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Republic of Zambia
Ministry of Energy and Water Development

The Study for Power System Development Master Plan in Zambia

Final Report
(Summary)

February 2010

JAPAN INTERNATIONAL COOPERATION AGENCY

Chubu Electric Power Co., Inc.

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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

Chapter 1 Introduction 1-1

1.1 Objective 1-1

1.2 Expected Key Outputs of Study 1-1

Chapter 2 Power Demand Forecast 2-1

2.1 The retail division 2-1

2.1.1 The residential-and-commercial sector 2-1

2.1.2 The industrial sector excluding mining 2-2

2.2 The mining sector 2-2

2.3 Premises of the forecast 2-2

2.3.1 Macro-economic growth 2-2

2.3.2 Population growth 2-2

2.3.3 Electrification ratio 2-2

2.4 Forecast scenarios 2-3

2.5 Forecast Results 2-3

Chapter 3 Generation Development Planning 3-1

3.1 Generation Development Scenarios 3-1

3.2 Generation Development Plan 3-2

3.2.1 Nominated Generation Development Projects 3-2

3.2.2 Target Supply Reliability 3-4

3.2.3 Generation Development Planning 3-4

Chapter 4 Interconnection Plan 4-1

4.1 Formulation policy 4-1

4.2 Results of calculation of the amount of electrical energy import and export 4-1

4.3 International power interchange in the future 4-4

Chapter 5 Transmission Development Plan 5-1

5.1 Current state of the transmission system in Zambia 5-1

5.2 Criteria applied in formulation of the transmission development plan 5-2

5.3 Transmission development plan in the scenario 1-1 5-3

5.4 Plan for transmission development in the scenario of coal-fired thermal power development (Scenario 1-2) 5-3

5.5 Summary of transmission development plans 5-7

Chapter 6 Distribution plan 6-1

6.1 Distribution plan subjects 6-1

6.2 Distribution expansion plan (by 2020) 6-1

6.2.1 Lusaka area 6-1
6.2.2 Southern area (Choma, Kafue, Mazabuka, Livingstone) 6-2
6.2.3 Copperbelt area (Kitwe) 6-3
6.2.4 Central area (Kapiri/Mkushi) 6-3

Chapter 7 Environmental and Social Consideration 7-1
7.1 Institutional Framework of Environmental and Social Considerations in Zambia 7-1
7.2 Principles and Methodology for Environmental and Social Considerations 7-1
7.3 Environmental and Social Impacts 7-1
7.3.1 Potential Environmental and Social Impacts and Mitigation Measures 7-1
7.3.2 Environmental Management Plan and Monitoring Activities 7-3
7.3.3 Local Stakeholder Consultations 7-3
7.3.4 Points to Consider at Project Implementation Stage 7-4

Chapter 8 Economic & Financial Analysis and Private Investment Promotion. 8-1
8.1 Economic & Financial Analysis 8-1
8.1.1 Economic Analysis 8-1
8.1.2 Financial Analysis 8-1
8.1.3 Recommendation on Economic and Financial Issues 8-3
8.2 Private Investment Promotion 8-4
8.2.1 Recommendation on Private Investment Promotion 8-4

Chapter 9 Optimal Power Development Plan 9-1
9.1 Formulation of Optimal Power Development Plan 9-1
9.2 Proposal regarding Cooperate Project 9-3
9.2.1 Proposal of a project for assistance 9-3
9.2.2 Package of support for expecting hydropower facilities 9-5
9.2.3 Package of support for expecting transmission facilities 9-6

List of Figures

Figure 2.1 Comparison of Demand in Different Scenarios 2-4
Figure 3.1 Capacity balance 3-6
Figure 3.2 Annual energy balance 3-6
Figure 4.1 Approximate amount of electrical energy import and export in ordinary years (Base case, Scenario 1-1) 4-2
Figure 4.2 Approximate amount of electrical import and export in ordinary years (Base case, Scenario 1-2) 4-2
Figure 4.3 Comparison of amounts of electrical energy import and export at wet, ordinary, and dry levels (Scenario 1-1) 4-3
Figure 4.4 Comparison of amounts of electrical energy import and export at wet, ordinary, and dry levels (Scenario 1-2) 4-3
Figure 5.1 Transmission system in Zambia 5-1
Figure 5.2 Zambian Power System on 2030 (Scenario1-1) 5-5
Figure 5.3 Zambian Power System on 2030 (Scenario 1-2) 5-6
Figure 8.1 Cost Breakdown 8-2
Figure 9.1 Outline about Lusiwasi ExpansionProject 9-6

List of Tables

Table 2.1 Premises of Each Scenario 2-3
Table 3.1 Hydropower development project matrix 3-3
Table 3.2 Target supply reliability 3-4
Table 3.3 Generation Development Plan (FY 2010-2030) 3-5
Table 4.1 Results of calculation of power and electrical energy import and export (Demand forecast : Base case) 4-4
Table 4.2 Results of calculation of power and electrical energy import and export (Demand forecast : High case) 4-4
Table 4.3 Study of shortage of imported power and electrical energy 4-5
Table 4.4 P rospects for power import from the DRC and South Africa 4-6
Table 5.1 Criteria applied in formulation of the transmission development plan 5-2
Table 5.2 Conditions of international power interchange in formulation of the transmission plan 5-2
Table 5.3 Amount of transmission facility development (kms) in Scenario 1-1 5-3
Table 5.4 Developing Plan of Coal Power Plant 5-4
Table 5.5 Amount of transmission facility development (kms) in Scenario 1-2 5-4
Table 5.6 Transmission development cost in Scenario 1-1 (million USD) 5-7
Table 5.7 Transmission development cost in Scenario 1-2 (million USD) 5-7
Table 6.1 Construction cost (Lusaka area) 6-2
Table 6.2 Construction cost (Southern area) 6-2
Table 6.3 Construction cost (Copperbelt area; Kitwe) 6-3
Table 6.4 Construction cost (Central area; Kapiri/Mkushi) 6-3
Table 7.1 Potential Environmental and Social Impacts and Mitigation Measures 7-2
Table 7.2 Overview of Stakeholder Consultations 7-3
Table 9.1 Total investment in Scenario 1-1 9-2
Table 9.2 Total investment in Scenario 1-2 9-2
Table 9.3 Estimate of development cost for the Project 9-5
Table 9.4 Example for package of support regarding transmission facilities (Lusaka area 2010～2015) 9-7
Table 9.5 Requisite cost (Lusaka area 2010～2015) 9-8
Table 9.6 Example unit for support (Copperbelt area 2010～2015) 9-8
Table 9.7 Requisite cost (Copperbelt area 2010～2015) 9-8
Table 9.8 Example unit for support (Southern region 2010～2015) 9-9
Table 9.9 Requisite cost (Southern region 2010～2015) 9-10
Table 9.10 Example unit for support (Northeastern region 2010～2015) 9-11
Table 9.11 Requisite cost (Northeastern region 2010～2015) 9-11
Table 9.12 Example unit for support (Itezhi-tezhi region 2010～2015) 9-12
Table 9.13 Requisite cost (Itezhi-tezhi region 2010～2015) 9-12

Chapter 1 Introduction

1.1 Objective

The objectives of the Study are to formulate the Power System Development Master Plan up to 2030 coordinating generation, transmission, and interconnection plan for the purpose of the achievement stabilizing the supply of power for the Republic of Zambia and the southern African community and to conduct technical transfer for counterpart in necessary techniques.

1.2 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;

Chapter 2 Power Demand Forecast

With regard to statistical data on power, the ZESCO statistics and the ZESCO billing data were used for the demand forecast analysis. The analysis also used macro-economic data for items including GDP released by the Central Statistical Office (CSO) and the International Monetary Fund (IMF).

To forecast the future power demand, 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.

In the analysis, the structure of the final consumption was split into the following three sectors. The reason for simplifying the demand structure is that statistical errors and omissions cannot be ignored due to the discontinuity of demand data if the demand structure is broken into small sub-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.

2.1 The retail division

2.1.1 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. The coefficient of determination (i.e., R^2) of 0.836 is assumed to be showing good correlation.

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

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

2.1.2 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. 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.

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

D_e: Energy demand (kWh)

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

a: Constant

b: Elasticity of GDP_{ind}

2.2 The mining sector

We integrated 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.

2.3 Premises of the forecast

2.3.1 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. 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 of the indicators 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. Conversely, the World Economic Outlook 2009 released by IMF in October 2009 foresaw GDP growth of 4.537% from 2008.

2.3.2 Population growth

The population of Zambia was 12.16 million in 2007. The average growth rate was 2.2 % per annum over the past ten years and 2.4% per annum over the past five years.

2.3.3 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. An increase in the electrification ratio translates into one in the number of customers. 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.

2.4 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.

Premises are detailed in Table 2.1. 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 2.1 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.

2.5 Forecast Results

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 2.1). 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. 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. 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.

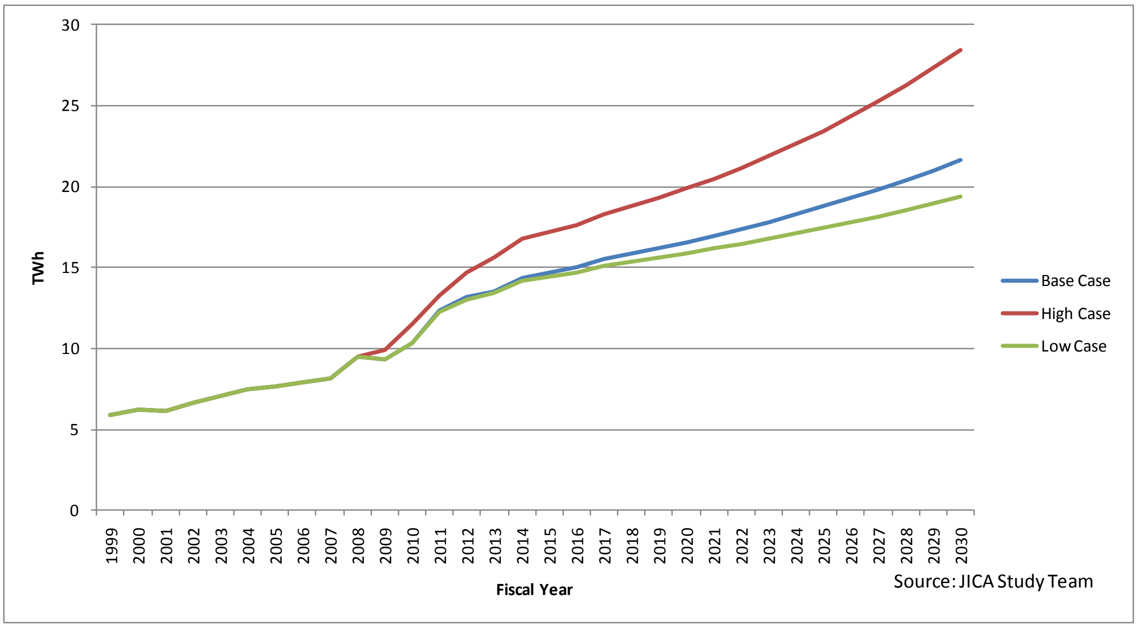

Figure 2.1 Comparison of Demand in Different Scenarios

Chapter 3 Generation Development Planning

3.1 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).

However, SAPP has currently no extra capacity as a whole and the power demand-supply situation in each member country is tight. Therefore, Scenario 1 was considered as the main scenario in this study[1], not expecting electricity import for the time being.

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.

The primary energy basis self-supply scenario (Scenario 1-1) has advantage of independence of primary energy from other countries in view 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.

[1] In the transmission planning, international connection and responding domestic transmission facilities were considered to import electricity while power import wasn't considered in the generation development planning.

3.2 Generation Development Plan

3.2.1 Nominated Generation Development Projects

(1) Hydropower projects

Evaluating the hydropower projects to be considered in the generation development from the viewpoint of economic efficiency, project progress, social and environmental consideration aspects and system requirement, hydropower development projects were prioritized as shown in Table 3.1.

(2) Other generation development projects

Maamba mine-mouth coal thermal project which is still under negotiation and imported coal thermal projects were considered other than hydropower 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 and 350 MW in the newspaper reports[2] issued in the current year. However, 200 MWe of domestic coal thermal was considered conservatively from the estimation of annual productivity of Maamba coal mines.

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

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.

[2] For example, see http://www.domain-b.com, January 10, 2009

Table 3.1 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	40 160	FS	7.41	△	△	△	○	3
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

3.2.2 Target Supply Reliability

The target supply reliability in generation development planning was set as **Table 3.2**.

Table 3.2 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

3.2.3 Generation Development Planning

(1) Generation development plan

Table 3.3 shows the power generation projects required against the demand estimated in Chapter 2. Maamba coal thermal and all the 17 hydropower projects indicated in Table 3.1 should be implemented in Scenario 1-1. On the other hand, the total 1,100 MW capacity of coal thermal including domestic and imported coal fired and the higher ranked 14 hydropower projects in Table 3.1 should be implemented in Scenario 1-2. In both scenarios quite the same projects were considered up to 2015 as some actions should be taken in such immediate future projects so far. Additionally, the installed capacity and the annual generation will increase almost in the same pace in both scenarios as the target is unique. As for the total project cost up to 2030, that of Scenario 1-2 which includes more coal thermal generation with lower initial investment is around US$ 200 million lower than that of Scenario 1-1. However, considering the fuel cost for coal thermal generation up to 2030, both scenarios will require almost the same amount of money in total.

Table 3.3 Generation Development Plan (FY 2010-2030)

FY	Scenario 1-1					Scenario 1-2				
	Project	Type	Capacity (MW)	Annual Energy (GWh)	Project cost (m US$)	Project	Type	Capacity (MW)	Annual Energy (GWh)	Project cost (m US$)
2013	Kariba North (ext)	RES	360	380	358	Kariba North (ext)	RES	360	380	358
	Itezhi Tezhi	RES	120	611	170	Itezhi Tezhi	RES	120	611	170
2014	Lusiwasi (ext)	ROR	10	40	134	Lusiwasi (ext)	ROR	10	40	134
		ROR	40	160			ROR	40	160	
	Maamba coal	Thermal	200	1,459	240	Maamba coal	Thermal	200	1,459	240
2015	Mutinondo	ROR	40	188	77	Mutinondo	ROR	40	188	77
	Luchenene	ROR	30	139	75	Luchenene	ROR	30	139	75
2016	Kabwelume Falls	RES	62	324	140	Kabwelume Falls	RES	62	324	140
	Kumdabwika Falls	RES	101	533	226	Kumdabwika Falls	RES	101	533	226
	Lunsemfwa	RES	55	462	271	Generic coal 1	Thermal	300	2,189	360
	Mkushi	RES	65	223	141					
2017	Kafue Gorge Lower	RES	750	2,400	1,745	Kafue Gorge Lower	RES	750	2,400	1,745
2018	Kabompo Gorge	RES	34	176	115	Lunsemfwa	RES	55	462	271
						Generic coal 2	Thermal	300	2,189	360
2019	Devil's Gorge	RES	500	2,802	1,808	--	--	--	--	--
2020	--	--	--	--	--	Mkushi	RES	65	223	141
						Kabompo Gorge	RES	34	176	115
2021	Mumbotuta Falls	RES	301	1,449	510	Generic coal 3	Thermal	300	2,189	360
2023	Mpata Gorge	RES	543	3,785	2,442	--	--	--	--	--
2024	--	--	--	--	--	Devil's Gorge	RES	500	2,802	1,808
2025	Mambilima Falls (site II)	RES	202	1,003	708	--	--	--	--	--
2026	--	--	--	--	--	Mumbotuta Falls	RES	301	1,449	510
2027	Batoka Gorge	RES	800	4,373	1,828	--	--	--	--	--
2029	Mambilima Falls (site I)	RES	124	609	481	Mpata Gorge	RES	543	3,785	2,442
	Total scenario 1-1		4,337	21,116	11,469	Total Scenario 1-2		4,111	21,698	9,532

(2) Capacity balance

Capacity balances for both scenarios are shown in Figure 3.1. In Scenario 1-1, as Kariba North extension and Itezhi Tezhi in 2013 and Maamba coal thermal in 2014 will be added in the power system, slight capacity reserve will be expected in 2014. It is after 2017 that the power system may have substantial reserve, when Kafue Gorge Lower starts operation. Finally, the power system in Scenario 1-1 will keep 40 to 60 percent of reserve margin after Devil's Gorge operation in 2019. On the other hand, Scenario 1-2 can realize earlier elimination of demand-supply gap as indicated in Figure 3.1 by introducing 500 MW coal thermal generation by 2016. After 2017, the power system will secure the sufficient supply reserve by the commencement of Kafue Gorge Lower project.

Scenario 1-1 **Scenario 1-2**

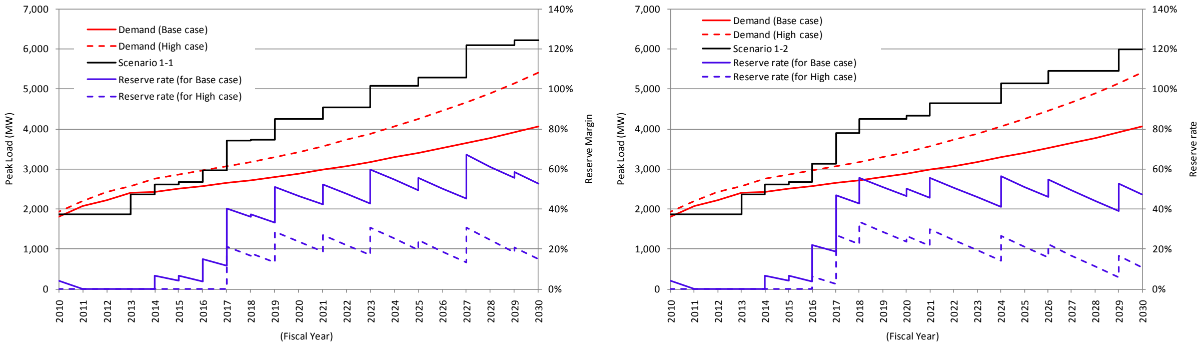

Figure 3.1 Capacity balance

(3) Energy balance

On the other hand, from the viewpoint of annual energy, power supply will be insufficient until 2019 in Scenario 1-1 and until 2018 in Scenario 1-2 as indicated in Figure 3.2.

Scenario 1-1 **Scenario 1-2**

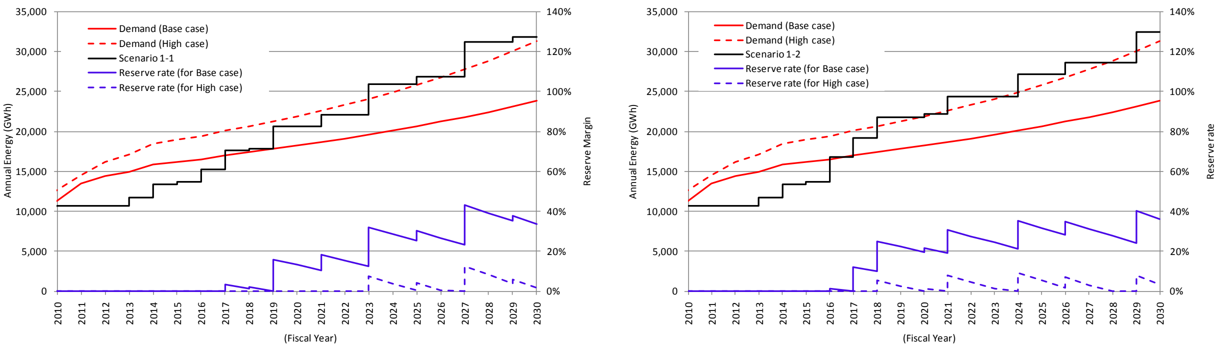

Figure 3.2 Annual energy balance

The capacity balance in Scenario 1-1 is shown in Figure 3.1. 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.

