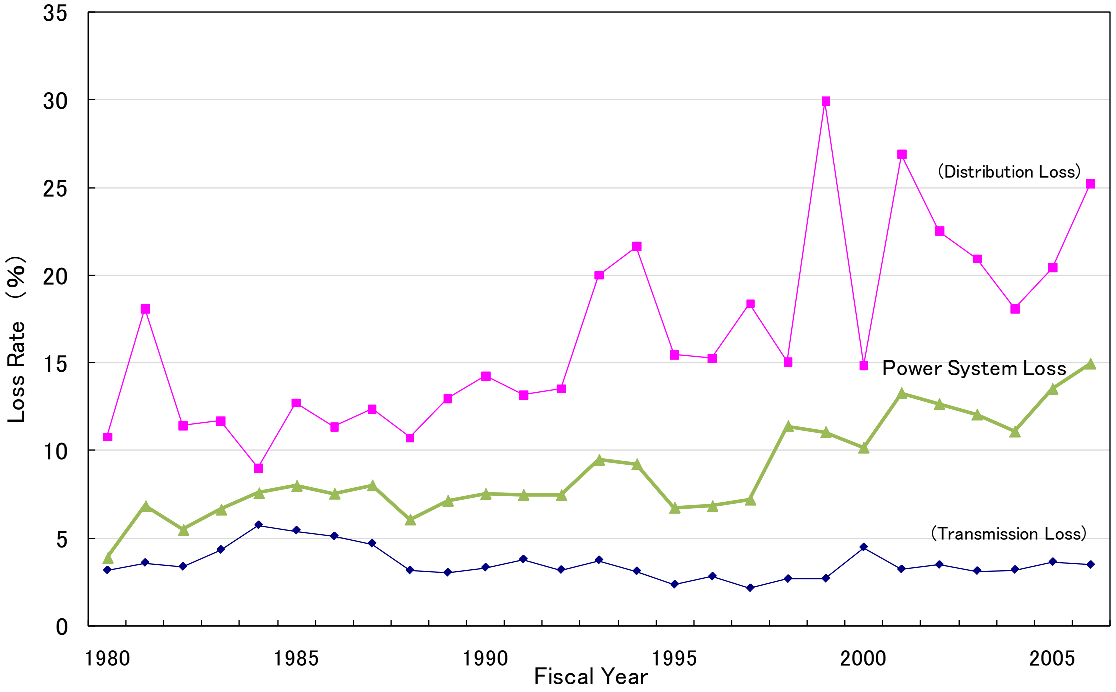
Figure 4.31 Duration curve identified each load time period

4.1.5 Power system loss

Power system loss consists of transmission loss and distribution loss. Transmission loss is the difference between the sending end electrical energy and the distribution end electrical energy (the electrical energy received at distribution substations plus the electrical energy involved in power wholesales and export). Division of this difference by the sending end electrical energy yields the transmission loss rate. Distribution loss is the difference between the electrical energy received at distribution substations and terminal power consumption. Division of this difference by the electrical energy received at distribution substations yields the distribution loss rate.

Figure 4.32 shows the trend of system loss at ZESCO since fiscal 1980, based on data in "ZESCO Statistics Yearbook of Electric Energy".

The transmission loss rate was 3.5 percent in fiscal 2006, and did not change greatly over the period in question. The distribution loss rate, on the other hand, varied significantly from year to year, and rose over the last three years. It reached 25.2 percent in fiscal 2006. The total system loss rate was 14.9 percent in fiscal 2006.



(Source) ZESCO Statistics Yearbook of Electric Energy

Figure 4.32 Trend of the system loss rate

4.1.6 Power import and export

Figure 4.33 presents actual data for power import and export over fiscal years 2002 - 2008.

With its wealth of hydropower resources, Zambia was once a net exporter[4] of electrical power. In fiscal 2002, however, it began to import power due to generation failures and outages for construction as part of power rehabilitation projects. In fiscal 2004 and 2007, it imported more power than it exported. The major factors behind the increased import were the long-term shutdown of generators for rehabilitation at the KNBPS and output decrease due to low inflow into KNBPS and VFPS in fiscal 2004, and demand increase and output decrease due to rehabilitation at the KNBPS in fiscal 2007.

As for the trend in recent years, Zambia's biggest partner in power transactions has been South Africa (ESKOM). In fiscal 2007, ESKOM accounted for 38 percent of Zambia's total power export and 54 percent of its total power import. The tight supply of power in Zimbabwe explains the increased export to that country. The reason for the decline in this export in fiscal 2008 was the long-duration opening of the international interconnection due to apprehensions about system instability in Zimbabwe. This interconnection is also the only interconnection for power transactions with South Africa (ESKOM), and its opening consequently also meant absence of an interconnection with South Africa. This combined with the decrease in capacity for power exports because of the rise in domestic demand slackened the overall power import and export

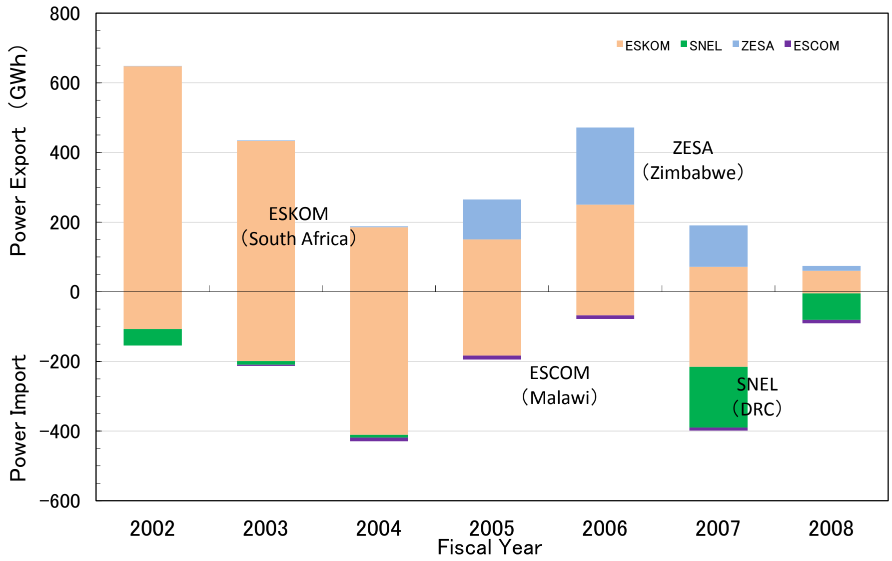
[4] Over the 20-year period of fiscal 1982 - 2001, Zambia exported an average of 1,470 GWh of power per year. It exported the most power in 1982, when its export to ZESA alone came to 3,756 GWh

activity in fiscal 2008.

A notable trend in more recent years is the sharp increase in power imports from the DRC. The DRC (SNEL) is anticipated to emerge as a new player to resolve difficulties (and particularly the power import shortage) in power transactions with South Africa (ESKOM) and Zimbabwe (ZESA). A provisional agreement for resolution of the supply capability shortage in Zambia had not yet been concluded at the time of writing.

As shown in Table 4.9, Zambia has power transaction agreements with Namibia, South Africa, and Zimbabwe.

Zambia's distribution system is interconnected with those of Botswana, Namibia, Zimbabwe, Tanzania, and the DRC. Zambia exports power to these countries. In fiscal 2007, it exported 25 GWh to Botswana, 26 GWh to Namibia, 3 GWh to Zimbabwe, 14 GWh to Tanzania, and 9 GWh to the DRC, for a total of 77 GWh. (Over the 20-year period from fiscal 1982 to 2001, Zambia exported an average of 1,470 GWh per year. Export was highest in 1982, when that to ZESA alone came to 3,756 GWh.)



(Source) ZESCO Statistics

Figure 4.33 Actual ZESCO power import and export (FY 2002 – FY 2008)

Table 4.9 Mutual agreements for power transactions

Countries	Utilities	Agreement
Namibia	NamPower	Firm agreement[5] for supply of 5 MW
South Africa	ESKOM	Non-firm agreement[6] for supply of up to 300 MW
Zimbabwe	ZESA	Non-firm agreement for supply of up to 150 MW

(Source) ZESCO

[5] An agreement for assurance of priority use of power transmission for a reserved capacity.

[6] An agreement for assurance of use of power transmission after determination of transmitted power use based on the firm agreement. However, use of the power transmission for the reserved capacity can be canceled for adjustment in times of transmission line congestion and response in times of unexpected contingency.

Table 4.10 shows the progress of construction on transmission ties for interconnection between Zambia and neighboring countries. These ties will assist to resolve the existing bottlenecks in the SAPP system and in executing new power transactions.

Table 4.10 Progress of construction of transmission inter-connection ties

Interconnection point and other country	Interconnection point in Zambia	Specifications	Progress of construction
DRC Kolwezi	Lumwana	330kV transmission line extension	Construction in Zambia has been completed for a distance of 268 km from the Luano substation to the Lumwana substation. There remains the leg of about 60 km from the Lumwana substation to the border with the DRC. The transmission line in the DRC is in the stage of detailed design; construction has not yet begun (the requisite distance is 100 km). The authorities are awaiting funding from the World Bank. The line is scheduled for completion in 2011.
	Luano	220kV transmission line reinforcement	Scheduled for completion in 2010
Namibia Katima Mulilo	Katima Mulilo	220kV transmission line extension	Construction has been completed between Livingstone in Zambia and the Katima-Mulilo leg in Namibia. The further leg extending into central Namibia is now under construction with HVDC cable. The Phase 1 construction with HVDC cable is scheduled for completion at a capacity of 300 MW before the end of fiscal 2010. The capacity is to be increased eventually to 600 MW, but the schedule for this construction has not yet been determined.
Tanzania Mbeya	Pensulo	330kV transmission line extension	The feasibility study and the EIA study have already been completed. Work is awaiting approval by the Tanzanian authorities.
Malawi Lilongwe		330kV transmission line extension	The feasibility study was finished in 1992, but another one should be implemented to reflect the latest situation.
Zimbabwe Hwange	Livingstone	330kV transmission line extension	Construction of this interconnection is scheduled for completion in mid 2010. The line is part of the ZIZABONA Interconnector Project for linkage of the four countries Zambia, Zimbabwe, Botswana, and Namibia. Technical and economic analyses have already been executed. More detailed studies are now being implemented jointly by ZESA and ZESCO.

4.2 Electricity tariff

The current average prices are calculated by ERB as follows.

Table 4.11 Average Electricity Price

Customer Category	Average Prices (US cents/kWh: 2006/07)
Mining	2.34
Residential	3.05
Large Power	2.07
Small Power	3.14
Commercial	5.87
Services	3.97
Exports	2.87
Total	2.66

The overall average electricity price is 2.66 USc/kWh whereas the residential price is 3.05 USc/kWh. On the other hand, the average prices for the mining customers and large customers show the lowest in the categories with 2.34 USc/kWh and 2.07 USc/kWh, respectively. The discrepancy of the cost-reflective matters among the customers has been identified and discussed. This aspect has led to the tariff adjustment of the recent couple of years.

The electricity tariff in Zambia has been revised on January 1st, 2008. The selected tariff schedule is as given below including the fixed, demand and energy charges. The above tariffs are exclusive of 3% government exercise duty and 17.5% Value Added Tax (VAT).

Table 4.12 Electricity Tariff Schedule (2008)

Category	Unit	Approved Tariff 2008 (ZMK)	Approved Tariff 2008 in US cents
Residential <R2- Consumption 101 to 400kWh>	Energy Charge/kWh	127.00	3.27
Commercial <C1-Consumption up to 700kWh>	Energy Charge/kWh	165.00	4.25
	Fixed Monthly Charge	29,972.00	772.87
Social Services <School, Hospital, Street Lighting, etc>	Energy Charge/kWh	144.00	3.71
	Fixed Monthly Charge	24,972.00	643.94
Small Power <MD-1 Capacity between 16-300kVA>	Max Demand Charge/kVA	15,094.00	389.22
	Energy Charge/kWh	99.00	2.55
	Fixed Monthly Charge	158,035.00	4075.17
Large Power <MD-3 Capacity between 2001-7500kVA>	Max Demand Charge/kVA	24,973.00	643.97
	Energy Charge/kWh	80.00	2.06
	Fixed Monthly Charge	346,808.00	8942.96

(Source) ZESCO Tariff Data in Web Site (2008)

The electricity price in Zambia is one of the lowest in the region. The following table shows the sales and revenues of power utilities in the region. The unit price of Zambia is 2.55 UScents/kWh.

Table 4.13 Comparison of Electricity Price

			2006-07		
			Sales (GWh)	Revenue (US$ mil.)	Unit Price (Cents/kWh)
1	Angola	ENE	2,006.0	184.30	9.19
2	Botswana	BPC	2,626.0	111.40	4.24
3	DR Congo	SNEL	5,697.0	180.00	3.16
4	Lesotho	LEC	420.0	34.20	8.14
5	Malawi	ESCOM	970.0	5.00	0.52
6	Mozambique	EDM	1,380.0	126.00	9.13
7	Namibia	NamPower	3,199.0	193.00	6.03
8	South Africa	ESKOM	208,316.0	5,926.00	2.84
9	Swaziland	SEB	855.8	55.50	6.49
10	Tanzania	TANESCO	2,549.0	188.00	7.38
11	Zambia	ZESCO	8,116.0	207.00	2.55
12	Zimbabwe	ZESA	10,293.0	130.00	1.26

(Source) JEPIC Data (2007)

The last tariff adjustment for ZESCO was in 2005 when the actual increase was only 11%. Thus ZESCO did not realize the tariff adjustment for the last three years. Before the 2005 increase, the adjustment was in 2003 when approximately 5% increase was realized. Given that the increase of the consumer prices in Zambia has been more than 15% p.a. for the last several years on average, the power tariff did not reflect the economic situation. ERB however approved the tariff adjustment for the next three years.

The approved tariff is a multi-year tariff to meet a number of conditions and requirements that spreads over three years of 2008-2010. The indicative increases for each year are as shown in the following table.

Table 4.14 Tariff Adjustment Schedule (Annual Increase Rate)

Customer Category	2008	2009	2010
Residential	26.8%	16.6%	11.9%
Commercial	1.3%	0.3%	0.3%
Social Services	6.8%	1.9%	1.9%
Small Power (MD1 & MD2)	16.2%	5.5%	4.5%
Large Power (MD3 & MD4)	27.5%	16.6%	2.2%

(Source) ERB Data in Web Site (2008)

Even though the multi-year tariff intends to fix the tariff schedule for the next three years, the tariff level will be reviewed by ERB at the end of each year based on the actual situation. Therefore it is critical to closely monitor the financial position of ZESCO in order to sustain the service delivery. The tariff increase scenario originally intends to enhance the performance and efficiency of ZESCO thereby motivating ZESCO to improve the operations and service delivery to end consumers.

The investment program for the next five years (2010-2014) is currently being examined by

ZESCO in consideration of the ERB-approved multi-year tariff increase. Even though ERB is not in a position to directly review and approve the investment program, the financial condition of ZESCO needs to meet the several financial targets agreed upon. It is necessary on the other hand for ZESCO to meet the technical and commercial benchmarks as well. Therefore the investment program will be critical for ZESCO to achieve both of the financial and technical benchmarks.

4.3 Financial situation

4.3.1 Key Performance Indicators (KPIs) for ZESCO

The financial position of ZESCO is monitored and evaluated by the Key Performance Indicators (KPIs) by ERB. The KPIs covers wide-ranging areas including (i) customer metering, (ii) cash management, (iii) staff productivity, and (iv) quality of services, (v) system loss. The salient features of the indicators can be summarized as follows.

i) Customer Metering

- All new customers are metered upon connection.
- All new residential connections should be done within 30 days after customer pays for connection.
- All un-metered customers are metered by March 2010. The milestone for this KPI is that one-third (1/3) of the backlog is metered every year till 2010.

ii) Cash Management

- All customers are billed timely and on a regular basis by December 2007.
- Reduce debtor days from current 180 days to not more than 60days by March 2010. The milestone for this KPI is that one-third (1/3) of the target is reduced every year till 2010.
- Total trade receivables do not exceed 17% of turnover by March 2010.
- Total receivables do not exceed 17% of total income by March 2010.

iii) Staff Productivity

- Increase number of customers per employee to 100 customers per employee by March 2010.
- Reduce staff costs from current level of 49% of operating budget to about 30% of operating budget by 2010.

iv) Quality of Service Supply

- Reduce annual unplanned outage to 5 hours per customers by March 2010.

v) System Loss

- Maintain transmission losses at 3% or less.
- Reduce distribution losses to 14% by March 2010.

The performance of the above-mentioned indicators is reviewed in the following section.

4.3.2 ZESCO Performance as of January 2009

The performance of ZESCO as of January 2009 can be summarized as follows.

Table 4.15 ZESCO KPI Summary as of third quarter of 2008

Indicator	Target	Actual	Difference
Customer Metering			
Unmetered Customers	95,039	132,143	(37,104)
Metering New Customers	6,115	766	(5,349)
Connection Time (days)	68	82	(14)
Cash Management			
(1) Total Receivables	38.47%	61.29%	(22.72%)
(2) Trade Receivables	36.19%	34.95%	2.14%
(3) Debtor Days	130.94	127.57	3.37
Staff Productivity			
(1) Customer-Employee Ratio	72	74	2
Quality of Service			
(1) Unplanned Outage	41	15	26
System Loss			
(1) Transmission Loss (%)	3.00	(3.56)	6.56
(2) Distribution Loss (%)	17.75	19.00	(1.25)

(i) Metering

Unmetered customer issue remains a challenge for ZESCO. Out of a total of 11,545 customers connected between April and September 2008, only 1,440 customers were metered. The number of new connection with meters is far below the total number of new connection made. Thus the number of the unmetered customers is increasing instead of decreasing.

The connection time for the new residential customers has not been improved during the year 2008. It takes still more than eighty two days for ZESCO to connect the new customers as of the third quarter of 2008. Therefore, it is considered that ZESCO needs to accelerate the efforts to improve the operational efficiency.

(ii) Cash Management

The target of the total and trade receivables is less than 17% of turnover by 2010. The total receivables as of the third quarter of 2008 were 61% which is far above the target whereas the trade receivables met the target. In fact, while the receivables are expected to reduce about 4.6% every six months, ZESCO needs to accelerate the improvement more than the originally intended pace.

(iii) Staff Productivity

The actual customer-employee ratio met the target as of the third quarter of 2008. ZESCO recorded a total reduction of 532 in the number of staff in the 2nd and 3rd quarters.

This could contribute the improvement of performance. ZESCO could be on the track to achieve the KPI target if the performance of the staff reduction in the 3rd quarter continues.

(iv) Quality of Service Supply

The distinction between planned and unplanned outages was made. Unplanned outage is broken down into 'unplanned outages" and "load shedding". The KPI of unplanned outage refers to the unplanned outage excluding the load shedding. The actual performance of the unplanned outages stood 15 hours for the 3rd quarter of 2008, which met the target

(v) System Loss

The transmission losses are to be maintained at 3% or less. The performance of the 3rd quarter was a negative value due to the flaw in data previously submitted to ERB. However the trend of the transmission losses in 2008 has been promising.

The target of the distribution losses is to reduce the losses to 14% by 2010. This can be translated to be approximately 2% reduction annually.

4.3.3 Financial Position of ZESCO

The past financial performance of ZESCO can be highlighted in the following table.

The financial performance of ZESCO for 2006-2008 was volatile mainly because of the exchange rate fluctuation. In 2006 ZESCO had a loss in operation due to the appreciation of Kwacha. On the other hand, in 2007 when the Kwacha was appreciated, while ZESCO had a operating profit, the fluctuation of foreign exchange gave a significant negative impact on the resulted loss for the year of K156 billion after the consideration of taxation. Therefore the exchange rate has been a significant factor for ZESCO finance particularly the liability management. This is increasingly a critical factor because the borrowings of ZESCO have been more than doubled for the last four years from 2004 to 2008. Therefore, the asset and liability management will continue to be a critical factor for the management of the capital expenditure for ZESCO.

Table 4.16 Five-Year Financial Record of ZESCO (2004-2008)

(Unit: Kwacha mil.)

Item	2008	2007	2006	2005	2004
P/L Account					
Revenue	94,2621	868,725	768,915	782,641	717,373
(Loss)/Profit before taxation	(13,271)	(218,212)	(76,812)	(71)	(34,828)
Taxation	48,629	62,117	(76,812)	(71)	(34,828)
Profit/(Loss) for the Year	35,358	(156,095)	42,339	35,633	41,676
B/S Account					
Property, Plant and Equipment	3,340,420	3,121,712	2,915,555	2,670,342	1,972,692
Investment in Joint Venture	3,115	-	-	-	-
Net Current (Liabilities)/Assets	(179,340)	(27,859)	51,394	100,654	134,894
Deferred Liabilities	(382,747)	(364,806)	(334,174)	(290,038)	(242,531)
Borrowings	(800,481)	(693,294)	(528,561)	(674,572)	(373,218)
Capital Grants and Contributions	(455,447)	(405,987)	(254,065)	(175,639)	(144,980)
Deferred Income Tax	(5,627)	(55,231)	(119,519)	(43,456)	(43,646)
Net Assets	1,609,893	1,574,535	1,730,630	1,688,291	1,303,211
Financed by					
Shares Capital	215	215	215	215	215
Reserves	1,609,678	1,574,320	1,730,415	1,688,076	1,302,996
Shareholders' Funds	1,609,893	1,574,535	1,730,630	1,688,291	1,303,211

(Source) ZESCO Annual Report (2008)

Table 4.17 Financial Performance Ratio

(Unit: Kwacha mil.)

Item	2008	2007	2006	2005	2004
Net Profit Margin	4%	(18%)	6%	5%	6%
Return on Capital Employed	0%	(10%)	2%	2%	3%
Current Ratio	0.82	0.97	1.07	1.14	1.26
Quick Ratio	0.79	0.92	0.98	1.06	1.16
Interest Coverage	(0.41)	0.85	11.76	3.32	7.34
Debt/Equity Ratio	74%	71%	65%	62%	58%
Gearing Ratio	33%	31%	23%	25%	22%
Debtor Days	147	176	168	189	172
Turnover per Employee (ZMK mil)	242	240	202	210	199
Deferred Liabilities per Employee (ZMK mil)	98	101	88	78	67
Asset Turnover	0.29	0.28	0.26	0.28	0.34

(Source) ZESCO Annual Report (2008)

The net profit margin has been decreased from 2006 to 2008 from 6% to 4%. ZESCO's net income showed a negative K156 billion in 2007, which resulted in the negative profit margin of 17%. Several reasons can be identified for the financial performance. One of the reasons is the low tariff level in consideration of the cost. The power tariff in Zambia has been one of the lowest in the region. The cost of power import is also a critical factor for the ZESCO finance. Due to the increasing domestic demand in Zambia and the limited generation capacity due to the rehabilitation projects, Zambia is now a net importer of energy from the SAPP. Given the high import tariff from the neighboring countries, ZESCO has experienced a net loss from the power trade. At the same time, ZESCO carried out the power shedding and has not met the increasing demand in 2008. These situations could lead the power supply services to a negative spiral of poorer performance.

4.3.4 Financial Support by Government

The current on-lending balance of the ZESCO debt that is guaranteed by GRZ is as summarized in the following.

Table 4.18 ZESCO On-lending Status

Donor	Tranche & Currency	Name of Project	Loan Amount (Kwacha mil.)
African Dev. Fund	1. AFU	Kafue Gorge Restoration	6,592
	1. JPY	Victoria Falls Katima Mulilo	4,850
	2. USD		4,850
	3. EUR		4,850
	1. EUR	Victoria Falls Katima Trans.	3,795
	2. JPY		3,795
	3. USD		3,795
	4. AFU		3,795
EIB	1. EUR	ZESCO Kariba North Bank Project	21,000
	2. EUR	Victoria Falls Project	20,500
	3. EUR	Power Rehabilitation Study	170
IDA	1. SDR	Power Rehabilitation Project	55,100
Belgium Gov.	1. EUR	Mapepe Substation	820
NDF	1. SDR	Power Rehabilitation Project	5,000
		Power Rehabilitation Project	6,082
		Total	144,994

Source) Ministry of Finance and Planning (2009)

The largest donor is IDA followed by EIB. The African Development Fund is also a large contributor. These three donors are the majority lenders to ZESCO.

The sovereign guarantees for the power sector were suspended due to one of the conditions of the debt relief under the HIPC initiatives. However, the Ministry of Finance and Planning states that s substantial funds guaranteed by the government is now ready to be provided to ZESCO in any forms of guarantees. The funds however are subject to review and approval by the government. The government guarantee would be expected to contribute to stabilize the ZESCO finance as well provide a comfort to private investment projects.

4.4 Power Situation of the surrounding countries

Table 4.19 shows the balance of power supply and demand in fiscal 2007 in countries that are SAPP members. As is clear from this table, at 9 percent, the supply reserve margin in SAPP as a whole was below the 10-percent target. At present, it is slightly lower at about 8 percent with the exclusion of Malawi, Angola, and Tanzania, which lack system interconnections with other SAPP members. According to the SAPP annual report (2007/2008), the tightness in the power supply is projected to continue until 2013, when new power stations are scheduled to commence operation.

The installed capacity is lower than the peak demand in Botswana, Mozambique, Lesotho, Namibia, and Swaziland, which depend heavily on power import. In South Africa, Malawi, Tanzania, and Zimbabwe as well, the supply reserve margin is less than 5 percent and the supply is therefore tight. The main power exporters are South Africa, Mozambique, and the DRC. The main power importers are South Africa, Botswana, Mozambique, Namibia, Swaziland, and Zimbabwe.

