No.

National Power Authority
The Republic of Sierra Leone

FINAL REPORT
ON
THE MASTER PLAN STUDY ON POWER SUPPLY IN WESTERN AREA
IN
THE REPUBLIC OF SIERRA LEONE

SUMMARY

SEPTEMBER 2009

JAPAN INTERNATIONAL COOPERATION AGENCY
（JICA）

YACHIYO ENGINEERING CO., LTD.

IDD
JR
09-062

PREFACE

In response to a request from the Republic of Sierra Leone, the Government of Japan decided to conduct the Master Plan Study on Power Supply in Western Area and entrusted to the study to the Japan International Cooperation Agency (JICA).

JICA selected and dispatched a study team headed by Mr. Kyoji Fujii of Yachiyo Engineering Co., LTD. (YEC) four times between November 2008 and August 2009.

The team held discussions with the officials concerned of the Government of Sierra Leone and conducted field surveys at the study area. Upon returning to Japan, the team conducted further studies and prepared this final report.

I hope that this report will contribute to the promotion of this project and to the enhancement of friendly relationship between our two countries.

Finally, I wish to express my sincere appreciation to the officials concerned of the Government of Sierra Leone for their close cooperation extended to the study.

September 2009

Atsuo Kuroda
Vice President
Japan International Cooperation Agency

Mr. Atsuo Kuroda
Vice President
Japan International Cooperation Agency

LETTER OF TRANSMITTAL

September 2009

Dear Sir,
It is my great pleasure to submit herewith the Final Report of “The Master Plan Study on Power Supply in Western Area in the Republic of Sierra Leone”.

The Study Team conducted field surveys in Sierra Leone over the period between November 2008 and August 2009 according to the contract with the Japan International Cooperation Agency (JICA).

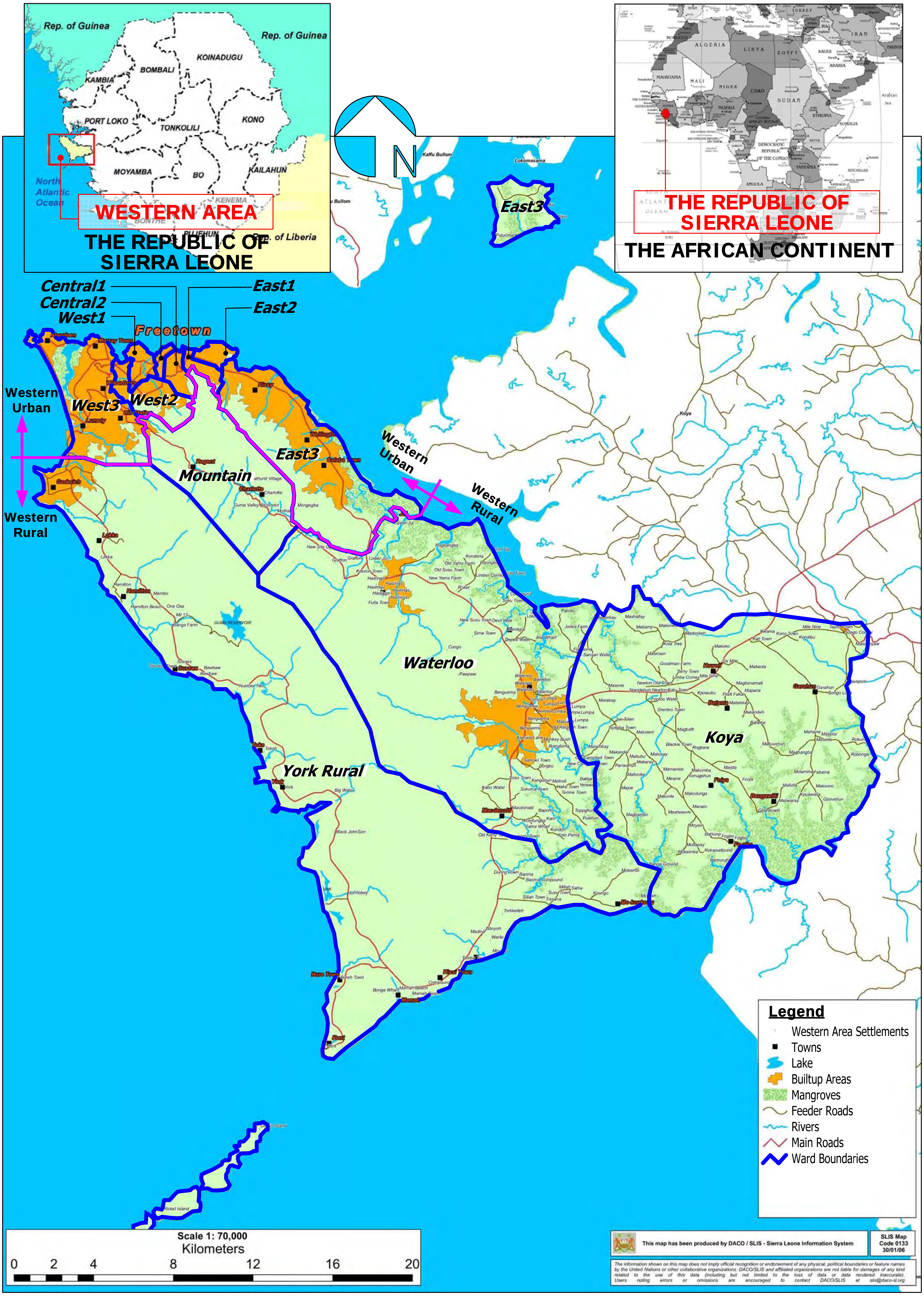
The Study Team compiled this report, which consists of the Master Plan Study on Power Supply in Western Area by 2025, including Power Development Planning, Improvement of Distribution System, Financial and Economic Analyses, Capacity Building, etc. through close consultations with officials concerned of the Government of the Republic of Sierra Leone and other authorities concerned.