On the other hand, from the viewpoint of annual energy, power supply will be insufficient until 2019 as indicated in Figure 3.2. 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

(4) 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 3.1; Batoka Gorge and Mambilima Falls (site I & II), should be developed.

Scenario 1-2 can realize earlier elimination of demand-supply gap as indicated in Figure 3.1 by introducing 500 MW coal thermal generation by 2016. After 2017, the power system will secure the sufficient supply reserve.

As for energy balance, Scenario 1-2 can secure supply reserve earlier[3] by introducing higher capacity coal thermal generation regularly in 2014, 2016 and 2016.

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

Chapter 4 Interconnection Plan

4.1 Formulation policy

Geographically, Zambia is situated in the center of SAPP. In the SAPP, it has the role of exporting power to South Africa, which is the biggest power consumer in SAPP, and power generated in the southern SAPP countries to northern ones such as Tanzania, whose supply-demand balance is worsening. In other words, it must function as a resilient backbone of SAPP in the facility aspect, through its possession and continued reinforcement of trunk transmission lines linking the northern and southern halves of SAPP.

However, the development of new power sources and construction of new system facilities in SAPP countries will probably not proceed smoothly, partly because of the influence of the prevailing economic downturn. It may also be noted that the role of SAPP at present is not that of a competitive power pool in which supply orders can be issued to power stations, but rather that of a forum for coordination of transactions among power enterprises on the basis of short- and long-term contracts. (SAPP members are confirmed their intentions to extensively incorporate competitive factors further in the future.)

For these reasons, the treatment of the interconnection plan in this chapter will not go into the details of contracts (partner countries, contract schemes, etc.) but instead discuss power import required by Zambia and its possible power export.

4.2 Results of calculation of the amount of electrical energy import and export

Figure 4.1 shows the results of the rough calculation in the case of ordinary water level years for hydropower generation in Scenario 1-1 of the generation development plan, in the base case of the power demand forecast and Figure 4.2 is one in Scenario1-2. In Scenario1-1 case, the generated output would continue to be short, and require import of 4,650 GWh in fiscal 2012. The requisite import would decline with the startup of the Maamba coal-fired power station (200 MW) and Kariba North Extension power station (360 MW) in fiscal 2014. In fiscal 2019, the supply and demand would be balanced with the startup of the Kafue Gorge Lower power station (750 MW). With the startup of large-scale hydropower stations at Devil's Gorge (500 MW) and other locations along the Zambezi in succeeding years, Zambia would become capable of exporting power in amounts up to 8,255 GWh.

As in the case of Scenario 1-1, the supply in the case of Scenario1-2 would be insufficient in the immediately succeeding years, but the input of a coal-fired power station in fiscal 2016 would support the base power and dramatically reduce the extent of supply shortage. Thereafter, a supply surplus could be steadily maintained through effective supply of base power by successive input of coal-fired power stations.

Figure 4.3 and Figure 4.4 show the results of calculations made for the cases of wet and dry years in Scenario 1-1 and 1-2 in the base demand forecast case, in addition to those for ordinary water years respectively.

It should be noted that, Figure 4.4 can be represented there would constantly be a surplus of about 2,000 GWh in the base case even in years with dry levels from beginning in fiscal 2016.

This figure is equivalent to the yearly amount of power generated by one of the candidate coal-fired power stations, and would constitute a sufficient level of reserve power.

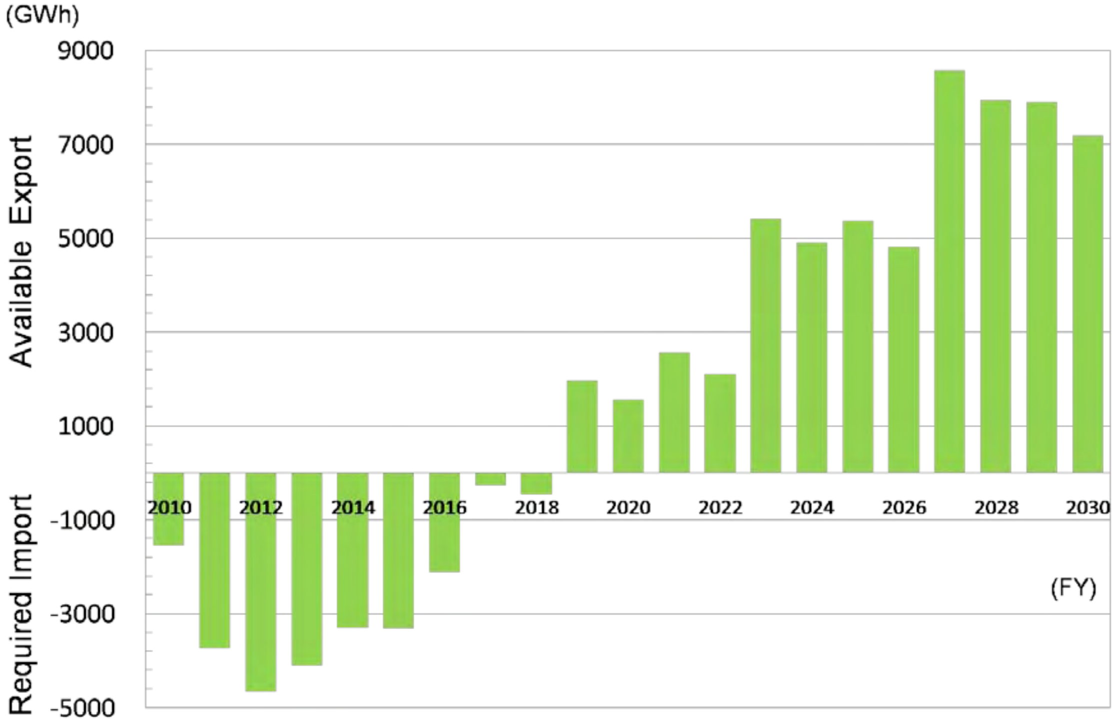

Figure 4.1 **Approximate amount of electrical energy import and export in ordinary years (Base case, Scenario 1-1)**

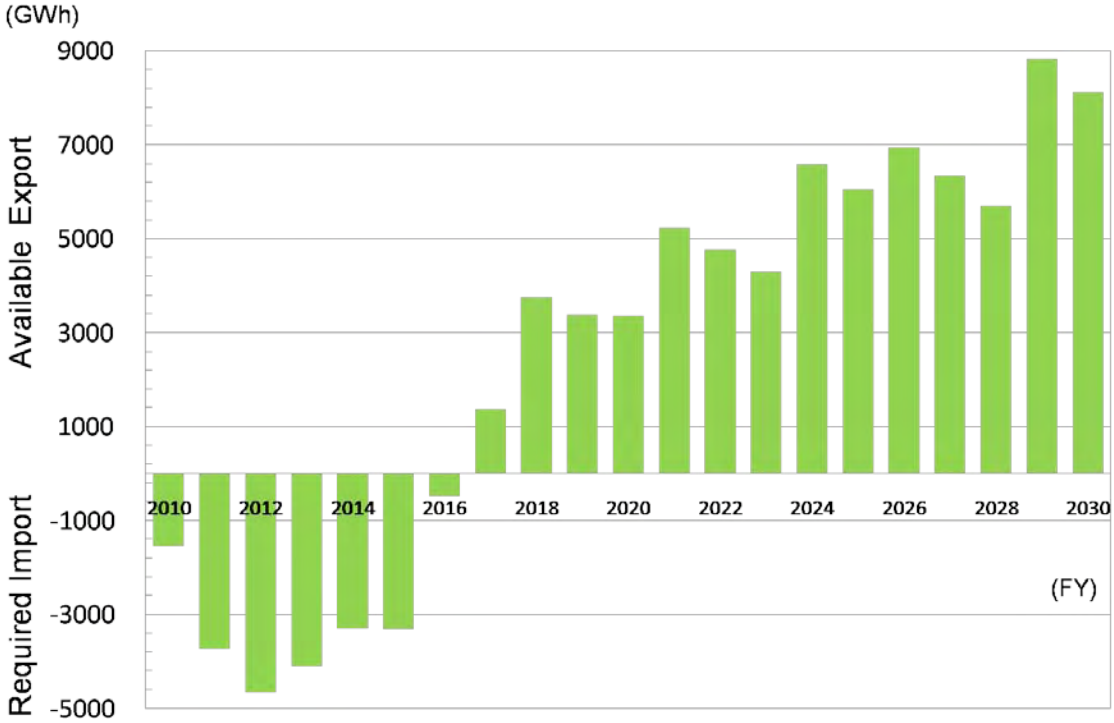

Figure 4.2 **Approximate amount of electrical import and export in ordinary years (Base case, Scenario 1-2)**

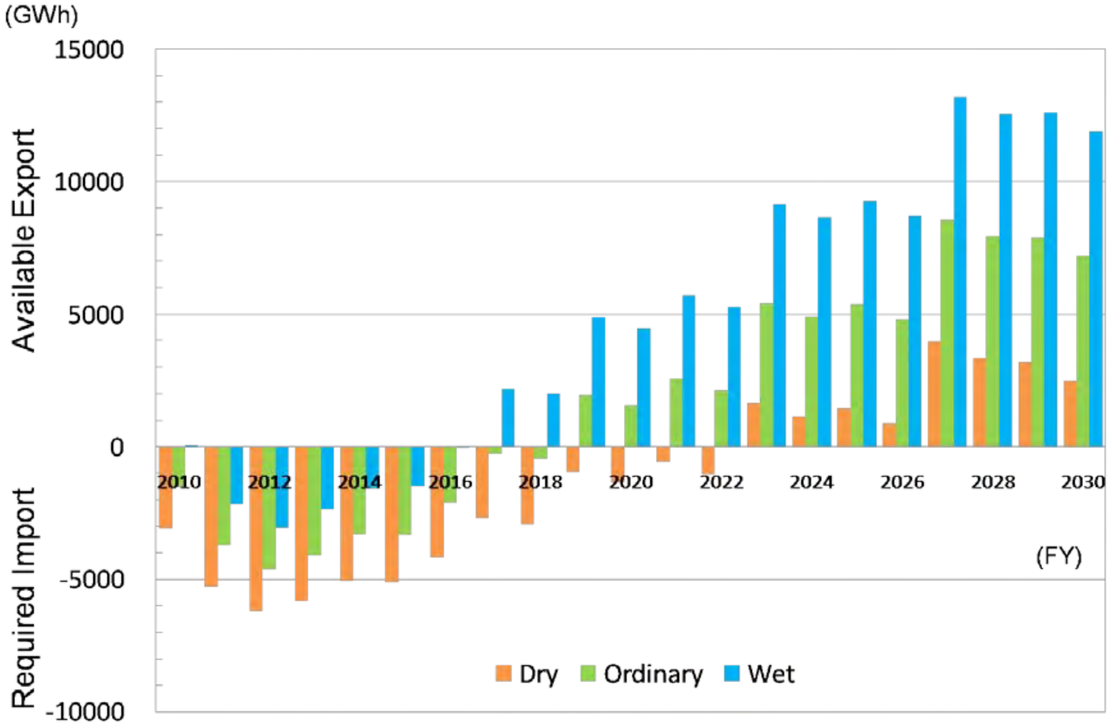

Figure 4.3 **Comparison of amounts of electrical energy import and export at wet, ordinary, and dry levels (Scenario 1-1)**

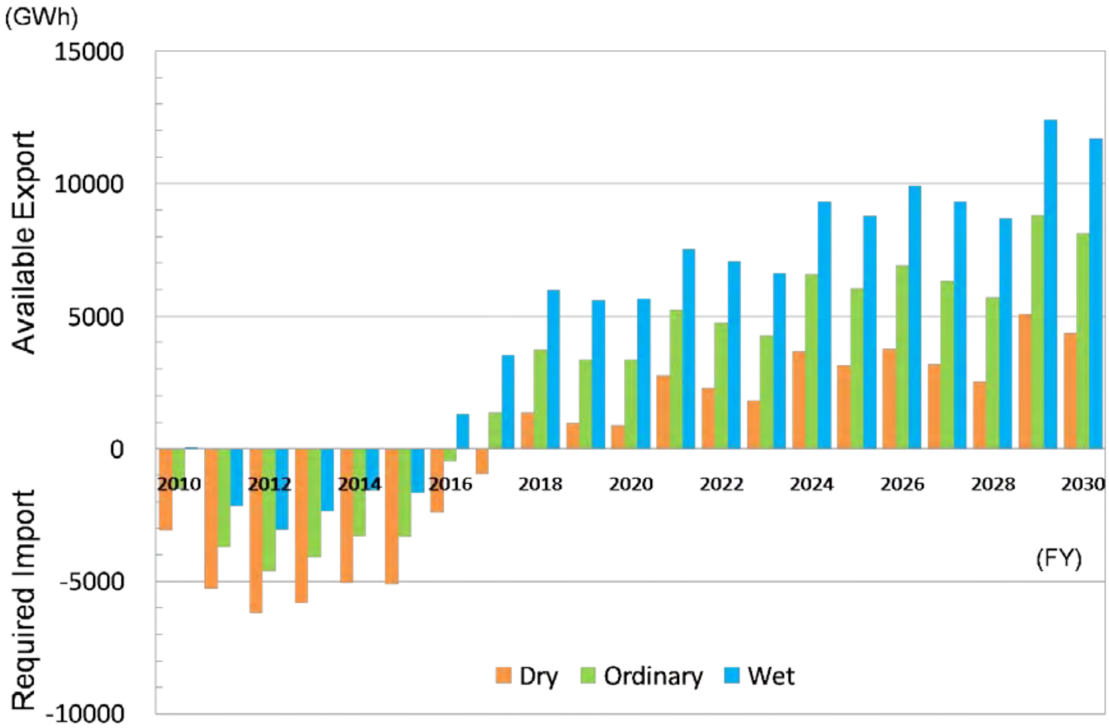

Figure 4.4 **Comparison of amounts of electrical energy import and export at wet, ordinary, and dry levels (Scenario 1-2)**

4.3 International power interchange in the future

Table 4.1 - Table 4.2 summarize the results of the rough calculation of electrical energy and power import and export (MW and TWh) described in the preceding sections.

In light of the figures in these tables, the matter which must be accorded top priority in studies by Zambia is the identity of a source for procurement of the shortage of power and electrical energy over the immediately following years

Table 4.3 shows the results of the examinations concerning shortage of power and electrical energy.

Table 4.1 Results of calculation of power and electrical energy import and export (Demand forecast : Base case)

Import and Export			2010	2015	2020	2025	2030
Export	Power(MW)				700	1000	1300
	Electrical Energy (TWh)	Wet			4.4/5.6	9.2/8.8	11.9/11.7
		Ordinary			1.5/3.3	5.3/6.0	7.2/8.1
		Dry			-/0.9	1.4/3.1	2.4/4.3
Import	Power(MW)		300	300			
	Electrical Energy (TWh)	Wet	0.2/0.2	1.5/1.6			
		Ordinary	1.5/1.5	3.3/3.3			
		Dry	3.1/3.1	5.1/5.1	1.3/-		

Note: Figures to the left of the / slashes are for Scenario 1-1, and those to the right, for Scenario 1-2.

Table 4.2 Results of calculation of power and electrical energy import and export (Demand forecast : High case)

Import and Export			2010	2015	2020	2025	2030
Export	Power(MW)				700	1000	1300
	Electrical Energy (TWh)	Wet			4.4/5.6	9.2/8.8	11.9/11.7
		Ordinary			1.5/3.3	5.3/6.0	7.2/8.1
		Dry			-/0.9	1.4/3.1	2.4/4.3
Import	Power(MW)		300	300			
	Electrical Energy (TWh)	Wet	0.2/0.2	1.5/1.6			
		Ordinary	1.5/1.5	3.3/3.3			
		Dry	3.1/3.1	5.1/5.1	1.3/-		

Note: Figures to the left of the / slashes are for Scenario 1-1, and those to the right, for Scenario 1-2.

Because the shortage would come in the immediately succeeding years, it would presumably be difficult for Zambia to develop new partners for supply of the shortages of power and electrical energy. Therefore, the study here was restricted to South Africa and the Democratic Republic of the Congo (DRC), with which Zambia currently has transactions.

For the routes for power reception, the Study Team selected the interconnection with the DRC (interconnection capacity of 600 MW[4]) and the interconnection with South Africa via Zimbabwe (Kariba South Route, interconnection capacity of 300 MW[5]).

The figures for interconnection line capacity noted above were obtained by multiplying the result of calculation using PSS/E, the system analysis simulation tool, by a fixed safety coefficient.

Table 4.3 Study of shortage of imported power and electrical energy

Required Volume			2010	2015	2020	2025	2030
Base Case	Requisite peak capacity (MW)		300	300			
	Requisite power	Wet	Base(100) Peak(200)	Base(200) Peak(100)			
		Ordinary	Base(200) Peak(100)	Base(300)			
		Dry	Base(400)	Base(600)	Base(300)		
High Case	Requisite peak capacity (MW)		300	300			
	Requisite power	Wet	Base(200) Peak(100)	Base(600)			
		Ordinary	Base(400)	Base(700)	Base(300)		
		Dry	Base(600)	Base(900)	Base(600)	Base(300)	

Note: "Base" refers to contracts for base power, and "Peak", to contracts for peak power. Figures in parentheses indicate the amounts of power to be contracted in MW.

A study must be made to determine whether or not the DRC (SNEL) and South Africa (ESKOM) are actually capable of supplying the amounts of power. In this connection, Table 4.4 shows related figures taken from a project report that was supported by the World Bank.

[4] This figure indicates the capacity of supply through a double-circuit 220kV transmission line and single-circuit 330kV transmission line.

[5] This figure indicates the capacity of supply through a double-circuit 330kV transmission line. The capacity appears to be heading for increase along with construction of the central corridor, but the feasibility of this project is still uncertain, and this prospective increase was consequently excluded from consideration. There is also a reception route via Namibia (the ZIZABONA Project), but this was also excluded from consideration due to uncertainty about its operation.

Table 4.4 Prospects for power import from the DRC and South Africa

Country	Interconnection Capaciry (MW)	Exportable power (MW)		
		2010	2015	2020
DRC	600	179	326～3740	55～3620
South Africa	300	Impossible	Impossible	Impossible or up to 1215
Ref.:Zimbabwe	(300)	Impossible	Impossible or up to 648	Impossible or up to 826

(Source) Prepared by the Study Team with data taken from the interim draft final report of the SAPP Regional Generation and Transmission Plan Study, 2008

Chapter 5 Transmission Development Plan

5.1 Current state of the transmission system in Zambia

Figure 5.1 presents a chart of the transmission system in Zambia. This system is marked by the following characteristics.

(1) Trunk transmission lines

These consist mainly of 330kV lines. The power flows from the large-scale hydropower stations in the south (such as Kariba North and Kafue Gorge) toward the Copperbelt area, and the voltage tends to fall as the flow proceeds north. SCADA data for the Luano substation in 2008 show that the 330kV bus voltage was not up to the standard (330kV plus or minus 5 percent) in about 40 percent of the time periods per year.

(2) Load transmission lines

These consist mainly of 66kV lines. In the northeastern and western areas, most are long-distance single-circuit lines, and do not meet the N-1 rule in many locations. Because power is transmitted over distances in excess of 100 km by 66kV lines, voltage drops greatly at the line ends. According to 2008 SCADA data for the Kasama substation, the 66kV bus voltage did not meet the standard (66kV plus or minus 5 percent) in more than one-third of the time periods per year.

For these reasons, it is consequently vital to find measures to keep voltage stability in the Zambian transmission system. In response, the formulation of the transmission plan emphasized this point.