Table 4.19 Power supply-demand balance in SAPP member countries (FY2007)

Country	Utility	Capacity (MW)			Energy (GWh)			
		Generation (Available)	Peak Load	Reserve Margin (%)	Generation Sent out	Sales	Import	Export
Botswana	BPC	120	493	-	657	2,815	2,572	0
Mozambique	EdM	174	365	-	222	1,380	1,352	309
	HCB	2,075	-	-	15,847	-	-	15,847
Angola	ENE	870	535	63%	3,293	2,362	21	0
Malawi	ESCOM	246	240	3%	1,447	1,166	0	0
South Africa	ESKOM	38,384	36,513	5%	239,108	224,367	10,998	11,368
Lesotho	LEC	70	109	-	486	478	49	7
Namibia	Nampower	360	449	-	1,576	3,259	2,045	0
Swaziland	SEB	50	196	-	126	856	993	0
DRC	SNEL	1,170	1,050	11%	7,581	6,100	78	1,014
Tanzania	TANESCO	680	653	4%	4,141	3,225	57	0
Zimbabwe	ZESA	1,825	1,758	4%	7,781	10,293	2,367	30
Zambia	ZESCO	1,630	1,468	11%	9,677	8,285	199	0
SAPP Total		47,654	43,829	9%	291,941	264,586	20,731	28,575
SAPP Interconnected Total		45,858	42,401	8%	283,060	257,833	20,653	28,575

Source: SAPP Annual Report 2007/2008

Chapter 5 Power Demand Forecast

5.1 Data used for forecast

5.1.1 Electricity statistics

The ZESCO statistics available in annual reports and the ZESCO billing data were used for the demand forecast analysis.

Data on final energy consumption in the ZESCO statistics have been revised twice. These data were disaggregated by tariff category up to fiscal 2000, but by industrial classification beginning in fiscal 2001. Furthermore, items of the industrial classification were revised again in fiscal 2005. For this reason, when time-series data by customer category are selected, they cannot retain continuity in tree periods, i.e., before fiscal 2001, between fiscal 2001 and 2004, and after fiscal 2004. Needless to say, this inconsistency is only observed in energy consumption by customer category; the figures for total energy consumption retain a continuity.

The billing data are disaggregated by tariff category. However, these data were revised in fiscal 2004 due to a change of the computer system, used for data processing. Data downloaded from the old system have substantial discrepancy with those in the ZESCO statistics and show figures that are 20 - 30% lower. Although the reason for this discrepancy is not clear, ZESCO explained that billing data had omissions and some of the billing data might not be reflected in the computer system.

Energy sales data downloaded from the new system, i.e., the Business Information System (BIS), is consistent with those of the ZESCO statistics. However, a comparison cannot be made in respect of energy consumption by consumer category between the billing system and the ZESCO statistical data because they use different customer categories.

On the question of which data reflect the actual final energy consumption more faithfully, the ZESCO statistics are the most reliable data in the view of ZESCO. In addition, other data on power generation capacity, generated energy, and electricity import and export are available in the ZESCO statistics, and relations among those data are also reliable.

5.1.2 Macro-economic indicators

The analysis used macro-economic data for items including GDP released by the Central Statistical Office (CSO). Although some data are also quoted from the database of the International Monetary Fund (IMF), the original data source is the Government of Zambia, and there is no discrepancy with those of the CSO.

5.2 Method of forecast

Two methods were used: one based on an econometric model, and the other, on an end-use model for which estimates for the future energy demand from large customers were added up. More specifically, the power demand in the retail division in four ZESCO franchises was forecasted using the econometric model, and the bulk power demand in the mining sector, for which power is supplied by CEC and ZESCO using transmission lines, by added up mining-project plans in the future.

5.2.1 Structure of final demand

To predict the future power demand, the structure of the final consumption was split into the following three sectors:

- the residential and the commercial sectors in the retail division;
- the industrial sector excluding the mining sector in the retail division; and
- the mining sector receiving bulk power supply.

The reason for simplifying the demand structure is that statistical errors and omissions cannot be ignored due to the discontinuity of demand data by either industrial classification or tariff category if the demand structure is broken into small sub-sectors. Actually, there are many discrepancies in the past demand data, and categories for disaggregating demand structure were changed twice (i.e., in fiscal 2001 and 2005) in the ZESCO statistics.

The residential and the commercial sectors were not split but aggregated. This is because small shops often operate their business in houses and it is therefore difficult to distinguish residential and commercial power consumption. Even though their profile may be commercial, customers often make a residential power supply contract.

Figure 5.1 shows a comparison of energy consumption among metered customers by tariff category. In fiscal 2007, customers in the most low-volume category of industrial use, i.e., Maximum Demand Tariff 1[7], consumed an annual average of more than 100GWh per contract. However, the corresponding averages were only 6GWh in the residential sector and 10GWh in the commercial sector. As this indicates, levels of power consumption in the residential and the commercial sectors are much lower than those in the industrial sector, and on roughly the same order.

There is another reason for aggregating the residential and the commercial sectors. Although the data for final energy consumption in the ZESCO statistics are disaggregated by industrial classification, it is not certain whether individual enterprises are categorized in the same classification in both the CSO GDP data and the ZESCO statistical data. For example, if we compare power consumption by industrial classification as reported in the ZESCO statistics, the figures changed significantly between fiscal 2004 and 2005. This means that some customers were categorized in "Industry A" in fiscal 2004 but "Industry B" in fiscal 2005. Furthermore, in fiscal 2005, customers categorized in "Others" increased sharply, perhaps because of difficulties encountered in customer classification.

[7] Consisting of customers whose capacity is in the range of 16 - 300kVA. "Maximum Demand Tariff 2" consists of customers whose capacity is in the range of 301 - 2,000kWA, "Maximum Demand Tariff 3," those whose capacity is in the range of 2,001 - 7,500kWA, and "Maximum Demand Tariff 4," those whose capacity is over 7,500kWA.

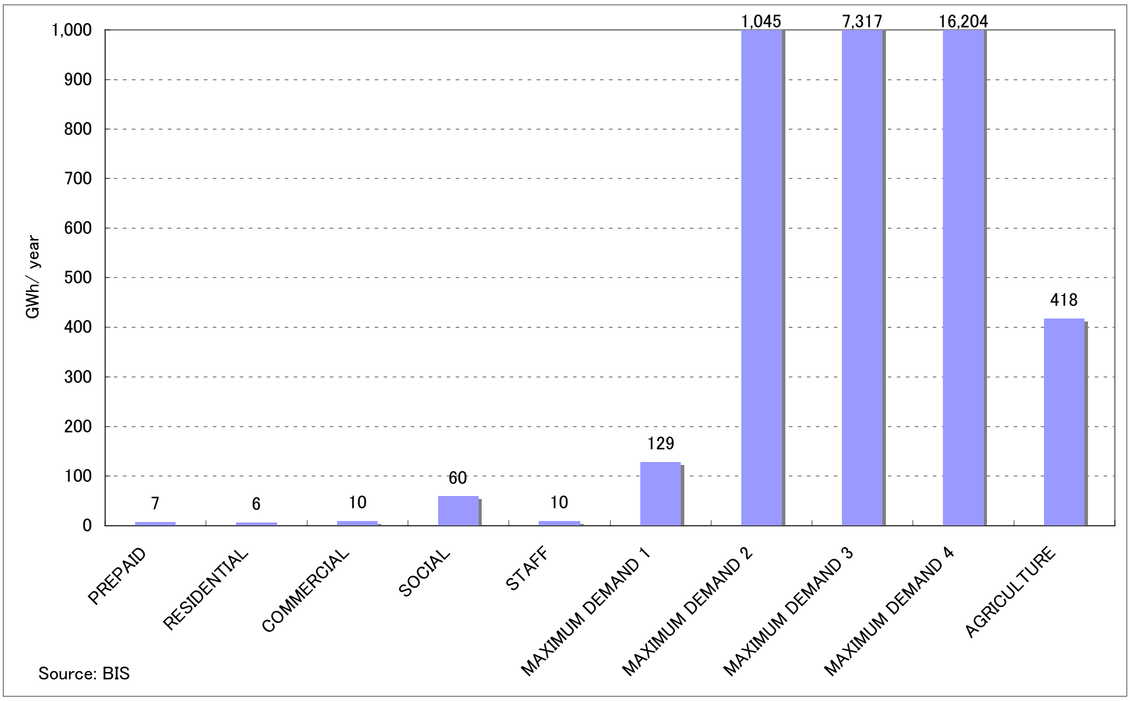


Figure 5.1 Annual Energy Consumption per Contract (Fiscal 2007)

5.2.2 Final energy consumption in the past

The data for fiscal 1999 - 2006 in the ZESCO statistics were used to estimate the GDP elasticity of energy consumption. As shown in Figure 5.2, final energy consumption exhibits a certain irregularity. Retail power sales in fiscal 2000 increased significantly compared to the previous and following years. Further, those in fiscal 2006 decreased as compared to the previous year.

It is not clear if this irregularity was caused by statistical error or actually occurred. In light of macro-economic conditions in Zambia, at least, this sort of significant change is unlikely. One possibility is that demand was curbed by limited power supply capacity and dropped below latent demand in some years.

In this connection, when analyzing and discussing past statistical data, it must be borne in mind that data contain irregular figures in some years.[8]

[8] Data themselves have errors and omissions, and they do not present a completely accurate picture of the customer situation. In addition, the ZESCO staff in charge of statistics said that the handling of data changed in some years. For these reasons, we had to accept a degree of data uncertainly.

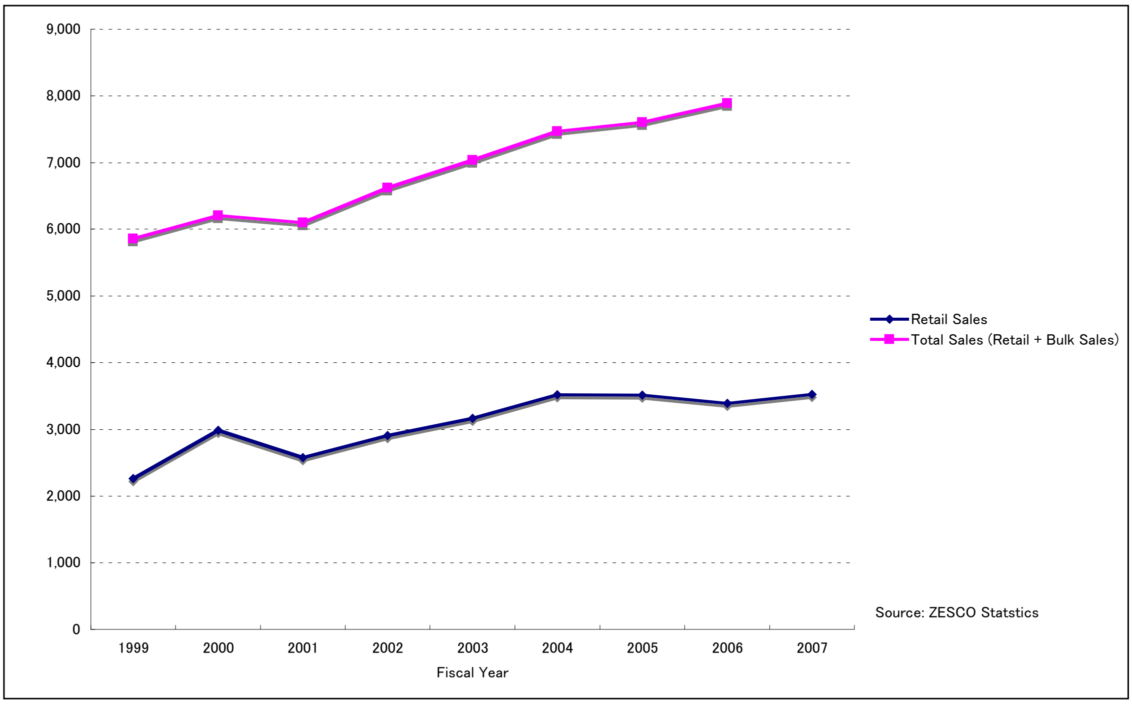


Figure 5.2 Final Energy Consumption in the Past (fiscal 1999 – 2007)

5.2.3 Power demand forecast for the retail division using an econometric model

As noted above, the retail division was divided into two sectors: the residential-and-commercial sector and the industrial sector excluding mining. We used statistical data for the years fiscal 1999 - 2006 for multivariate analysis, but data on energy consumption for these two sectors were not available in the ZESCO statistics.

Due to this restriction, we estimated energy consumption in the two sectors using the billing system data. The billing system data and the ZESCO statistical data are consistent with each other for total energy consumption in fiscal 2005 and 2006, and we therefore did not have any problems in handling data for this period. Because the billing system data up to fiscal 2004 do not include all energy consumption, however, we cannot directly use these data. On the premise that the actual ratio of energy consumptions in two sectors was the same as that derived from the billing system data, which apprehended a only limited number of customers, we distributed the total energy consumption in the ZESCO statistical data between the two sectors using said ration in order to obtain estimates for energy consumption in each.

(1) The residential-and-commercial sector

Energy consumption in the residential-and-commercial sector is strongly affected by increase in household income and electrification ratio. We applied the following equation to estimate energy demand in this sector using the number of customers and per-capita GDP data as explanatory variables. Here, per-capita GDP represents household income, and the number of customers, the electrification ratio. Future demand is estimated using the elasticity of each explanatory variable derived from the past data.

$$\log D_e = a + b_1 * \log GDP_{pc} + b_2 * \log N$$

D_e: Energy demand (kWh)

GDP_{pc}: Per-capita GDP (1994 kwacha)

N: Number of customers in the residential-and-commercial sector

a: Constant

b_1: Elasticity of per-capita GDP

b_2: Elasticity of the number of customers in the residential-and-commercial sector

The results of regression using the past data between fiscal 1999 and 2007 is shown in Table 5.1. The original data themselves have errors and monitions, as mentioned above. Therefore, the coefficient of determination (i.e., R^2) of 0.836 is assumed to be showing good correlation. The normalized values of line-slope—b_1 and b_2—are 0.41 and 0.51, and the effect of increase in the number of customers against increase in energy demand is slightly stronger than that in per-capita GDP (household income).

Table 5.1 Coefficients of Regression Line (the Residential-and-Commercial Sector)

a	b_1	b_2	Coefficient of determination, R^2
2.40241	0.566434	0.943780	0.835706

(Source) JICA Study Team.

(2) The industrial sector excluding mining

In the equation for estimating the demand in the industrial sector excluding mining, the value-added product of industry (i.e., GDP by sector) was used as an explanatory variable to obtain GDP elasticity in the sector.

$$\log D_e = a + b * \log GDP_{ind}$$

D_e: Energy demand (kWh)

GDP_{ind}: Added value of the industrial sector (1994 kwacha)

a: Constant

b: Elasticity of GDP_{ind}

As in the case of the residential-and-commercial sector, a regression analysis was performed using data for the past nine years (fiscal 1999 – 2007). The results are shown in Table 5.2. Although the value of the coefficient of determination (i.e., R^2) is not so good as that in the residential-and-commercial sector analysis, correlation is observed. Assuming that there is much irregularity (including inconsistency) in the past nine-year data and that considerable error is to be expected, this result is on an acceptable level.

Table 5.2 Coefficients of the Regression Line (the Industrial Scoter Excluding Mining)

a	b	Coefficient of determination, R^2
14.1978	0.874445	0.550992

(Source) JICA Study Team

5.2.4 Power demand forecast for the mining sector using the end-use model based on mining project integration

Table 5.3 and Table 5.4 show the result of integration of data for new mining projects in CEC and ZESCO franchises. Although individual project lists are the latest ones updated by both companies, we must understand that the schedule of each project may change depending on economic conditions.

From the viewpoint of an investor, projects scheduled over the short and medium terms have a fairly high probability of execution, but those scheduled over the long term (more than 10 years in the future) will be occasionally revised in accordance with the economic conditions, and consequently are more uncertain.

Table 5.3 Forecast for New Mining Projects by the CEC

Low scenario

Cnages in peak demand (MW)

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Luanshaya Copper Mines		−17	−17	−17	−17	−17	−17	−17	−17	−17	−17	−17
Chambishi Metals, Cobalt Smelter		−51	−51									
Chambishi Metals, SX		−23	−23									
Konkola Copper Mines, Nchanga Smelter Ramp-up Pjhase 1		35	35	35	35	35	35	35	35	35	35	35
Konkola Copper, Mines Nchanga Smelter Ramp-up Pjhase 2							25	25	25	25	25	25
Konkola Copper, Mines New Konkola Concentrator		20	20	20	20	20	20	20	20	20	20	20
Konkala Copper Mines, New Shaft				15	15	15	15	15	15	15	15	15
Konkola Copper Mines, Dewatering increases at New Shaft							25	25	25	25	25	25
Mopani Copper Mines, Nkana Mine		−60	−60									
Mopani Copper Mines, Muflira Mine		−47	−47	−47	−47	−47	−47	−47	−47	−47	−47	−47
NFM Africa Mining			4	4	4	4	4	4	4	4	4	4
Total	528	385	389	538	538	538	588	588	588	588	588	588

Energy demand (MWh)

CEC	4,023,994	2,934,162	2,964,647	4,100,206	4,100,206	4,100,206	4,481,266	4,481,266	4,481,266	4,481,266	4,481,266	4,481,266

High scenario

Cnages in peak demand (MW)

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Luanshaya Copper Mines		−17	−17									
Chambishi Metals, Cobalt Smelter		−51										
Chambishi Metals, SX		−23										
Konkola Copper Mines, Nchanga Smelter Ramp-up Pjhase 1		45	45	45	45	45	45	45	45	45	45	45
Konkola Copper Mines, Nchanga Smelter Ramp-up Pjhase 2					40	40	40	40	40	40	40	40
Konkola Copper Mines, New Konkola Concentrator		20	20	20	20	20	20	20	20	20	20	20
Konkola Copper Mines, Processing of Chingola Refractory							55	55	55	55	55	55
Konkala Copper Mines, New Shaft				15	15	15	15	15	15	15	15	15
Konkola Copper Mines, Dewatering increases at New Shaft							25	25	25	25	25	25
Mopani Copper Mines, Nkana Mine												
Mopani Copper Mines, Muflira Mine		−47	−47									
NFM Africa Mining			4	4	4	4	4	4	4	4	4	4
Tea Mining, Konkola North				20	20	20	20	20	20	20	20	20
Mulianshi Project					35	35	35	35	35	35	35	35
Caledonis Nama Mine						50	50	50	50	50	50	50
Total	528	455	533	632	707	757	837	837	837	837	837	837

Energy demand (MWh)

CEC	4,023,994	3,467,646	4,062,100	4,816,598	5,388,188	5,769,248	6,378,944	6,378,944	6,378,944	6,378,944	6,378,944	6,378,944

Note: Load factor = 87%

Source: CEC

Table 5.4 Outlook for New Contracts with Mining Companies by ZESCO

Projected Demand (MW)

	MW	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Mining	**495**	**0**	**132.3**	**235.3**	**343**	**435**	**515**	**535**	**560**	**565**	**565**	**590**
Lumwana (Equinox)	160		73.3	73.3	90	90	90	90	90	90	90	90
Kansanshi Increment	60		12	12	12	12	32	52	72	72	72	72
Nodola Lime Uprating	10		10	10	10	10	10	10	10	10	10	10
Mkushi North Mine	40			20	40	40	40	40	40	40	40	40
Mazabuka Nikel Mine	7		7	7	7	7	7	7	7	7	7	7
Kabompo Copper & Gold Mine	60				30	60	100	100	100	100	100	100
Omega Mine	5			8	8	8	8	8	8	8	8	8
Chambishi Copper Smelter			30	40	50	60	80	80	80	85	85	110
Kafue Smelter	48			33	33	43	43	43	48	48	48	48
Kabwe Smelter	105			32	63	105	105	105	105	105	105	105

Energy demand (MWh)

Mining	LF=87%	0	985,106	1,752,044	2,553,978	3,239,010	3,834,690	3,983,610	4,169,760	4,206,990	4,206,990	4,393,140

Source: ZESCO

5.3 Premises of the forecast

5.3.1 Macro-economic growth

Zambia has enjoyed steady economic growth since 1999 and maintained a growth rate of around 6% per annum from 2006 to 2008 (see Figure 5.3). In the fifth National Development Plan, the Government of Zambia also set a target of at least 7% per annum for economic growth over the years 2006 - 2010. While actual figures did not reach the target, the country has continued to achieve sustainable economic growth.

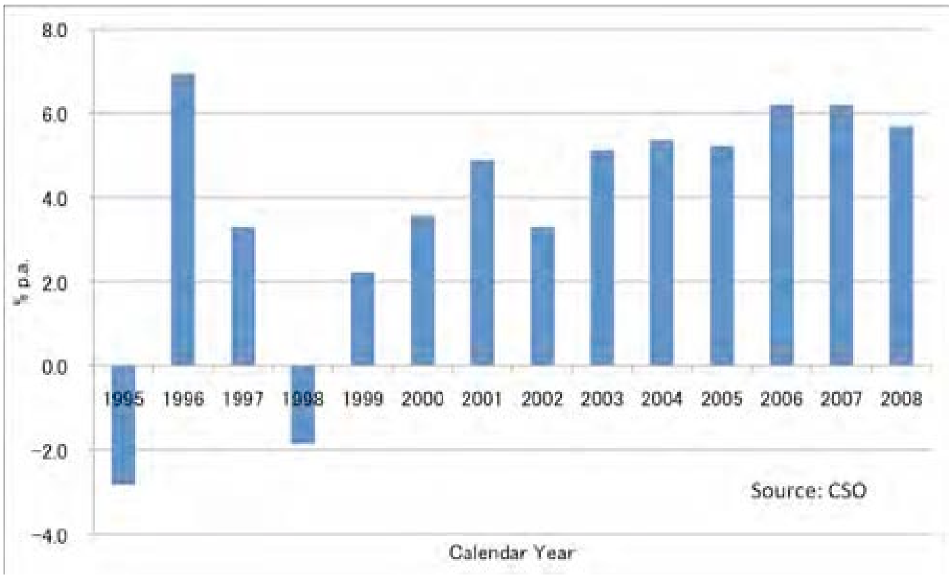


Figure 5.3 Trend of GDP Growth (1995 – 2008)

The question is how the global recession triggered by financial crisis in autumn of 2008 will affect Zambia's economy. Although it is very difficult to say at present, one indicator of the future course is the Global Economic Prospect released annually by the World Bank. In the 2009 Prospect, economic growth in the year 2009 is expected to decline to 4.6% per annum [9](see Table 5.5).

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[9] The World Economic Outlook 2009 released by IMF in October 2009 foresaw GDP growth of 4.537% from 2008. Coincidentgally, the CSO of the GOZ announced its estimate of the GDP growth in 2009, i.e., 6.3% p.a. There is a big

Table 5.5 Prospect for Zamia's Economic Growth

Calendar Year					Prediction		
	1991-2000	2005	2006	2007	2008	2009	2010
GDP at market prices (2000 US$), % p.a.	0.7	5.2	6.2	6.2	6.1	4.6	6.0

(Source) The World Bank

5.3.2 Population growth

The population of Zambia was 9.78 million in 1997, 10.8 million in 2002, and 12.16 million in 2007 (see Figure 5.4). During this period, the average growth rate was 2.2 % per annum over the past ten years and 2.4% per annum over the past five years.

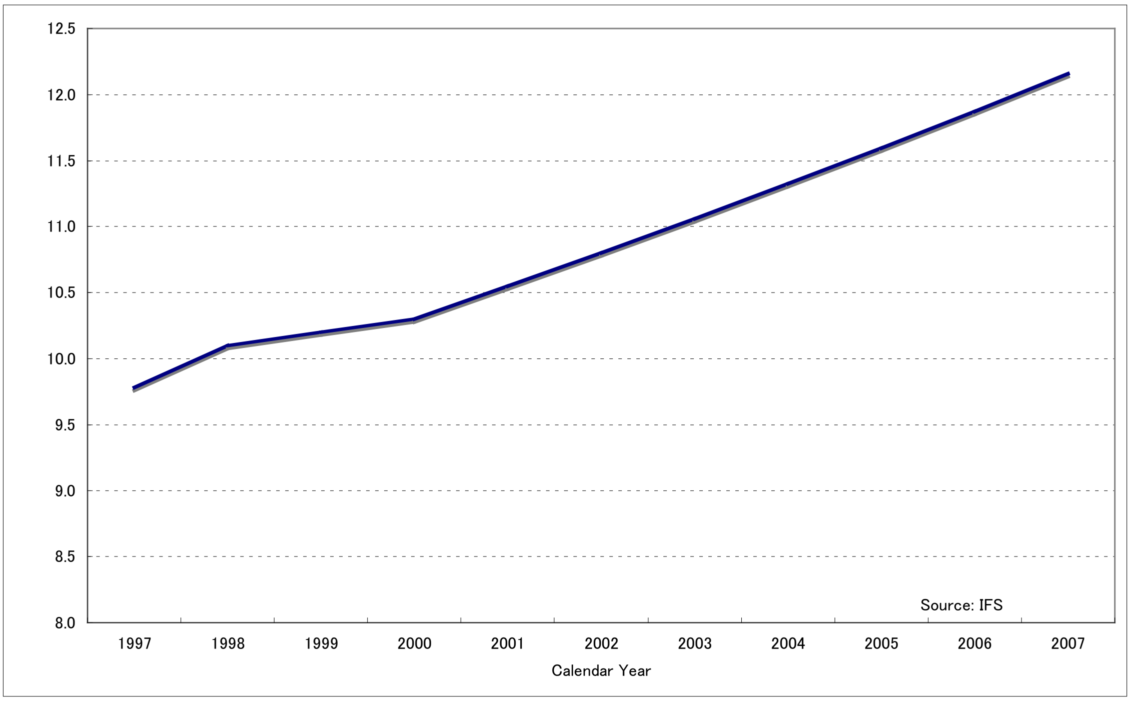


Figure 5.4 Trend of Population Growth (1997 – 2007)

5.3.3 Electrification ratio

The overwhelming majority of the customers are in the residential-and-commercial sector. In fiscal 2005, the customers in this sector accounted for 93% of total number of contracts (see Figure 5.5).