On behalf of the Study Team, I would like to express my sincere appreciation to officials concerned of the Government of Sierra Leone and other authorities concerned for their cooperation, assistance, and heartfelt hospitality extended to the Study Team.

We are also deeply grateful to the Japan International Cooperation Agency, the Ministry of Foreign Affairs, the Ministry of Economy, Trade and Industry, and the Embassy of Japan in Ghana for their valuable suggestions and assistance during the course of the Study.

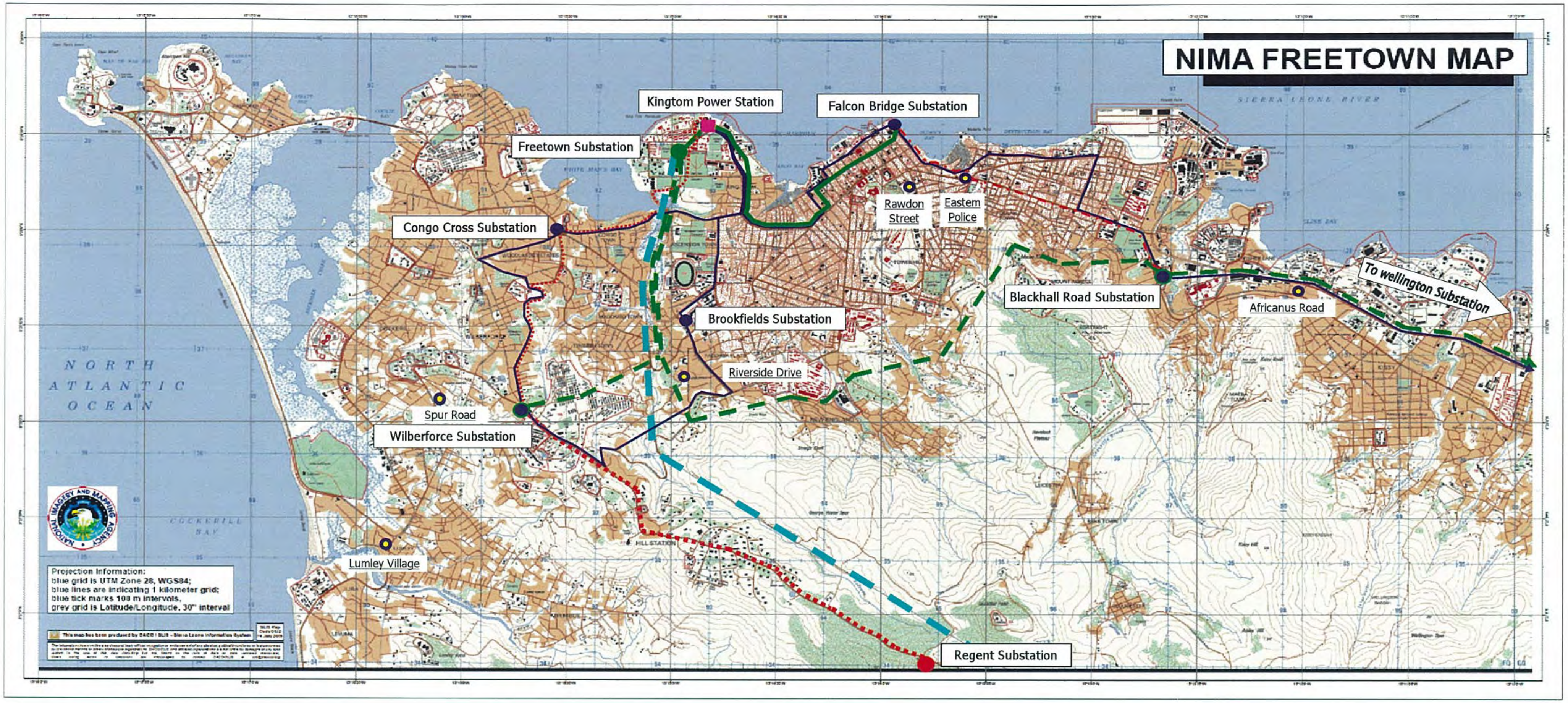
Yours faithfully,

Kyoji Fujii
Team Leader
The Master Plan Study on Power Supply
in Western Area in the Republic of Sierra
Leone



LOCATION MAP OF THE STUDY AREA (WESTERN AREA)

Project Sites



[Remarks]

- ■ Kingtom Power Station
- ● 11 kV Primary Substation
- ◉ 11 kV Secondary Substation
- ● 33 kV Substation (Existing)
- ● 33 kV Substation (the World Bank Project)
- ● 33 kV Substation (Japan's Grant Aid Project:Procurment and Installtion)

- —— 11 kV Distribution Line (Existing)
- ········ 11 kV Distribution Line (Japan's Grant Aid Project:Procurment and Installtion)
- –·–·– 11 kV Distribution Line (Japan's Grant Aid Project:Procurment(Installation by NPA))
- —— 33 kV Distribution Line (Existing:Faulty)
- – – – 33 kV Distribution Line (World Bank Project)