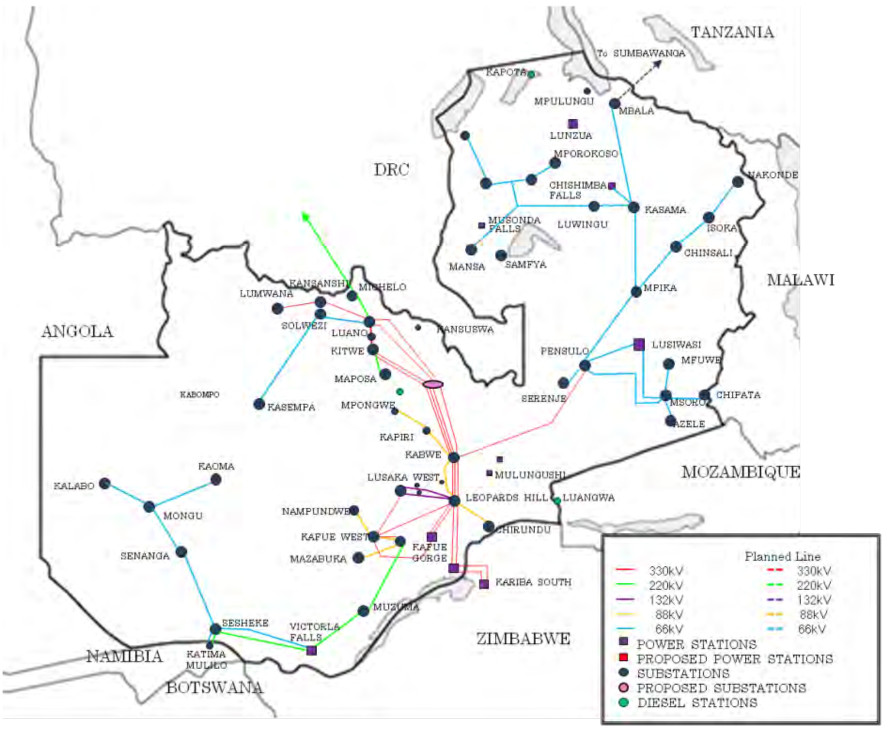

Figure 5.1 Transmission system in Zambia

5.2 Criteria applied in formulation of the transmission development plan

Table 5.1 shows the criteria applied in formulation of plans for transmission development in Zambia. The N-1 rule, which is used as the standard criteria around the world, and is also applied in Zambia. In areas with a low demand density such as the northeastern and western ones, however, this criterion cannot be met because the transmission lines have only one circuit. Although this situation is unavoidable when there are only limited finances available for promoting rural electrification (RE), areas covered only by single-circuit transmission lines should be reduced as far as possible into the future. For this purpose, the Study Team formulated the plan with a view to a phased shrinkage of areas not up to the N-1 rule.

Table 5.1 Criteria applied in formulation of the transmission development plan

Item	Criteria
Station Bus Voltages	Steady state: +/-5% of the nominal value
	Contingency conditions: +/-10% of nominal value
Equipment Loading	Steady state: Within Rated Current of equipment
	Short time overload: 20% above Rated Current for 20 minutes maximum
System Operation Security	System should stand a single contingency
System Stability	System stability (voltage and angle) is to be maintained following a single contingency outage after a permanent line to ground fault on any transmission line or transformer. For single circuit supply arrangements, the criterion will be relaxed.
Power Factor	0.95 (for transmission planning)
Frequency	With SAPP Interconnection: 49.95 - 50.05 Hz range 90% of the time
	Isolated Case: above 49 Hz

The plan formulation also considered the influence of international power interchange. Because the transmission system must deliver a stable function even in the case of international interchange, the Study Team analyzed and studied each of two cases: a base case (without international interchange) and an interconnecting case (the condition thought to be the toughest for the Zambian system). Table 5.2 shows the cases analyzed.

Table 5.2 Conditions of international power interchange in formulation of the transmission plan

Year	Base Case		Interconnecting Case	
	Import	Export	Import	Export
2015	0	0	-Sesheke 200MW	-Nakonde 200MW
2020			-Sesheke 200MW -Victoria Falls 200MW	-Nakonde 400MW
2025				
2030				

In Zambia, power sources are concentrated in the south, and power consequently always flows from the south to the north. As a result, a further magnification of this flow by import of power from Namibia and export of power to Tanzania would be the toughest condition for the Zambian system. The case of international interchange was therefore postulated as shown in Table 1-3. Power import from the DRC would supress the flow from south to north, and therefore alleviates the burden on the system in the aspects of both thermal capacity and voltage stability. Similarly, import from Kariba South would curb the flow between Victoria Falls and Lusaka, and therefore also be more advantageous than import from Namibia.

5.3 Transmission development plan in the scenario 1-1

The results of the demand forecast and power development plan served as the basis for formulation of the transmission plan in Zambia in the base scenario (Scenario 1-1). The formulation included a power flow analysis and study of N-1 rule.

Table 5.3 present specific figures for the amount of transmission facilities earmarked for development in the plan for transmission development in the scenario 1-1. Figure 5.2 Shows system diagrams for the years 2030. It can be seen that the amount of transmission facilities to be developed would peak in a relatively early phase (2010 - 2015). This is because the problem of voltage stability, which is now very difficult to maintain, must be resolved early in order to cope with future power source development.

Table 5.3 Amount of transmission facility development (kms) in Scenario 1-1

Year	Voltage of Transmission Line (kV)			
	66	132	220	330
2010-2015	194	2,562	599	3,668
2015-2020	5	1,494	0	389
2020-2025	0	241	0	2,142
2025-2030	0	236	0	140

5.4 Plan for transmission development in the scenario of coal-fired thermal power development (Scenario 1-2)

This transmission plan was formulated based on the results of the case of development of coal-fired thermal power sources (Scenario 1-2). The conditions as regards the demand forecast and international power interchange were the same as in Scenario 1-1. In this scenario, the siting of coal-fired power stations would have a great influence on transmission planning. The locations of the power station sites were taken as Table 5.4.

Table 5.4 Developing Plan of Coal Power Plant

Install year	Capacity (MW)	Location
2014	200	Maamba
2016	300	Maamba
2018	300	Kitwe
2021	300	Kitwe

Table 5.5 shows the amount of transmission facilities to be developed in the plan based on coal-fired thermal power development scenario (scenario 1-2) and Figure 5.3 shows system diagrams for the years 2030. It can be seen that the amount of transmission facilities to be developed would peak in a relatively early phase (2010 - 2015), but the degree of concentration would be lower than in Scenario 1-1. This is because the coal-fired power stations developed in the Kitwe district would reduce the flow of power through transmission lines to the north, and this reduction would relax conditions in respect of both thermal capacity and voltage stability relative to Scenario 1-1.

Table 5.5 Amount of transmission facility development (kms) in Scenario 1-2

Year	Voltage of Transmission Line (kV)			
	66	132	220	330
2010-2015	194	2,562	599	3,668
2015-2020	5	1,474	0	205
2020-2025	0	261	0	104
2025-2030	0	236	0	1,203

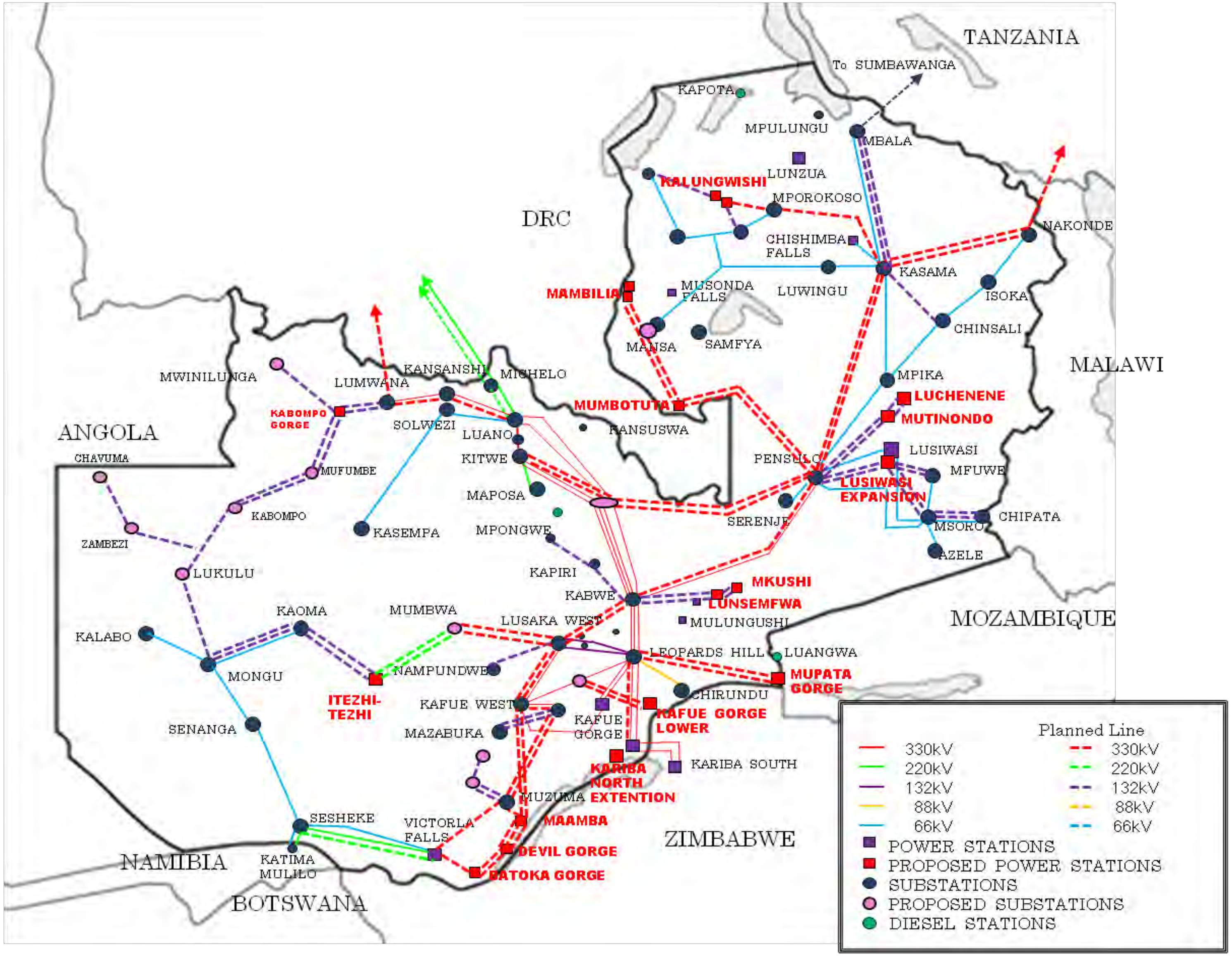

Figure 5.2 Zambian Power System on 2030 (Scenario1-1)

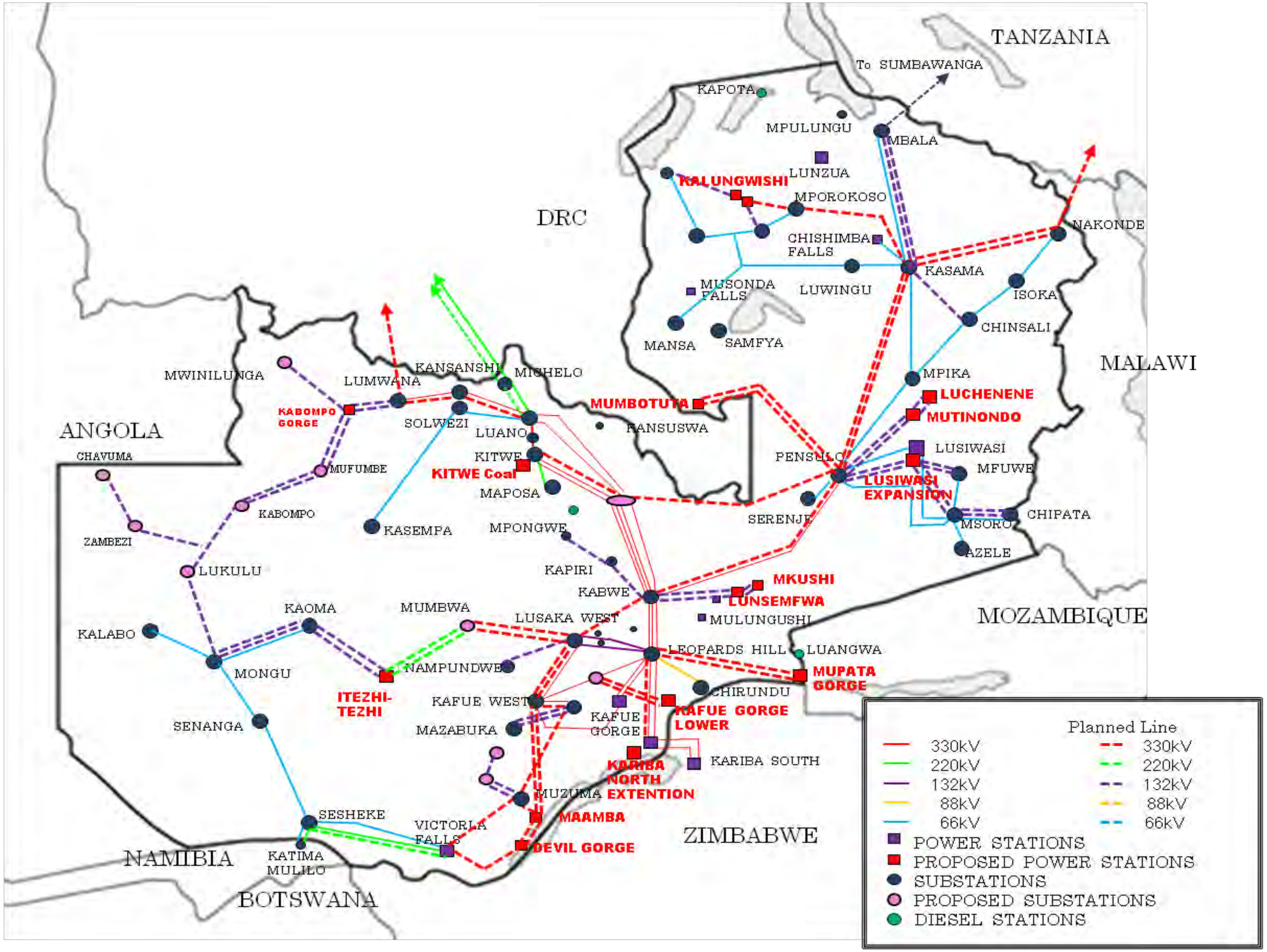

Figure 5.3 Zambian Power System on 2030 (Scenario 1-2)

5.5 Summary of transmission development plans

This section presents the cost of transmission development and transmission loss to summarize the plans prepared for transmission development. Table 5.6 shows the transmission development costs in Scenario 1-1, and Table 5.7, those in Scenario 1-2. These cost figures were calculated on the basis of equipment costs in 2008, and do not reflect factors such as future inflation rates.

Table 5.6 Transmission development cost in Scenario 1-1 (million USD)

Year	Transmisson Line	Switchgear	Transformer	Total
2010-2015	1,324	133	126	1,583
2015-2020	295	33	42	371
2020-2025	597	52	27	675
2020-2030	74	8	16	98
Total	2,290	226	211	2,728

Table 5.7 Transmission development cost in Scenario 1-2 (million USD)

Year	Transmisson Line	Switchgear	Transformer	Total
2010-2015	1,324	133	126	1,583
2015-2020	259	29	35	324
2020-2025	41	9	35	86
2020-2030	310	25	13	348
Total	1,934	197	210	2,341

From these tables, it can be seen that the cost of transmission development in Zambia would be very high and in 2030 reach a cumulative USD2.7 billion in Scenario 1-1 and USD2.3 billion in Scenario 1-2. The amounts required in the 2010 - 2015 phase would be particularly high, accounting for more than 50 percent of the total to 2030. The reason is that the transmission system in Zambia at present is operating under extremely tough conditions, and to meet any further demand increase will require a substantial increase in the trunk system and other component systems.

It also can be seen that Scenario 1-2 has generally lower development costs than Scenario 1-1 and would shift the development to a later phase (2025 - 2030). This is because the construction of coal-fired power stations at Kitwe would reduce the flow of power from south to north, and the development at Mambilima and Mumbotuta would be delayed.

Chapter 6 Distribution plan

The Study Team prepared a plan for distribution system expansion by 2020 based on the results of the demand estimates and transmission plan formulation. This chapter is not a master plan for all areas of the Zambia and all distribution facilities as shown below.

6.1 Distribution plan subjects

The power facilities that are subjects of the preparation of the distribution plan in this study are as follows.

- 33 kV distribution lines from bulk supply points (BSPs[6]) to 33/11 kV substations.
- 33 kV distribution lines interconnecting 33/11 kV substations
- 33/11 kV substations

The subject areas in the study are Lusaka, Choma, Kafue, Livingstone, Mazabuka, Kapiri/Mkushi, Ndola, and Kitwe.

6.2 Distribution expansion plan (by 2020)

The Study Team prepared a plan for distribution system expansion by 2020 based on the results of the demand estimates and transmission plan formulation. The results are as follows.

6.2.1 Lusaka area

(1) Results of distribution plan

- Expansion of 33/11 kV substations and 33 kV distribution lines (by 2020)

  Almost all of the 33/11 kV substations will be in an overload status along with demand increase. Almost all 33 kV distribution lines will become overloaded as well and have voltage drops beyond the standard, it is necessary to replace them with large-capacity lines or install additional lines. The amounts of construction are 165 km for 33kV lines and 36 units for 33/11 kV transformers.

- Installation of additional 132 kV transmission lines and 132/33 kV BSPs (by 2020)

  Additional 132 kV transmission lines and 132/33 kV BSPs will be constructed in order to meet the demand in the Lusaka area.

(2) Construction cost

Table 6.1 shows the construction cost for Lusaka area.

[6] Distribution substations supplying power to 33 kV distribution lines, equivalent to what are called secondary substations in Japan.

Table 6.1 Construction cost (Lusaka area)

	2010 - 2015	2016 - 2020	Total
Transmission	62.6	10.6	73.2
Distribution	24.0	13.4	37.4
Total	86.6	24.0	110.6

6.2.2 Southern area (Choma, Kafue, Mazabuka, Livingstone)

(1) Results of distribution plan

- Expansion of 33 kV distribution lines (by 2020)

  Due to demand increase, the voltage drop would exceed the limit on several 33 kV distribution lines. As a result, it will be necessary to replace existing lines with large-capacity ones or install additional lines. The amounts of construction are 284 km for 33kV lines and 15 units for 33/11 kV transformers.

- Installation of additional 132 kV transmission lines and 132/33 kV BSPs (by 2020)

  In certain areas, the demand increase would make it difficult to supply load through distribution lines. For this reason, the plan calls for installation of additional 132 kV transmission lines and 132/33 kV BSPs.

(2) Construction cost

Table 6.2 shows the construction cost for southern area.

Table 6.2 Construction cost (Southern area)

Construction Cost		2010 - 2015	2016 - 2020	Total
Choma	Transmission	6.8	0.6	7.4
	Distribution	7.3	-	7.3
	Total	14.1	0.6	14.7
Kafue	Transmission	1.3	-	1.3
	Distribution	-	-	-
	Total	1.3	-	1.3
Livingstone	Transmission	-	-	-
	Distribution	2.9	-	2.9
	Total	2.9	-	2.9
Mazabuka	Transmission	26.8	-	26.8
	Distribution	3.0	1.2	4.2
	Total	29.8	1.2	31.0

6.2.3 Copperbelt area (Kitwe)

(1) Results of distribution plan

- Expansion of 33 kV distribution lines (by 2020)

  Due to demand increase, the voltage drop would exceed the limit on several 33 kV distribution lines. As a result, it will be necessary to replace existing lines with large-capacity ones or install additional lines. The amounts of construction are 46 km for 33kV lines and 3 units for 33/11 kV transformers.

- Installation of additional 66 kV transmission lines and 66/33 kV BSPs (by 2020)

  Additional 66 kV transmission lines and 66/33 kV BSPs will be installed (at Chambishi, Chati, and Katembula) to meet the demand in the Kitwe area.