An increase in the electrification ratio translates into one in the number of customers. The rate of increase in the number of customers reached more than 10% per annum in the second half of the 1990s, but has slowed since 2000. The rate of increase in the number of customers in the residential and commercial sector, which is the major target of electrification, averaged around 4% per annum between fiscal 2003 and 2007, when macroeconomic conditions stabilized (see Figure 5.6).

difference between the World Bnak/IMF and the CSO estimates. The CSO commented that fundamental difference is the methodology used for constant price estimates of taxes less subsidies on subsidies.

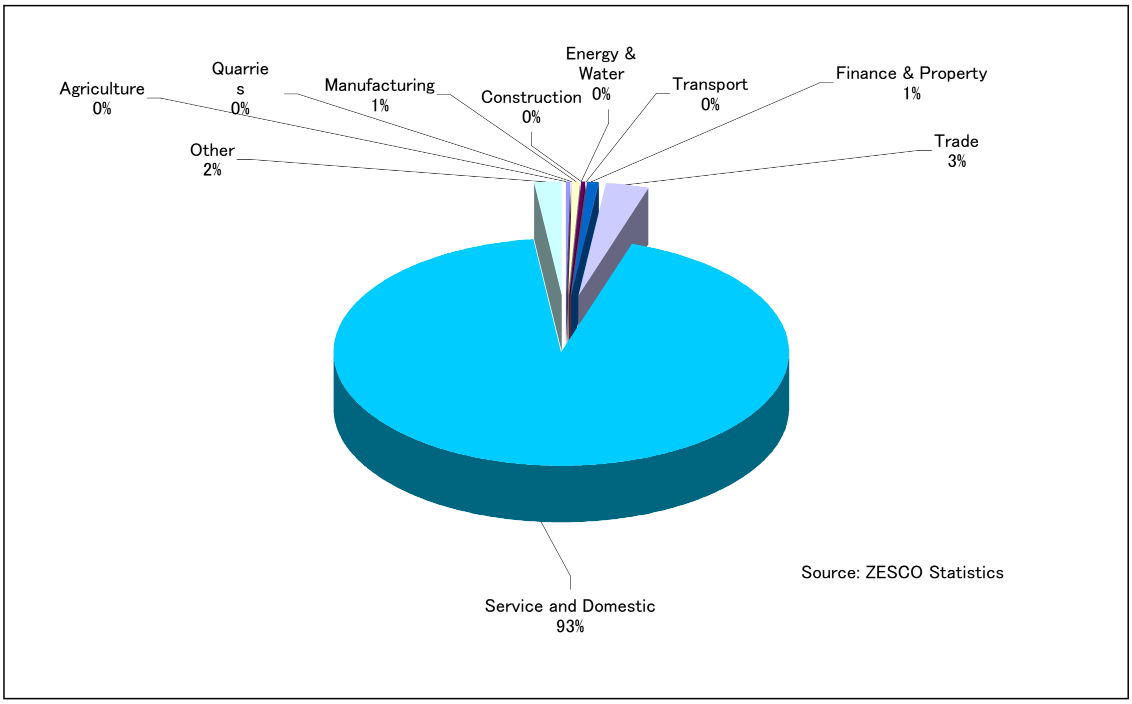


Figure 5.5 Breakdown of the Number of Customers (Fiscal 2005)

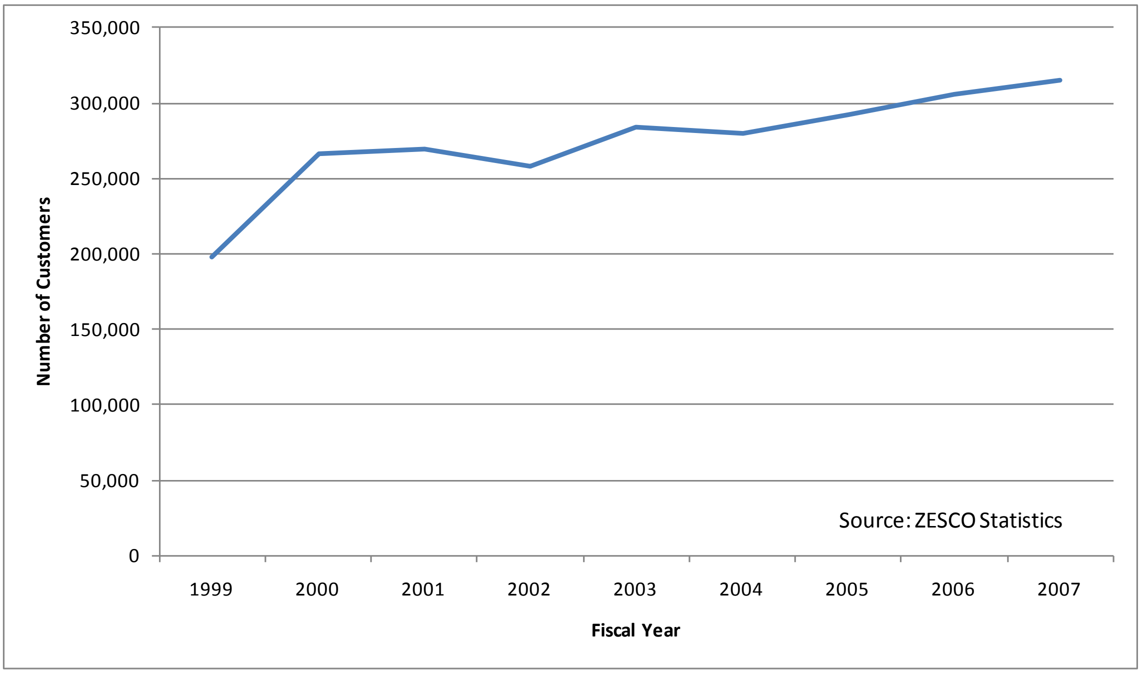


Figure 5.6 Trend of the Number of Customers (Fiscal 1999 – 2007)

5.3.4 Forecast scenarios

Based on differences in respect of macro-economic conditions, population growth, and customer increase rate, we drafted three scenarios: base, high, and low cases (see Table 5.6).

Table 5.6 Forecast Scenarios

Base case	● The prevailing resection will continue until the end of fiscal 2011, but economy will recover beginning in fiscal 2012 and grow at a rate of 6% per annum, on a per with that achieved in the first half of the 2000s. ● The number of customers will increase at a rate of 4% per annum.
High case	● The economy will recover in fiscal 2011, i.e., one year earlier than in the base case, and continue to grow at a rate of 7% per annum. ● The number of customers will increase at a rate of 6% per annum.
Low case	● The economy will recover in fiscal 2013, i.e., one year later than in the base case, and continue to grow at a rate of 5% per annum. ● The number of customers will increase at a rate of 3.5% per annum.

(Source) JICA Study Team.

Premises are detailed in Table 5.7. With regard to the future macroeconomic outlook, for another one or two years, GDP growth in Zambia will probably decline due to the effects of the international financial crisis. During this period of economic downturn, we put the growth rate at 4.5% p.a. quoting forecasts of international institutions. After recovery from the global recession, GDP growth is assumed to be 6% p.a., which is equivalent to the actual growth rate from the mid 2000s to just before the financial crisis, in the base-case scenario, and 7% p.a.—i.e., the target figure in the government's economic development plan—in the high-case scenario. The 5 % p.a. rate in the low-case scenario is the same level of economic growth, which the country experienced during the early 2000s.

Population growth is forecast at 2.3% p.a. following the historical trend. The electrification rate is forecast to increase at the rate of 4% p.a. equivalent to that of increase in the number of customers in the residential and commercial sector for the past five years, in the base-case scenario, 6% p.a. in the high-case scenario, and 3.5% p.a. in the low-case scenario.

Table 5.7 Premises of Each Scenario

	Base case	High case	Low case
Economic growth (GDP)	Fiscal 2008-11: 4.5% p.a. Beginning in fiscal 2012: 6% p.a.	Fiscal 2008-10: 4.5% p.a. Beginning in fiscal 2011: 7% p.a.	Fiscal 2008-12: 4.5% p.a. Beginning in fiscal 2013: 5% p.a.
Population growth	2.3% p.a.	2.3% p.a.	2.3% p.a.
Growth of electrification ratio	4% p.a.	6% p.a.	3.5% p.a.

(Source) JICA Study Team.

5.4 Forecast Results

5.4.1 Fiscal year basis

In the base case, the energy demand of 8.1 billion kWh (8.1TWh) in fiscal 2007 will increase to 16.6 billion kWh (16.6TWh) in fiscal 2020 and 21.6 billion kWh (21.6TWh) in fiscal 2030 (see Figure 5.7).

The average growth rates in this case are 5.7% per annum for the thirteen years between fiscal 2007 and 2020, and 4.4% per annum for the twenty-three years up to fiscal 2030. It may be noted that the growth rate during the fiscal 1999 - 2007 period was 4.1% per annum.

In the high case, energy demand will amounted to 19.9 billion kWh (19.9TWh) in fiscal 2020 and 28.5 billion kWh (28.5TWh) in fiscal 2030 (see Figure 5.8). The average growth rates are 7.1% per annum for the thirteen years between fiscal 2007 and 2020 , and 5.6% per annum for the twenty-three years up to fiscal 2030.

In the low case, energy demand will amount to 15.9 billion kWh (15.9TWh) in fiscal 2020 and 19.4 billion kWh (19.4TWh) in fiscal 2030 (see Figure5.8). The average growth rates are 5.3% per annum for the thirteen years between fiscal 2007 and 2020, and 3.9% per annum for the twenty-three years up to fiscal 2030.

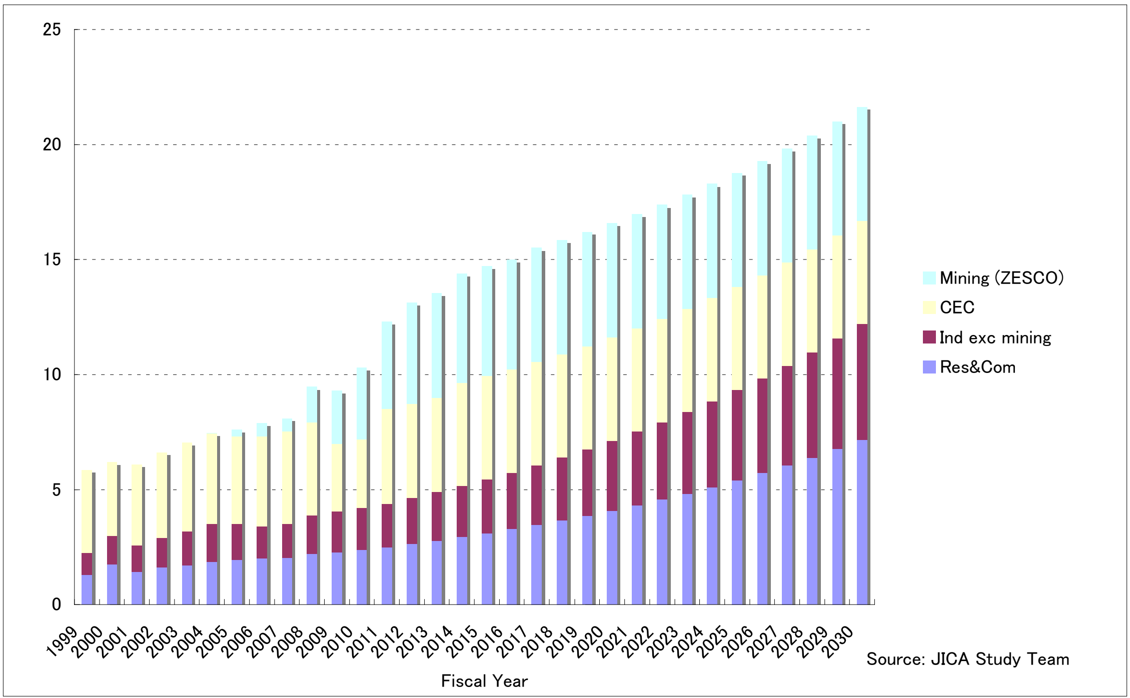


Figure 5.7 Energy Demand Forecast (Base case)

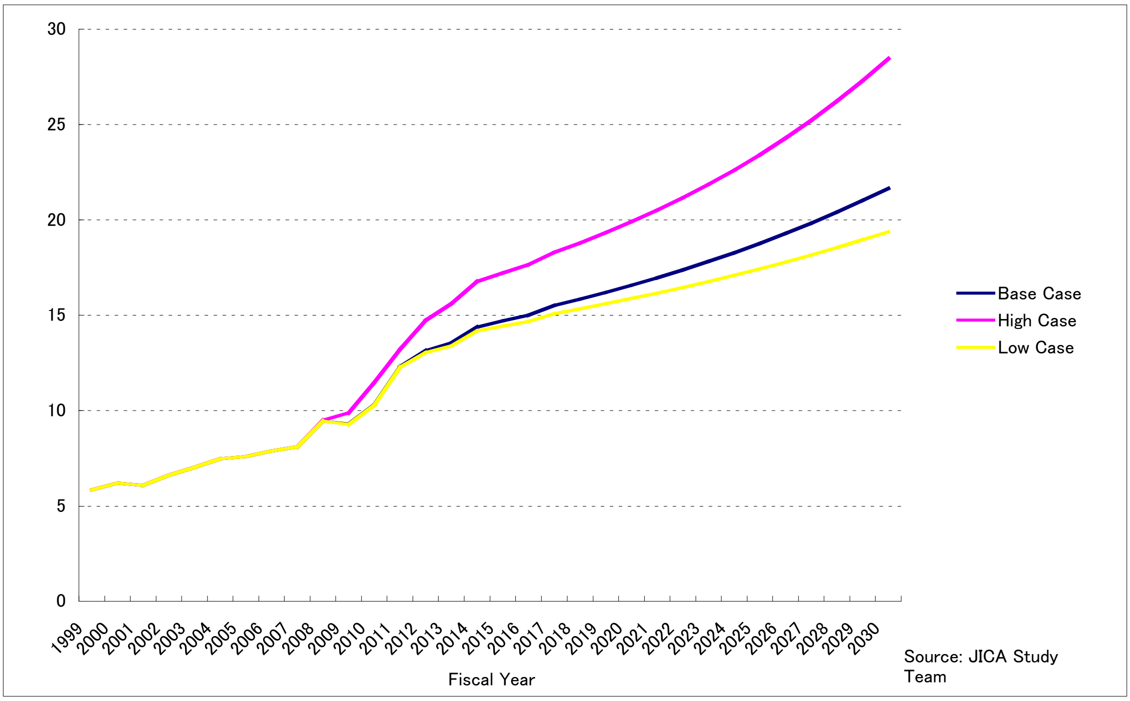


Figure 5.8 Comparison of Demand in Different Scenarios

5.4.2 Calendar year basis

The forecast presented above is based on fiscal year used for the ZESCO accenting system, which starts on April 1 and ends on March 31 of the following year. Table 5.8 shows the energy demand forecast upon conversion to the calendar year. In making the conversion, we estimated the calendar-year figure by adding one quarter of the forecast for the previous fiscal year to the three quarters of the forecast for the current fiscal year.

Table 5.8 Energy Demand Forecast (Converted to Calendar Year Basis)

Base case (Unit: kWh)

CY	Res&Com	Ind exc mining	Total of retail	CEC	Mining (ZESCO)	Total
2000	1,629,072,929	1,175,852,048	2,804,924,977	3,312,212,000		6,117,136,977
2001	1,507,322,656	1,172,260,123	2,679,582,779	3,443,413,500		6,122,996,279
2002	1,579,610,076	1,246,875,567	2,826,485,643	3,660,052,250		6,486,537,893
2003	1,688,147,151	1,415,512,198	3,103,659,350	3,829,437,000		6,933,096,350
2004	1,813,022,270	1,619,230,907	3,432,253,177	3,916,487,750	14,747,696	7,363,488,623
2005	1,926,903,679	1,589,973,480	3,516,877,159	3,840,055,750	216,134,408	7,573,067,316
2006	1,993,688,478	1,427,315,925	3,421,004,403	3,905,190,000	491,533,721	7,817,728,124
2007	2,018,606,842	1,470,686,530	3,489,293,373	4,002,272,450	561,503,402	8,053,069,225
2008	2,144,524,320	1,656,848,994	3,801,373,314	4,023,993,600	1,300,332,752	9,125,699,666
2009	2,256,037,522	1,759,372,643	4,015,410,165	3,206,619,900	2,121,812,702	9,343,842,767
2010	2,353,508,331	1,828,411,616	4,181,919,947	2,957,025,600	2,914,997,852	10,053,943,399
2011	2,455,190,310	1,900,159,725	4,355,350,035	3,816,315,900	3,629,255,402	11,800,921,337
2012	2,587,550,366	1,993,473,416	4,581,023,782	4,100,205,600	4,247,273,402	12,928,502,784
2013	2,735,897,564	2,097,678,977	4,833,576,541	4,100,205,600	4,507,883,402	13,441,665,543
2014	2,892,749,675	2,207,331,714	5,100,081,389	4,386,000,600	4,684,725,902	14,170,807,891
2015	3,058,594,295	2,322,716,368	5,381,310,664	4,481,265,600	4,759,185,902	14,621,762,166
2016	3,233,946,976	2,444,132,567	5,678,079,542	4,481,265,600	4,768,493,402	14,927,838,544
2017	3,419,352,825	2,571,895,598	5,991,248,423	4,481,265,600	4,908,105,902	15,380,619,925
2018	3,615,388,201	2,706,337,233	6,321,725,434	4,481,265,600	4,954,643,402	15,757,634,436
2019	3,822,662,508	2,847,806,584	6,670,469,092	4,481,265,600	4,954,643,402	16,106,378,094
2020	4,041,820,086	2,996,671,014	7,038,491,100	4,481,265,600	4,954,643,402	16,474,400,102
2021	4,273,542,217	3,153,317,089	7,426,859,306	4,481,265,600	4,954,643,402	16,862,768,308
2022	4,518,549,241	3,318,151,581	7,836,700,821	4,481,265,600	4,954,643,402	17,272,609,823
2023	4,777,602,794	3,491,602,526	8,269,205,320	4,481,265,600	4,954,643,402	17,705,114,322
2024	5,051,508,183	3,674,120,336	8,725,628,518	4,481,265,600	4,954,643,402	18,161,537,520
2025	5,341,116,877	3,866,178,965	9,207,295,843	4,481,265,600	4,954,643,402	18,643,204,845
2026	5,647,329,167	4,068,277,146	9,715,606,313	4,481,265,600	4,954,643,402	19,151,515,315
2027	5,971,096,955	4,280,939,678	10,252,036,632	4,481,265,600	4,954,643,402	19,687,945,634
2028	6,313,426,717	4,504,718,796	10,818,145,512	4,481,265,600	4,954,643,402	20,254,054,514
2029	6,675,382,633	4,740,195,601	11,415,578,234	4,481,265,600	4,954,643,402	20,851,487,236
2030	7,058,089,892	4,987,981,571	12,046,071,463	4,481,265,600	4,954,643,402	21,481,980,465

High Case

CY	Res&Com	Ind exc mining	Total of retail	CEC	Mining (ZESCO)	Total
2000	1,629,072,929	1,175,852,048	2,804,924,977	3,312,212,000		6,117,136,977
2001	1,507,322,656	1,172,260,123	2,679,582,779	3,443,413,500		6,122,996,279
2002	1,579,610,076	1,246,875,567	2,826,485,643	3,660,052,250		6,486,537,893
2003	1,688,147,151	1,415,512,198	3,103,659,350	3,829,437,000		6,933,096,350
2004	1,813,022,270	1,619,230,907	3,432,253,177	3,916,487,750	14,747,696	7,363,488,623
2005	1,926,903,679	1,589,973,480	3,516,877,159	3,840,055,750	216,134,408	7,573,067,316
2006	1,993,688,478	1,427,315,925	3,421,004,403	3,905,190,000	491,533,721	7,817,728,124
2007	2,018,606,842	1,470,686,530	3,489,293,373	4,002,272,450	561,503,402	8,053,069,225
2008	2,162,303,296	1,656,848,994	3,819,152,290	4,023,993,600	1,300,332,752	9,143,478,642
2009	2,299,259,258	1,759,372,643	4,058,631,901	3,606,732,900	2,121,812,702	9,787,177,503
2010	2,424,617,355	1,828,411,616	4,253,028,972	3,913,486,200	2,914,997,852	11,081,513,024
2011	2,600,644,481	1,930,212,152	4,530,856,633	4,627,973,700	3,629,255,402	12,788,085,735
2012	2,804,313,127	2,047,856,549	4,852,169,676	5,245,290,900	4,247,273,402	14,344,733,978
2013	3,023,932,019	2,172,671,248	5,196,603,266	5,673,983,400	4,507,883,402	15,378,470,068
2014	3,260,750,294	2,305,093,271	5,565,843,565	6,226,520,400	4,684,725,902	16,477,089,867
2015	3,516,114,917	2,445,586,277	5,961,701,194	6,378,944,400	4,759,185,902	17,099,831,496
2016	3,791,478,339	2,594,642,184	6,386,120,523	6,378,944,400	4,768,493,402	17,533,558,325
2017	4,088,406,760	2,752,782,891	6,841,189,651	6,378,944,400	4,908,105,902	18,128,239,953
2018	4,408,589,036	2,920,562,108	7,329,151,144	6,378,944,400	4,954,643,402	18,662,738,946
2019	4,753,846,286	3,098,567,291	7,852,413,577	6,378,944,400	4,954,643,402	19,186,001,379
2020	5,126,142,247	3,287,421,703	8,413,563,950	6,378,944,400	4,954,643,402	19,747,151,752
2021	5,527,594,448	3,487,786,592	9,015,381,040	6,378,944,400	4,954,643,402	20,348,968,842
2022	5,960,486,251	3,700,363,509	9,660,849,760	6,378,944,400	4,954,643,402	20,994,437,562
2023	6,427,279,837	3,925,896,766	10,353,176,604	6,378,944,400	4,954,643,402	21,686,764,406
2024	6,930,630,215	4,165,176,038	11,095,806,253	6,378,944,400	4,954,643,402	22,429,394,055
2025	7,473,400,318	4,419,039,129	11,892,439,447	6,378,944,400	4,954,643,402	23,226,027,249
2026	8,058,677,289	4,688,374,907	12,747,052,196	6,378,944,400	4,954,643,402	24,080,639,998
2027	8,689,790,040	4,974,126,418	13,663,916,458	6,378,944,400	4,954,643,402	24,997,504,260
2028	9,370,328,186	5,277,294,182	14,647,622,368	6,378,944,400	4,954,643,402	25,981,210,170
2029	10,104,162,460	5,598,939,702	15,703,102,162	6,378,944,400	4,954,643,402	27,036,689,964
2030	10,895,466,732	5,940,189,177	16,835,655,909	6,378,944,400	4,954,643,402	28,169,243,711

Low Case

CY	Res&Com	Ind exc mining	Total of retail	CEC	Mining (ZESCO)	Total
2000	1,629,072,929	1,175,852,048	2,804,924,977	3,312,212,000		6,117,136,977
2001	1,507,322,656	1,172,260,123	2,679,582,779	3,443,413,500		6,122,996,279
2002	1,579,610,076	1,246,875,567	2,826,485,643	3,660,052,250		6,486,537,893
2003	1,688,147,151	1,415,512,198	3,103,659,350	3,829,437,000		6,933,096,350
2004	1,813,022,270	1,619,230,907	3,432,253,177	3,916,487,750	14,747,696	7,363,488,623
2005	1,926,903,679	1,589,973,480	3,516,877,159	3,840,055,750	216,134,408	7,573,067,316
2006	1,993,688,478	1,427,315,925	3,421,004,403	3,905,190,000	491,533,721	7,817,728,124
2007	2,018,606,842	1,470,686,530	3,489,293,373	4,002,272,450	561,503,402	8,053,069,225
2008	2,140,056,477	1,656,848,994	3,796,905,470	4,023,993,600	1,300,332,752	9,121,231,822
2009	2,245,239,197	1,759,372,643	4,004,611,840	3,206,619,900	2,121,812,702	9,333,044,442
2010	2,335,858,310	1,828,411,616	4,164,269,926	2,957,025,600	2,914,997,852	10,036,293,378
2011	2,430,134,861	1,900,159,725	4,330,294,586	3,816,315,900	3,629,255,402	11,775,865,888
2012	2,528,216,466	1,974,723,279	4,502,939,745	4,100,205,600	4,247,273,402	12,850,418,747
2013	2,639,250,814	2,058,711,936	4,697,962,750	4,100,205,600	4,507,883,402	13,306,051,752
2014	2,758,169,865	2,148,446,041	4,906,615,906	4,386,000,600	4,684,725,902	13,977,342,408
2015	2,882,447,156	2,242,091,431	5,124,538,587	4,481,265,600	4,759,185,902	14,364,990,089
2016	3,012,324,118	2,339,818,590	5,352,142,708	4,481,265,600	4,768,493,402	14,601,901,710
2017	3,148,053,061	2,441,805,431	5,589,858,492	4,481,265,600	4,908,105,902	14,979,229,994
2018	3,289,897,662	2,548,237,624	5,838,135,286	4,481,265,600	4,954,643,402	15,274,044,288
2019	3,438,133,481	2,659,308,929	6,097,442,410	4,481,265,600	4,954,643,402	15,533,351,412
2020	3,593,048,492	2,775,221,555	6,368,270,047	4,481,265,600	4,954,643,402	15,804,179,049
2021	3,754,943,645	2,896,186,523	6,651,130,168	4,481,265,600	4,954,643,402	16,087,039,170
2022	3,924,133,450	3,022,424,051	6,946,557,501	4,481,265,600	4,954,643,402	16,382,466,503
2023	4,100,946,590	3,154,163,957	7,255,110,547	4,481,265,600	4,954,643,402	16,691,019,549
2024	4,285,726,555	3,291,646,076	7,577,372,632	4,481,265,600	4,954,643,402	17,013,281,634
2025	4,478,832,314	3,435,120,697	7,913,953,012	4,481,265,600	4,954,643,402	17,349,862,014
2026	4,680,639,010	3,584,849,018	8,265,488,028	4,481,265,600	4,954,643,402	17,701,397,030
2027	4,891,538,687	3,741,103,622	8,632,642,310	4,481,265,600	4,954,643,402	18,068,551,312
2028	5,111,941,057	3,904,168,974	9,016,110,031	4,481,265,600	4,954,643,402	18,452,019,033
2029	5,342,274,291	4,074,341,936	9,416,616,228	4,481,265,600	4,954,643,402	18,852,525,230
2030	5,582,985,853	4,251,932,313	9,834,918,166	4,481,265,600	4,954,643,402	19,270,827,168

Source: JICA Study Team.