- ■■■■ 33 kV Distribution Line (Japan's Grant Aid Project:Procurment and Installtion)
- ▬ ▬ 161 kV Sub-transmission Line (Plan)

Scale 0 0.5 1km


Freetown Peninsula


Sierra Leone

Source of the Map: http://www.daco-sl.org/encyclopedia/2_data/2_3b3_t.htm

CONTENTS

LIST OF FIGURES AND TABLES

Chapter 1

Chapter 2

Chapter 3

Chapter 4

Chapter 5

Chapter 6

Chapter 7

1. Introduction

1.1 Background of the Study and Present Conditions of the Country

The Republic of Sierra Leone (hereinafter referred to as “Sierra Leone”) is located in the western part of the African continent facing the Atlantic and has a population of 5.32 million (National Electoral Commission, 2008) and a total land area of some 70,000 km^2.

The civil war in Sierra Leone ended in 2002 after approximately 11 years of fighting and its recent progress to a growth period from the post-war reconstruction period is illustrated by an annual GDP growth rate of 7%. However, such factors causing socioeconomic instability as crime, a high unemployment rate, absolute poverty and the uneven distribution of resources have not yet been solved. The economic growth of the country has been hampered by the destruction of basic infrastructure in the civil war and the malfunctioning of the existing infrastructure due to the lack of proper maintenance.