(2) Construction cost

Table 6.3 shows the construction cost for Copperbelt area.

Table 6.3 Construction cost (Copperbelt area; Kitwe)

Construction Cost	2010 – 2015	2016 - 2020	Total
Transmission	-	-	-
Distribution	1.2	0.7	1.9
Total	1.2	0.7	1.9

6.2.4 Central area (Kapiri/Mkushi)

(1) Results of distribution plan

- Expansion of 33 kV distribution lines (by 2020)

  Due to demand increase, the voltage drop would exceed the limit on several 33 kV distribution lines. As a result, it will be necessary to replace existing lines with large-capacity ones or install additional lines. The amounts of construction are 118 km for 33kV lines and 2 units for 33/11 kV transformers.

(2) Construction cost

Table 6.4 shows the construction cost for Central area.

Table 6.4 Construction cost (Central area; Kapiri/Mkushi)

Construction Cost	2010 – 2015	2016 - 2020	Total
Transmission	22.2	8.8	31.0
Distribution	5.2	-	5.2
Total	27.4	8.8	36.2

Chapter 7 Environmental and Social Consideration

7.1 Institutional Framework of Environmental and Social Considerations in Zambia

In Zambia, Environmental Protection and Pollution Control (Environmental Impact Assessment) Regulations, 1997 provides the legal framework for Environmental Impact Assessment (EIA) including criteria for categorizing projects that require EIA and the procedures of EIA. When planning sub-projects included in the master plan such as the construction of power stations, dams and transmission lines, project developers are required to take necessary procedures in accordance with the EIA Regulations. The Environmental Council of Zambia is responsible for the execution of the EIA Regulations.

Other relevant laws and regulations include Zambia Wildlife Act 1998 which provides the framework for the management of protected areas and wildlife, and Forest Act 1973 which stipulates the management of national and local forest reserves. There are 19 national parks and 35 game management areas in Zambia, and these protected areas account for approximately 30 % of the country's surface land. The protected areas are managed by Zambia Wildlife Authority (ZAWA). With respect to forest reserves, 180 national forests and 307 local forests are designated, and the Forestry Department manages the forests based on Forest Act. In addition to the two, environmental standards for air pollution, water pollution and noise, and land tenure systems should be given due considerations.

7.2 Principles and Methodology for Environmental and Social Considerations

The objectives of environmental and social considerations (ESC) at the master plan stage are to identify potential impacts at an earlier stage, and to mitigate or avoid significant adverse impacts of sub-projects by taking into account the identified impacts when determining detailed locations and specifications of facilities. This enables to clarify points to consider in determining the locations and specifications at the feasibility study (F/S) and/or detailed design study (D/D) stages, and eventually contributes to the smooth implementation of EIA at these stages.

This ESC Study examines potential environmental and social impacts and necessary mitigation measures through literature reviews, surveys on sampled existing power facilities, interviews with experts and relevant institutions, and stakeholder consultations.

7.3 Environmental and Social Impacts

7.3.1 Potential Environmental and Social Impacts and Mitigation Measures

Table 7.1 demonstrates environmental and social impacts that shall be given due attention in relation to sub-projects included in the master plan.

Table 7.1 Potential Environmental and Social Impacts and Mitigation Measures

Impact		Description of Impact	Mitigation Measures
Involuntary Resettlement	A	Large-scale involuntary resettlement due to the creation of reservoirs; Involuntary resettlement due to the construction of power plants and transmission lines	Avoiding sites where involuntary resettlement may is likely to occur; Consultations with project affected persons and local representatives and acquisition of their agreement; Formulation and implementation of a project-specific resettlement plan; Necessary compensation; Formulation and implementation of a plan for the restoration of income and livelihoods
Impacts on Local Economy and Land Use	A	Changes in land use including agricultural and forestry land; Acquisition of land; Loss of livelihood means; Land use restriction under transmission lines	Prior explanation of a project plan to local residents; Formulation and implementation of a project-specific land acquisition plan; Necessary compensation ; Formulation and implementation of a plan to support the restoration of income
Local Social Institutions	B	Loss of social institutions; Social separation by facilities	Consultations with social institutions; Elaboration of mitigation measures
Water Usage/ Water Rights	B	Water intake for hydropower projects; Intake of coolant water for thermal power stations	Coordination with water right holders; Consensus building on the volume and pattern of water intake.
Sanitation and Infectious Diseases (HIV)	B	Spread of HIV/AIDS due to the influx of construction workers; Diseases in relocation destination	Education for construction workers and local residents on HIV and other infectious diseases
Cultural Heritage	C	Impacts such as relocation of cultural heritages due to the construction of dams, reservoirs, power plants and transmission lines	Consultations with local residents, local governments and chiefs; Identification of heritages to be given due attention; Revision of project plans; Mitigation measures such as relocation of cultural heritages
Soil Erosion	B	Erosion caused by civil works; Erosion around reservoirs	Construction of drainage; Avoiding rainy season for civil works; Vegetation Conservation; Re-vegetation
Local Hydrology and Groundwater	A	Changes in the distribution and level of adjacent groundwater due to the creation of reservoirs and low-water sections	Determination of water intake volume and pattern based on a hydrological survey; Monitoring on water level and quality of adjacent water bodies and wells; Feedback measures based on the monitoring result
Flora and Fauna, and Biodiversity	A	Adverse impacts on protected areas and wildlife; Tree and vegetation clearance during civil works and under transmission lines	A survey on flora and fauna around project site; Incorporation of the survey result into a project plan; Measures to avoid, minimize and mitigate potential impacts
Landscape	B	Changes in landscape due to the construction of dams, reservoirs, power plants and transmission lines	Consultations with local residents, local governments and chiefs; Identification of landscape to be affected; Revision of project plans such as route change; Mitigation measures such as re-vegetation
Air Pollution	B	Air pollution by emission gas of thermal power plants	Coal pretreatment; Installment of flue desulfurization and denitration devices, and electrostatic precipitator.
Waste	B	Construction wastes and waste soils; Coal and fly ash from thermal power stations; PCB waste oils from old transformers	Proper disposal of construction wastes and soils, and coal and fly ash from thermal power stations; Contractual agreement on proper disposal of wastes; Proper storage of PCB waste oils
Noise/ Vibration	C	Noise and vibration during construction works	Prior notification of civil work hours and durations; Considerations on design and layout of thermal power stations and substations
Bottom Sediment	B	Sediment in reservoirs	Regular dredging; Construction of sediment pool dam
Accident/ Safety	B	Accidents during construction works and facility operation	Safety education for construction workers and facility operators

[Legend] A: Significant impacts expected B: Certain impacts expected
C: Impacts unknown D: Negligible impacts

7.3.2 Environmental Management Plan and Monitoring Activities

When planning and implementing a power development project, an environmental management plan shall be formulated to implement necessary environmental measures and to minimize adverse impacts. The plan shall cover 1) mitigation measures to be taken; 2) environmental monitoring items and methodologies; and 3) implementation mechanism of environmental measures at least.

In particular, environmental monitoring activities shall be given high priority. Whether proposed mitigation measures are actually implemented, whether proposed measures are adequate to mitigate impacts, and whether unexpected impacts occur shall be monitored taking into account the characteristics of individual environmental and social impacts.

7.3.3 Local Stakeholder Consultations

The Study Team held several stakeholder consultations as indicated in Table 7.2.

Table 7.2 Overview of Stakeholder Consultations

Date	Venue	Participants
5 June 2009	Serenje District, Central Province	Serenje District Development Coordinating Committee*1
3 June 2009	Mailou, Central Province	Chief Mailou, who governs areas around Lushiwasi Power Station
9 June 2009	Itezhi-Tezhi District, Southern Province	Itezhi-Tezhi District Development Coordinating Committee*1
10 June 2009	Kaingu, Southern Province	Chief Kaingu, who governs areas around Itezhi-Tezhi Dam
18 June 2009	Lusaka	Government Agencies such as ZAWA, Forestry Department and National Heritage Conservation Committee, NGOs, Univ. of Zambia

Note 1: A committee in which extension offices of government agencies, district council, representatives of farmers, representatives of commercial sector, NGOs and other relevant institutions participate

In the stakeholder meetings, participants showed their expectations on the benefits of power development projects such as increase in job opportunities and enhancement of local economy associated with the construction and operation of power facilities, and consequent the improvement of living standards. On the other hand, they also had concerns about negative impacts such as involuntary resettlement, land acquisition and loss of livelihood means, and social changes and increase in risks of infectious diseases due to the influx of settlers. With respect to involuntary resettlement and land acquisition whose impacts could be significant, participants largely accept them as far as sufficient explanation and consultations are held in advance, proper compensation is provided, and support for rebuilding livelihoods is given.

At the project planning and implementation stage, stakeholder consultations shall be held prior to the determination of project locations and details of specifications, and stakeholder's agreement shall be obtained in advance. It should be noted that chiefs as traditional authorities, local government institutions such as District Development Coordinating Committees of respective districts, and regional offices of government agencies such as ZAWA shall be consulted as well as project affected persons.

7.3.4 Points to Consider at Project Implementation Stage

(1) Execution of Necessary Procedures

Environmental Impact Assessment Regulation, 1997 requires certain categories of power sector projects to conduct EIA or relevant procedures. It is, therefore, critical for project developers to take necessary procedures in consultation with ECZ.

(2) Environmental and Social Consideration Study according to Project Locations

When ESC Study is conducted at the F/S stage, it is necessary to predict potential impacts according to the individual conditions of project sites and facility specifications.

In particular, if sites for dams and reservoirs and transmission line routes are specified, developers are required to conduct detailed investigations on involuntary resettlement and land acquisition, and impacts on protected areas and ecosystem. In addition, based on the investigations, mitigation measures shall be elaborated according to predicted impacts.

(3) Considerations for Alternative Locations

In formulating mitigation measures, the first priority should be put on seeking the alternative locations to avoid potential impacts. If certain impacts are unavoidable, measures to minimize the impacts, or mitigation measures such as compensations should be taken into account. F/S should, therefore, prepare more than one option regarding location selection, and determine the final location taking into account environmental and social impacts of respective options.

(4) Environmental Management System

If projects are expected to have certain impacts at project planning and implementation stage, it is necessary for project developers to establish a comprehensive Environmental Management Plan including environmental measures to be taken during construction works and at the operational and maintenance phases, and environmental monitoring activities, and to avoid or minimize adverse impacts. In terms of hydropower development projects, monitoring activities on involuntary resettlement process and unexpected impacts on ecosystem are essential. In particular, monitoring on ecosystem is critical since impacts on ecosystem cannot be thoroughly assessed in advance.

Chapter 8 Economic & Financial Analysis and Private Investment Promotion

8.1 Economic & Financial Analysis

8.1.1 Economic Analysis

(1) Future Prospect

The projection of the government budget from 2008 to 2010 remains tight given the difficult economic situation of the country and the world, and the tight borrowing ceiling policy. The domestic borrowing will be limited to 1.2% of GDP in 2008 and 1.0% of GDP in 2009 and 2010. The net external borrowing will be projected less than 0.6% of GDP in 2008 and 0.7% of GDP in 2009 and 2010.

(2) Private Financing Needs for Power Sector

The government recognizes the importance of developing the power system in the country in view of supporting the private sector development. The needs for rural electrification in the future are also well understood. On the other hand the financing needs for the future power development are beyond the government budget allocation to the energy sector.

The JICA Study estimates that the future financing needs for the power system development would be more than US$ 14 billion for the next twenty-one years including the financing from the private sector. On the other hand, the current budget allocation level for the economic affairs including other infrastructure is approximately K3,000 billion, which can be converted to US$ 600 million. Therefore it is unlikely for the government budget to finance the substantial portion of the public investment.

8.1.2 Financial Analysis

The financial analysis examines the corporate finance of ZESCO rather than the investment return of each sub-project such as IRR. This is because of the existing studies that have already discussed the return and bankability of each project by the feasibility study including IRR. The JICA Study examines the impact on the investment projects on the ZESCO finance when the projects are developed.

(1) Assumptions for Analysis

The study period is from Year 2009/10 to 2030/31.

a. Assumptions for Revenue

The assumptions were made for macro economics, exchange rate, annual sales, and power tariff.

b. Assumptions for Cost

The assumptions were made for depreciation, new generation plants, cost reductions, and tax.

c. Assumptions for Cash Flow

The assumptions were made for investment needs and borrowing.

(2) Findings from Financial Analysis

(i) Overall Financial Performance

The analysis results of the margin show the sound financial performance. The asset return is also generally more than the expected level of eight percent.

(ii) Operating Costs

The actual operating cost breakdown is also shown in the below figure.

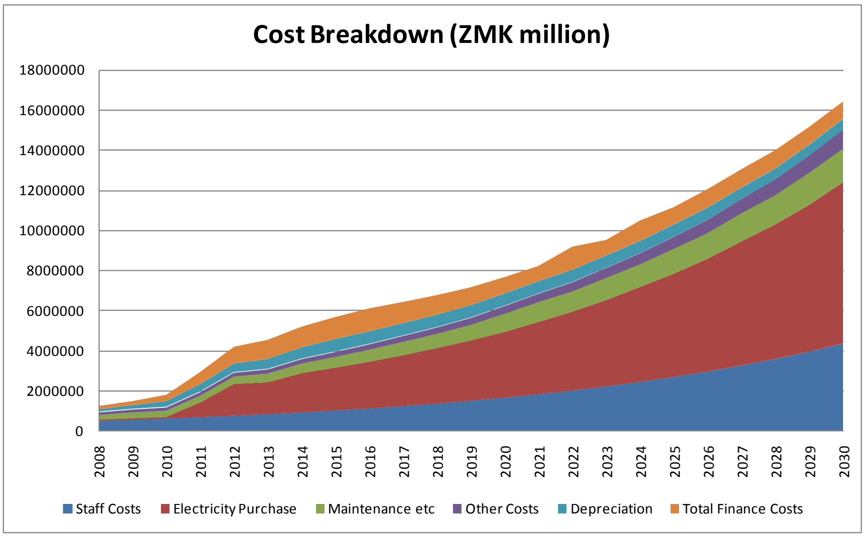

Figure 8.1 Cost Breakdown

(Source) JICA Study (2009)

The power supply costs are expected to show a high increase based on the ERB scenario but to have a moderate increase after 2013. The staff costs show a moderate increase compared with the total cost but a slightly higher than other costs such as maintenance and depreciation. On the other hand, the electricity purchase is expected to increase substantially over the period due to the increase of the purchase from IPPs.

(iii) Cost of Service

The supply costs of services of ZESCO will increase for all the customer categories. The residential customer will have a large increase until 2012. The increase after 2012 however is a moderate because the tariff will achieve the cost-reflective level by the time. The overall average cost shows the increase from 207 ZMK/kWh in 2009 to 830 ZMK/kWh in 2030. The increase can be translated to approximately seven percent per year. The increase would be a little lower than the assumed average domestic inflation rate which is ten percent per year.

(iv) Cash Position

The cash arrangement for ZESCO would be an issue during the period when the large amount of investment would be made, particularly from 2012 to 2017. The cash requirement will be mostly due to the projected expansion of the transmission network. After the year 2018, ZESCO will have a sound cash position.

8.1.3 Recommendation on Economic and Financial Issues

ZESCO aims to continue the improvement of management including the reduction of personnel costs. The Study has found some important factors and future perspectives on the management of power sector. The following items are critical for the economic and financial matters on the power sector master plan.

(1) Future Perspectives for Capital Expenditure

The development plan shows the optimum scenario for future capital expenditure. The study expects that the sequential development will be conducted according to the proposed schedule. However if the development plan faces any slippage in the schedule, ZESCO would need to procure power from neighboring countries and may need additional funds for the purchase. Therefore since the delay in the project schedule would cause another increase of the power tariff, the implementation should be carried out in line with the original plan.

(2) Financing for Future Investment

As the investment plan shows, the large amount cash expenditure projects are planned in the coming years, particularly from around 2012 to 2016. While the power tariff is expected to achieve the economic tariff that reflect the cost of power services, the funds to invest in the additional infrastructure still remains an issue to ZESCO. The study assumed that ninety percent of the fund would be contributed by the debt financing that would presumably guaranteed by the government. However the discussion on the financial issue needs to be carried out with the Ministry of Finance and National Planning.

(3) Cost of Services

The cost of services will increase due to the factors such as the inflation, the additional development requirements, the investment to improve the efficiency and reliability of power supply, and the payment obligation to IPPs. On the other hand the efficiency gain is also expected including the system loss reduction, the operation cost reduction in real term, and the overall cost saving from the scale of economy. The supply costs could also be further reduced by the utilization of the SAPP interconnection. It is recommended that ZESCO would take various initiatives to improve the management performance in a proactive manner and demonstrate the achievements to the concerned parties including ERB.

Moreover, it is expected that ZESCO would improve the service efficiency and performance in terms of the services from metering, billing, and collection. These would include the overall service level improvement for customers as well as the reduction of the receivables.

(4) Foreign Currency Position

ZESCO has basically two currencies for revenue such as Zambian Kwacha and US Dollars because the payment from mining customers is made in the foreign currency and the retail customers pay in the local currency. ZESCO then utilize the revenue in foreign currency to settle the payment for the debt services in foreign currency, the import equipment, the power purchase, and goods, and others. Currently ZESCO has s surplus in the foreign currency account balance due to the revenue from the power sales in foreign currency. However it is expected that the payment in foreign currency will increase over the period due to the increase of the power purchase from the private power producers. Therefore given the potential depreciation of the local currency against the foreign currency, the foreign currency management is increasingly important and critical for ZESCO. Even at this point, the exchange fluctuation causes the impact on the profit of ZESCO. In terms of the management of the foreign currencies, ZESCO's account will face the cash shortage in the future due to the increase of the foreign cash payment to the IPPs. Therefore the asset and liability management will be important to ZESCO.

(5) Power Tariff Adjustment

As shown in the financial analysis, the regular tariff adjustment will be inevitable even if the performance of ZESCO will improve due to the power supply cost increase. Therefore ERB should adjust the power tariff in a continuous and timely manner based on the ZESCO's performance and the economic and business situations. The consideration on the power tariff continues to be critical because it would have a significant impact on the ZESCO finance. In addition, the foreign currency portion in the power tariff should also be adjusted in a timely manner to reflect the changes in foreign exchange to address the settlement needs for foreign currencies.

8.2 Private Investment Promotion

8.2.1 Recommendation on Private Investment Promotion

(1) To provide clear framework and system for encouraging private investment

The framework should be updated and strengthened by necessary statutory instruments on the issues such as incentives for tax/duty, grid code/open access, environmental matters, and other legislations and regulations. Many investors' concerns do not rest in the profitability and the technical risks of the specific projects but in the unclear legal situations and surrounding regulatory circumstances. If the conditions for the investment such as various taxes and import duties are certain to the investors, the investors will be more confident on the project implementation.

(2) To accelerate processes for the review and approval of private investment project

There are already some projects in the pipeline that are waiting for administrative guidance and clearance. The instruction and support by GRZ are critical for implementation of projects because the advices of the government would drive the directions of the projects. The critical aspects on the projects include (i)environmental issues, (ii)licensing for project development, (iii)power tariff and PPA negotiation, (iv)design and construction, and (v)water rights matters.

The process should also be simplified and clearly understood by private investors. Some private investors also complain the slow processing by the government organizations and the complexity of clearance procedures. Since some of the investors could be new to the power market in Zambia, the facilitation by the government experts would lower the barriers to enter the market.

(3) To enhance the capacity for coordination and review of the applications of the private power development

ERB appears to be occupied with the burning issues at hand such as the tariff issues, the monitoring of the performance agreement with ZESCO, and the revision of the grid code. ERB can take the lead in establishing the standard and good practice for regulating the private investment projects. FPI can also be upgraded to reflect the recent changes in the power sector and articulate the scope of works and the methodology for the regulation of the private power development by ERB. The tariff negotiation will be increasingly important when dealing with the diverse needs of different private investors and projects.