5.4.3 Peak Demand Forecast Result

Forecast of the peak demand(MW) up to 2030 requires an estimate of the current peak demand to serve as the standard. The peak demand in 2008-09 (including system loss) was sought by the following equation.

$$P_{peak} = (P_{SCADA} + P_{u.d..} + P_{s.d})_t$$

Here, Pscada = the maximum total system load recorded by SCADA

Pud = unmeasured demand

Psd = surprise demand.

(1) Maximum total system load

In examination of the peak demand based on SCADA data, the Pscada was determined with attention to the following points.

- The peak demand in Zambia tends to occur in July.
- The peak demand occurs between 7:00 and 10:00 AM, and 4:00 - 9:00 PM, as shown in the aforementioned daily load curve.

(2) Unmeasured demand

The unmeasured demand is defined as the demand that physically cannot be measured by SCADA. In the case of SCADA, the items falling under this definition are private power generation within the system and the off-grid demand in the northeastern and northern provinces.

A. Private power generation within the system

As shown in ZESCO statistics, the Copperbelt Energy Corporation PLC (CEC) has gas-fired power generation facilities with a combined capacity of 80 MW. The chief purpose of these facilities is to assure the minimum requisite power in times of emergency. CEC also frequently starts up the generatorsfor peak lopping.

In addition, Konkola Copper Mines (KCM) owns gas-fired generation facilities with a combined capacity of 20 MW at Nkana. As in the case of CEC, the purpose is to assure the minimum requisite power in times of emergency.

In light of this situation, the demand met by private generation facilities was estimated at 40 MW[10].

Table 5.9 Private generation facilities in Zambia

Station	Machine type	Installed capacity[MW]	Available capacity[MW]	Owner
Bancroft	Gas turbine	20	20	CEC
Luano	Gas turbine	40	40	CEC
Luanshya	Gas turbine	10	10	CEC
Mufulila	Gas turbine	10	10	CEC
Nkana	Gas turbine	20	20	KCM
Total		100	100	

(Source) Prepared by the Study Team based on ZESCO annual statistics

B. Off-grid demand

In Zambia, the transmission system does not yet cover all of the country, and there is some off-grid systems (also termed independent systems) not connected to the transmission system. The main power sources in these systems are diesel generators and mini hydropower plants.

The diesel power generation facilities are installed mainly in North-West Province and supply power to small-scale local systems.

[10] This assumption dose not have precise evidence but we decide to estimate the value equal to the maximum available capacity among the plants because we have to ready for the serious situation.

Table 5.10 shows actual data for their operation over the period in question.

Mini-hydropower facilities consist of the facilities owned by ZESCO in Northern Province (shown in Table 5.11). In an interview, ZESCO stated that, due to problems with them, these facilities cannot be connected to the transmission system and instead supply power to a small-scale local system

In addition, there are some mini hydropower generation facilities owned by private enterprises, such as that at Zengamina (700 kW).

The off-grid demand was estimated to total 10 MW.

Table 5.10 Actual data for operation of diesel generation facilities

Plant Name	Location	Available Capacity [MW]	Demand record（Jul.-Sep.'08）	
			MWh	MW
KABOMPO	North-Western	1.160	437	0.5
ZAMBEZI	North-Western	0.960	419	0.6
MWINILUNGA	North-Western	1.360	564	0.8
CHAVUMA	North-Western	0.800	146	0.2
LUKULU	Western	0.320	371	0.3
LWANGWA	Lusaka	0.732	391	0.3
KAPUTA	Northern	0.550	254	0.3
MUFUMBWE	North-Western	0.400	112	0.3
CHAMA	Eastern	0.263	N/A	0.3
		Total	2694	3.6

(Source)ZESCO annual statistic

Table 5.11 Actual data for operation of mini hydropower generation facilities

Plant Name	Location	Available Capacity [MW]	Demand record（Jul.-Sep.'08）	
			MWh	MW
KABOMPO	North-Western	1.160	437	0.5
ZAMBEZI	North-Western	0.960	419	0.6
MWINILUNGA	North-Western	1.360	564	0.8
CHAVUMA	North-Western	0.800	146	0.2
LUKULU	Western	0.320	371	0.3
LWANGWA	Lusaka	0.732	391	0.3
KAPUTA	Northern	0.550	254	0.3
MUFUMBWE	North-Western	0.400	112	0.3
CHAMA	Eastern	0.263	N/A	0.3
		Total	2694	3.6

(Source)ZESCO annual statistic

(3) Surprise demand

The term "surprise demand" refers to demand that cannot be recorded due to external factors, even though it should be recordable by SCADA. The external factors are planned and unplanned outages.

A. Planned outages (rolling blackout or load shedding)

In the distribution system in Zambia, power is supplied by ZESCO. Planned outages are implemented in order to curtail overload operation of distribution facilities. ZESCO has established a total of four divisions (Lusaka, Southern, Northern, and Copperbelt) for operation and management of the distribution system. The Study Team surveyed the situation as regards planned outages at each division.

a. ZESCO Lusaka Division

The Lusaka Division has a power demand that is from two to three times as high as those in other divisions. It includes supply to Lusaka towns in its vicinity (such as Kafue and Mazabuka), and the area extending to Kabwe in Central Province. The division compiles daily data.

Table 5.12 presents data on planned outages in the area under the jurisdiction of the ZESCO Lusaka Division.

Table 5.12 Data on planned outages in the distribution system in 2008 in the Lusaka Division area

Month	Load Shedding (MWh)	Ref.:' Total System Load' given by SCADA(MWh)
Jan.	5168.8	756826.9
Feb.	9244.3	733901.4
Mar.	8748.1	803343
Apr.	11834.8	782262.8
May	8216.2	858510.9
Jun.	7868.4	884268
Jul.	12048.4	929060.7
Aug.	10878.2	859046
Sep.	10298.3	805556.7
Oct.	5803.5	853900.5
Nov.	2819.2	816993.9
Dec.	1128.9	832338.7

b. ZESCO Southern Division

The Southern Division is in charge of the area centered around Livingstone, Sesheke and Kasane, which are points of interconnection with Namibia and Botswana; and the vicinity of Muzuma. Table 5.13 and Table 5.14 show these schedules for planned outages for the

Southern Division.

Table 5.13 Schedule for planned distribution system outages in the Livingstone area

Day of the week	Term	Max demand [MW]
Monday	5:30-9:00	1.2
	17:00-21:00	5.0
Tuesday	5:30-9:00	0.0
	17:00-21:00	5.0
Wednesday	5:30-9:00	0.5
	17:00-21:00	3.0
Thursday	5:30-9:00	1.2
	17:00-21:00	6.5
Friday	5:30-9:00	0.5
	17:00-21:00	5.0
Saturday	5:30-9:00	0.0
	17:00-21:00	5.0
Sunday	5:30-9:00	1.7
	17:00-21:00	3.0

Table 5.14 Schedule for planned distribution system outages in the Choma area

Day of the week	Term	Max demand [MW]
Monday	5:30-9:00	5.0
	18:00-21:00	4.0
Tuesday	5:30-9:00	3.0
	18:00-21:00	4.0
Wednesday	5:30-9:00	4.0
	18:00-21:00	8.0
Thursday	5:30-9:00	4.0
	18:00-21:00	5.0
Friday	5:30-9:00	5.0
	18:00-21:00	5.0
Saturday	5:30-9:00	2.0
	18:00-21:00	4.0
Sunday	5:30-9:00	2.0
	17:00-21:00	5.0

c. ZESCO Copperbelt and Northern divisions

The ZESCO Copperbelt Division is based in Kitwe, the hub of the copper mining industry, and covers Kalulushi, Mufulira, Chingola, and Chililabombwe.

The information from the Copperbelt Division is a list of load shedding due to frequency fluctuation, not actual data on planned outages as received from the other divisions. Because planned outages are made in the major cities of Lusaka and Livingstone, it is thought that the Copperbelt Division also makes them.

Table 5.15 List of load shedding at the Copperbelt Division

Frequency threshold	Amount of Load shedding(MW)
48.75Hz -	5
48.50Hz -	7.5
48.00Hz -	5.0
47.75Hz -	7.5
Total	25.0

(Source) Prepared by the Study Team based on information obtained from ZESCO

The ZESCO Northern Division, which is based in Ndola, a major city alongside Kitwe, also disclosed its schedule for planned outages. However, there were no details of the demand volume, and the Division is planning a series of rotating outages in the northern and southern areas under its jurisdiction between 18:30 and 20:30. The amount of outage during the week is estimated at 25 MW.

The combined amount of planned outage in these divisions is estimated at 60 MW.In sum, the peak demand in fiscal 2008-09 (including system loss) was put at 1,600 MW.

Table 5.16 Calculation of peak demand to serve as the standard

Attribute	Load (MW)
P_{SCADA}	1512
$P_{u.d..}$	50
$P_{s.d}$	60
P_{peak}	1600

The Study Team made forecasts for the peak demand(MW) in each of three cases: base case, high case, and low case. The results are shown in tables Table 5.17 -Table 5.19 and Figure 5.9.

In the base case, the peak demand in fiscal 2030 is forecast at 4,066 MW, about 2.5 times as high as that of 1,600 MW in fiscal 2008 (for an average increase rate of 4.3 percent). Similarly, it was forecast at 5,406 MW, about 3.4 times as high (for an average increase rate of 5.7 percent) in the high case and 3,544 MW, about 2.2 times as high (for an average increase rate of 3.7 percent) in the low case.

Table 5.17 Peak Demand Forecast Result (Base Case Scenario)

(Base Case Senario)

Term	Total Consumption at Customers (GWh)	Peak Demand (MW)														
		CEC				Mining(Zesco)				Retail				Coincident Factor	Total (MW)	Load Factor
		GWh	Loss	LF	MW	GWh	Loss	LF	MW	GWh	Loss	LF	MW			
2008-09	9,242	4,024	3.2%	0.91	521	1,323	3.2%	0.61	256	3,894	24.4%	0.55	1,000	0.90	1,600	0.74
2009-10	9,006	2,934	3.2%	0.91	380	2,016	3.2%	0.61	390	4,056	24.4%	0.55	1,041	0.90	1,631	0.71
2010-11	9,932	2,965	3.2%	0.91	384	2,743	3.2%	0.61	531	4,224	24.4%	0.55	1,084	0.90	1,801	0.71
2011-12	11,853	4,100	3.2%	0.91	531	3,354	3.2%	0.61	649	4,399	24.4%	0.55	1,129	0.90	2,080	0.72
2012-13	12,542	4,100	3.2%	0.91	531	3,801	3.2%	0.61	735	4,642	24.4%	0.55	1,191	0.90	2,214	0.72
2013-14	12,947	4,100	3.2%	0.91	531	3,949	3.2%	0.61	764	4,898	24.4%	0.55	1,257	0.90	2,299	0.72
2014-15	13,784	4,481	3.2%	0.91	580	4,136	3.2%	0.61	800	5,168	24.4%	0.55	1,326	0.90	2,438	0.72
2015-16	14,069	4,481	3.2%	0.91	580	4,136	3.2%	0.61	800	5,453	24.4%	0.55	1,399	0.90	2,504	0.71
2016-17	14,370	4,481	3.2%	0.91	580	4,136	3.2%	0.61	800	5,753	24.4%	0.55	1,477	0.90	2,574	0.71
2017-18	14,687	4,481	3.2%	0.91	580	4,136	3.2%	0.61	800	6,071	24.4%	0.55	1,558	0.90	2,647	0.71
2018-19	15,022	4,481	3.2%	0.91	580	4,136	3.2%	0.61	800	6,405	24.4%	0.55	1,644	0.90	2,725	0.71
2019-20	15,378	4,481	3.2%	0.91	580	4,136	3.2%	0.61	800	6,759	24.4%	0.55	1,735	0.90	2,806	0.70
2020-21	15,740	4,481	3.2%	0.91	580	4,136	3.2%	0.61	800	7,132	24.4%	0.55	1,830	0.90	2,893	0.70
2021-22	16,142	4,481	3.2%	0.91	580	4,136	3.2%	0.61	800	7,525	24.4%	0.55	1,931	0.90	2,984	0.70
2022-23	16,557	4,481	3.2%	0.91	580	4,136	3.2%	0.61	800	7,941	24.4%	0.55	2,038	0.90	3,080	0.70
2023-24	16,996	4,481	3.2%	0.91	580	4,136	3.2%	0.61	800	8,379	24.4%	0.55	2,151	0.90	3,181	0.69
2024-25	17,458	4,481	3.2%	0.91	580	4,136	3.2%	0.61	800	8,841	24.4%	0.55	2,269	0.90	3,288	0.69
2025-26	17,946	4,481	3.2%	0.91	580	4,136	3.2%	0.61	800	9,329	24.4%	0.55	2,394	0.90	3,401	0.69
2026-27	18,461	4,481	3.2%	0.91	580	4,136	3.2%	0.61	800	9,844	24.4%	0.55	2,527	0.90	3,520	0.69
2027-28	19,005	4,481	3.2%	0.91	580	4,136	3.2%	0.61	800	10,388	24.4%	0.55	2,666	0.90	3,646	0.68
2028-29	19,578	4,481	3.2%	0.91	580	4,136	3.2%	0.61	800	10,962	24.4%	0.55	2,813	0.90	3,778	0.68
2029-30	20,184	4,481	3.2%	0.91	580	4,136	3.2%	0.61	800	11,567	24.4%	0.55	2,968	0.90	3,918	0.68
2030-31	20,823	4,481	3.2%	0.91	580	4,136	3.2%	0.61	800	12,206	24.4%	0.55	3,133	0.90	4,066	0.68

Table 5.18 Peak Demand Forecast (High Case Scenario)

(High Case Senario)

Term	Total Consumption at Customers (GWh)	Peak Demand (MW)														
		CEC				Mining(Zesco)				Retail				Coincident Factor	Total (MW)	Load Factor
		GWh	Loss	LF	MW	GWh	Loss	LF	MW	GWh	Loss	LF	MW			
2008-09	9,265	4,024	3.2%	0.91	521	1,323	3.2%	0.61	256	3,918	24.4%	0.55	1,006	0.90	1,600	0.74
2009-10	9,589	3,468	3.2%	0.91	449	2,016	3.2%	0.61	390	4,106	24.4%	0.55	1,054	0.90	1,699	0.72
2010-11	11,107	4,062	3.2%	0.91	526	2,743	3.2%	0.61	531	4,302	24.4%	0.55	1,104	0.90	1,940	0.73
2011-12	12,777	4,817	3.2%	0.91	623	3,354	3.2%	0.61	649	4,607	24.4%	0.55	1,182	0.90	2,204	0.73
2012-13	14,123	5,388	3.2%	0.91	697	3,801	3.2%	0.61	735	4,934	24.4%	0.55	1,266	0.90	2,423	0.74
2013-14	15,003	5,769	3.2%	0.91	747	3,949	3.2%	0.61	764	5,284	24.4%	0.55	1,356	0.90	2,574	0.74
2014-15	16,174	6,379	3.2%	0.91	826	4,136	3.2%	0.61	800	5,660	24.4%	0.55	1,453	0.90	2,764	0.74
2015-16	16,577	6,379	3.2%	0.91	826	4,136	3.2%	0.61	800	6,062	24.4%	0.55	1,556	0.90	2,857	0.74
2016-17	17,009	6,379	3.2%	0.91	826	4,136	3.2%	0.61	800	6,494	24.4%	0.55	1,667	0.90	2,956	0.73
2017-18	17,471	6,379	3.2%	0.91	826	4,136	3.2%	0.61	800	6,957	24.4%	0.55	1,786	0.90	3,063	0.73
2018-19	17,968	6,379	3.2%	0.91	826	4,136	3.2%	0.61	800	7,453	24.4%	0.55	1,913	0.90	3,177	0.72
2019-20	18,500	6,379	3.2%	0.91	826	4,136	3.2%	0.61	800	7,985	24.4%	0.55	2,050	0.90	3,300	0.72
2020-21	19,071	6,379	3.2%	0.91	826	4,136	3.2%	0.61	800	8,556	24.4%	0.55	2,196	0.90	3,432	0.72
2021-22	19,683	6,379	3.2%	0.91	826	4,136	3.2%	0.61	800	9,168	24.4%	0.55	2,353	0.90	3,573	0.71
2022-23	20,340	6,379	3.2%	0.91	826	4,136	3.2%	0.61	800	9,825	24.4%	0.55	2,522	0.90	3,724	0.71
2023-24	21,044	6,379	3.2%	0.91	826	4,136	3.2%	0.61	800	10,529	24.4%	0.55	2,702	0.90	3,886	0.70
2024-25	21,799	6,379	3.2%	0.91	826	4,136	3.2%	0.61	800	11,285	24.4%	0.55	2,896	0.90	4,060	0.70
2025-26	22,610	6,379	3.2%	0.91	826	4,136	3.2%	0.61	800	12,095	24.4%	0.55	3,104	0.90	4,247	0.70
2026-27	23,479	6,379	3.2%	0.91	826	4,136	3.2%	0.61	800	12,964	24.4%	0.55	3,327	0.90	4,447	0.69
2027-28	24,412	6,379	3.2%	0.91	826	4,136	3.2%	0.61	800	13,897	24.4%	0.55	3,567	0.90	4,662	0.69
2028-29	25,412	6,379	3.2%	0.91	826	4,136	3.2%	0.61	800	14,898	24.4%	0.55	3,824	0.90	4,893	0.69
2029-30	26,486	6,379	3.2%	0.91	826	4,136	3.2%	0.61	800	15,972	24.4%	0.55	4,099	0.90	5,140	0.68
2030-31	27,638	6,379	3.2%	0.91	826	4,136	3.2%	0.61	800	17,124	24.4%	0.55	4,395	0.90	5,406	0.68

Table 5.19 Peak Demand Forecast (Low Case Scenario)

(LowCase Senario)

Term	Total Consumption at Customers (GWh)	Peak Demand (MW)														
		CEC				Mining(Zesco)				Retail				Coincident Factor	Total (MW)	Load Factor
		GWh	Loss	LF	MW	GWh	Loss	LF	MW	GWh	Loss	LF	MW			
2008-09	9,236	4,024	3.2%	0.91	521	1,323	3.2%	0.61	256	3,888	24.4%	0.55	998	0.90	1,600	0.74
2009-10	8,993	2,934	3.2%	0.91	380	2,016	3.2%	0.61	390	4,043	24.4%	0.55	1,038	0.90	1,629	0.71
2010-11	9,912	2,965	3.2%	0.91	384	2,743	3.2%	0.61	531	4,205	24.4%	0.55	1,079	0.90	1,797	0.71
2011-12	11,826	4,100	3.2%	0.91	531	3,354	3.2%	0.61	649	4,372	24.4%	0.55	1,122	0.90	2,075	0.72
2012-13	12,447	4,100	3.2%	0.91	531	3,801	3.2%	0.61	735	4,547	24.4%	0.55	1,167	0.90	2,193	0.72
2013-14	12,798	4,100	3.2%	0.91	531	3,949	3.2%	0.61	764	4,748	24.4%	0.55	1,219	0.90	2,266	0.72
2014-15	13,576	4,481	3.2%	0.91	580	4,136	3.2%	0.61	800	4,959	24.4%	0.55	1,273	0.90	2,392	0.72
2015-16	13,796	4,481	3.2%	0.91	580	4,136	3.2%	0.61	800	5,180	24.4%	0.55	1,329	0.90	2,443	0.72
2016-17	14,027	4,481	3.2%	0.91	580	4,136	3.2%	0.61	800	5,410	24.4%	0.55	1,388	0.90	2,496	0.71
2017-18	14,267	4,481	3.2%	0.91	580	4,136	3.2%	0.61	800	5,650	24.4%	0.55	1,450	0.90	2,551	0.71
2018-19	14,518	4,481	3.2%	0.91	580	4,136	3.2%	0.61	800	5,901	24.4%	0.55	1,515	0.90	2,609	0.71
2019-20	14,780	4,481	3.2%	0.91	580	4,136	3.2%	0.61	800	6,163	24.4%	0.55	1,582	0.90	2,670	0.71
2020-21	15,054	4,481	3.2%	0.91	580	4,136	3.2%	0.61	800	6,437	24.4%	0.55	1,652	0.90	2,733	0.71
2021-22	15,339	4,481	3.2%	0.91	580	4,136	3.2%	0.61	800	6,723	24.4%	0.55	1,725	0.90	2,800	0.70
2022-23	15,638	4,481	3.2%	0.91	580	4,136	3.2%	0.61	800	7,021	24.4%	0.55	1,802	0.90	2,869	0.70
2023-24	15,950	4,481	3.2%	0.91	580	4,136	3.2%	0.61	800	7,333	24.4%	0.55	1,882	0.90	2,941	0.70
2024-25	16,276	4,481	3.2%	0.91	580	4,136	3.2%	0.61	800	7,659	24.4%	0.55	1,966	0.90	3,016	0.70
2025-26	16,616	4,481	3.2%	0.91	580	4,136	3.2%	0.61	800	7,999	24.4%	0.55	2,053	0.90	3,095	0.70
2026-27	16,971	4,481	3.2%	0.91	580	4,136	3.2%	0.61	800	8,354	24.4%	0.55	2,144	0.90	3,177	0.69
2027-28	17,342	4,481	3.2%	0.91	580	4,136	3.2%	0.61	800	8,725	24.4%	0.55	2,239	0.90	3,263	0.69
2028-29	17,730	4,481	3.2%	0.91	580	4,136	3.2%	0.61	800	9,113	24.4%	0.55	2,339	0.90	3,353	0.69
2029-30	18,135	4,481	3.2%	0.91	580	4,136	3.2%	0.61	800	9,518	24.4%	0.55	2,443	0.90	3,446	0.69
2030-31	18,557	4,481	3.2%	0.91	580	4,136	3.2%	0.61	800	9,941	24.4%	0.55	2,551	0.90	3,544	0.68

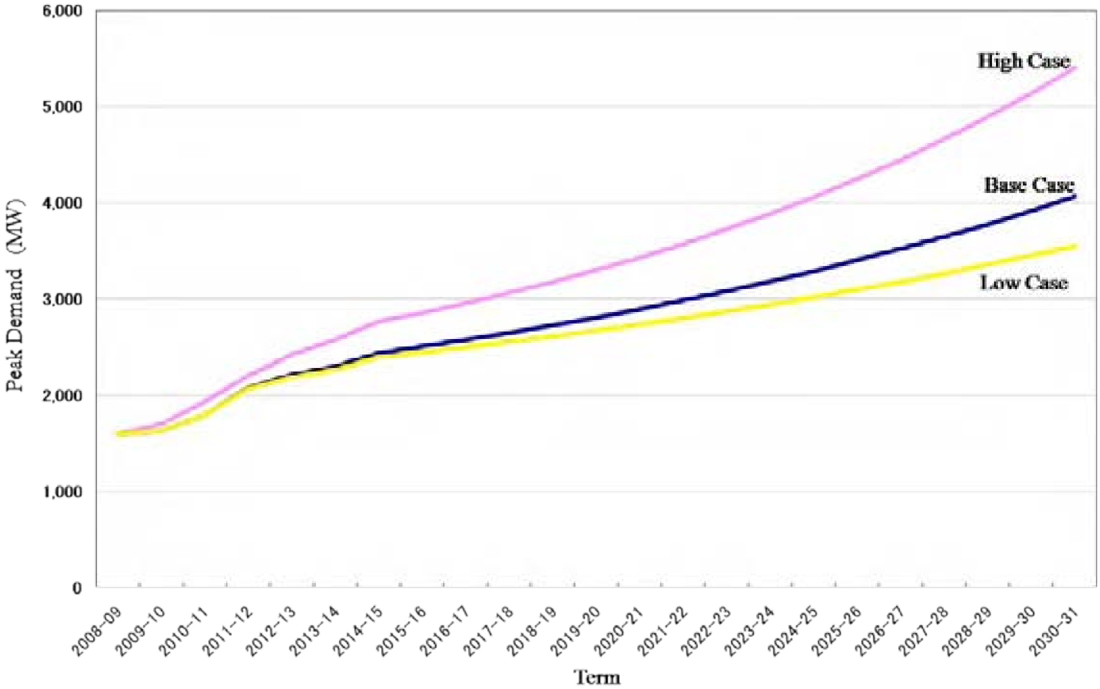


Figure 5.9 Peak Demand Forecast

Reference

Central Statistical Office (2005), Living Conditions Monitoring Survey Report 2004, Ministry of Labor and Social Security, Lusaka, Zambia

Central Statistical Office (2007), Labour Force Survey Report 2005, Ministry of Labor and Social Security, Lusaka, Zambia

International Monetary Fund, International Financial Statistics, various issues, Washington, DC

Ministry of Finance (2006), Fifth National Development Plan 2006-2010, Lusaka, Zambia

Republic of Zambia (2006), Vision 2030—A prosperous Middle-income Nation By 2030, Lusaka, Zambia

World Bank (2008), Global Economic Prospect—Commodities at Crossroads 2009, Washington, DC

ZESCO Limited, Annual Report, various issues, Lusaka, Zambia

Chapter 6 Generation Development Planning

6.1 Generation Development Situation

6.1.1 Existing power development plan

There has been no additional generation development in Zambia since 1970s when the construction of the existing hydropower plants was completed. In recent years, however, there have finally emerged practical signs of development to meet the demand growth.