The electricity sector in particular is suffering from the insufficient policy planning and implementation capacity of the competent ministry and the insufficient business management and system maintenance capacity of electric power companies. As a result, the daily supply of electricity is not guaranteed let alone the long-term development of the power supply. The operating balance of the National Power Authority (NPA), which is responsible for power supply in the Freetown Capital Region, is experiencing a chronic deficit and the NPA is finding it difficult to procure sufficient fuel for power generation. As far as the power supply facilities are concerned, the Kingtom Power Station, the only power station owned by the NPA, has seven diesel power generating units. In reality, however, only two of these units are operable and power supply to the capital largely depends on private power companies. The available distribution capacity falls short of the power demand because of the breakdown and deterioration of some of the facilities.

Under these circumstances, the Government of Sierra Leone, the World Bank and donors have identified the improvement of the electricity sector to be the top priority and various donors have been providing assistance for this sector. Various measures are essential to improve the present situation in order to achieve a sustainable power supply. These include the rehabilitation and extension of the power supply system and improvement of the business management and human resources development of the NPA. Against this background, the Government of Sierra Leone has made a request to the Government of Japan to implement a development study to formulate a sustainable power supply plan for the capital region (Western Area).

1.2 Contents of the Study

Contents of the Study are listed as follows;

(1) Power Demand Forecast

(2) Power Plant Development Plan

(3) Distribution System Rehabilitation, Reinforcement and Extension Plan with Detailed Implementation Plan that includes Project Packages and Priorities

(4) Capacity Development Plan for NPA Staffs (Power Generation and Distribution)

(5) Recommendations to Electricity Tariff System

(6) Evaluation of the Business Management of the NPA

(7) Financial and Economic Analysis on Proposed Power Development Plan

(8) Environmental and Social Considerations on Possible Power Development Project

1.3 Basic Policies of the Study

The following basic policies are adopted by the Study for the formulation of the Master Plan.

(1) Compatibility with Development Plans and Strategies

The Master Plan for the electricity sector to be formulated under the Study will contribute to the achievement of the policy goals of the national development plan (Vision 2025), the poverty reduction strategy and the energy sector policies in Sierra Leone. At present, the Pre-Identification Study for the Freetown Development Plan is in progress with EU assistance. The progress of the Freetown Development Plan will be closely monitored under the Study so that the eventual Master Plan is compatible with the Freetown Development Plan.

(2) Introduction of Time Frame to Suit the Power Supply Situation

As power supply in the capital region is currently facing a crisis situation, the first five years of the target period of 15 years of the Master Plan are considered to constitute the “urgent rehabilitation period”. During this period, emphasis will be placed on the renewal of the power supply equipment and facilities to meet the current power demand.

(3) Formulation of a Concrete and Realistic Implementation Plan for the Master Plan