(4) To increase the government support to fund the project preparation and implementation by the private sector

Funds to support the private sector initiatives need to be revisited. There would be certainly needs and benefits for the intervention by the government for instance to mobilize the domestic capitals by local investors even though the number of the domestic investors would be less than the international players. The government funds for infrastructure development that are related with the power projects also play a significant role in the project implementation. These would include the access road construction, the substation and other facilities for evacuating power, the information and communication facilities, and the other social services. These public facilities and services should not be a bottleneck for the implementation of private investment projects.

Chapter 9 Optimal Power Development Plan

This chapter sets forth the optimal power development plan for Zambia based on the optimal plans for power source development, international power interchange, and the transmission and distribution systems. It also treats selected projects thought to require assistance from Japan for implementation of the optimal power development plan.

9.1 Formulation of Optimal Power Development Plan

In formulating the optimal plan, the Study Team examined and analyzed the following two scenarios.

- Scenario 1: self-sufficient supply of power

  Premised on satisfaction of the domestic demand entirely with domestic power sourcles, in the interest of energy security.

- Scenario 2: power interchange through SAPP

  Premised on delayed development of domestic sources taking account of power import (through power interchange) from SAPP, in the interest of economic merit and feasibility.

Examination of these two scenarios revealed that both have certain problems, as follows.

- Scenario 1

  Development of hydropower sources requires a lot of time and money. Reliance solely on development of hydropower sources in Zambia would make it impossible to maintain the energy balance in the short term and result in supply shortage. In addition, there is not a sufficient volume of other energy resources (e.g., coal) in Zambia, and this would make it difficult to resolve the energy shortage for the time being. As such, it would also be necessary to consider the case of import of energy resources.

- Scenario 2

  Over the short term, the supply of power will probably remain on the short side in other SAPP countries as well as Zambia, and it would therefore be difficult to purchase power through SAPP on a stable basis. It may also be noted that the situation of power source development in SAPP countries is lagging due to factors such as a lack of funds, and a reduction of the amount of power source development domestically based on reliance on power interchange would entail high risks. There is, in addition, a substantial lack of clarity about the future prices to be applied in power interchange, and it is not certain whether a dependence on interchange would be linked to a cost reduction.

In light of these issues, the Study Team applied the following policy in formulation of the optimal power development plan.

- Scenario 1

The Study Team will examine the case of import of energy resources for use in domestic power generation (Scenario 1-2) in addition to that of dependence entirely on domestic energy resources (Scenario 1-1).

- Scenario 2

Because of the high risks associated with delayed development of domestic power sources by relying on power development among other SAPP countries, Zambia will not implement a power development plan premised on active construction of international interconnections. However, as a member of SAPP, Zambia must work for achievement of power interchange in times of emergency, both for itself and between neighboring countries through it. It therefore shall be assumed that Zambia will make plans so that its transmission system will be able to cope with international interchange requirements. This factor shall be taken into account in the case of both Scenario 1-1 and Scenario 1-2.

The Study Team formulated the optimal power development plan in accordance with this policy. Table 9.1 shows the total investment in the case of Scenario 1-1, and Table 9.2, that in the case of Scenario 1-2.

Table 9.1 Total investment in Scenario 1-1

Unit: million US$

	2010-2015	2016-2020	2021-2025	2026-2030	Total
Generation	1,054	4,446	2,952	3,017	11,469
Transmission	1,583	371	675	98	2,728
Total	2,637	4,817	3,627	3,115	14,197

Table 9.2 Total investment in Scenario 1-2

Unit: million US$

	2010-2015	2016-2020	2021-2025	2026-2030	Total
Generation	1,054	3,358	2,678	3,150	10,240
Transmission	1,583	324	86	348	2,341
Total	2,637	3,682	2,764	3,498	12,581

As is clear from these figures, the requisite investment would be lower in Scenario 1-2, by about 1,616 million dollars. These estimates, however, are for the initial investment and do not include cost of fuel (coal). Based on the state of progress in the existing projects, the development will be exactly the same as in the plan up to 2015. At present, there are absolutely no prospects for the import of coal assumed in Scenario 1-2. From now on, studies must be made of items such as import sources, transport principals, and form of supply to power stations.

9.2 Proposal regarding Cooperate Project

9.2.1 Proposal of a project for assistance

(1) Rolling of the power development master plan (TA project)

The master plan for power development prepared in this study is to be officially approved by the Zambian government (through the Ministry of Energy and Water Resources) as the national long-term power development plan.

The following two points are thought to be important in moving the long-term plan into implementation.

- ✓ Formulation of medium-term (three - five-year) and short-term (one-year) plans based on the long-term ones for specification of what must be done in the near future.
- ✓ Periodic revision of the long-term plan for reflection of the supply-demand situation and the project progress.

Approaches on these agenda are expected to be made by staff of the DOE on their own initiative. Considering the staffing limitations and paucity of experience so far, as well as Study Team experiences in implementation of this study, the DOE staff will require some sort of support for a certain period. More specifically, the task will probably require a technical assistance project involving the dispatch of a long-term expert to ascertain overall matters such as the scheduling for updating of the power development plan and a short-term expert in constituent technologies such as demand forecasting, power source plans, transmission plans, and distribution plans.

(2) Distribution master plan (development study)

This project was proposed by the counterpart institution (DOE) to fill the gap between the previously formulated rural electrification (RE) master plan and the power development master plan formulated in this study.

In Zambia, there has not been sufficient replacement and reinforcement of existing distribution facilities. Overall, distribution facilities are marked by a high degree of deterioration and chronic overload in operation. Implementation of a distribution master plan nationwide from a comprehensive perspective is required for improvement of the current status, replacement and reinforcement of distribution facilities, and reduction of distribution loss. Unlike the replacement and reinforcement of generation and transmission facilities, which entail comparatively large-scale construction, the period from the drafting of plans to the execution of the construction work would presumably be relatively short.

As noted in Chapter 9, the distribution plan prepared in this study does not cover all regions and distribution facilities in Zambia. This work would consequently have to be promoted by the extension of coverage to the regions and facilities not covered in this study.

(3) Potential hydropower study (development study)

Although a study has been made of potential hydropower in North-Western Province[7], there has not been a nationwide study of this sort. As noted in Chapter 3, statistics compiled by the World Energy Council (WEC) contain the following estimates.

- Theoretical potential hydropower: 53 TWh p.a.
- Technically exploitable potential: 30 TWh p.a.
- Economically exploitable potential: 11 TWh p.a.

The estimate for economically exploitable potential corresponds fairly neatly with the total already developed, and that for technically exploitable potential, with the sum of the total already developed and the total for candidate projects owned by the government (OPPPI).

There has been a sufficient supply of power thus far from the three major hydropower stations (Victoria Falls, Kariba North Bank, and Kafue Gorge), and this presumably accounts for the low degree of interest in potential hydropower. As clarified in the study, the hydropower projects that are already candidates for development will barely be able to meet the power demand up to 2030, and there is a need for study of prospective sources in the subsequent years. In addition, electrification by mini hydropower sources is one of the promising options for remote rural areas not covered in plans for grid extension for the foreseeable future. This, too, points to a need for a nationwide uniform study of potential hydropower, including mini hydropower.

More specifically, there is a need for study of the possibilities for construction of run-of-river power stations not only on the big international rivers (Zambezi and Luapula) but also on their tributaries (in Western and Luapula provinces) and on small-scale rivers in the Northern and Eastern provinces. Studies should also consider the implementation of feasibility studies at certain promising locations and link them to early project implementation.

(4) Hydropower site feasibility study (development study)

As shown in Table 6.5, feasibility studies have not yet been started for many of the 16 hydropower development projects owned by the OPPPI. The projects on the Zambezi and Luapula rivers are particularly important as they are on a large scale and their combined capacity of 2,470 MW would account for more than half of the total to be developed in the years leading up to 2030. Because they involve internatinonal rivers, the development will presumably be executed jointly with Zimbabwe or the Democratic Republic of the Congo. As such, they will require a longer development lead time than purely domestic projects.

Recent years have seen mounting concern about the impact of hydropower development on the environment and society. In not a few cases, hydropower development in developing countries has been deferred because of environmental and social issues. This points to a need for assessment with reference not only to Zambia's environmental standards but also the environmental guidelines of JICA and other international aid institutions. In light of these

[7] NORPLAN A.S (2000), “Small Hydropower Pre-Investment Study North-Western Province, Zambia”

factors, it would also be effective to conduct the feasibility studies with Japanese ODA while monitoring the activities of the World Bank and other multilateral aid institutions.

9.2.2 Package of support for expecting hydropower facilities

Project for expansion of the Lusiwasi power station

The particulars of the Lusiwasi project are presented in Section 6.1.2, which describes the progress of power source development projects, and the case study in Chapter 10. The project consists of two plans, one for an increase in the capacity of the existing station, which has one of 12 MW (four 3-MW units), by 40 MW (through installation of two 20-MW units), and the other for construction of a new reservoir upstream of the existing station and a new run-of-river hydropower station (installed with two 5-MW units for an output of 10 MW) downstream of this reservoir. (See the attached figure.)

ZESCO is currently conducting a feasibility study, and the scheme for development after the study has not yet been defined. There consequently appears to be ample room for receipt of assistance from Japan for materialization of the project. It may also be noted that the project is a composite of two plans, one plan for capacity enlargement and the other for construction of a new station. This holds the prospect of assistance for one or the other individually, and heightens the flexibility as regards various assistance schemes.

The following is a rough estimate of the development cost.

Table 9.3 Estimate of development cost for the Project

	Upstream part	Expansion part
Capacity (MW)	10 (5 x 2units)	40 (20 x 2units)
Construction Period	14 months	28 months
Project Cost (million US$)	32.68	101.32

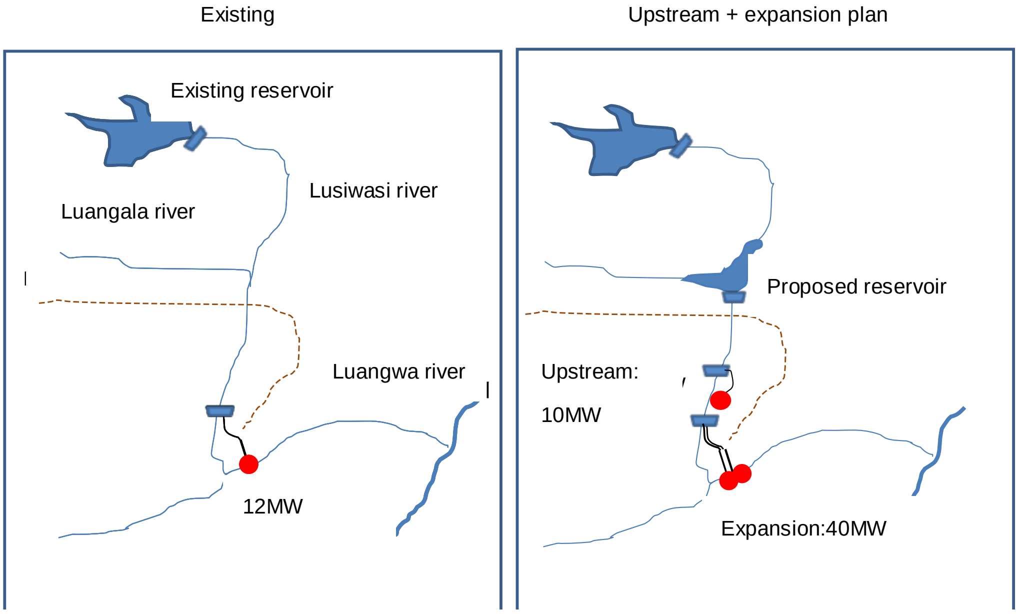

Figure 9.1 Outline about Lusiwasi ExpansionProject

9.2.3 Package of support for expecting transmission facilities

Procurement of funds is a major issue for moving the master (long-term) plan formulated in this study into the stage of implementation. As described above, the investment required for power source and transmission line facilities over the 21-year period from 2010 to 2030 will be in the range of 12.6 - 14.2 billion dollars[8] in total and average in the range of 500 million - 1 billion dollars per year. The magnitude of these figures comes into focus when it is considered that the total national budget for public works investment in Zambia is currently around 500 million dollars per year. There are hopes for participation of private capital, as suggested by the negotiations now under way in accordance with official policy for projects in the power sector, and particularly in the generation division. On the other hand, regarding transmission one it is less hopes for participation of privators.

This is because it is forcused transmission projects in very near future (2010 – 2015) especially. Following are expected package it is arranged.

(1) Improvement of the transmission and distribution network in the Lusaka area

The demand for power in the area of the national capital of Lusaka continues to grow, and the capacity of the existing transmission and distribution facilities is nearing its limits. The area is served by 330-, 132-, and 88-kv transmission systems and 33- and 11-kv distribution systems. Of these, the 88-kV system is in state of severe deterioration and applies a voltage that is in little use anywhere else around the world. As such, it poses an obstacle to operation of the transmission facilities. For this reason, the Study Team proposes installation of a new 330/132-kV substation at Lusaka South to serve the Lusaka area, expansion of the 132-kV

8 The figure here does not include distribution.

transmission and 33-kV distribution networks, and elimination of the dilapidated 88-kV transmission network. The resulting increase in transmission and distribution facility capacity and unification of voltage classes will improve facility operation and increase reliability.

-Period of implementation：2010-2015

-Subject facilities

a. Substations

330/132-kV Lusaka South substation (newly installed)

Five 132/33-kV substations

(Mapepe, Conventry A, Waterworks, Woodland, and Avondale) (newly installed)

17 distribution substations(33/11-kV) (reinforcement)

b. Transmission lines

132kVtransmission lines (extension by 216km)

33-kV distribution lines (extension by 96 km)

Table 9.4 Example for package of support regarding transmission facilities (Lusaka area 2010～2015)

Name	Length (km)	Type
Coventry - Leopards Hill 2nd	28	132kV Wolf
Coventry - Lusaka West 2nd	7	132kV Wolf
Roma - Lusaka West 2nd	15	132kV Wolf
Leopards Hill – Avondale 1st	15	132kV Zebra
Leopards Hill – Avondale 2nd	15	132kV Zebra
Mapepe - Lusaka South 1st	20	132kV Wolf
Mapepe - Lusaka South 2nd	20	132kV Wolf
Lusaka South – Waterworks 1st	14	132kV Zebra
Lusaka South – Waterworks 2nd	14	132kV Zebra
Lusaka South – Woodlands 1st	13	132kV Zebra
Lusaka South – Woodlands 2nd	13	132kV Zebra
Lusaka South – Coventry A 1st	21	132kV Zebra
Lusaka South - Coventry A 2nd	21	132kV Zebra
33kV distribution lines	96	

Table 9.5 Requisite cost (Lusaka area 2010～2015)

Item	Cost (million USD at 2008)
Transmission Line	28
Substation (for Transmission)	35
Distribution Line	13
Substation (for Distribution)	11
Total	87

(2) Voltage measure (stabilizing voltage) in the Copperbelt area

Copper mining, one of Zambia's major industries, is concentrated in this area, which is also a power demand center occupying about half of the total demand in the country. At present, however, it does not contain a power source, and depends on sources in southern Zambia (Kariba North and Kafue Gorge) for its supply. As a result, the supply is characterized by significant voltage drop due to the long-distance, high-capacity transmission, and by fluctuation of voltage accompanying that in load among large-scale customers (mines). Measures to stabilize voltage are consequently necessary, also for stable operations in copper-related industries. The Study Team therefore proposes input of the following facilities to stabilize voltage in the northern region. The SVC input would not be necessary if a coal-fired power station is built at Kitwe.

-Period of implementation：2010-2015

-Subject facilities：

a. Substations

Intermediate switching station (one, newly installed)

SVC, plus or minus 100 MVar (one, at Kitwe)

b. Transmission lines

Table 9.6 Example unit for support (Copperbelt area 2010～2015)

Name	Length (km)	Type
Luiano - Kansanshi 2nd	127	330kV 2-Bison
Kansanshi – Lumwana 2nd	72	330kV 2-Bison

Table 9.7 Requisite cost (Copperbelt area 2010～2015)

Item	Cost (million USD at 2008)
Transmission Line	22
Substation (Switching Station)	20
SVC	10
Total	52

(3) Improvement of transmission lines in the southern region

In this region, there are plans for development of large-scale power sources, such as a coal-fired station at Maamba and hydropower stations at Batoka Gorge and Devil Gorge. In addition, power interchange would be conducted through the transmission network in this region upon construction of an international interconnection with Namibia. For the future Zambian power system, the transmission lines in this region are therefore among the most important. Because of this, it is essential to bolster the transmission network in this region in preparation for the future. The Study Team proposes installation of the following facilities in order to encourage the development of new power sources and expand the international interchange power.

-Period of implementation：2010-2015

-Subject facilities

a. Substations

Two substations (Muzuma, Victoria Falls) (reinforcement)

Two substations (Choma, Monze) (newly installed)

b. Transmission lines

Voltage upgrade (220kV→330kV）348km

330-kV transmission lines (extension by 725km)

220 kV transmission lines (extension by 224km)

132kVtransmission lines (extension by 132km)

Table 9.8 Example unit for support (Southern region 2010～2015)

Name	Length (km)	Type
Victoria Falls – Muzuma Upgrade	159	330kV 2-Bison
Muzuma – Kafue Town Upgrade	189	330kV 2-Bison
Sesheke - Victoria Falls 2nd	224	220kV Bison
Victoria Falls – Maamba	180	330kV 2-Bison
Maamba – Muzuma	55	330kV 2-Bison
Maamba- Kafue West 1st	245	330kV 2-Bison
Maamba- Kafue West 2nd	245	330kV 2-Bison
Muzuma – Choma 1st	26	132kV Wolf
Muzuma – Choma 2nd	26	132kV Wolf
Choma – Monze	80	132kV Wolf

Table 9.9　　　　　Requisite cost (Southern region 2010～2015)

Item	Cost (million USD at 2008)
Transmission Line	352
Substation	42
Total	394

(4) Improvement of transmission lines in the northeastern region

The northeastern part of Zambia is currently served by a 66-kV transmission network, but the voltage is low for the transmission distance, and this is causing problems of voltage drop and transmission loss. Future plans for this region include international interconnection with Tanzania and development of hydropower sources at Lusiwasi, Kundabwika, and Kabwelume. Improvement of the transmission network is also required for promotion of this hydropower development.

In light of the above, the Study Team proposes input of the following facilities for promotion of power source development and voltage stabilization in the northeastern region.

-Period of implementation：2010-2015

-Subject facilities

a. Substaions

Six substatations (Kasama, Nakonde, Mporokoso, Pensulo, Chinsali, Mbala) (reinforcement)

b. Transmission lines

330-kV transmission lines (extension by 1,628 km)

132-kV transmission lines (extension by 607 km)

Table 9.10　Example unit for support (Northeastern region 2010～2015)

Name	Length (km)	Type
Pensulo – Kasama 1st	380	330kV 2-Bison
Pensulo – Kasama 2nd	380	330kV 2-Bison
Pensulo – Kabwe 2nd	298	330kV 2-Bison
Kasama – Nakonde 1st	210	330kV 2-Bison
Kasama – Nakonde 2nd	210	330kV 2-Bison
Kasama – Mporokoso	150	330kV 2-Bison
Kasama – Mbala 1st	161	132kV Wolf
Kasama – Mbala 2nd	161	132kV Wolf
Kasama – Chinsali	105	132kV Wolf
Pensulo – Lusiwasi 1st	90	132kV Wolf
Pensulo – Lusiwasi 2nd	90	132kV Wolf

Table 9.11　Requisite cost (Northeastern region 2010～2015)

Item	Cost (million USD at 2008)
Transmission Line	445
Substation	45
Total	490

(5) Improvement of transmission network around Itezhi-tezhi

Along with construction of the Itezhi-tezhi power station, there are plans for construction of a transmission line to link it with Lusaka. This power station will also be the point for supply of power to the western region further in the future. Electrification of areas in the western region of Zambia will require construction of a transmission line leading westward from Itezhi-tezhi. The investment required for this transmission network conditioning is shown below.