According to the government office OPPPI to promote private power investment, projects shown in Table 6.1 are listed as candidates in Zambia.

13 projects except Maamba coal thermal are hydropower development, and have about 5,360 MW capacity in total.

Table 6.1 Generation Projects List by OPPPI

No.	Project	Capacity (MW)	Project sponsor	Current status (as of Dec '08)
1	Kariba North extension	360	ZESCO	Under construction
2	Batoka Gorge	800	n/a	Pre-F/S completed
3	Devil's Gorge	800	n/a	n/a
4	Mpata Gorge	600	n/a	n/a
5	Kafue Gorge Lower	750	n/a	Under F/S
6	Itezhi Tezhi	120	ZESCO/TATA	Under D/D
7	Mumbotuta Falls	301	n/a	n/a
8	Mambilima Falls (5 PS's)	1,100	n/a	n/a
9	Kalungwishi	218	Lunzua Power Authority	Under negotiation on I/A
10	Kabompo Gorge	34	CEC/TATA	Under F/S
11	Lusiwasi extension	62	ZESCO or Private	Under F/S
12	Mutinondo/ Luchenene	40 30	Power Min	Under negotiation on I/A
13	Lunsemfwa/ Mkushi Rivers	147	Lunsemfwa Hydro	Under F/S
14	Maamba coal	n/a	n/a	n/a
	Total	**5,362**		

(Source) Assembled by the Study Team hearing from OPPPI

The SAPP generation development plan supported by the World Bank, listed six generation projects with the total capacity 2,390 MW up to 2030 in Zambia, indicated in Table 6.2. Among them, Kariba North and Kafue Gorge projects are planned to raise their capacities as a part of ongoing power rehabilitation projects, and expected to complete in 2009. Therefore, additional power capacity after 2010 comes to 2,030 MW, which may meet the base case power demand, but miss the high case one by 1,000 MW, indicated in Section 5.4.

Table 6.2 Generation Projects List by SAPP

	Project Name	Type	Capacity Added (MW)	Operating Year
1	Kariba North Refurbishment	Hydro	210	2008-2009
2	Kafue Gorge Upper Refurbishment	Hydro	150	2009
3	Kariba North Extension	Hydro	360	2012
4	Itezhi-Tezhi	Hydro	120	2013
5	Kafue Gorge Lower	Hydro	750	2017
6	Batoka Gorge	Hydro	800	2017
Total			**2,390**	

(Source) SAPP Regional Generation and Transmission Expansion Plan Study (Draft Final Report (interim), May 2008) and Interview by JICA Study Team

In addition, five projects shown in Table 6.3 are nominated as immediate future projects in the latest annual report (2008) of ZESCO. Among them, ZESCO is the developer of the rehabilitation of the existing power stations; Kafue Gorge and Kariba North. However, as for Kafue Gorge Lower and Maamba, the developers are not yet decided and, the developer of Kabompo is the joint venture of private CEC and TATA, according to Table 6.1.

Table 6.3 Generation Projects List by ZESCO

	Project	Type	Capacity (MW)	Expected date	Expected project cost (US$ million)
1	Kafue Gorge Rehabilitation	Hydro	60	2008	
2	Kariba North Rehabilitation	Hydro	30	2008	
3	Kafue Gorge Lower	Hydro	750	2012	600
4	Kabompo	Hydro	34	2012	--
5	Maamba	Coal Thermal	500	2014	192
Total			**1,374**		

(Source) ZESCO Annual Report, 2008

As mentioned above, there are some project lists gathered by different organizations, which enough covers the power demand up to 2030. On the other hand, project details such as commercial operation years and installed capacities are not consistent with each other. Therefore, the Study Team summarized the latest progress and specification of the projects listed in Table 6.1, Table 6.2 and Table 6.3 in the following part, scanning the existing information such as the F/S reports and hearing from the relevant government organizations and developers.

6.1.2 Current status of generation projects

(1) Rehabilitation of existing power stations

The existing three major power stations (Victorial Falls, Kariba North Bank and Kafue Gorge) were built before the 1970s. At all of the existing power stations, facility reliability has degraded substantially due to aging. In response, power rehabilitation projects (PRPs) has been executed with aid from the World Bank to extend facility life at existing stations and assure supply over the short term to meet the demand, which has been tightening the supply in recent years. Taken together, PRPs increased output by 210 MW. Although PRPs cover not only generation facilities but also transmission and distribution facilities, this account concerns mainly the increase in generation facility output.

i) Victoria Falls Hydropower Station

The Victoria Falls Hydropower Station consists of three stations (A, B, and C) with respective outputs of 8, 60, and 40 MW, for a total of 108 MW. While it did not expand the capacity, the PRP lengthened the service life and increased reliability. The station personnel indicated that the PRP work began in 2003 and was finished in 2006.

ii) Kariba North Bank Hydropower Station

The Kariba North Bank Hydropower Station is installed with four 150 MW generators and has a total output of 600 MW. The PRP is to raise the capacity per generator to 180 MW and the total output to 720 MW, for an increase of 120 MW from before.

According to personnel at the station, the PRP began in 2002, and work on the first three units has already been completed. The work on the fourth is scheduled for completion in 2010. There are reports to the effect that the turbines were not replaced for the first two units, which consequently cannot operate at full output if the water level is too low.

iii) Kafue Gorge Hydropower Station

The Kafue Gorge Hydropower Station is equipped with six generators, each with a capacity of 150 MW, for a total output of 900 MW. The PRP is aimed at raising the output of each unit from 150 to 165 MW, for a total output of 990 MW, or 90 MW more than before the rehabilitation.

According to the station personnel, the PRP work began in 2001 and proceeded for two units at a time. Work on units 3 - 6 has already been completed, and that on units 1 and 2 is scheduled for completion in February 2009.

Table 6.4 Output increases in power rehabilitation projects (PRP)

Power Station	Capacity (MW)		Increase (MW)
	Before PRP	After PRP	
Victoria Falls	108	108	--
Kariba North Bank	600 (150 x 4 units)	720 (180 x 4 units)	120
Kafue Gorge	900 (150 x 6 units)	990 (165 x 6 units)	90

(2) New hydropower development projects

The progress of the new waterpower project is summarized in Table 6.5 and speak below the summary of each project.

Table 6.5 State of progress of new hydropower development projects

No.	Project	Capacity (MW)	Developer	Progress		Related documents
				Pre-FS	FS	
1	Kariba North Bank Extension	360	ZESCO	✓✓	✓✓	> 2x180 Kariba North Bank Extension Hydropower Station Basic Design Report, 2008 > Kariba North Bank Power Station Extension Final Feasibility Study Report, 2005
2 3 4	Mpata Gorge Devil's Gorge Batoka Gorge	543 500 800	ZRA	✓✓		> Batoka Gorge Hydro Electric Scheme Feasibility Report, 1993
5	Itezhi Tezhi	120	ZESCO /TATA	✓✓	✓✓	> Feasibility Study for Itezhi Tezhi Hydro Electric Project (2x60MW), 2007
6	Kafue Gorge Lower	750	N.Y	✓✓	✓	> FS under Preparation by IFC > Site Selection Report for the Kafue Gorge Lower Hydroelectric Project,2006
7	Lusiwasi Extension	50	ZESCO or Private	✓✓	✓	> FS under preparation by ZESCO > Small Hydropower Stations Rehabilitation and Upgrading Study, 1997
8	Mumbotuta Falls - Site CX	 301	n/a	✓✓		> Development of Hydroelectric Power in the Luapula and Northern Areas of Zambia, 2001
9	Mambilima Falls - Site II - Site I	 202 124	n/a	✓✓		
10	Kabwelume Falls	62	Lunzua Power Authority (Private)	✓✓		> Under negotiation of Implementation Agreement
11	Kundabwika Falls	101				
12	Mutinondo	40	Power Min (Private)			> Implementation Agreement to be designed in 2009
13	Luchenene	30				
14	Lunsemfwa	55	LHPC (Private)		✓	> FS to be completed by 2010
15	Mkushi	65			✓	
16	Kabompo	34	CEC/TATA	✓✓	✓	> FS ongoing by private > Small Hydropower Pre-Investment Study North-Western Province, 2000

✓✓ Completed
✓: Ongoing or prepared

i) Kariba North Bank Extension Project

This project is aimed at extension of the capacity of the Kariba North Bank Hydropower Station (720 MW) by 360 MW (through installation of two 180 MW generators). A Chinese firm (Sinohydro Corporation Ltd.) commenced construction with the Chinese government's assistance in fiscal 2008, and plans to install the new units into operation in 2013.

Table 6.6 Outline of the Kariba North Bank Extension Project

Item	Description
Dam & Reservoir	Kariba dam (Existing) Construction of new intake at the upstream of the existing one
Installed Capacity (MW)	360 (180MW x 2units)
Turbine & Generator	Francis, Vertical shaft
Rated power (MW)	183.7 (1unit)
Rated discharge (m^3/s)	227.6 (1unit)
Rated water head (m)	89
Intake	2 intake chamber Invert elevation: 458m
Headrace Tunnel	Diameter: 7.8m
Powerhouse	Underground Length: 51m, Width: 24m Elevation of generator floor: 385.5m Installation elevation:372.5m
Tailrace Tunnel	Horseshoe type Maximum height: 9.8m

Source: 2 x 180MW Kariba North Bank Extension Hydropower Station Basic Design Report (2008)

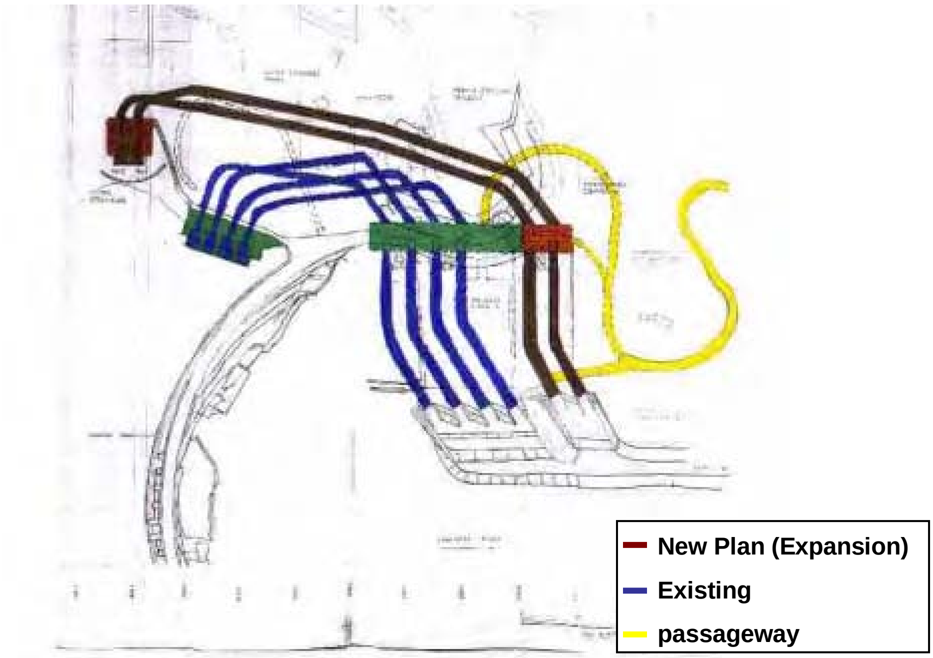


Figure 6.1 Layout of the Kariba North Bank Extension Project

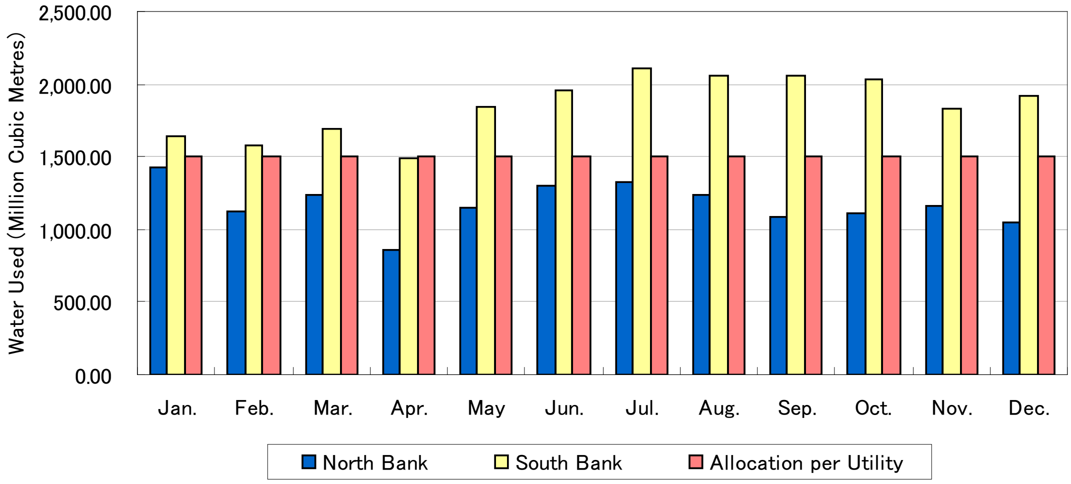
The Kariba North Bank Hydropower Station lies on the main Zambezi channel, and the amount of water it may use to generate power is determined by the ZRA. Basically, the yearly amount of water allocated for power generation is evenly split with the South Bank Hydropower Station in Zimbabwe. According to the Kariba North Bank Power Station Extension Final Feasibility Study Report 2005, the increase brought by the Kariba North Expansion Project is calculated at 380 gigawatt-hours (GWh) per year. A look at the procedure reveals that this calculation was made by extrapolating the amount of generated power from the amount of water discharged from the floodgate in the past instead of the yearly amount of water allocated to Zambia. The discharge from the floodgate is surplus water, and its diversion for power generation would result in a commensurate increase in output. Interviews with station personnel, however, indicated a lack of clarity about handling of the discharge when it became necessary to discharge water from the floodgate. In actual operation, the station must effectively operate in overall terms, i.e., with both the preexisting and additional capacity, within the yearly water allocation determined in advance by the ZRA. This, in turn, requires full operation during peak periods and reduction of the amount of water use during low-load periods to adjust the balance of water inflow and outflow. The Kariba North Bank Project is for generation using a reduced flow of water during low-load periods, and therefore may be regarded as a facility with a low plant factor, developed for peak application, as opposed to a base source.

In 2007, the Kariba North Bank Hydropower Station utilized 14.1 billion cubic meters of water for power generation. This figure was less than the allocation of 18 billion cubic meters (see Table 6.7 and Figure 6.2). The gap was presumably due to the decrease in water use for power generation because operation of one unit was suspended for the rehabilitation work. In ZESCO's annual report as well, the possible generated output in this year was put at 510 MW. Because the post-rehabilitation output is supposed to be 660 MW, calculation of the yearly water use at 660 MW applying the output ratio as is yields a figure of 18.2 billion cubic meters, or about the same as the annual allocation. Unless the allocation is increased, the amount of water use for the increase of 360 MW will have to be derived within the allocation limit. Without a change in the conventional pattern of operation of the existing facilities, it will not be possible to acquire the extra amount of water required for use of the additional capacity. There is a need for effective operation together with the existing capacity (660 MW).

Table 6.7 Amount of water use for power generation at KNBPS & KSBPS

month	Kariba North Bank			Kariba South Bank			Cumulative Allocation for Kariba Complex (MCM)	Cumulative Water Used at Kariba Complex (MCM)	Allocation Rate (%)
	Water Allocated (MCM)	Water Used (MCM)	Allocation rate (%)	Water Allocated (MCM)	Water Used (MCM)	Allocation rate (%)			
Jan.	1,500.00	1,421.04	95%	1,500.00	1,641.83	109%	3,000.00	3,062.87	102%
Feb.	1,500.00	1,127.95	75%	1,500.00	1,583.46	106%	6,000.00	5,774.28	96%
Mar.	1,500.00	1,236.68	82%	1,500.00	1,685.99	112%	9,000.00	8,696.95	97%
Apr.	1,500.00	854.87	57%	1,500.00	1,487.98	99%	12,000.00	11,039.80	92%
May	1,500.00	1,143.39	76%	1,500.00	1,849.42	123%	15,000.00	14,032.61	94%
Jun.	1,500.00	1,304.83	87%	1,500.00	1,953.67	130%	18,000.00	17,291.11	96%
Jul.	1,500.00	1,322.11	88%	1,500.00	2,103.31	140%	21,000.00	20,716.53	99%
Aug.	1,500.00	1,237.51	83%	1,500.00	2,055.01	137%	24,000.00	24,009.05	100%
Sep.	1,500.00	1,091.42	73%	1,500.00	2,054.10	137%	27,000.00	27,154.57	101%
Oct.	1,500.00	1,106.09	74%	1,500.00	2,032.57	136%	30,000.00	30,293.23	101%
Nov.	1,500.00	1,158.02	77%	1,500.00	1,830.89	122%	33,000.00	33,282.14	101%
Dec.	1,500.00	1,050.77	70%	1,500.00	1,922.12	128%	36,000.00	36,255.03	101%
Total	18,000.00	14,054.68	78%	18,000.00	22,200.35	123%	36,000.00	36,255.03	101%

(Source) Zambezi River Authority, Annual Report and Accounts for the year ended 31st December 2007



(Source) Zambezi River Authority, Annual Report and Accounts for the year ended 31st December 2007

Figure 6.2 Amount of water use for power generation at the KNBPS & KSBPS

ii) Itezhi Tezhi Project

The Itezhi Tezhi (ITT) Project is sited on the Kafue River, a tributary of the Zambezi. The reservoir already built was constructed in 1978 and has a capacity of 6 billion cubic meters. It acts to level the flow disparity between the wet and dry seasons, and supplies water to the Kafue Gorge (KG) Hydropower Station. The area extending downstream from the ITT reservoir on the Kafue River has an extremely flat topography. More specifically, it is characterized by an average grade to the KG reservoir (also downstream) of 0.0025 percent, a corresponding horizontal distance of about 230 kilometers, and a vertical disparity of 5 - 6 meters. For these reasons, it takes water discharged from the ITT reservoir about 90 days to reach the KG reservoir serving the KG Hydropower Station downstream. Nevertheless, the flow-adjusting function of the ITT reservoir makes a positive contribution to operation of the KG Hydropower Station and to other water use (for agriculture and drinking).

The ITT Project was studied in 1977 ("Itezhi Tezhi Power Station Preinvestment Study", SWECO), and there were plans for construction of a generation facility with a capacity of 80 MW downstream of the existing dam. In a feasibility study executed in 1999 ("Feasibility Study of the Itezhi Tezhi Hydroelectric Project", Harza), however, the capacity was revised upward to 120 MW. In a subsequent study ("Itezhi Tezhi Hydro Electric Project", Tata Consulting Engineers Limited (TCE), 2007), the plan was revised again on the grounds that an aboveground station was more economical than the underground one which had been planned. The plan for the underground station had already been authorized by the EIA in 2006, and the EIA again authorized the aboveground type in January 2009. This paved the way for further preparations for development.

The plans call for use of one of the two existing discharge pipes as a raceway and expansion of the station capacity, without modification of the existing structures (i.e., the reservoir and dam).

Because the reservoir operation will not change upon plant construction, the discharge pattern will probably remain basically the same. As a result, there should be no impact on operation of the Kafue Gorge Hydropower Station.

As its operators are ZESCO and Tata, a foreign-affiliated private company, the ITT Project is one of development based on public-private partnership. The two have already established the Itezhi Tezhi Power Corporation (ITTPC), which has an SPC status.

Table 6.8 Outline of the Itezhi Tezhi Project

Name of the HP	Itezhi Tezhi
General information	
Region, District	Itezhi-Tezhi District, Southern Province of Zambia
Special Purpose Company (SPC)	Itezhi Tezhi Power Corporation (ITTPC) Limited
Shareholders	ZESCO Limited and TATA Africa Holdings (SA) (PTY) Limited
Installed capacity (MW)	120 MW (2 x 60 MW)
Type of generation	Base load (24 hours generation)
Catchment area (km^2)	Kafue basin - 150,000 Km^2
Maximum Generation Discharge (m^3/s)	306 m^3/s
Net head (m)	40 m
Plant factor (%)	95%
Annual generation (GWh)	611
Project framework	
Current status	Bidding governed by the World Bank eligibility rules and procedures EPC Bid Documents issued on 8 December 2008 on ICB basis Site Visit & Pre Bid Meeting held from 20 to 23 January 2009, Tender Opening to be held on 20 March 2009
Expected start month/year of construction	EPC Contract Award – June 2009 Contractor Mobilization – August 2009 Project Completion – 2013 (December 2012*)
Construction period	46 months (42months*)
Total project cost (US$)	Estimated total project cost – 164.95million (2007 price level), (US$200million*)
Technical information	
Dam type	Existing, Rock-fill dam
Dam height and crest length (m)	Existing, Maximum height is 51m and crest length is 1,400 m
Type and number of spillway gate	Existing, Three radial spillway gates
Area of the reservoir (m^2)	390 km^2 at Full Supply Level
Total storage capacity (m^3)	6,000 million m^3
Effective storage capacity (m^3)	5,300 million m^3
Type, size and length (m) of headrace	i) Indicative dimensions only. Bidders to optimize the design

Name of the HP	Itezhi Tezhi
	ii) Existing tunnel, 15m diameter & 410m length from intake iii) Horseshoe concrete lined tunnel, 9m diameter & 145m length iv) Concrete lined surge shaft with diameters 10m riser & 30m upper v) Concrete or steel lined tunnel, 9m diameter & 50m length
Type , size and length (m) of penstock	Circular steel lined tunnel, 6m diameter and 5m length from bifurcation
Type and size (m) of power house	Surface Power House constructed of RCC Machine hall size: 87 m long x 23.2 m wide x 49 m high Transformer hall size: 52m long x 15m wide x 21 m high Tail race channel of trapezoidal section, 20m width & 150m long
Type of turbine	Vertical shaft Kaplan
Environmental impact	According to hearing from the ITTPC, Environmental and Socio-economic impact to be mitigate according to the Environmental Impact Management Plan No resettlements (Project site has been a restricted area) There are no known archaeological/heritage sites within the project area

(*) Hearing base
(Source) TCE Consultation Engineers Ltd. Feasibility Report for Itezhi Tezhi Hydro Electric Project (2 x 60MW)
JICA Study Team, Hearing from Itezhi Thezhi Power Corporation (ITTPC)

The ITT Project is characterized by public-private partnership, as noted above. For this reason, an interview was held with the ITTPC, the concerned SPC, in February 2009. The following information was obtained from this interview.

- The ITT Project offtaker is ZESCO, which is also, however, one of the SPC investors. In the interest of fair contracting under this circumstance, the SPC has hired advisors in the areas of commercial transactions and financing as well as a technical consultant, and is conducting deliberations on the details of the power purchasing agreement (PPA).
- Construction of transmission lines is the responsibility of ZESCO. An agreement has been reached to incorporate a provision for generation compensation in the event of delay in construction of transmission lines.
- Operation and maintenance are scheduled to be outsourced, but the details have not yet been determined. The basic outline must be firmed up by the time of PPA conclusion.
- In spite of the outlays by ZESCO, the project is for an independent power producer (IPP). In the ITTPC's interpretation, this means that it is outside the application scope for governmental procurement rules. The ITTPC intends to promote the project while conferring with government-related agencies on this interpretation.

As this indicates, procedures are moving ahead in consultation with concerned agencies because there is no precedent for development based on public-private partnership. Incentives under consideration for the project include a tax holiday for five years, exemption from import duties, and exemption from the value-added tax (VAT). The detailed determinations require discussion with the government, and there are apprehensions that this will take considerable time.

iii) Kafue Gorge Lower Project

The Kafue Gorge Lower (KGL) Project is planned for a site about 200 meters downstream of the Kafue Gorge (KG) Hydropower Station. Preparations are being made for a feasibility study for it. It would be the most downstream project on the Kafue River; the ITT Hydropower Project utilizing the ITT reservoir is moving ahead upstream of it. Together with the KG Hydropower Station directly upstream, it will form part of the river system development on the Kafue.

According to information obtained from the IFC in February 2009, the feasibility study was then being implemented. However, there are problems including the lack of an access road to the candidate site and of a boring exploration, and three sites are still under study for the dam. In spite of this, the detailed specifications of the plan were to be determined in the early part of fiscal 2009. The KGL Project is located directly downstream of the KG Hydropower Station and would construct a reservoir with a certain storage capacity. As a result, it would enable variation in the operating pattern of the existing KG Hydropower Station. For example, it would be effective to operate the KG Hydropower Station in peak periods because its capacity of 990 MW is the largest in Zambia. By having re-regulation apply to the KGL Hydropower Station, this would enable peak operation that takes account of change in the flow duration downstream. It would also make it possible to place the KGL Hydropower Station itself in peaktime operation using its effective reservoir capacity. Another prospect under study is the installation of facilities to moderate changes in the downstream flow situation, such as a weir with a height of about 10 meters. Coordination with upstream facilities is indispensable for efficient operation and peak accommodation. In any case, the KGL Project may be regarded as one that will have a big influence on plans for power plants on the Kafue River system.