-Period of implementation：2010-2015

-Subject facilities

a. Substaions

Mumbwa substation (newly installed)

Two switching stations (Kaoma,Mongu) (newly installed)

b. Transmisson lines

330-kV transmission lines (extension by 210 km)
220-kV transmission lines (extension by 290 km)
132-kV transmission lines (extension by 545 km)

Table 9.12　Example unit for support (Itezhi-tezhi region 2010～2015)

Name	Length (km)	Type
Lusaka West – Mumbwa 1st	105	330kV 2-Bison
Lusaka West – Mumbwa 2nd	105	330kV 2-Bison
Mumbwa – Itezhi tezhi 1st	145	220kV Bison
Mumbwa – Itezhi tezhi 2nd	145	220kV Bison
Itezhi tezhi – Kaoma 1st	180	132kV Wolf
Itezhi tezhi – Kaoma 2nd	180	132kV Wolf
Kaoma – Mongu	185	132kV Wolf

Table 9.13　Requisite cost (Itezhi-tezhi region 2010～2015)

Item	Cost (million USD at 2008)
Transmission Line	177
Substation	30
Total	207

Although each of these transmission and distribution projects must be executed in the near future (within the next five years), they entail a high expense for which it may be impossible to raise funds all at once. The Study Team consequently considered measures for phased implementation of these projects.

The following are two conceivable options for approaches to phased implementation of the projects.

(a) Ordering of the priority of regions for development, followed by improvement/expansion of the system in specific regions based on this priority

(b) System improvement/expansion without satisfaction of the N-1 condition as a first step, followed by addition of transmission lines and satisfaction of the N-1 condition once funds have been procured

Of these two, the (b) approach cannot be recommended, considering the current status of the Zambian system. More specifically, the current system has a poor voltage stability, which means that satisfaction of the N-1 condition or lack of the same would not make a big difference in the amount of initial investment. In addition, construction would be made inefficient by division of the transmission line work into two phases. As such, the following section focuses on the (a) approach.

Priority 1st: "Improvement of the transmission and distribution network in the Lusaka area", and "Voltage measure in the Copperbelt area"

In the first place, the projects thought to have the highest priority are that for transmission and distribution lines in the Lusaka area and the measures for voltage stability in the Copperbelt region. This is because the capacity for transmission to these important areas is now reaching its limits, and it may become impossible to send power to them. Power source development at Kitezhi-tezhi and Kariba North Extension is slated for the coming years, and effective use of the power from these sources requires execution of these two projects.

Projects for power source lines and international interconnections may be cited as having the next-highest priority. This account takes up three for conditioning of transmission networks in the southern and northeastern regions and around Itezhi-tezhi. Their order of priority is as follows.

Priority 2nd : Improvement of transmission lines in the southern region

This region is an important zone for power source development plans, which envision the development of large-scale sources at Maamba and other sites at an early stage in addition to the construction of an international interconnection in the ZIZABONA project. This is to be followed by development of other large-scale hydropower stations at sites such as Devil's Gorge and Batoka Gorge. Because of the prospect of continued supply shortage over the coming years, the power interchange through the interconnection and supply from the coal-fired power station at Maamba are of crucial importance for the Zambian system. These factors lay behind the high priority of this transmission development project.

Priority 3rd : Improvement of transmission lines in the northeastern region

In this region, there are plans for development of a power source at Kalungwishi and construction of an international interconnection with Tanzania. The priority is a little lower than that of the southern region, because the Kalungwishi source will be developed somewhat later than Maamba, and there are not good prospects for a large supply of power from Tanzania.

And a project for construction of a transmission line from Itezhi-tezhi to Lusaka is already proceeding in step with the power station construction. It may also be noted that, while it is important for voltage stabilization and rural electrification in the western region, the construction of a transmission line westward from Itezhi-tezhi has less priority than transmission to Lusaka, the national capital, and Copperbelt, the center of demand associated with mining.

Appendix

Table A- 1 Result of the demand forecast at substations

Peak Demand (MW)

Substation	2008	2010	2015	2020	2025	2030
Kalabo	1	1.1	1.6	1.8	2.4	3.1
Mongu	3	3.4	4.7	5.4	7.2	9.4
Senanga	1	1.1	1.6	1.8	2.4	3.1
Sesheke	1	1.1	1.6	1.8	2.4	3.1
Zambezi	5	5.6	7.8	9	12	15.7
Kazunlula	4	4.5	6.3	7.2	9.6	12.5
Vincria Falls	15	16.9	23.5	27.1	35.9	47
Maamba	5	5.6	7.8	9	12	15.7
Muzuma	10	11.3	15.6	18.1	23.9	31.3
Nampundwe	12	13.5	18.8	21.7	28.7	37.6
Mazabuka	38	42.8	59.4	68.7	91	106.6
Monze			5.6	7.3	9.6	12.5
Kafue Town	30	33.8	46.9	54.2	71.8	94
Mapepe	14	15.8	21.9	25.3	33.5	43.9
Water Works1	30	33.8	46.9	54.2	71.8	94
Water Works2	40	45	62.6	72.3	95.8	125.3
Coventry Street	15	16.9	23.5	27.1	35.9	47
Coventry Street	80	90	125.1	144.6	191.5	250.6
Coventry Street	25	28.1	39.1	45.2	59.9	78.3
Lusaka West	70	78.8	109.5	126.5	167.6	219.3
Roma	100	112.5	156.4	180.7	239.4	313.3
Chirundu	1	1.1	1.6	1.8	2.4	3.1
Chongwe	7	7.9	10.9	12.6	16.8	21.9
Fig Tree	6	6.8	9.4	10.8	14.4	18.8
Kabwe	27	30.4	42.2	48.8	64.6	84.6
Kapiri Muposi	12	13.5	18.8	21.7	28.7	37.6
Mpongwe	6	6.8	9.4	10.8	14.4	18.8
BRKHL	13	14.6	20.3	23.5	31.1	40.7
Cosak	50	3	78.2	81.9	87.8	96.7
Chisenga	24	31	41.5	43.4	46.6	51.3
Chambishi	25	3	39.1	40.9	43.9	48.3
Solwezi	10	11.3	15.6	16.3	17.5	19.3
Kabundi	16	18	25	26.2	28.1	30.9
Stadium	70	78.8	109.5	114.6	123	135.4
Avenue	53	94.6	117.9	123.4	132.4	145.8

Substation	2008	2010	2015	2020	2025	2030
Bancroft	77	106.6	180.4	188.9	202.6	223.1
Bancroft North	20	22.5	31.3	32.8	35.2	38.7
Kansanshi	90	101.3	140.8	147.4	158.2	174.1
Lumwana1	30	33.8	46.9	49.1	52.7	58
Lumwana2	15	16.9	23.5	24.6	26.4	29.1
Chambishi	10	11.3	15.6	16.3	17.5	19.3
Kansuswa	12	13.5	18.8	19.7	21.1	23.2
Mufulira	57	64.1	89.2	93.4	100.2	110.3
Kankoyo	34	2	2	2.1	2.2	2.5
Mufulira West	6	6.8	9.4	9.8	10.6	11.6
C.S.S.(Kitwe)	24	27	37.5	39.3	42.1	46.4
Turf	14	15.8	21.9	22.9	24.6	27.1
Kitwe	35	39.4	54.7	57.3	61.4	67.6
Mill	32	36	50.1	52.4	56.3	61.9
Nkana	26	29.3	40.7	42.6	45.7	50.3
Mindola	35	2	54.7	57.3	61.4	67.6
Fikondi	5	5.6	7.8	8.2	8.8	9.6
Chibulma	8	9	12.5	13.1	14	15.5
Maposa	1	1.1	1.6	1.7	1.8	2
Pamodzi	28	31.5	43.8	45.9	49.2	54.2
Depot Road	18	20.3	28.2	29.5	31.7	34.9
Skyways	43	48.4	67.3	70.5	75.6	83.2
Ndola Refinery	2	2.3	3.1	3.2	3.5	3.8
Mushili	5	5.6	7.8	8.2	8.8	9.6
Bwana Mukubwa	11	12.4	17.2	18	19.3	21.3
Baluba	13	14.6	20.3	21.3	22.8	25.1
Maclaren	1	1.1	1.6	1.7	1.8	2
Irwin	1	1.1	1.6	1.7	1.8	2
Roan	10	11.3	15.6	16.3	17.5	19.3
Luanshya Minic	16	18	25	26.2	28.1	30.9
Stoke	1	1.1	1.6	1.7	1.8	2
Serenje	1	1.1	1.6	1.8	2.4	3.1
Mfuwe	5	5.6	7.8	9	12	15.7
Chipata	7	7.9	10.9	12.6	16.8	4.9
Azele	2	2.3	3.1	3.6	4.8	6.3
KANON	6	6.8	9.4	10.8	14.4	18.8
KAOMB	7	7.9	10.9	12.6	16.8	21.9

Substation	2008	2010	2015	2020	2025	2030
Mpika	3	3.4	4.7	5.4	7.2	9.4
Chinsali	1	1.1	1.6	1.8	2.4	3.1
Isoka	1	1.1	1.6	1.8	2.4	3.1
Nakonde	1	1.1	1.6	1.8	2.4	3.1
Mbala	4	4.5	6.3	7.2	9.6	12.5
Kasama	4	4.5	6.3	7.2	9.6	12.5
Luwingu	2	2.3	3.1	3.6	4.8	6.3
Mansa	2	2.3	3.1	3.6	4.8	6.3
Kawambwa Tea	2	2.3	3.1	3.6	4.8	6.3
Mporokoso	2	2.3	3.1	3.6	4.8	6.3
Frontier	26	29.3	40.7	40.7	40.7	40.7
Kaoma		3.8	5.4	7.0	9.2	12.0
Chavuma		0.3	0.4	0.6	0.8	1.0
Kabompo		2.2	3.1	4.1	5.3	7.0
Mufumbwe		1.3	1.8	2.3	3.1	4.0
Mwinilunga		1.9	2.7	3.5	4.6	6.0
Zambezi		2.2	3.1	4.1	5.3	7.0
Lukuku		2.2	3.1	4.1	5.3	7.0
Mbereshi		2.2	3.1	4.1	5.3	7.0
Nchelenge		2.6	3.6	4.7	6.1	8.0

Table A- 2 Transmission Development Plan (Scenario 1-1)

Id	From	To	Install Year	Length (km)	Voltage (kV)	Conductor Type
3	Kariba North	Leopards Hill	2010-2015	123	330	2-Bison
2	Kabwe	Pensulo	2010-2015	298	330	2-Bison
1	Kabwe	Lusaka West	2010-2015	100	330	2-Bison
2	Luano	Kansanshi	2010-2015	197	330	2-Bison
1	Pensulo	Kasama	2010-2015	380	330	2-Bison
2	Pensulo	Kasama	2010-2015	380	330	2-Bison
1	Kafue West	Maamba	2010-2015	245	330	2-Bison
2	Kafue West	Maamba	2010-2015	245	330	2-Bison
2	Kafue West	Lsaka West	2010-2015	34	330	2-Bison
1	Kafue Town	Muzuma(UP Grade)	2010-2015	189	330	2-Bison
2	Kansanshi	Lumuwana	2010-2015	72	330	2-Bison
1	Kasama	Nakonde	2010-2015	210	330	2-Bison
2	Kasama	Nakonde	2010-2015	210	330	2-Bison
1	Kasama	Mporokoso	2010-2015	150	330	2-Bison
1	Victoria Falls	Muzuma(UP Grade)	2010-2015	159	330	2-Bison
1	Victoria Falls	Batoka Gorge	2010-2015	40	330	2-Bison
1	Victoria Falls	Muzuma	2010-2015	159	330	2-Bison
1	Batoka Gorge	Devil Gorge	2010-2015	70	330	2-Bison
1	Devil Gorge	Maamba	2010-2015	70	330	2-Bison
1	Maamba	Muzuma	2010-2015	55	330	2-Bison
2	Kansanshi	Lumuwana	2010-2015	72	330	2-Bison
1	Mumbwa	Lusaka West	2010-2015	105	330	2-Bison
2	Mumbwa	Lusaka West	2010-2015	105	330	2-Bison
2	Luano	Michelo	2010-2015	31.9	220	2-HD153
1	Luano	Stadium	2010-2015	16.4	220	2-Lion
2	Luano	Stadium	2010-2015	16.4	220	2-Lion
1	Michelo	Bankroft	2010-2015	10	220	2-HD153
2	Michelo	Bankroft	2010-2015	10	220	2-HD153
2	Victoria Falls	Sesheke	2010-2015	224	220	Bison
1	Mumbwa	Itezhi-Tezhi	2010-2015	145	220	Bison
2	Mumbwa	Itezhi-Tezhi	2010-2015	145	220	Bison
2	Coventry	Leopards Hill	2010-2015	28	132	Wolf
2	Coventry	Lusaka West	2010-2015	7	132	Wolf
2	Roma	Lusaka West	2010-2015	15	132	Wolf

Id	From	To	Install Year	Length (km)	Voltage (kV)	Conductor Type
1	Leopards Hill	Avondale	2010-2015	15	132	Zebra
2	Leopards Hill	Avondale	2010-2015	15	132	Zebra
1	Kasama	Mbala	2010-2015	161	132	Wolf
2	Kasama	Mbala	2010-2015	161	132	Wolf
1	Kasama	Chinsali	2010-2015	105	132	Wolf
1	Pensulo	Lusiwasi	2010-2015	90	132	Wolf
2	Pensulo	Lusiwasi	2010-2015	90	132	Wolf
1	Pensulo	Kanon	2010-2015	20	132	Wolf
2	Pensulo	Kanon	2010-2015	20	132	Wolf
1	Pensulo	Mutindo	2010-2015	110	132	Wolf
2	Pensulo	Mutindo	2010-2015	110	132	Wolf
1	Lusiwasi	Msoro (Upgrade)	2010-2015	115	132	Wolf
2	Lusiwasi	Msoro	2010-2015	115	132	Wolf
1	Lusiwasi	Mfuwe	2010-2015	80	132	Wolf
2	Lusiwasi	Mfuwe	2010-2015	80	132	Wolf
1	Kabwe	Kapiri Mposhi	2010-2015	96	132	Wolf
1	Itezhi-Tezhi	Kaoma	2010-2015	180	132	Wolf
2	Itezhi-Tezhi	Kaoma	2010-2015	180	132	Wolf
1	Kaoma	Mongu	2010-2015	185	132	Wolf
1	Nampundwe	Lusaka West	2010-2015	60	132	Wolf
1	Kafue Town	Mazabuka	2010-2015	52	132	Zebra
2	Kafue Town	Mazabuka	2010-2015	52	132	Zebra
1	Mazabuka	Monze	2010-2015	60	132	Wolf
1	Mapepe	Lusaka South	2010-2015	20	132	Wolf
2	Mapepe	Lusaka South	2010-2015	20	132	Wolf
1	Lusaka South	Waterworks	2010-2015	14	132	Zebra
2	Lusaka South	Waterworks	2010-2015	14	132	Zebra
1	Lusaka South	Woodlands	2010-2015	13	132	Zebra
2	Lusaka South	Woodlands	2010-2015	13	132	Zebra
1	Lusaka South	Coventry A	2010-2015	21	132	Zebra
2	Lusaka South	Coventry A	2010-2015	21	132	Zebra
1	Coventry A	Coventry B	2010-2015	1	132	Zebra
2	Coventry A	Coventry B	2010-2015	1	132	Zebra
1	Muzuma	Choma	2010-2015	26	132	Wolf
2	Muzuma	Choma	2010-2015	26	132	Wolf
1	Choma	Monze	2010-2015	80	132	Wolf

Id	From	To	Install Year	Length (km)	Voltage (kV)	Conductor Type
1	Mutinond	Luchene	2010-2015	45	132	Wolf
2	Mutinond	Luchene	2010-2015	45	132	Wolf
2	Stadium	Avenue	2010-2015	1.27	66	2-HD124
3	Stadium	Avenue	2010-2015	1.27	66	2-HD124
2	Chisenga	Luano	2010-2015	11.4	66	Lynx
2	Mufulira	Kankoyo	2010-2015	0.4	66	2-HD124
2	Maposa	Dola Hill	2010-2015	21.3	66	Lynx
1	Maposa	Pamodzi	2010-2015	25	66	Lynx
2	Maposa	Pamodzi	2010-2015	25	66	Lynx
2	Ndola Refinery	Skyways	2010-2015	1.5	66	HD124
2	Pamodzi	Depot Road	2010-2015	6.3	66	Lynx
2	Kanon	Kaomb	2010-2015	21	66	Wolf
2	KZNGL	Victoria Falls	2010-2015	80	66	Wolf
	New SWS (Internal of Kabwe – Kitwe, LuanoLine)		2010-2015			
	Lusaka South SS (Internal of Leopards Hill – Kafue West Line)		2010-2015			
2	Kabwe	Lusaka West	2015-2020	100	330	2-Bison
3	Kafue West	Lsaka West	2015-2020	34	330	2-Bison
2	Devil Gorge	Maamba	2015-2020	70	330	2-Bison
1	Kundabwika	Mporokoso	2015-2020	95	330	2-Bison
1	Kafue Gorge Lower	Lusaka South	2015-2020	45	330	2-Bison
1	Kafue Gorge Lower	Lusaka South	2015-2020	45	330	2-Bison
1	Mukushi	Lunsemfwa	2015-2020	10	132	Wolf
2	Mukushi	Lunsemfwa	2015-2020	10	132	Wolf
1	Kundabwika	Kabwelume	2015-2020	25	132	Zebra
2	Kundabwika	Kabwelume	2015-2020	25	132	Zebra
1	Kundabwika	Nchelenge	2015-2020	75	132	Wolf
1	Kabwelume	Kawambwa Tea	2015-2020	30	132	Wolf
1	Msoro	Chipata(Up grade)	2015-2020	80	132	Wolf
2	Msoro	Chipata	2015-2020	80	132	Wolf
1	Kabwe	Lunsemfwa	2015-2020	65	132	Zebra
2	Kabwe	Lunsemfwa	2015-2020	65	132	Zebra
1	Kabwe	BRKHL	2015-2020	3	132	Wolf
2	Kabwe	BRKHL	2015-2020	3	132	Wolf

Id	From	To	Install Year	Length (km)	Voltage (kV)	Conductor Type
1	Kapiri Mposhi	Mpongwe	2015-2020	60	132	Wolf
1	Lumwana	Kabompo Gorge	2015-2020	70	132	Wolf
2	Lumwana	Kabompo Gorge	2015-2020	70	132	Wolf
1	Kabompo Gorge	Mwinilunga	2015-2020	100	132	Wolf
1	Kabompo Gorge	Mufumbwe	2015-2020	110	132	Wolf
1	Mufumbwe	Kabompo	2015-2020	105	132	Wolf
1	Kabompo	Mumbeji	2015-2020	80	132	Wolf
1	Mongu	Lukulu	2015-2020	160	132	Wolf
1	Lukulu	Mumbeji	2015-2020	80	132	Wolf
1	Mumbeji	Zambezi	2015-2020	75	132	Wolf
1	Zambezi	Chavuma	2015-2020	80	132	Wolf
1	Lusaka South	Chawama	2015-2020	6	132	Wolf
2	Lusaka South	Chawama	2015-2020	6	132	Wolf
1	University	Chelston	2015-2020	5	132	Zebra
2	University	Chelston	2015-2020	5	132	Zebra
1	Avondale	Chelston	2015-2020	5.7	132	Zebra
2	Avondale	Chelston	2015-2020	5.7	132	Zebra
3	Ndola Refinery	Skyways	2015-2020	1.5	66	HD124
2	Dola Hill	Pamodzi	2015-2020	3.7	66	Lynx
3	Kitwe	New SWS	2020-2025	91	330	2-Bison
4	Kitwe	New SWS	2020-2025	91	330	2-Bison
1	Leopards Hill	Mpata Gorge	2020-2025	255	330	2-Bison
2	Leopards Hill	Mpata Gorge	2020-2025	255	330	2-Bison
1	Pensulo	Mumbotuta	2020-2025	190	330	2-Bison
2	Pensulo	Mumbotuta	2020-2025	190	330	2-Bison
1	Pensulo	New SWS	2020-2025	219	330	2-Bison
2	Pensulo	New SWS	2020-2025	219	330	2-Bison
2	Kafue West	Kafue Town	2020-2025	3	330	2-Bison
2	Kafue Town	Muzuma	2020-2025	189	330	2-Bison
1	Mumbotuta	Mambilima	2020-2025	210	330	2-Bison
1	Mumbotuta	Mansa	2020-2025	130	330	2-Bison
1	Mambilima	Mambilima Site2	2020-2025	10	330	2-Bison
2	Mambilima	Mambilima Site2	2020-2025	10	330	2-Bison
1	Mambilima	Mansa	2020-2025	80	330	2-Bison
2	Kaoma	Mongu	2020-2025	185	132	Wolf
1	Makeni	Lusaka West	2020-2025	13	132	Zebra