Table 6.9 Outline of the Kafue Gorge Lower Project

Name of the HP	Kafue Gorge Lower
General information	
Region, District	Kafue Gorge, Kafue
Installed capacity (MW)	750 (187.5 x 4 units)
Type of generation	Peaking station, Storage dam
Catchment area (km^2)	815
Maximum Generation Discharge (m^3/s)	434 (108.5 m^3 x 4)
Net head (m)	186 (approx. yet to be designed)
Plant factor (%)	32 (at 750MW)
Annual generation (GWh)	2,400
Project framework	
Current status	Feasibility Study to be completed by May 2009
Expected start month/year of construction	2011
Construction period	55 months
Total project cost (US$)	738 million (2005 price level)
Technical information	
Dam type	RCC dam
Dam height and crest length (m)	120 (approx.)
Area of the reservoir (km^2)	2.14 at 610 m elevation
Type of turbine	Francis Turbine
Environmental impact	According to hearing from the IFC, an update of EIA yet to be finalized soon. (So far the project has minimal impact with regards to resettlement.

Source: MWH, Site Selection Report for the Kafue Gorge Lower Hydroelectric Project (2006)
JICA Study Team, Hearing from IFC

In 2008, the IFC concluded an advisory agreement with the Zambian government related to KGL hydropower development, for work in areas such as feasibility studies and arrangements for investors.

The following outline derives from a presentation of the project by the IFC. Although the peak accommodation and other aspects of the operating pattern have not yet been fixed, the reservoir is expected to have an effective capacity sufficient for about two days' worth of operation. The main specifications are a dam height of 120 meters, headrace tunnel length of 8 kilometers, vertical shaft length of 200 meters, and aboveground construction. Although the project will not entail relocation of any residents, it is likely to have an economic impact on 12,000 (in 2,000 households), mainly in connection with fishing. A trial calculation yielded a project cost of 1,874 million dollars. As for technical considerations, the geology of the tunnel area and parts traversed by waterways has not yet been sufficiently determined because an additional boring exploration has not been made. There are anticipated to be additional problems such as difficult conditions for engineering and construction in zoning for dams and headrace, as the work must be executed in a narrow valley.

iv) Lusiwasi Expansion Project

The Lusiwasi Expansion Project is aimed at adding 50 MW to the capacity of the existing Lusiwasi Hydropower Station (run-of-river type, output of 12 MW) owned by ZESCO. The station lies on the Lusiwasi River, which is a tributary of the Luangwa River running through South Luangwa National Park. On the western side of this park is a hilly region with elevation differences of about 500 meters. Other hydropower plants to be described below are planned for rivers running through this hilly region, and all of these plans are being promoted under private initiative.

The plan for expansion consists of two stages. The first stage is an upstream plan for installation of a new weir between the existing intake and the Lusiwasi reservoir to create a reservoir, and construction of a run-of-river type hydropower station with an output of 10 MW. In the second stage, a capacity of 40 MW is to be added to the existing Lusiwasi Hydropower Station.

The feasibility study is scheduled to be finished by 2010.

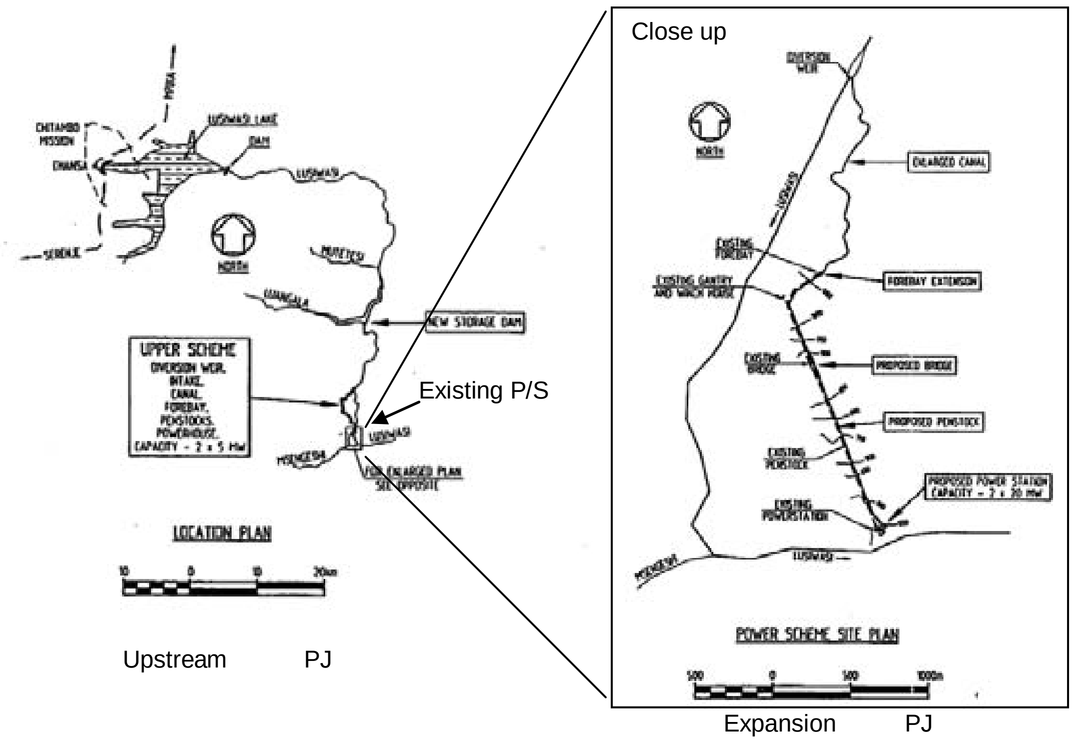


Figure 6.3 Layout of the Lusiwasi Expansion Project

Table 6.10 Outline of the Lusiwasi Expansion Project

	Upper scheme	Expansion	Existing
Capacity (MW)	10 (5 x 2units)	40 (20 x 2units)	12 (3 x 4units)
Design discharge (m^3/s)	13.3	9.6	2.9
Gross Head (m)	95	522.6	522.6
Net Head (m)	90	500	509.2
Turbine	Francis, Horizontal	Pelton, Horizontal	Pelton, Horizontal
Generation (GWh)	40.3	160.1	48.8
Plant Factor (%)	46.0	45.7	46.4
Project Cost (million US$) (1997 price level)	19.52	60.53	-
Construction Period	14 months	28 months	-

(Source) Knight Piesold Limited, Small Hydropower Stations Rehabilitation and Upgrading Study Final Report (1997)

v) Kabompo Gorge Project

Led by the private sector, the Kabompo Gorge Project is aimed at development of a hydropower station with an output of 34 MW in the Kabompo Gorge on the Kabompo river, which flows through North-Western Province. At present (2009), the CEC and the Indian capital TATA are collaborating in preparations for a feasibility study.

Table 6.11 Outline of the Kabompo Project

Name of the HP	Kabompo
General information	
Region, District	Northwestern Province, Mwinilunga District
Installed capacity (MW)	34 (17 x 2 units)
Catchment area (km^2)	2,300
Maximum Generation Discharge (m^3/s)	24
Net head (m)	160
Plant factor (%)	59
Annual generation (GWh)	176
Project framework	
Current status	Evaluation of RFP for Consulting Services for bankable feasibility study
Expected start month/year of construction	2010
Construction period	42 months
Total project cost (US$)	65.9 million (2000 price level) (US$ 77.3 million include the Transmission line)
Technical information	
Dam type	Concrete Arch (under review)
Dam height and crest length (m)	68
Area of the reservoir (km^2)	28.1
Total storage capacity (m^3)	289 million
Effective storage capacity (m^3)	274 million
Type of turbine and generator	Vertical Francis
Environmental impact	According to the TATA Zambia Ltd., preliminary EIA indicated a moderate impact on the human settlements and medium to high impact on fauna and flora due to undisturbed nature of the project site

Source: NORPLAN A.S, Small Hydropower Pre-Investment Study North-Western Province, Zambia (2000)
JICA Study Team, Hearing from TATA Zambia Ltd

vi) Mutinondo/ Luchenene Projects

The Mutinondo and Luchenene projects are to take shape on the Munyamadzi River and its tributary, respectively. The Munyamadzi flows through the Muchinaga Escarpment, which makes for an elevation difference of about 500 meters, to the west of South Luangwa National Park. Both rivers flow into the Luangwa, which flows through the middle area of South Luangwa National Park.

These projects are for the development of two hydropower stations in the hilly region spreading out on the western side of South Luangwa National Park, at a site about 100 kilometers northwest of the existing Lusiwasi Hydropower Station. It envisions construction of one station on the Munyumadzi River with a capacity of 40 MW, and the other on a tributary of the Munyumadzi with a capacity of 30 MW. For both, the plans are being promoted with a Zambian private company (Power Min) serving as the developer.

Table 6.12 Outline of the Mutinondo Project

Name of the HP	Mutinondo
General information	
Region, District	Northern Province, Mpika
Installed capacity (MW)	40 (1 unit)
Type of Generation	Run of river
Catchment area (km^2)	841
Maximum Generation Discharge (m^3/s)	9.96
Net head (m)	460
Plant factor (%)	53.7
Annual generation (GWh)	188
Project framework	
Current status	Pre-feasibility study
Expected start month/year of construction	After 2010
Construction period	36 months
Total project cost (US$)	67 million (2008 price level)
Technical information	
Dam type	Concrete weir
Dam height and crest length (m)	7m, 20m crest length
Type, size and length(m) of headrace	Low pressure steel conduit, 1.5m diameter, 1,000m
Type, size and length(m) of penstock	Steel, 1.5m diameter, 1,080m
Type, size (m) of Power house	Surface, 27m x 30m
Type of turbine	Vertical axis Pelton
Environmental impact	According to the PowerMin, little flow in by-passed channel and visual impact due to civil work and access road

(Source) JICA Study Team, Hearing from PowerMin

Table 6.13 Outline of the Luchenene Project

Name of the HP	Luchenene
General information	
Region, District	Northern Province, Mpika
Installed capacity (MW)	30 (1 unit)
Type of Generation	Run of river
Catchment area (km^2)	813
Maximum Generation Discharge (m^3/s)	9.08
Net head (m)	380
Plant factor (%)	52.9
Annual generation (GWh)	139
Project framework	
Current status	Pre-feasibility study
Expected start month/year of construction	After 2010
Construction period	36 months
Total project cost (US$)	65 million (2008 price level)
Technical information	
Dam type	Concrete weir
Dam height and crest length (m)	7 m, 20 m crest length
Type, size and length(m) of headrace	Low pressure steel conduit, 1.5m diameter, 1,480m
Type, size and length(m) of penstock	Steel, 1.5 m diameter, 870m
Type, size (m) of Power house	Surface, 26 m x 28 m
Type of turbine and generator	Vertical axis pelton
Environmental impact	According to the PowerMin, little flow in by-passed channel and visual impact due to civil work and access road

Source: JICA Study Team, Hearing from PowerMin

vii) Lunsemfwa/Mkushi Projects

Lunsemfwa and Mkushi projects are planned by Lusemfwa Hydropower Company, a private power producer which sells to ZESCO. It is for construction of a new hydropower station with an output of 55 MW downstream of the existing Lunsemfwa Hydropower Station. The company also has plans to increase the capacity of the existing 18 MW station by 6 MW along with this downstream development. It is also making plans for construction of a 65 MW Hydropower Station on the Mkushi River adjacent to Lunsemfwa.

Table 6.14 Outline of the Lunsemfwa Project

Name of the HP	Lunsemfwa
General information	
Region, District	Central Province, Kabwe
Installed capacity (MW)	55
Catchment area (km^2)	3,600
Maximum Generation Discharge (m^3/s)	19
Net head (m)	330.5
Plant factor (%)	95.9
Annual generation (GWh)	462
Project framework	
Current status	Conceptual study
Expected start month/year of construction	2011 if feasibility viable
Construction period	48 months
Total project cost (US$)	138 million (2008 price level)
Technical information	
Dam type	Earth fill dam
Dam height and crest length (m)	48.8 m, 366 m crest length
Type and number of spillway gate	Radial Mechanical spill gates, 2 gates
Total storage capacity (m^3)	695 million
Effective storage capacity (m^3)	670 million
Type, size and length(m) of headrace	4.0 m diameter, 13,000 m
Type, size and length(m) of penstock	Concrete/Steel lined 2.75/2.3dia., 359m
Type, size (m) of Power house	Underground, 12m x 55m
Type of turbine	Francis
Environmental impact	According to the Lunsemfwa hydropower company, no resettlement, Area not inhabited. Result in Mining and agricultural in the area. No precious animals, area is in a gorge.

(Source) JICA Study Team, Hearing from Lunsemfwa Hydropower Company

Table 6.15 Outline of the Mkushi Project

Name of the HP	Mkushi
General information	
Region, District	Central Province, Kabwe
Installed capacity (MW)	65
Catchment area (km^2)	8,440
Maximum Generation Discharge (m^3/s)	21
Net head (m)	357.5
Plant factor (%)	39.2
Annual generation (GWh)	223
Project framework	
Current status	Conceptual study
Expected start month/year of construction	2011 if feasibility viable
Construction period	48 months
Total project cost (US$)	163 million (2008 price level)
Technical information	
Dam type	Earth fill dam
Dam height and crest length (m)	48.8m, 366m crest length
Type and number of spillway gate	Radial Mechanical spill gates, 2 gates
Total storage capacity (m^3)	260 million
Effective storage capacity (m^3)	245 million
Type, size and length(m) of headrace	4.0m diameter, 3,000m
Type, size and length(m) of penstock	Concrete/ Steel lined 2.75/2.3dia., 388m
Type, size (m) of Power house	12m x 48m
Type of turbine	Francis
Environmental impact	According to the Lunsemfwa hydropower company, no resettlement, Area not inhabited. Result in Mining and agricultural in the area. No precious animals, area is in a gorge.

(Source) JICA Study Team, Hearing from Lunsemfwa Hydropower Company

viii) Kalungwisi River Kabwelme Falls/ Kundabwika Falls Project

The Kalungwisi River forms the border between Luapula and Northern provinces, which are both situated in northern Zambia. A study[11] was made of hydropower development in this region in 2001. An assessment of the development prospects concluded that plants could possibly be constructed near Kabwelme Falls and Kundabwika Falls on the Kalungwisi River.

At present (2009), the Lunzua Power Authority, a private capital, is making preparations for development at both sites.

[11] Harza, Development of Hydroelectric Power in the Luapula and Northern Areas of Zambia (2001)

Table 6.16 Outline of the Kabwelume Falls Project

Name of the HP	Kabwelume Fall
General information	
Region, District	Luapula & Northern Province
Installed capacity (MW)	62
Catchment area (km^2)	10,868
Maximum Generation Discharge (m^3/s)	127.6
Net head (m)	54.9
Plant factor (%)	59.7
Annual generation (GWh)	324 (with 6 m^3release for the fall)
Project framework	
Current status	Implementation Agreement negotiation as of Dec 2008
Expected start month/year of construction	2016
Construction period	43 months
Total project cost (US$)	126.89 million (2000 price level)
Technical information	
Dam type	RCC Gravity dam
Dam height and crest length (m)	Maximum height 14m, and 1,400m crest length
Type and number of spillway gate	Free flow spillway
Area of the reservoir (km^2)	2.53
Total storage capacity (m^3)	15.22 million
Effective storage capacity (m^3)	2.44 million
Type, size and length (m) of headrace	i) Fully concrete lined, 8 m wide invert side slopes of 3H to 1V ii) Longitudinal average slope of 0.11%, 1,400m length
Type, size and length (m) of penstock	5 m dia, surface steel
Type, size (m) of Power house	Surface 2.5km downstream of the fall, on the right bank
Type of turbine	Vertical Francis
Environmental impact	Few or No resettlements

(Source) Harza, Development of Hydroelectric Power in the Luapula and Northern Areas of Zambia (2001)

Table 6.17 Outline of the Kundabwika Falls Project

Name of the HP	Kundabwika Fall
General information	
Region, District	Luapula & Northern Province
Installed capacity (MW)	101
Catchment area (km^2)	12,602
Maximum Generation Discharge (m^3/s)	148.8
Net head (m)	76.7
Plant factor (%)	60.3
Annual generation (GWh)	533 (with 6 m^3release for the fall)
Project framework	
Current status	Implementation Agreement negotiation as of Dec 2008
Expected start month/year of construction	2016
Construction period	39 months
Total project cost (US$)	211.42 million (2000 price level)
Technical information	
Dam type	RCC Gravity dam
Dam height and crest length (m)	Maximum height 27.5m, and 211m crest length
Type and number of spillway gate	4 radial gates (12m x14m)
Area of the reservoir (km^2)	12.6
Total storage capacity (m^3)	111.8 million
Effective storage capacity (m^3)	11.8 million
Type, size and length(m) of headrace	i) Fully concrete lined, 8 m wide invert side slopes of 3H to 1V ii) Longitudinal average slope of 0.11%, 1,550m length
Type, size and length(m) of penstock	5.5 m diameter, surface steel
Type, size (m) of Power house	Surface 3.4 km downstream of the fall, on the left bank
Type of turbine	Vertical Francis
Environmental impact	Estimated number of persons to be relocated is 60 persons.

(Source) Harza, Development of Hydroelectric Power in the Luapula and Northern Areas of Zambia (2001)

ix) Luapula River Mumbotuta Falls Site CX/Mambilima Falls Site II, Site I Project

The Luapula River forms the border between Luapula Province and the DRC. In 2001, a study[12] was made on hydropower development in northern Zambia, in Luapula and Northern provinces. The assessment of the prospects for hydropower development on the Luapula River concluded that stations could possibly be constructed at Site CX near the Mumbotuta Falls and sites II and I near the Mambilima Falls.

The Luapula River forms an international border, but there are no rules or other procedure for

[12] Harza, Development of Hydroelectric Power in the Luapula and Northern Areas of Zambia (2001)

development on such rivers with the DRC, and also no organ that could discharge a role like that of the ZRA for the Zambezi. This situation points to the need for consultation between the two countries and preparation of rules for coordination on matters such as development on the Luapula and water rights.

There has also not been any actual progress in the Mumbotuta Falls and Mambilia Falls projects since the study in 2001.

Table 6.18 Outline of the Mumbotuta Falls Site CX Project

Name of the HP	Mumbotuta Falls Site CX
General information	
Region, District	Luapula Province
Installed capacity (MW)	301
Catchment area (km^2)	115, 400
Maximum Generation Discharge (m^3/s)	520
Net head (m)	65.4
Plant factor (%)	55.0
Annual generation (GWh)	1,449
Project framework	
Construction period	49 months
Total project cost (US$)	482.91 million (2000 price level)
Technical information	
Dam type	Concrete Facing Rock Fill Dam (CFRD)
Dam height and crest length (m)	Maximum height 75.5m, and 600m crest length
Type and number of spillway gate	Free Overflow, 400m – long
Type, size (m) of Power house	Surface Right bank downstream of the dam
Type of turbine and generator	Vertical Francis

(Source) Harza, Development of Hydroelectric Power in the Luapula and Northern Areas of Zambia (2001)

Table 6.19 Outline of the Mambilima Falls Site II Project

Name of the HP	Mambilima Falls Site II
General information	
Region, District	Luapula Province
Installed capacity (MW)	202
Catchment area (km^2)	155,527
Maximum Generation Discharge (m^3/s)	701.1
Net head (m)	32.6
Plant factor (%)	56.7
Annual generation (GWh)	1003
Project framework	
Construction period	56 months
Total project cost (US$)	637.88 million (2000 price level)
Technical information	
Dam type	Concrete Facing Rock Fill Dam (CFRD)
Dam height and crest length (m)	Maximum height 49.0m, and 3,400m crest length
Type and number of spillway gate	Free Overflow, 150m – long
Type, size (m) of Power house	Surface Right bank downstream of the dam
Type of turbine and generator	Vertical Kaplan

(Source) Harza, Development of Hydroelectric Power in the Luapula and Northern Areas of Zambia (2001)

Table 6.20 Outline of the Mambilima Falls Site I Project

Name of the HP	Mambilima Falls Site I
General information	
Region, District	Luapula Province
Installed capacity (MW)	124
Catchment area (km^2)	155,527
Maximum Generation Discharge (m^3/s)	704.0
Net head (m)	19.9
Plant factor (%)	56.1
Annual generation (GWh)	609
Project framework	
Construction period	48 months
Total project cost (US$)	460.06 million (2000 price level)
Technical information	
Dam type	Concrete Facing Rock Fill Dam (CFRD)
Dam height and crest length (m)	Maximum height 34.0 m, and 1,600 m crest length
Type and number of spillway gate	Free Overflow, 260m – long
Type, size (m) of Power house	Surface Right bank downstream of the dam
Type of turbine and generator	Vertical Kaplan

(Source) Harza, Development of Hydroelectric Power in the Luapula and Northern Areas of Zambia (2001)

x) Batoka Gorge, Devil's Gorge, and Mpata Gorge Project

These projects are for development on the main channel of the Zambezi River. As such, the development rights are basically held by the ZRA, which is executing the feasibility studies and making preparations required for the development. A study[13] concerning the Batoka Gorge Project was made in 1993, but there has been no concrete progress since then. There have not been any detailed studies concerning the Devil's Gorge and Mpata Gorge projects, and no detailed information is available about them.

In addition to coordination with Zimbabwe, promotion of the Batoka Gorge Project requires consideration of Victoria Falls, which is a World Heritage site, and the existence of many stakeholders in connection with irrigation and other items upstream. The district is also one of the major sightseeing spots in Zambia, and coordination with stakeholders in the tourism industry is therefore also essential. The current plans envision a maximum water level of 762 meters. The upstream edge of the reservoir at this level would extend about 10 kilometers downstream of Victoria Falls at the grade indicated on a 1/250,000-scale topographical map.

Table 6.21 Outline of Batoka Gorge, Devil's Gorge, and Mpata Gorge projects

Name of the HP	Batoka Gorge	Devil's Gorge	Mpata Gorge
General Information			
Region, Disistrict	Kazungula	kazungula	Luangwa
Installed capacity	1,600 MW (800MW)	1,000 MW(500MW)	1,085 MW(543MW)
Catchment area (km^2)	508,000	-	-
Rated net head (m)	166.55	-	-
Plant factor (%)	62.4	40.0	79.6
Annual generation (GWh)*	8,745	5,604	7,570
Project framework			
Construction period	7 years	-	-
Total project cost (million US$)	1,681 (1993 price level)	1,072 (1993 price level)	1,516 (1993 price level)
Technical information			
Dam type	RCC Gravity Arch	Double Curvature Concrete Arch	Double Curvature Concrete Arch abutting onto a concrete gravity wing on the right bank
Dam height & crest length (m)	Maximum height 181 m	Maximum height 181 m, and 695 m crest length	Maximum height 78 m, and 480 m crest length
Area of the reservoir (km^2)	25.6	780	1,230
Type of power house	Underground	Underground	surface
Type of turbine	Francis	Francis	Francis

Source: ZRA, Batoka Gorge hydro electric scheme feasibility report (1993)
ZRA Home page

(3) Other Generation Development Plan

Thermal power, renewable energy generation will be considerable as domestic generation sources other than hydropower. Small generation facilities less than 30 MW will be out of

[13] ZRA, Batoka Gorge Hydro Electric Scheme Feasibility Report (1993)

scope since this study is in kind a master plan.

As seen in Appendix, domestic primary energy resource which can be developed up to 2030 is limited to coal from Maamba Collieries.

As for the Maamba project, ZCCM-Investment Holdings (ZCCM-IH), the owner of Maamba Collieries Limited, has been negotiating a contract on resuscitation of coal productivity and construction of a thermal power plant, with a foreign investor. ZCCM-IH keeps fully confidential in this regard since it is still under negotiation, while Singapore's Nava Bharat is nominated as the preferred bidder and the capacity of mine-mouth power station is 350 MW, according to some newspaper reports.

6.2 Power Development Situation of the Adjacent Countries

Table 6.22 and Table 6.23 show the power development plan for the adjacent countries described in the draft final report (interim, May 2008) of SAPP Regional Generation and Transmission Expansion Plan Study by the World Bank. With regard to the expansion plan for Namibia (NamPower) and Tanzania (TANESCO), the information has been updated by the interview result with the relevant staff in the 2nd field study. In the future expansion plans, the generating capacity of 61,642MW will be added except for Zambia. About 75 % of 61,642 MW is the installing generating capacity for the development plan of South Africa. The available generating capacity of total SAPP is 47,654MW in the end of the fiscal year of 2007.

Table 6.22 Power Development Plan for the Adjacent Countries (1)
(BPC, EdM, ESCOM, ESKOM, LEC, NamPower, SNEL)

Utility	Project name	Type	Capacity Added (MW)	Operating Year
BPC	Morupule B	Thermal	1,200	2012 - 2015
EdM	Mavuzi & Chicamba - Refurbishment	Hydro	35	2008 - 2009
	Mphanda Nkuwa	Hydro	1,300	2020
	Sub-Total		1,335	
ENE	Gas Turbine - Rehabilitation	Thermal	107	2008 - 2013
	TG-12.5	Thermal	13	2008
	ENE Diesels	Thermal	2	2008
	Benguela	Thermal	83	2008
	Capanda 2	Hydro	260	2008
	TG-20	Thermal	20	2008
	TG-40	Thermal	80	2009 - 2010
	TG-60	Thermal	60	2009
	Gove - Refurbishment	Hydro	60	2010
	Cambambe 2	Hydro	260	2013
	ENE Combined Cycle Plants	Thermal	1,200	2014 - 2023
	ENE Gas Turbine Plants	Thermal	300	2017 - 2025
	Sub-Total		2,445	
ESCOM	Tedzani 1 & 2 - Refurbishment	Hydro	40	2008
	Kaphichira 2	Hydro	64	2010
	Songwe	Hydro	340	2014 - 2016
	Sub-Total		444	
ESKOM	Camden DE-mothball	Thermal	190	2008
	Arnot Upgrade2	Thermal	200	2008 - 2011
	Grootvlei DE-mothball	Thermal	940	2008 - 2009
	Cape OCGT Phase2	Thermal	1,200	2008
	Komati De-mothball	Thermal	909	2008 - 2011
	DME OCGT	Thermal	1,050	2010
	Maedupi Coal	Thermal	4,230	2012 - 2015
	Braamhoek Pumped Strage	Hydro	1,332	2012 - 2013
	Bravo Coal	Thermal	4,800	2013 - 2016
	Generic Coal	Thermal	11,610	2014 - 2025
	Steelpoort Pumped Storage	Hydro	1,484	2015 - 2016
	Generic Pumped Storage	Hydro	2,968	2016 - 2024
	Generic Nuclear	Nuclear	18,702	2017 - 2025
	Hendrina Retirement	Thermal	-1,895	2022
	Arnot Retirement	Thermal	-2,280	2024
	Sub-Total		45,440	
LEC	Muela 2	Hydro	110	2012
	Oxbow	Hydro	80	2017
	Sub-Total		190	
NamPower	Van ECK Retirement	Thermal	-108	2011
	Luderitz	Wind	42	2011
	Ruacana 4th Unit	Hydro	92	2012
	Paratus Retirement	Thermal	-24	2012
	Kudu	Thermal	800	2013
	Baynes	Hydro	500	2016
	Walvis Bay	Thermal	400	-
	Sub-Total		1,702	
SNEL	Zongo - Refurbishment	Hydro	60	2008 - 2011
	Koni - Refurbishment	Hydro	42	2008
	Mwadingusha - Refurbishment	Hydro	36	2008 - 2010
	Sanga - Refurbishment	Hydro	8	2008 - 2011
	Nseke - Refurbishment	Hydro	62	2009
	Nzilo - Refurbishment	Hydro	27	2009
	Inga 2 - Refurbishment	Hydro	640	2010 - 2014
	Inga 1 - Refurbishment	Hydro	120	2012 - 2013
	Busaga	Hydro	240	2019 - 2022
	Zongo 2	Hydro	120	2021
	Nzilo 2	Hydro	120	2023
	Sub-Total		1,475	

Source: SAPP Regional Generation and Transmission Expansion Plan Study (Draft Final Report (Interim), May 2008) and Interview by JICA study team

Table 6.23 Power Development Plan for the Adjacent Countries (2) (TANESCO, ZESA)

Utility	Project name	Type	Capacity Added (MW)	Operating Year
TANESCO	Aggreko, Alstom, Dowans1,2 Retirement	Thermal	-183	2008
	Tegata	Thermal	41	2009
	Small Diesel, Ubungo Retirement	Thermal	-55	2009
	Kinyerezi1	Thermal	100	2009
	Kinyerezi2	Thermal	100	2010
	Kiwira1	Thermal	200	2010
	Kiwira2	Thermal	200	2012
	Ruhudji	Hydro	358	2014
	Wind	Wind	50	2015
	Rusumo Falls	Hydro	21	2015
	Kakono	Hydro	53	2017
	Mpanga	Hydro	144	2018
	Wind	Wind	50	2018
	Mchuchuma1	Thermal	200	2019
	Rumakali	Hydro	222	2021
	Masigira	Hydro	118	2022
	Songas1 Retirement	Thermal	-40	2023
	Mnazi Gas	Thermal	150	2023
	Songas2 Retirement	Thermal	-110	2024
	Mnazi Gas	Thermal	150	2024
	Mchuchuma2	Thermal	200	2024
	Songas3 Retirement	Thermal	-37	2025
	Stiegler's Gorge1	Hydro	300	2025
	Mchuchuma3	Thermal	200	2026
	Local Gas	Thermal	150	2027
	Stiegler's Gorge2	Hydro	600	2027
	Tegata IPTL, GT Retirement	Thermal	-141	2027
	Coastal GT CNG	Thermal	300	2028
	Stiegler's Gorge3	Hydro	300	2029
	Coastal CC LNG1	Thermal	174	2029
	Kenyerezi1 Retirement	Thermal	-100	2029
	Local Coal	Thermal	200	2030
	Kenyerezi2 Retirement	Thermal	-100	2030
	Coastal CC LNG2	Thermal	174	2030
	Sub-Total		3,989	
ZESA	Hwange - Refurbishment	Thermal	480	2008 - 2009
	Kariba South Extension	Hydro	300	2014
	Hwange Extension	Thermal	600	2015
	Lupane	Thermal	300	2015
	Gokwa North	Thermal	1,050	2015 - 2023
	Batoka Gorge	Hydro	800	2017
	Sub-Total		3,530	
Total			61,642	

(Reference)

Utility	Project name	Type	Capacity Added (MW)	Operating Year
ZESCO	Kariba North Refurbishment	Hydro	210	2008 - 2009
	Kafue Gorge Upper Refurbishment	Hydro	150	2009
	Kariba North Extension	Hydro	360	2012
	Itezhi-Tezhi	Hydro	120	2013
	Kafue Gorge Lower	Hydro	750	2017
	Batoka Gorge	Hydro	800	2017
	Sub-Total		2,390	

Source: SAPP Regional Generation and Transmission Expansion Plan Study (Draft Final Report (Interim), May 2008) and Interview by JICA study team

6.3 Generation Development Scenarios

Taking the Southern Africa Power Pool (SAPP) into consideration, the following two generation development scenarios will be nominated;

i) Domestic power supply will fully cover the domestic power demand to enhance the national energy security (Scenario 1), and

ii) Domestic generation development will be set back expecting power import from SAPP, from the view point of economical efficiency and feasibility (Scenario 2).

The Scenario 2 includes the scenario in an extreme case which contains no generation development but transmission system to import power. Generally for most hydropower generations in Zambia, coal thermal power generations in the coal-borne South Africa, Botswana etc. become economically dominant. However, it is high-risk causing an irreparable situation to expect for electricity import in this master plan excessively, due to the following reasons;

- Currently, SAPP has no extra capacity as a whole and the power demand-supply situation in each member country is tight,
- There is no guarantee that the generation development plan of each SAPP member countries progresses on schedule,
- It may not become always advantageous to Zambia in the case of pricing by the relative contract without SAPP having no price transparent market.

As a matter of course, wide area power trade may bring merits such as reduction of generation development (investment cost) by improving the system reliability, reduction of operation and maintenance cost, fuel costs reduction by economical system operation etc, so that such reliable interconnection plan should be reflected in the master plan if exists. Consequently, Scenario 1 was selected as the base generation development scenario in this study in which only domestic power supply is available for domestic power demand, while domestic transmission system was planned corresponding to the international power interconnection lines which has already been specifically planned.

In this case, when power trade plan including price negotiation is clarified in the future, the generation development plan can be easily adjusted just by delaying the future plan.

Additionally, Scenario 1 will be classified as the following two sub-scenarios;

1) Primary energy basis self-supply,
2) Electricity basis self-supply.

Specifically, in the first scenario, hydropower and domestic coal are considered as primary energy source usable for power generation, and in the second one, imported coal from neighboring coal producing countries like the South Africa, Zimbabwe, Mozambique etc. is additionally available. In the case of Japan, electric power supply is 100 % secured by domestic generation due to its geographical reason of insularity, but self-sufficiency of total primary energy remains around 4 % (19 % even if considering nuclear energy).

The primary energy basis self-supply scenario (Scenario 1-1) has advantage of independence of primary energy from other countries from the viewpoint of energy security, but supply reliability in the dry year/season will be low reviewing the past record of power supply because most of power is supplied by hydropower power stations including the existing ones. Electricity basis self-supply scenario (Scenario 1-2) has realistic alternative to import coal from neighboring coal producing countries. As stated, coal thermal generation generally has advantage in generation cost comparing with hydropower generation, and is suitable to introduce private investment thanks to its low initial investment requirement. Moreover, it has merit of diversification of generation and securing the power supply free from the natural conditions such as drought.

In this manner, both scenarios were investigated in this study as they had good and bad points.

6.4 Generation Development Plan

6.4.1 Nominated Generation Development Projects

(1) Hydropower projects

The specifications of hydropower development projects considered in the generation development planning are shown in Table 6.24 on the basis of the generation development situation noted in 6.1.2.

Table 6.24 Hydropower development projects list (as of March 2009)

River	Province	Project	Capacity (MW)	Developer	Status of Progress	Project Cost (Million US$)	Environmental & Social consideration
Zambezi	Southern	Kariba North Extension	360	ZESCO	Construction	318.65 (2005 price)	No significant impacts (Using existing dam and reservoir. Additional installation of water intake gate.)
	Lusaka	Mpata Gorge	543 (1,085)	ZRA	n/a	758.00 (1993 price)	Coordination with Zimbabwe Impacts on ecosystem (located within Luano GMA and adjacent to Lower Zambezi NP)
	Southern	Devil's Gorge	500 (1,000)	ZRA	n/a	536.00 (1993 price)	Coordination with Zimbabwe. Certain impacts on river ecosystem
	Southern	Batoka Gorge	800 (1,600)	ZRA	Pre-FS completed (1993)	855.80 (1993 price)	Coordination with Zimbabwe Certain impacts on river ecosystem
Kafue	Southern	Itezhi Tezhi	120	ZESCO /TATA	FS completed (2007) D/D ongoing	164.95 (2007 price)	Impacts on ecosystem (Using existing dam and reservoir, but located within Namwala GMA, adjacent to Kafue NP, and upstream of Kafue flats Ramsar site). No resettlement anticipated
	Lusaka	Kafue Gorge Lower	750	N.Y.	Under preparation of FS by IFC	738.35 (2005 price)	No resettlement anticipated Impacts on ecosystem (located within Chiawa GMA)
Luapula	Luapula	Mumbotuta Fall - Site CX	301	N.Y.	Pre-FS completed (2001)	482.91 (2000 price)	Coordination with DRC Impacts on ecosystem (located within Mansa GMA)
	Luapula	Mambilima Fall - Site II - Site I	 202 124	N.Y.	Pre-FS completed (2001)	637.88 460.06 (2000 price)	Coordination with DRC Certain impacts on river ecosystem
Kalungwishi	Luapula &Northern	Kabwelume Falls Kundabwika Falls	62 101	Lunzua Power Authority	Pre-FS completed (2001) I/A under negotiation	126.89 211.42 (2000 price)	Impacts on ecosystem (located within /adjacent to Lusenga Plains NP, and upstream of Lake Mweru wa Ntipa Ramsar site)
Others	Central	Lusiwasi Extension	50	ZESCO	FS ongoing	80.05 (1997 price)	Impacts on ecosystem (located adjacent to South Luangwa NP) No or little resettlement anticipated
	Northern	Mutinondo	40	Power Min	I/A under negotiation	67.00 (2008 price)	Impacts on ecosystem (located adjacent to South Luangwa NP, North Luangwa NP and Munyamadzi GMA) No or little resettlement anticipated
	Northern	Luchenene	30	Power Min	I/A under negotiation	65.00 (2008 price)	
	Central	Lunsemfwa	55	Lunsemfwa	Under preparation of FS	138.00 (2008 price)	Impacts on ecosystem (located adjacent to / within Luano GMA) No or little resettlement anticipated
	Central	Mkushi	65	Lunsemfwa	Under preparation of FS	163.00 (2008 price)	
	North Western	Kabompo	34	CEC/TATA	Under preparation of FS	65.90 (2000 price)	Impacts on ecosystem (located adjacent to Masele-Matebo NP)
Total			4,137				

(2) Other generation development projects

i) Domestic coal thermal (Maamba mine-mouth coal thermal)

The rated output of Maamba mine-mouth coal thermal was described as 500 MW in the generation list of ZESCO (Table 6.3) and 350 MW in the newspaper reports[14] issued in the current year.

On the other hand, productivity of Maamba coal mines is 1 million tonnes per year at full capacity. Considering the domestic industrial use of 200,000 tonnes per year, 700,000 to 800,000 tonnes of coal can be used for power generation at most. Zambian coals are classified in bituminous to subbituminous with low volatile matter which is suitable for stoker boilers with lower thermal efficiency, not for PC[15] boilers with higher thermal efficiency. Relation between annual coal supply and expected generation output is shown in Table 6.25. Assuming 30 percent of thermal efficiency and 700,000 tonnes of annual coal supply conservatively, expected generation output will be less than 200 MWe. Therefore, the study took the installed capacity of the domestic coal power generation (Maamba mine-mouth coal thermal) as 200 MWe class.

Table 6.25 Relation between coal supply and generation output

Thermal efficiency	Annual coal supply (metric ton/ year)		
	700,000	750,000	800,000
30 %	196 MWe	210 MWe	224 MWe
35 %	229 MWe	245 MWe	262 MWe
40 %	262 MWe	280 MWe	299 MWe

(Source) Study Team

ii) Imported coal thermal generation

There is no plan of importing coal so far in the national policy documents such as NEP. However, even though production capacity of domestic coal is recovered, annual production will remain approximately 1 million tonnes annually, corresponding to 200 MW class power generation. Considering the required additional power supply is 4,000 MW up to 2030, including reserve, approximately 15 % of coal generation facility as a drought countermeasure can make the reserve margin less compared with hydropower generation only. It is about 1,000 MW that should be introduced by 2030 when total generation capacity comes to 6,000 MW. In this case, 260,000 to 360,000 tonnes of coal are required annually from the calculation shown in Table 6.25. At present, domestic productivity of coal is short, so that coal import was considered.

Moreover, compared with hydropower generation, coal thermal generation has the following benefit;

- Easy to invite private investment: less initial investment and smaller natural climate

[14] For example, see http://www.domain-b.com, January 10, 2009
[15] Pulverized Coal

risks,

- Shorter construction period: advantageous to overcome the immediate future demand-supply gap,
- Small geographical limitation: site selection close to demand centres.

As might be expected, when domestic coal productivity is enhanced in the future, some imported coal thermal projects may be simply converted into domestic coal thermal projects.

6.4.2 Estimation of unit generation cost of projects

(1) Reevaluation of project costs

Preceding the estimation of economical efficiency of each generation project, reevaluation of each project cost was conducted. It is necessary to bring the construction costs of each project into conformance with each other, as far as possible. Table 6.26 shows the results of a compilation of construction costs based on the limited information in terms of the net construction cost, consisting of the costs for civil and mechanical work, contingency and engineering.

Table 6.26 Estimation of net construction cost

No.	Project	Price level at the study conducted time								Ref.
		Civil Work (A)	Electoro Mechanical Work (B)	Contingency (C)	C/(A+B) (%)	Engineering & Administration (D)	D/(A+B+C) (%)	Net Construction Cost (million US$) (E)	Price Level (year)	
1	Kariba North Expansion	94.4	87.9	23.0	12.6%	48.8	23.8%	254.1	2005	[1]
2	Itezhi Tezhi	63.9	41.4	13.7	13.0%	17.0	14.3%	136.0	2007	[2]
3	Kafue Gorge Lower	507.0	533.0	109.7	10.6%	230.0	20.0%	1,379.7	2008	[3]
4	Lusiwasi Expansion	37.7	31.8	4.7	6.7%	5.9	8.0%	80.0	1997	[4]
5	Batoka Gorge	606.0	449.5	118.4	11.2%	98.7	8.4%	1,272.7	1993	[5]
6	Devil's Gorge	374.8	278.0	73.2	11.2%	61.1	8.4%	787.0	1993	[5]
7	Mpata Gorge	506.2	375.4	98.9	11.2%	82.5	8.4%	1,063.0	1993	[5]
8	Mumbotuta Fall, CiteCX	164.2	47.1	43.6	20.6%	26.8	10.5%	281.6	2000	[6]
9	Mambilia Fall site2	244.0	43.7	60.9	21.2%	34.9	10.0%	383.3	2000	[6]
10	Mambilia Fall site1	165.1	39.9	42.3	20.6%	24.7	10.0%	272.0	2000	[6]
11	Kabompo Gorge	30.8	23.3	5.7	10.5%	6.0	10.1%	65.9	2000	[7]
12	Kalungwishi Kabwelume Falls	43.8	16.9	10.9	18.0%	7.2	10.0%	78.8	2000	[6]
13	Kalungwishi Kundabwika Falls	74.1	27.4	16.8	16.5%	11.8	10.0%	130.1	2000	[6]
14	Mutinondo	30.0	24.5	5.6	10.3%	6.1	10.1%	66.2	2008	[8]
15	Luchenene	31.0	21.7	5.7	10.8%	5.9	10.1%	64.3	2008	[8]
16	Lunsemfwa	106.0	83.0	19.0	10.1%	21.0	10.1%	229.0	2009	[9]
17	Mkushi	60.0	38.0	10.0	10.2%	11.0	10.2%	119.0	2009	[9]

[1] ZESCO,Kariba North Bank Power Station Extension Final Feasibility Study Report (2005)
[2] ITPC, Feasibility Study Report for Itezhi Tezhi Hydro Electric Project (2x60MW) (2007)
[3] Interim Summary Report, Kafue Gorge Lower Hydroelectric Power Project (2009)
[4] ZESCO, Small hydropower stations, Rehabilitation and Upgrading Study Final Report (1997)
[5] ZRA,Batoka Gorge Hydropower Scheme-Feasibility Study Final report (1993)
[6] ZESCO,Feasibility Study of the Development Hydroelectric Power in the Luapula and Northern Areas of Zambia (2001)
[7] Hearing from the developer, TATA Zambia limited
[8] Hearing from the developer,PowerMin
[9] Hearing from the developer,Lunsemfwa Company

Next, an estimate was made of the project cost in 2009. The figure for the civil work cost assumes an escalation at the rate of 4.5 percent annually. For the mechanical cost, the plan cost index (PCI) was utilized to obtain the 2008 prices as the latest figure, and these were applied as the 2009 prices. Figures for the contingency and engineering cost were calculated on the basis of the respective rates shown in Table 6.27. The addition of interest during construction to the net construction cost obtained in this manner was taken as the project cost as of 2009. The interest during construction was arrived at by application of a discount rate of 10 percent.

Table 6.27 Estimate of project cost (as of 2009)

No.	Project	Price Level (year)	Plant Cost Index at price level year	Plant Cost Index ratio (2008/price level year)	Price level at 2009					Construction period (year)	Interest during construction (%)	Construction cost (million US$)
					Civil Work (A')	Electoro Mechanical Work (B')	Contingency (C')	Engineering & Administration (D')	Net Construction Cost (million US$) (E')			
1	Kariba North Expansion	2005	128.7	1.18	112.6	104.0	27.3	58.0	302.0	4.0	18.53	357.9
2	Itezhi Tezhi	2007	153.7	0.99	69.8	41.0	14.4	17.9	143.1	4.0	18.53	169.6
3	Kafue Gorge Lower	2008	152.4	1.00	529.9	533.0	112.1	235.0	1,410.0	5.0	23.78	1,745.3
4	Lusiwasi Expansion	1997	118.9	1.28	63.9	40.7	7.0	8.9	120.6	2.5	11.13	134.0
5	Batoka Gorge	1993	120.4	1.27	1,225.6	569.0	201.3	167.9	2,163.7	7.0	35.14	2,924.1
6	Devil's Gorge	1993	120.4	1.27	757.9	351.8	124.5	103.8	1,338.0	7.0	35.14	1,808.2
7	Mpata Gorge	1993	120.4	1.27	1,023.7	475.2	168.1	140.2	1,807.3	7.0	35.14	2,442.4
8	Mumbotuta Fall, CiteCX	2000	100.0	1.52	244.0	71.7	65.2	40.0	420.9	4.5	21.12	509.8
9	Mambilia Fall site2	2000	100.0	1.52	362.6	66.5	90.8	52.0	571.9	5.0	23.78	707.8
10	Mambilia Fall site1	2000	100.0	1.52	245.3	60.8	63.2	36.9	406.2	4.0	18.53	481.5
11	Kabompo Gorge	2000	100.0	1.52	45.8	35.5	8.6	9.1	99.0	3.5	16.00	114.9
12	Kalungwishi Kabwelume Falls	2000	100.0	1.52	65.1	25.8	16.3	10.7	117.9	4.0	18.53	139.7
13	Kalungwishi Kundabwika Falls	2000	100.0	1.52	110.2	41.7	25.1	17.7	194.7	3.5	16.00	225.8
14	Mutinondo	2008	152.4	1.00	31.4	24.5	5.7	6.2	67.8	3.0	13.53	77.0
15	Luchenene	2008	152.4	1.00	32.4	21.7	5.9	6.0	66.0	3.0	13.53	74.9
16	Lunsemfwa	2009	-	1.00	106.0	83.0	19.0	21.0	229.0	4.0	18.53	271.4
17	Mkushi	2009	-	1.00	60.0	38.0	10.0	11.0	119.0	4.0	18.53	141.1

Escalation	4.5%
Interest during construction is the value at the 10% discountrate.	
Plant Cost Index: Japan Machinery Center for Trade and Investment,JMC, 2008 PCI / LF (Plant cost index / Location factor)	

(2) Computation of unit generation cost

Based on the project cost indicated in Table 6.27, the unit construction cost and unit generation cost were calculated. The premises of calculation of unit generation cost is shown in Table 6.28.

Table 6.28 Premise on computation of unit generation cost

Item	Unit	Hydropower	Coal Thermal
Annual hours	hrs	8,765.8	
Development cost	US$/kW	each project cost	1,200
Discount rate	%	10%	
Life Time	Years	50	30
Capital Recovery Factor	--	0.1009	0.1061
Fixed O&M cost	US$/MW-Yr	1%	8,040
Variable O&M cost	US¢/kWh		0.142
Heat rate	kcal/kWh	--	2,473
[Fuel: Coal]			
Price	US$/ton	--	70
	US¢/Gcal	--	1,167
Heat content	Kcal/kg	--	6,000
	GJ/ton	--	25.01

Table 6.29 shows the results of calculation of unit construction costs and unit generation costs. Figure 6.4 and Figure 6.5 also shows the relation between installed capacity and unit generation cost, and between capacity factor and unit generation cost, respectively.