Id	From	To	Install Year	Length (km)	Voltage (kV)	Conductor Type
2	Makeni	Lusaka West	2020-2025	13	132	Zebra
1	Matero	Lusaka West	2020-2025	15	132	Zebra
2	Matero	Lusaka West	2020-2025	15	132	Zebra
2	Batoka Gorge	Devil Gorge	2025-2030	70	330	2-Bison
3	Devil Gorge	Maamba	2025-2030	70	330	2-Bison
2	Kabompo Gorge	Mufumbwe	2025-2030	110	132	Wolf
2	Mufumbwe	Kabompo	2025-2030	105	132	Wolf
3	Lusaka South	Coventry A	2025-2030	21	132	Zebra

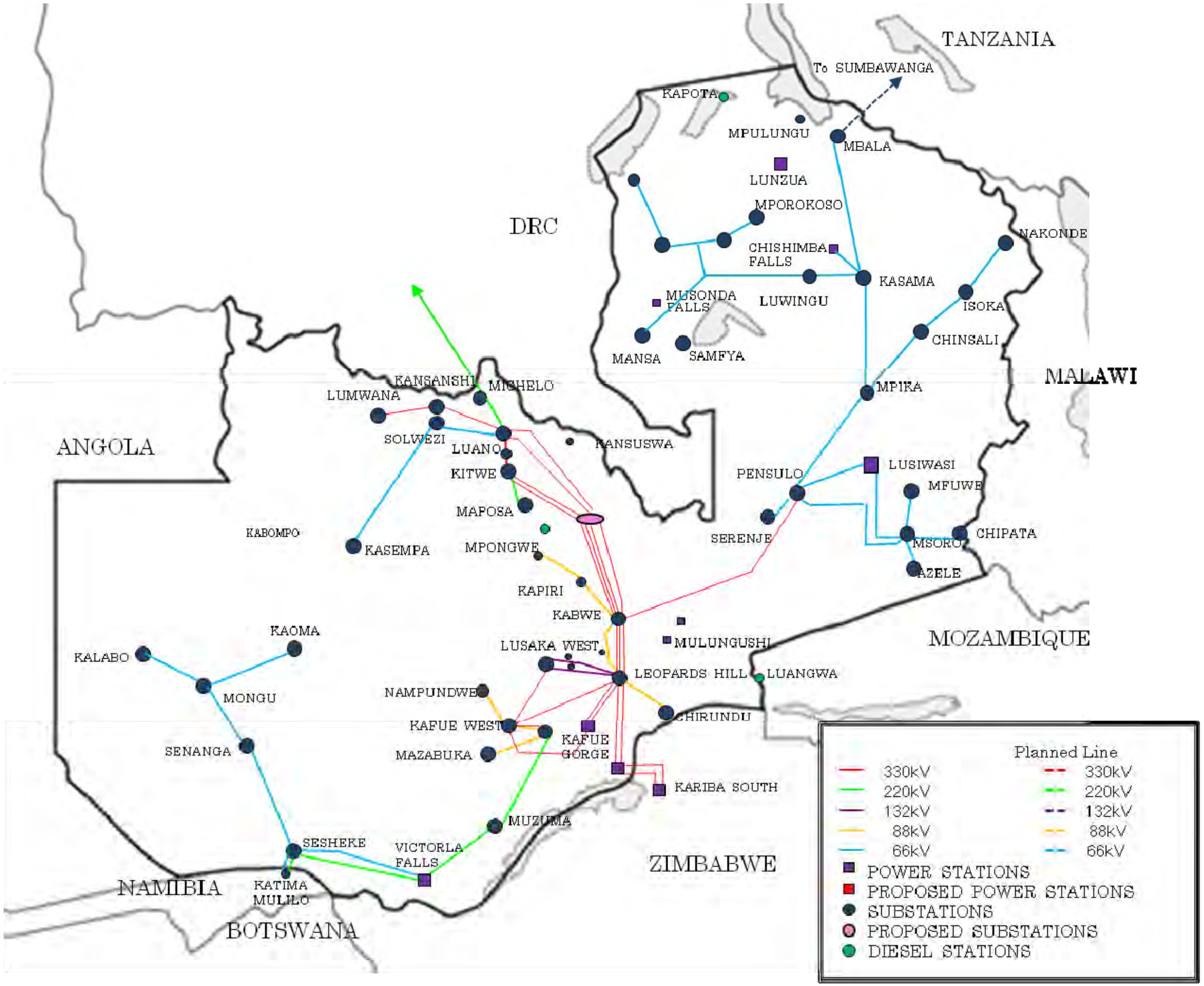

Figure A- 1 Zambian Power System on 2010

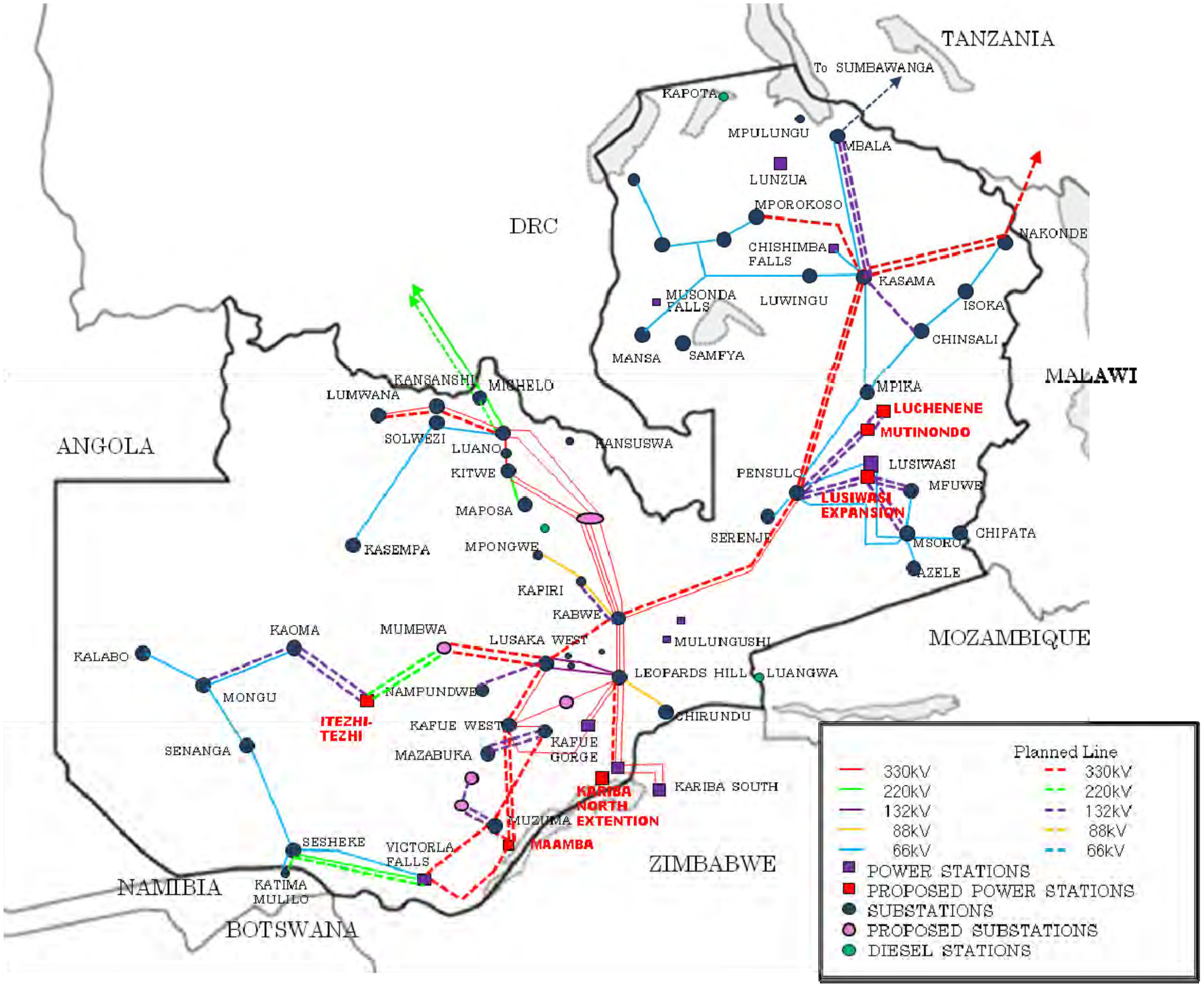

Figure A- 2 Zambian Power System on 2015 (Scenario1-1)

Figure A- 3 Zambian Power System on 2020 (Scenario1-1)

Figure A- 4 Zambian Power System on 2025 (Scenario1-1)

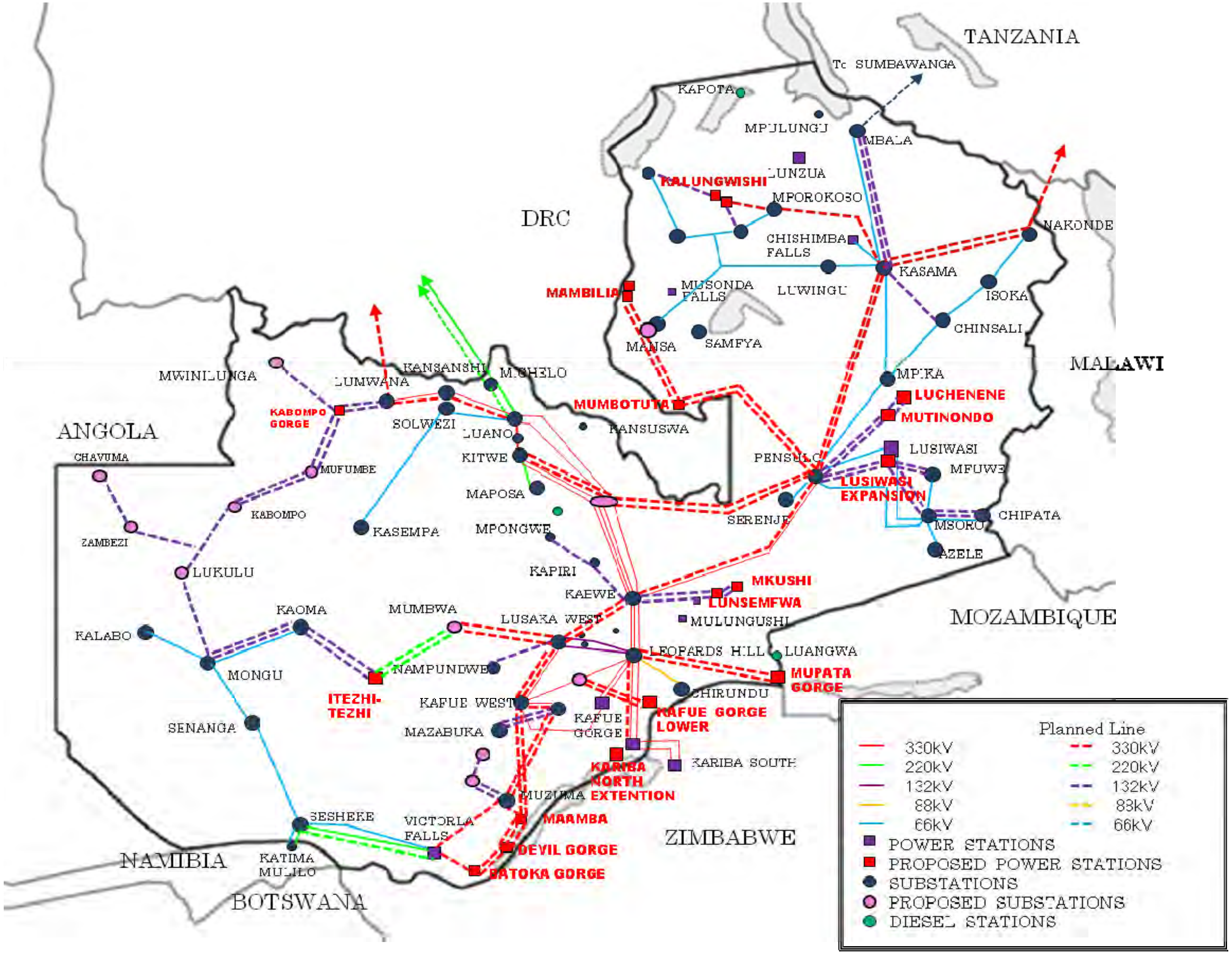

Figure A- 5 Zambian Power System on 2030 (Scenario1-1)

Table A- 3　Transmission Development Plan (Scenario 1-2)

Id	From	To	Install Year	Length (km)	Voltage (kV)	Conductor Type
3	Kariba North	Leopards Hill	2010-2015	123	330	2-Bison
2	Kabwe	Pensulo	2010-2015	298	330	2-Bison
1	Kabwe	Lusaka West	2010-2015	100	330	2-Bison
2	Luano	Kansanshi	2010-2015	197	330	2-Bison
1	Pensulo	Kasama	2010-2015	380	330	2-Bison
2	Pensulo	Kasama	2010-2015	380	330	2-Bison
1	Kafue West	Maamba	2010-2015	245	330	2-Bison
2	Kafue West	Maamba	2010-2015	245	330	2-Bison
2	Kafue West	Lsaka West	2010-2015	34	330	2-Bison
1	Kafue Town	Muzuma(UP Grade)	2010-2015	189	330	2-Bison
2	Kansanshi	Lumuwana	2010-2015	72	330	2-Bison
1	Kasama	Nakonde	2010-2015	210	330	2-Bison
2	Kasama	Nakonde	2010-2015	210	330	2-Bison
1	Kasama	Mporokoso	2010-2015	150	330	2-Bison
1	Victoria Falls	Muzuma(UP Grade)	2010-2015	159	330	2-Bison
1	Victoria Falls	Batoka Gorge	2010-2015	40	330	2-Bison
1	Victoria Falls	Muzuma	2010-2015	159	330	2-Bison
1	Batoka Gorge	Devil Gorge	2010-2015	70	330	2-Bison
1	Devil Gorge	Maamba	2010-2015	70	330	2-Bison
1	Maamba	Muzuma	2010-2015	55	330	2-Bison
2	Kansanshi	Lumuwana	2010-2015	72	330	2-Bison
1	Mumbwa	Lusaka West	2010-2015	105	330	2-Bison
2	Mumbwa	Lusaka West	2010-2015	105	330	2-Bison
2	Luano	Michelo	2010-2015	31.9	220	2-HD153
1	Luano	Stadium	2010-2015	16.4	220	2-Lion
2	Luano	Stadium	2010-2015	16.4	220	2-Lion
1	Michelo	Bankroft	2010-2015	10	220	2-HD153
2	Michelo	Bankroft	2010-2015	10	220	2-HD153
2	Victoria Falls	Sesheke	2010-2015	224	220	Bison
1	Mumbwa	Itezhi-Tezhi	2010-2015	145	220	Bison
2	Mumbwa	Itezhi-Tezhi	2010-2015	145	220	Bison
2	Coventry	Leopards Hill	2010-2015	28	132	Wolf
2	Coventry	Lusaka West	2010-2015	7	132	Wolf
2	Roma	Lusaka West	2010-2015	15	132	Wolf
1	Leopards Hill	Avondale	2010-2015	15	132	Zebra
2	Leopards Hill	Avondale	2010-2015	15	132	Zebra
1	Kasama	Mbala	2010-2015	161	132	Wolf
2	Kasama	Mbala	2010-2015	161	132	Wolf

Id	From	To	Install Year	Length (km)	Voltage (kV)	Conductor Type
1	Kasama	Chinsali	2010-2015	105	132	Wolf
1	Pensulo	Lusiwasi	2010-2015	90	132	Wolf
2	Pensulo	Lusiwasi	2010-2015	90	132	Wolf
1	Pensulo	Kanon	2010-2015	20	132	Wolf
2	Pensulo	Kanon	2010-2015	20	132	Wolf
1	Pensulo	Mutindo	2010-2015	110	132	Wolf
2	Pensulo	Mutindo	2010-2015	110	132	Wolf
1	Lusiwasi	Msoro	2010-2015	115	132	Wolf
2	Lusiwasi	Msoro	2010-2015	115	132	Wolf
1	Lusiwasi	Mfuwe	2010-2015	80	132	Wolf
2	Lusiwasi	Mfuwe	2010-2015	80	132	Wolf
1	Kabwe	Kapiri Mposhi	2010-2015	96	132	Wolf
1	Itezhi-Tezhi	Kaoma	2010-2015	180	132	Wolf
2	Itezhi-Tezhi	Kaoma	2010-2015	180	132	Wolf
1	Kaoma	Mongu	2010-2015	185	132	Wolf
1	Nampundwe	Lusaka West	2010-2015	60	132	Wolf
1	Kafue Town	Mazabuka	2010-2015	52	132	Zebra
2	Kafue Town	Mazabuka	2010-2015	52	132	Zebra
1	Mazabuka	Monze	2010-2015	60	132	Wolf
1	Mapepe	Lusaka South	2010-2015	20	132	Wolf
2	Mapepe	Lusaka South	2010-2015	20	132	Wolf
1	Lusaka South	Waterworks	2010-2015	14	132	Zebra
2	Lusaka South	Waterworks	2010-2015	14	132	Zebra
1	Lusaka South	Woodlands	2010-2015	13	132	Zebra
2	Lusaka South	Woodlands	2010-2015	13	132	Zebra
1	Lusaka South	Coventry A	2010-2015	21	132	Zebra
2	Lusaka South	Coventry A	2010-2015	21	132	Zebra
1	Coventry A	Coventry B	2010-2015	1	132	Zebra
2	Coventry A	Coventry B	2010-2015	1	132	Zebra
1	Muzuma	Choma	2010-2015	26	132	Wolf
2	Muzuma	Choma	2010-2015	26	132	Wolf
1	Choma	Monze	2010-2015	80	132	Wolf
1	Mutinond	Luchene	2010-2015	45	132	Wolf
2	Mutinond	Luchene	2010-2015	45	132	Wolf
2	Stadium	Avenue	2010-2015	1.27	66	2-HD124
3	Stadium	Avenue	2010-2015	1.27	66	2-HD124
2	Chisenga	Luano	2010-2015	11.4	66	Lynx
2	Mufulira	Kankoyo	2010-2015	0.4	66	2-HD124
2	Maposa	Dola Hill	2010-2015	21.3	66	Lynx
1	Maposa	Pamodzi	2010-2015	25	66	Lynx