Table 6.29 Unit construction cost and unit generation cost of generation projects

	Project	Capacity (MW)	Annual Energy (GWh)	Capacity Factor (%)	Project Cost (million $)	Unit capital cost ($/kW)	Levelized capital cost (¢/kWh)	O&M cost (¢/kWh) Fixed	Variable	Fule cost (¢/kWh)	Unit generation cost (¢/kWh)
1	Kariba North Extension	360	380	12.0%	358	994	9.50	0.94		--	10.44
2	Itezhi Tezhi	120	611	58.1%	170	1,417	2.81	0.28		--	3.08
3	Lusiwasi Extension	80	200	28.6%	134	1,675	6.74	0.67		--	7.41
4	Mutinondo	40	188	53.6%	77	1,925	4.13	0.41		--	4.54
5	Luchenene	30	139	52.9%	75	2,500	5.44	0.54		--	5.98
6	Lunsemfwa	55	462	95.8%	271	4,927	5.92	0.59		--	6.50
7	Mkushi	65	223	39.1%	141	2,169	6.38	0.63		--	7.01
8	Kabompo Gorge	34	176	59.1%	115	3,382	6.59	0.65		--	7.24
9	Kabwelume Falls	62	324	59.6%	140	2,258	4.36	0.43		--	4.79
10	Kundabwika Falls	101	533	60.2%	226	2,238	4.28	0.42		--	4.70
11	Kafue Gorge Lower	750	2,400	36.5%	1,745	2,327	7.33	0.73		--	8.06
12	Mambilima Falls SiteI	124	609	56.0%	481	3,879	7.97	0.79		--	8.76
13	Mambilima Falls SiteII	202	1,003	56.6%	708	3,505	7.12	0.71		--	7.83
14	Mumbotuta Falls	301	1,449	54.9%	510	1,694	3.55	0.35		--	3.90
15	Batoka Gorge	800	4,372	62.3%	1,462	1,828	3.37	0.33		--	3.71
16	Devil's Gorge	500	2,802	63.9%	904	1,808	3.25	0.32		--	3.58
17	Mpata Gorge	543	3,785	79.5%	1,221	2,249	3.25	0.32		--	3.58
	Total Hydro	**4,167**	**19,656**	**53.8%**	**8,738**	**2,097**	**4.484**	**0.445**		--	**4.928**
	Coal Thermal Power	200	1,459	83.2%	240	1,200	1.74	0.110	0.142	2.885	4.88

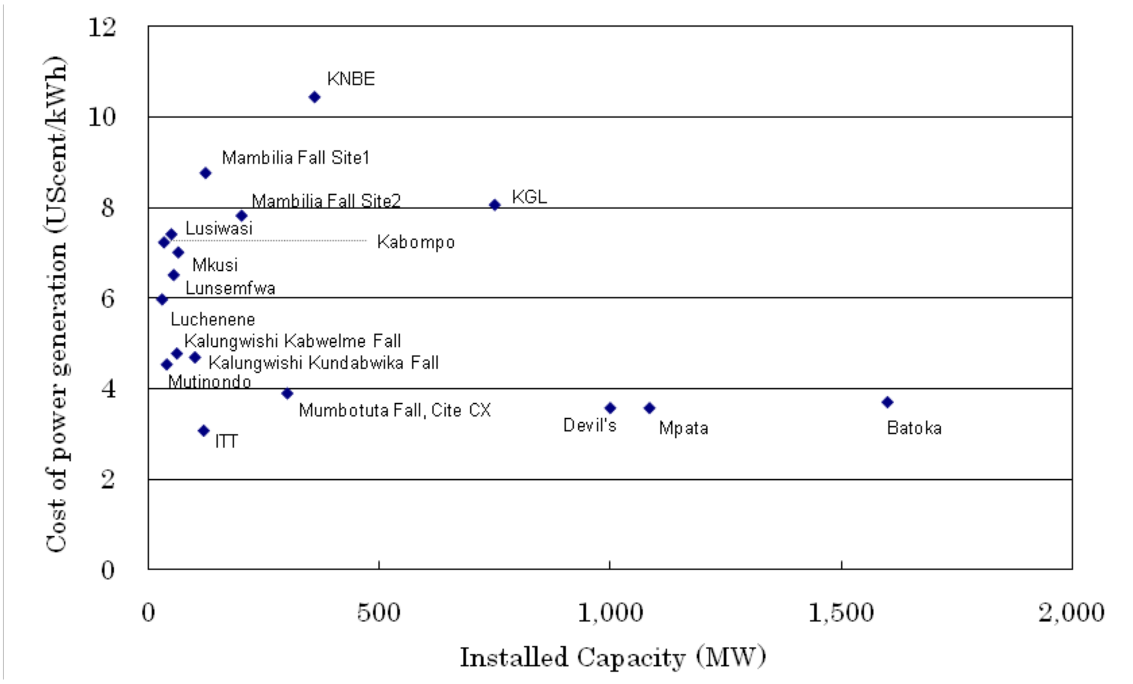


Figure 6.4 Relation between installed capacity and unit generation cost

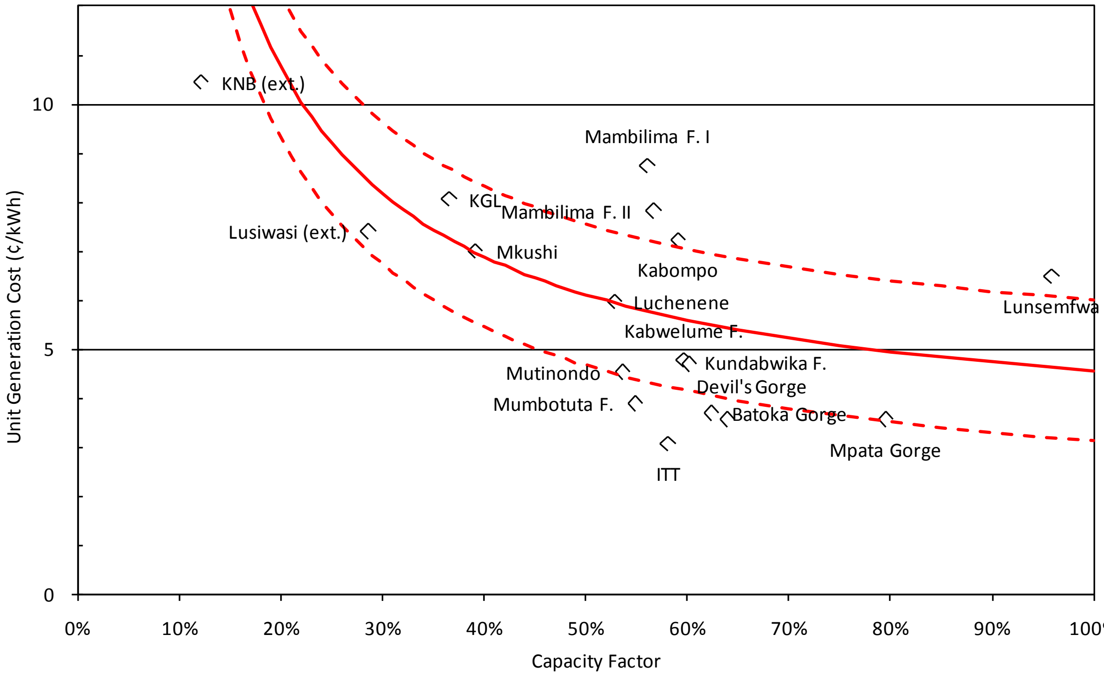


Figure 6.5 Relation between capacity factor and unit generation cost

As shown in Table 6.29, the average unit construction of 17 hydropower projects was US$ 2,097/kW, and the average unit generation cost of hydropower projects was US¢4.928/kWh, almost equivalent to that of coal thermal generation. The unit generation costs of Itezhi-Tezhi project which needs power station installation only by utilizing the exiting reservoir, and the large scale Zambezi River three projects (Batoka Gorge, Devil's Gorge and Mpata Gorge) with high capacity factor, were relatively low. On the other hand, the unit generation costs of peaking power project; Kariba North extension and Kafue Gorge Lower, were high.

It should be noticed that unit generation costs of three projects along Zambezi River may increase by reevaluation of project costs in the future which were originally estimated in 1993 and which no detailed study was conducted on Devil' Gorge and Mpata Gorge projects so far.

It is desirable that further study should be conducted to elaborate the project design and estimate the project cost, as the unit generation cost will affect the future electricity tariff setting.

(3) Sensitivity of unit generation cost of coal thermal generation

The details of Maamba project is still unrevealed as the feasibility study has not been conducted. As for imported coal thermal generation projects, capital investment in coal transportation should be considered adding power plant investment. As internationally unit generation cost of coal thermal power is commonly around US¢5/kWh, the big deviation hardly happen. Here sensitivity analysis regarding plant costs and (coal) fuel costs to figure out the fluctuation band width of unit generation cost of thermal power generation, was conducted for confirmation since there were so many unknown factors at present. Additionally, capital investment on coal transportation should be included in the fuel price.

Calculating six patterns of unit generation costs with assumption of US$ 1,200/ 1,500/kW of unit construction cost and US$ 35/ 70/ 105/ton of coal price, unit generation cost varies between US¢3.44/kWh and US¢6.76/kWh as indicated in Table 6.30, which are almost on the same level with hydropower project cost in Table 6.29 while hydropower project costs need further investigation as stated before. Taking added value in light of energy diversification ready for drought into consideration, coal thermal projects should be taken in generation development plan.

Table 6.30 Sensitivity of unit generation cost of coal thermal generation

Fuel price (US$/ton)	Unit capital cost (US$/kW)	Levelized capital cost (US¢/kWh)	O&M cost (US¢/kWh) Fixed	O&M cost (US¢/kWh) Variable	Fuel cost (US¢/kWh)	Total (US¢/kWh)
35	1,200	1.745	0.110	0.142	1.443	3.44
	1,500	2.181				3.88
70	1,200	1.745			2.885	4.88
	1,500	2.181				5.32
105	1,200	1.745			4.328	6.33
	1,500	2.181				6.76

(Source) JICA Study Team

6.4.3 Hydropower development project matrix

Evaluating the hydropower projects indicated in Table 6.24 from the viewpoint of economic efficiency, project progress, social and environmental consideration aspects and system requirement, hydropower development project matrix was formulated as shown in Table 6.31. As unit generation costs were taken as the indicator of economic efficiency, it is unfair to simply compare peak generation projects with lower capacity factor with base generation projects with higher capacity factor, so that unit generation costs of hydropower projects were compared with those of coal thermal generation projects with the same capacity factor (see red lines in Figure 6.5. As for project progress, many projects are still in the stage of Pre F/S or conceptual design, so that the projects which F/S's were completed, and/or the project sponsors were decided, were given higher priority. From the social and environmental aspects, there found no serious concern detected due to no detailed investigation like F/S's in many projects, which were given lower priority. Amidst of tight power demand-supply situation, every project has significant importance, but the projects located in the northern region of the country where the existing generation facilities are less, were given higher priority.

Evaluating these four indicators, 17 projects were prioritized and generation development plan was formulated along with the ranking. However, in most of the projects there were no feasibility studies conducted so far, the ranking in Table 6.31 will be subject to change due to the further study results. For instance, the project cost of Kafue Gorge Lower project were estimated as US$ 800 million less than half of current figure before the current feasibility study was conducted supported by IFC. It is noted that such modification should happen in the future.

Table 6.31 Hydropower development project matrix

	Project	Type	Developer	Capacity (MW)	Annual Energy (GWh)	Stage	Unit gen. cost (¢/kWh)		Implement-ation	Social & environ. Consideration	Site location (system requirement)	Rank
1	Kariba North (ext)	RES	ZESCO	360	380	Construction	10.44	○	○	○	○	1
2	Itezhi Tezhi	RES	ZESCO/TATA	120	611	DD	3.08	○	○	○	△	2
3	Lusiwasi (ext)	ROR	ZESCO	10	40	FS	7.41	△	△	△	○	3
				40	160							
4	Kafue Gorge Lower	RES	n/a	750	2,400		8.06	△	△	△	△	10
5	Mutinondo	ROR	Power Min	40	188	Pre FS/ concept	4.54	△	△	△	○	4
6	Luchenene	ROR	Power Min	30	139		5.97	△	△	△	○	5
7	Kabwelume Falls	RES	LPA	62	324		4.78	○	△	×	○	7
8	Kumdabwika Falls	RES	LPA	101	533		4.70	○	△	×	○	6
9	Kabompo Gorge	RES	CEC/TATA	34	176		7.23	×	△	×	○	11
10	Mambilima Falls I	RES	n/a	124	609		8.76	×	×	×	○	17
11	Mumbotuta Falls	RES	n/a	301	1,449		3.90	○	×	×	○	13
12	Mambilima Falls II	RES	n/a	202	1,003		7.82	×	×	×	○	15
13	Batoka Gorge	RES	ZMB-ZWE govt.	800	4,373		3.71	○	△	×	△	16
14	Lunsemfwa	RES	LHPC	55	462		6.51	×	△	×	○	8
15	Mkushi	RES	LHPC	65	223		7.01	△	△	×	○	9
16	Devil's Gorge	RES	ZMB-ZWE govt.	500	2,802	n/a	3.58	○	×	△	△	12
17	Mpata Gorge	RES	ZMB-ZWE govt.	543	3,785		3.58	○	×	△	△	14
	Total			**4,137**	**19,657**		**4.928**					

(Legend) ○: Good, △: Fair, × Poor or No information

6.4.4 Target Supply Reliability

Reserve margin and/or LOLP (Loss of Load Probability) are generally used as target supply reliability.

Reserve margin was selected as the target for generation development planning and the following margins were considered;

i) Dry year reserve: 16% (based on the latest 30 years statistics),
ii) Planned maintenance: 13% (45 days per year),
iii) Degradation: 5%,
iv) Forced outage: 5%, and
v) Others: 11%.

Total reserve margin came to 50 percent[16] for installed capacity in total.

Table 6.32 Target supply reliability

Items	Targets	Remarks
Target demand	Base case	
Reserve margin	50% for installed capacity	For Maintenance work, drought reserve
Drought reserve	20% margin in energy balance	Statistically 16% less generation in drought years

The target reserve margin set here can be diminished by considering the international power trade. However, no specific trade plan is presented, and SAPP has only 6 percent of reserve margin as a whole. Therefore, conservative target was established.

6.4.5 Generation Development Planning

(1) Primary energy basis self-supply scenario (Scenario 1-1)

Considering the primary energy self-supply, power generation other than hydropower is Maamba mine-mouth coal thermal station (200 MW) only, and all the hydropower projects in Table 6.31 should be realized to secure the supply reliability set in Table 6.32. Generation projects list for Scenario 1-1 is shown in Table 6.33.

[16] Definition of Reserve Margin is various by a country. In case of taking total installed capacity as denominator, many developing countries set the target of 30 to 40 percent. However, higher value were set here since Zambia was subject to suffer drought influence due to high hydropower proportion.

Table 6.33 Generation projects list for Scenario 1-1

	Project	Province	Type	Developer	Capacity (MW)	Annual Energy (GWh)	Project cost (m US$)
2013	Kariba North (ext)	Southern	RES	ZESCO	360	380	358
	Itezhi Tezhi	Southern	RES	ZESCO/TATA	120	611	170
2014	Lusiwasi (ext)	Central	ROR	ZESCO	10	40	134
		Central	ROR	ZESCO	40	160	
	Maamba coal	Southern	Thermal	Nava Bharat	200	1,459	240
2015	Mutinondo	Northern	ROR	Power Min	40	188	77
	Luchenene	Northern	ROR	Power Min	30	139	75
2016	Kabwelume Falls	Luapula & Northern	RES	LPA	62	324	140
	Kumdabwika Falls		RES	LPA	101	533	226
	Lunsemfwa	Central	RES	LHPC	55	462	271
	Mkushi	Central	RES	LHPC	65	223	141
2017	Kafue Gorge Lower	Lusaka	RES	n/a	750	2,400	1,745
2018	Kabompo Gorge	North Western	RES	CEC/TATA	34	176	115
2019	Devil's Gorge	Southern	RES	ZMB-ZWE gvt	500	2,802	1,808
2021	Mumbotuta Falls	Luapula	RES	n/a	301	1,449	510
2023	Mpata Gorge	Lusaka	RES	ZMB-ZWE gvt	543	3,785	2,442
2025	Mambilima Falls (site II)	Luapula	RES	n/a	202	1,003	708
2027	Batoka Gorge	Southern	RES	ZMB-ZWE gvt	800	4,373	1,828
2029	Mambilima Falls (site I)	Luapula	RES	n/a	124	609	481
Total scenario 1-1					**4,337**	**21,116**	**11,469**

The capacity balance in Scenario 1-1 is shown in Figure 6.6. As Kariba North extension and Itezhi Tezhi in 2013 and Maamba coal thermal in 2014 will be added in the power system, slight reserve for capacity will be expected in 2014. It is after 2017 that the power system may has substantial reserve, when Kafue Gorge Lower starts operation. These four projects are quite important to overcome the demand-supply gap for the time being. Finally, the power system will keep 40 to 60 percent of reserve margin after Devil's Gorge operation in 2019.

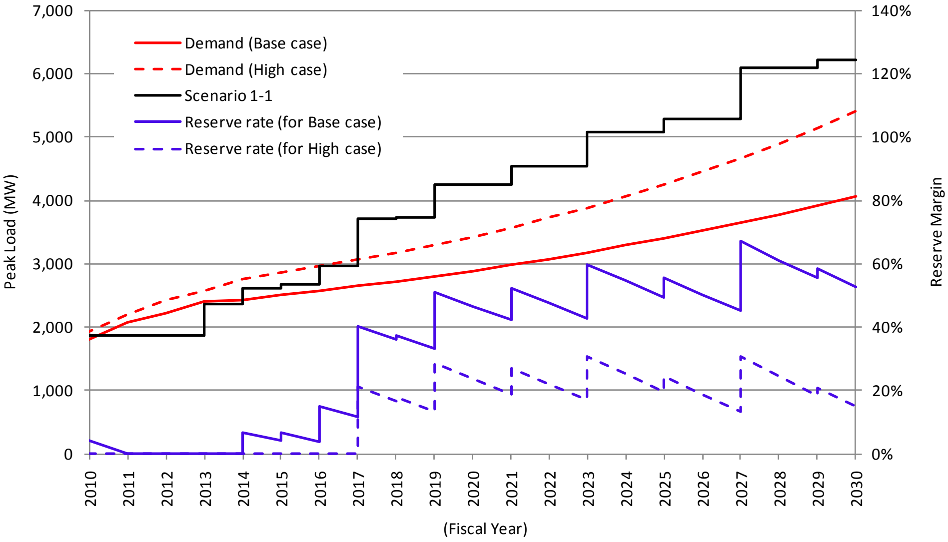


Figure 6.6 Capacity balance in Scenario 1-1

On the other hand, from the viewpoint of annual energy, power supply will be insufficient until 2019 as indicated in Figure 6.7. That is to say, as hydropower plants with lower capacity factor are the primary generation sources in this scenario, annual energy will be short while capacity balance is sufficient. As a countermeasure, electricity import in the low load period can be taken if peak supply is enough by operating hydropower stations. On the other hand, by modifying some projects to have more capacity factor with decreasing their peak power, other alternative which can reduce the initial investment costs will be suggested

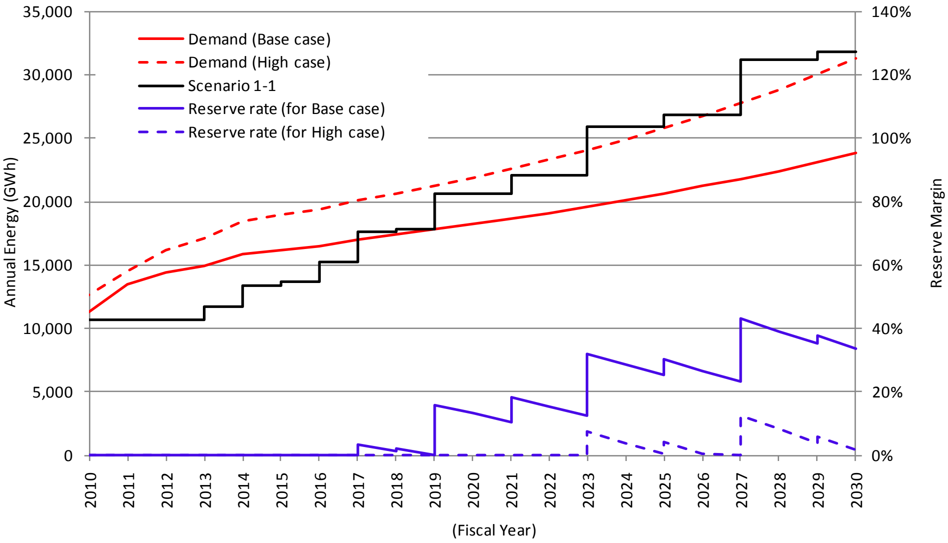


Figure 6.7 Energy balance in Scenario 1-1

(2) Electricity basis self-supply scenario (Scenario 1-2)

Formulating generation development with one-fourth of total capacity of coal thermal generation including import coal thermal, 14 hydropower projects excluding lower priority projects in Table 6.31; Batoka Gorge and Mambilima Falls (site I & II), should be developed.

Table 6.34 Generation projects list for Scenario 1-2

	Project	Province	Type	Developer	Capacity (MW)	Annual Energy (GWh)	Project cost (m US$)
2013	Kariba North (ext)	Southern	RES	ZESCO	360	380	358
	Itezhi Tezhi	Southern	RES	ZESCO/TATA	120	611	170
2014	Lusiwasi (ext)	Central	ROR	ZESCO	10	40	134
		Central	ROR	ZESCO	40	160	
	Maamba coal	Southern	Thermal	Nava Bharat	200	1,459	240
2015	Mutinondo	Northern	ROR	Power Min	40	188	77
	Luchenene	Northern	ROR	Power Min	30	139	75
2016	Kabwelume Falls	Luapula & Northern	RES	LPA	62	324	140
	Kumdabwika Falls		RES	LPA	101	533	226
	Generic coal 1	n/a	Thermal	Private	300	2,189	360
2017	Kafue Gorge Lower	Lusaka	RES	n.y.	750	2,400	1,745
2018	Lunsemfwa	Central	RES	LHPC	55	462	271
	Generic coal 2	n/a	Thermal	Private	300	2,189	360
2020	Mkushi	Central	RES	LHPC	65	223	141
	Kabompo Gorge	North Western	RES	CEC/TATA	34	176	115
2021	Generic coal 3	n/a	Thermal	Private	300	2,189	360
2024	Devil's Gorge	Southern	RES	ZMB-ZWE gvt	500	2,802	1,808
2026	Mumbotuta Falls	Luapula	RES	n/a	301	1,449	510
2029	Mpata Gorge	Lusaka	RES	ZMB-ZWE gvt	543	3,785	2,442
Total Scenario 1-2					**4,111**	**21,698**	**9,532**

Scenario 1-2 can realize earlier elimination of demand-supply gap as indicated in Figure 6.8 by introducing 500 MW coal thermal generation by 2016. After 2017, the power system will secure the sufficient supply reserve.

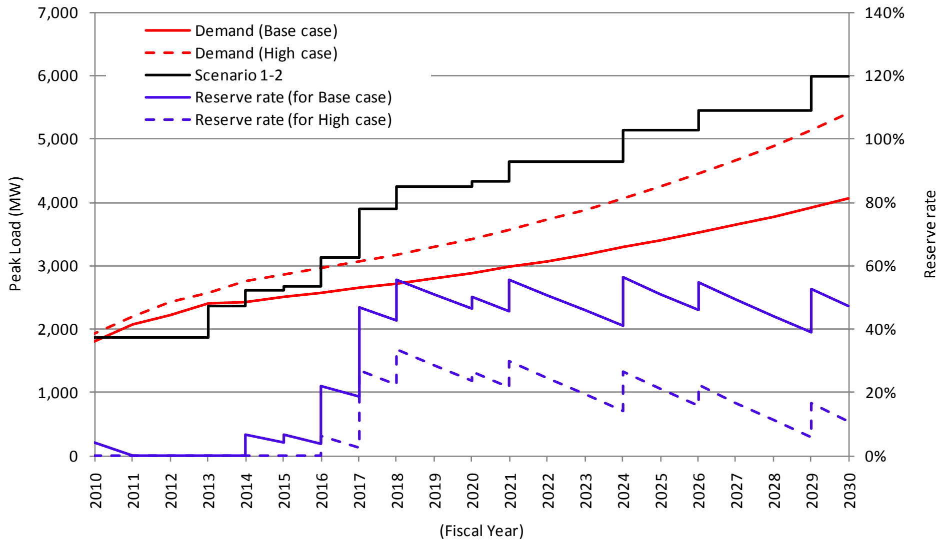


Figure 6.8 Capacity balance in Scenario 1-2

As for energy balance, Scenario 1-2 can secure supply reserve earlier[17] by introducing higher capacity coal thermal generation regularly in 2014, 2016 and 2018.

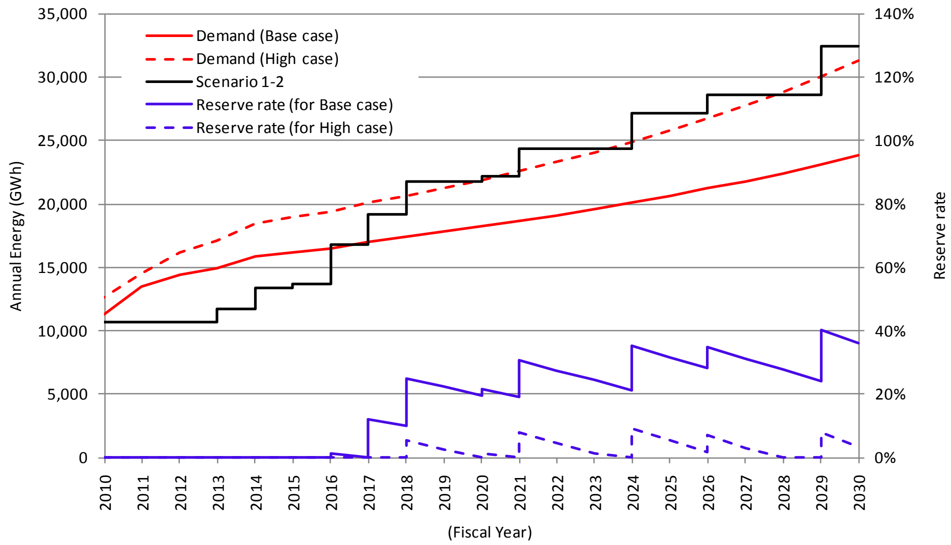


Figure 6.9 Energy balance in Scenario 1-2

[17] Actually Scenario 1-2 needs lower reserve margin as it introduces more coal thermal generation, free from drought influence.

6.4.6 Summary of generation development plan

Table 6.35 summarizes the two generation development scenarios above mentioned. As planned with the same target supply reliability, both scenarios need almost same amount of installed capacity and annual energy generation. The initial investment of Scenario 1-2 is lower which includes more coal thermal generation with lower initial investment. However, the difference between both scenarios is US$ 1,937 million, and divided by the difference of coal thermal generation energy; 2,189 GWh×38 years = 83,182 GWh, it comes to US¢ 2.33/kWh, which is almost the same as the fuel cost of coal thermal generation indicated in Table 6.29. Therefore, both scenarios have almost the same economic efficiency.

Table 6.35 Summary of generation development planning

		Scenario 1-1			Scenario 1-2		
		Installed capacity (MW)	**Annual energy (GWh)**	**Investment (m US$)**	**Installed capacity (MW)**	**Annual energy (GWh)**	**Investment (m US$)**
-2015	Total	800	3,054	1,054	800	2,978	1,054
	Hydro	600	1,518	814	600	1,442	814
	Coal	200	1,459	240	200	1,459	240
2016-2020	Total	1,567	6,920	4,446	1,667	8,496	3,358
	Hydro	1,567	6,920	4,446	1,067	3,888	2,638
	Coal	0	0	0	600	4,378	720
2021-2025	Total	1,046	6,237	3,660	800	4,991	2,168
	Hydro	1,046	6,237	3,660	500	2,687	1,808
	Coal	0	0	0	300	2,189	360
2026-2030	Total	924	4,982	2,309	844	5,234	2,952
	Hydro	924	4,982	2,309	844	5,234	2,952
	Coal	0	0	0	0	0	0
Total	**Total**	**4,337**	**21,193**	**11,469**	**4,111**	**21,698**	**9,532**
	Hydro	**4,137**	**19,734**	**11,229**	**3,011**	**13,672**	**8,212**
	Coal	**200**	**1,459**	**240**	**1,100**	**8,026**	**1,320**