Id	From	To	Install Year	Length (km)	Voltage (kV)	Conductor Type
2	Maposa	Pamodzi	2010-2015	25	66	Lynx
2	Ndola Refinery	Skyways	2010-2015	1.5	66	HD124
2	Pamodzi	Depot Road	2010-2015	6.3	66	Lynx
2	Kanon	Kaomb	2010-2015	21	66	Wolf
2	KZNGL	Victoria Falls	2010-2015	80	66	Wolf
	New SWS (Internal of Kabwe – Kitwe, LuanoLine)		2010-2015			
	Lusaka South SS (Internal of Leopards Hill – Kafue West Line)		2010-2015			
1	Kundabwika	Mporokoso	2015-2020	95	330	2-Bison
1	Kafue Gorge Lower	Lusaka South	2015-2020	45	330	2-Bison
1	Kafue Gorge Lower	Lusaka South	2015-2020	45	330	2-Bison
1	Kitwe	Kitwe Coal	2015-2020	10	330	2-Bison
2	Kitwe	Kitwe Coal	2015-2020	10	330	2-Bison
1	Kundabwika	Kabwelume	2015-2020	25	132	Zebra
2	Kundabwika	Kabwelume	2015-2020	25	132	Zebra
1	Kundabwika	Nchelenge	2015-2020	75	132	Wolf
1	Kabwelume	Kawambwa Tea	2015-2020	30	132	Wolf
1	Msoro	Chipata	2015-2020	80	132	Wolf
2	Msoro	Chipata	2015-2020	80	132	Wolf
1	Kabwe	Lunsemfwa	2015-2020	65	132	Zebra
2	Kabwe	Lunsemfwa	2015-2020	65	132	Zebra
1	Kabwe	BRKHL	2015-2020	3	132	Wolf
2	Kabwe	BRKHL	2015-2020	3	132	Wolf
1	Kapiri Mposhi	Mpongwe	2015-2020	60	132	Wolf
1	Lumwana	Kabompo Gorge	2015-2020	70	132	Wolf
2	Lumwana	Kabompo Gorge	2015-2020	70	132	Wolf
1	Kabompo Gorge	Mwinilunga	2015-2020	100	132	Wolf
1	Kabompo Gorge	Mufumbwe	2015-2020	110	132	Wolf
1	Mufumbwe	Kabompo	2015-2020	105	132	Wolf
1	Kabompo	Mumbeji	2015-2020	80	132	Wolf
1	Mongu	Lukulu	2015-2020	160	132	Wolf
1	Lukulu	Mumbeji	2015-2020	80	132	Wolf
1	Mumbeji	Zambezi	2015-2020	75	132	Wolf
1	Zambezi	Chavuma	2015-2020	80	132	Wolf
1	Lusaka South	Chawama	2015-2020	6	132	Wolf
2	Lusaka South	Chawama	2015-2020	6	132	Wolf
1	University	Chelston	2015-2020	5	132	Zebra

Id	From	To	Install Year	Length (km)	Voltage (kV)	Conductor Type
2	University	Chelston	2015-2020	5	132	Zebra
1	Avondale	Chelston	2015-2020	5.7	132	Zebra
2	Avondale	Chelston	2015-2020	5.7	132	Zebra
3	Ndola Refinery	Skyways	2015-2020	1.5	66	HD124
2	Dola Hill	Pamodzi	2015-2020	3.7	66	Lynx
3	Kafue West	Lsaka West	2020-2025	34	330	2-Bison
2	Devil Gorge	Maamba	2020-2025	70	330	2-Bison
1	Mukushi	Lunsemfwa	2020-2025	10	132	Wolf
2	Mukushi	Lunsemfwa	2020-2025	10	132	Wolf
2	Kaoma	Mongu	2020-2025	185	132	Wolf
1	Makeni	Lusaka West	2020-2025	13	132	Zebra
2	Makeni	Lusaka West	2020-2025	13	132	Zebra
1	Matero	Lusaka West	2020-2025	15	132	Zebra
2	Matero	Lusaka West	2020-2025	15	132	Zebra
3	Kitwe	New SWS	2025-2030	91	330	2-Bison
1	Leopards Hill	Mpata Gorge	2025-2030	255	330	2-Bison
2	Leopards Hill	Mpata Gorge	2025-2030	255	330	2-Bison
1	Pensulo	Mumbotuta	2025-2030	190	330	2-Bison
2	Pensulo	Mumbotuta	2025-2030	190	330	2-Bison
1	Pensulo	New SWS	2025-2030	219	330	2-Bison
2	Kafue West	Kafue Town	2025-2030	3	330	2-Bison
2	Kabompo Gorge	Mufumbwe	2025-2030	110	132	Wolf
2	Mufumbwe	Kabompo	2025-2030	105	132	Wolf
3	Lusaka South	Coventry A	2025-2030	21	132	Zebra

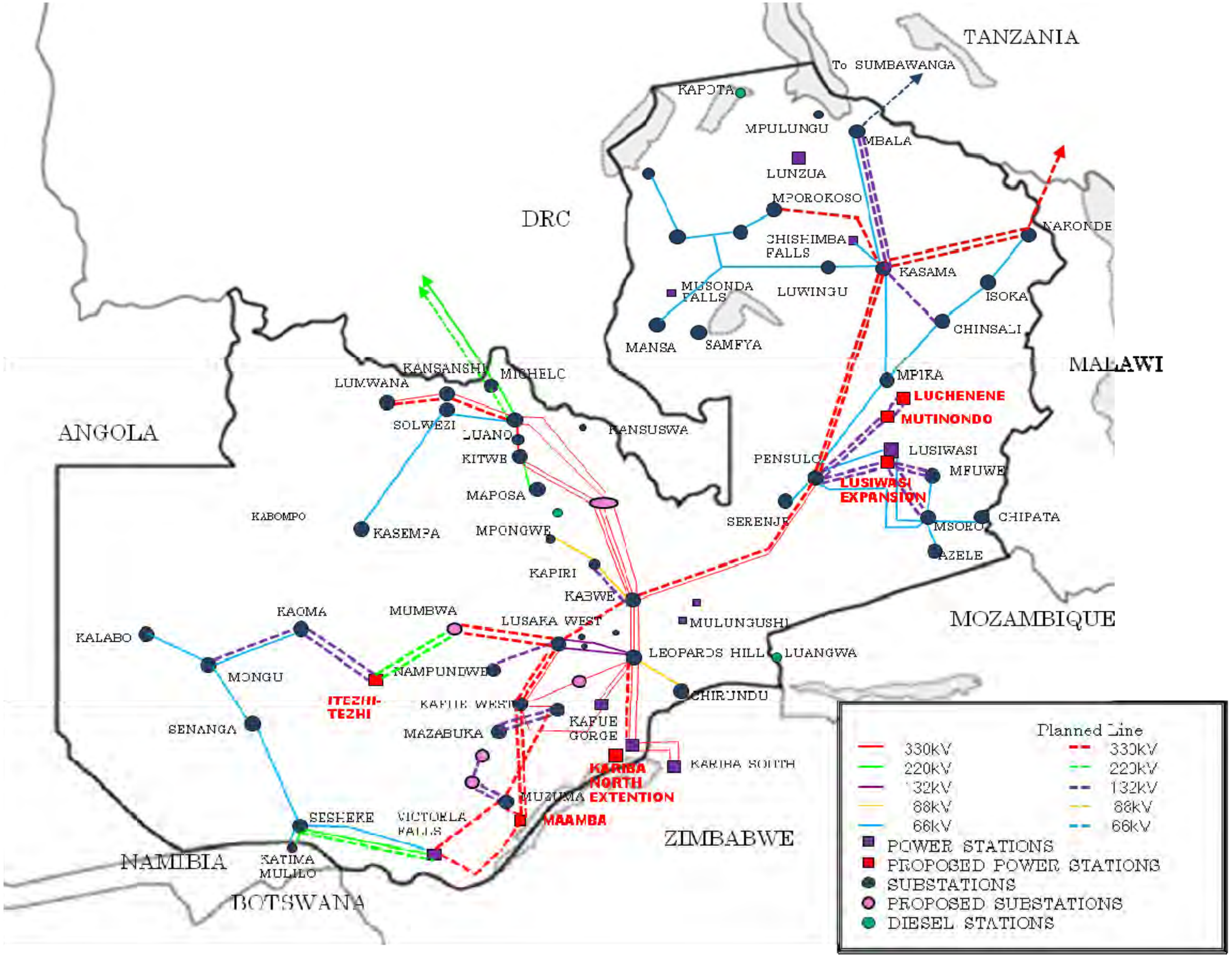

Figure A- 6 Zambian Power System on 2015 (Scenario1-2)

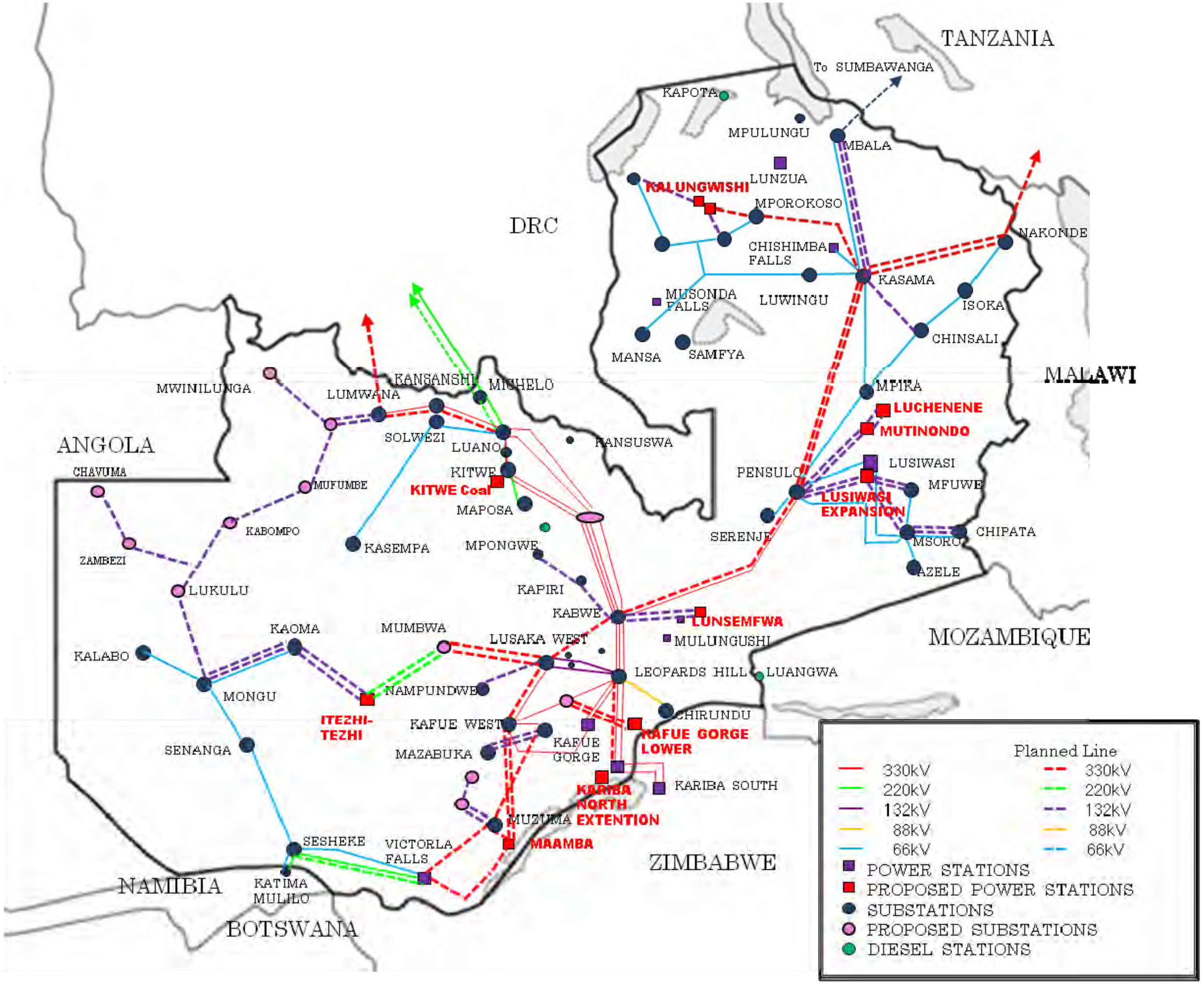

Figure A- 7 Zambian Power System on 2020 (Scenario1-2)

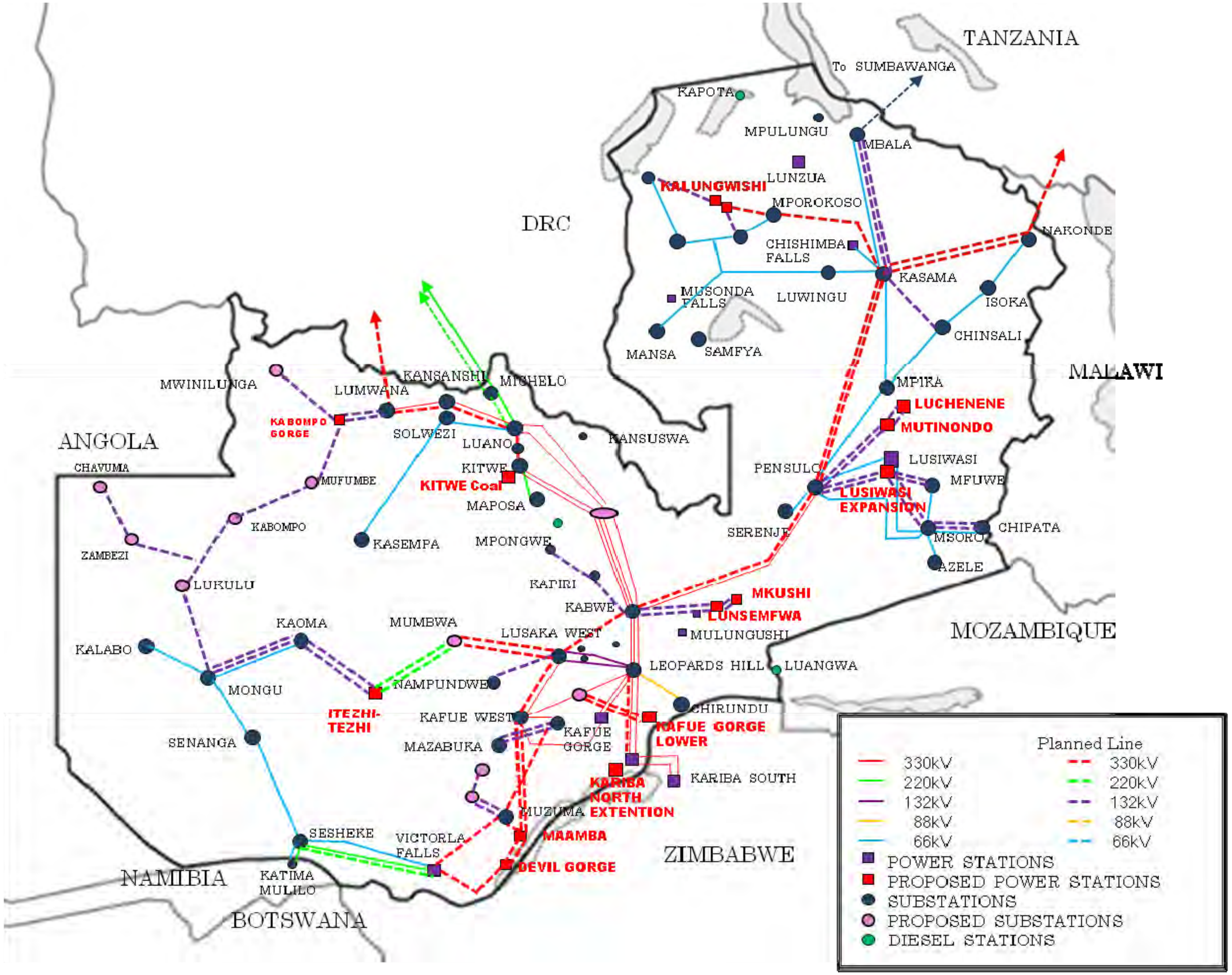

Figure A- 8 Zambian Power System on 2025 (Scenario1-2)

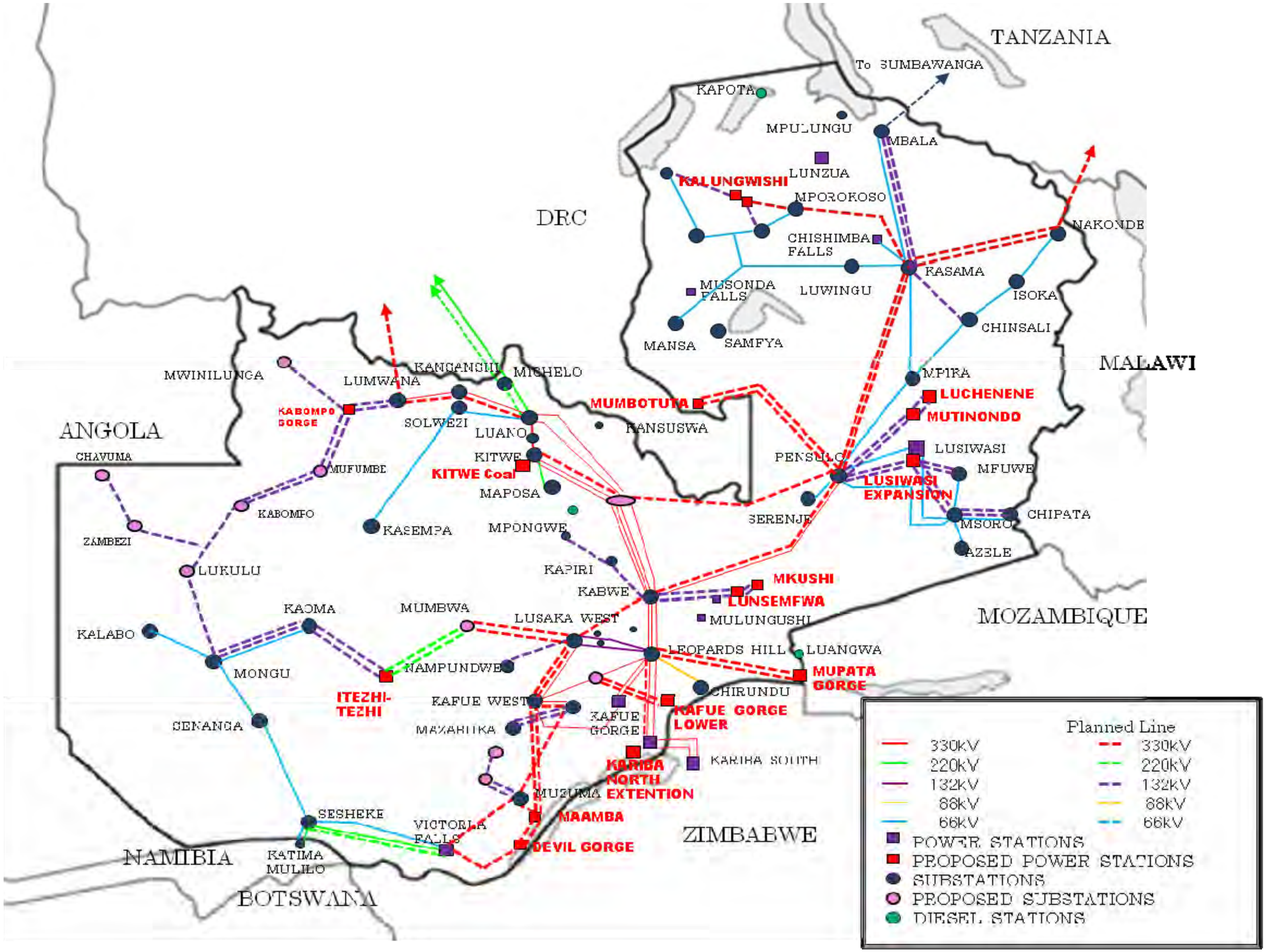

Figure A- 9 Zambian Power System on 2030 (Scenario1-2)

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