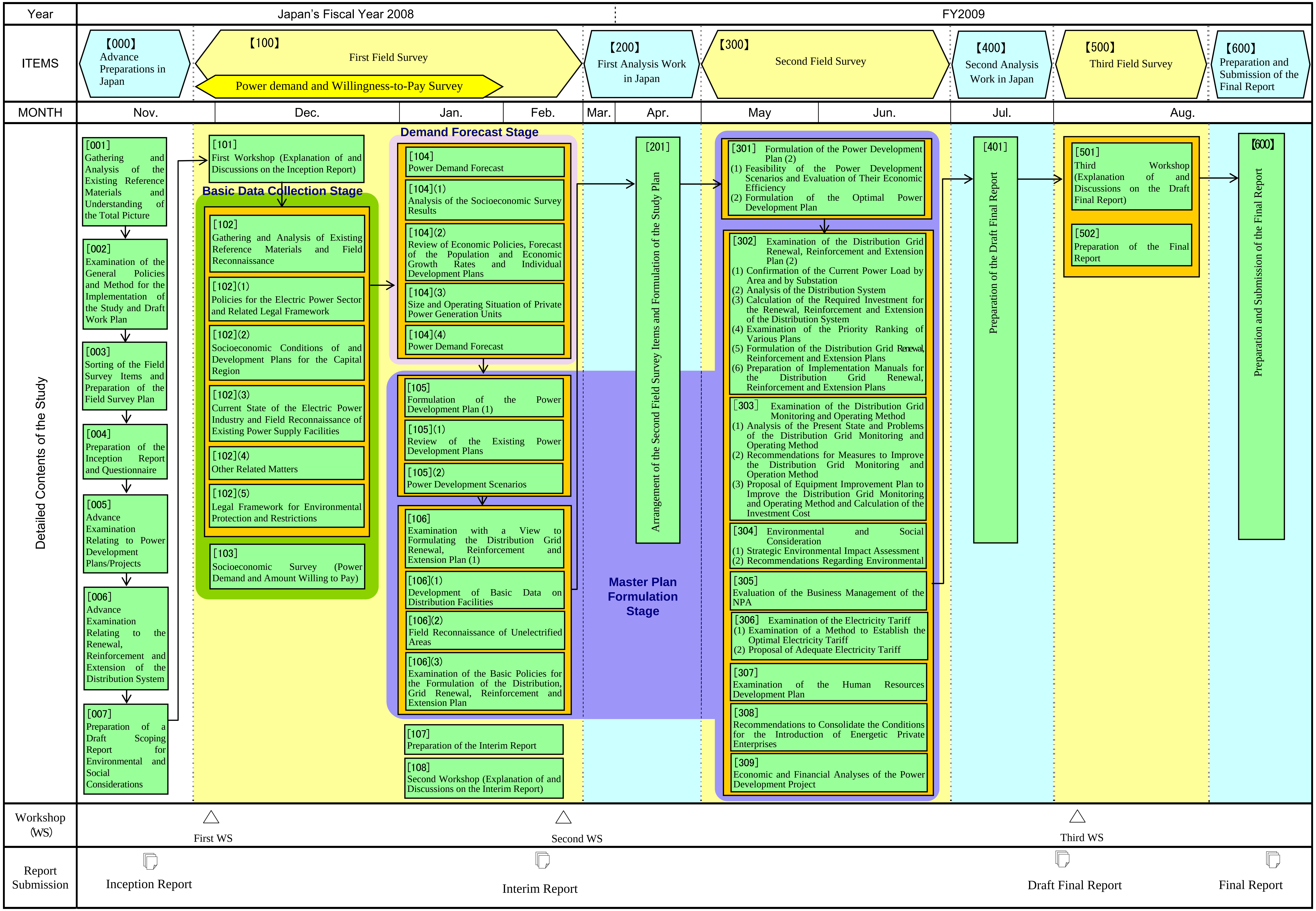
The Study is required to formulate an implementation plan for the Master Plan for the renewal, reinforcement and extension of the distribution grid. The Study Team will prepare a project package with fund raising from donors and other relevant matters in mind while utilising its rich experience in the formulation and implementation of grant aid projects. The cost, construction period, concrete components and benefits will be clearly defined for each project so that the Government of Sierra Leone will find it easy to prepare requests for financial assistance to be made to donors.

(4) Coordination with donors and authorities concerned

The JICA Study Team will share information and exchange opinions with expected donors and authorities concerned to facilitate the smooth implementation of the Master Plan Study and financial and technical assistance in the future.

1.4 Formulation Process of the Master Plan

Formulation Process of the Master Plan is described in Fig. 1.4-1.



[001] Gathering and Analysis of the Existing Reference Materials and Understanding of the Total Picture

[002] Examination of the General Policies and Method for the Implementation of the Study and Draft Work Plan

[003] Sorting of the Field Survey Items and Preparation of the Field Survey Plan

[004] Preparation of the Inception Report and Questionnaire

[005] Advance Examination Relating to Power Development Plans/Projects

[006] Advance Examination Relating to the Renewal, Reinforcement and Extension of the Distribution System

[007] Preparation of a Draft Scoping Report for Environmental and Social Considerations

[101] First Workshop (Explanation of and Discussions on the Inception Report)

[102] Gathering and Analysis of Existing Reference Materials and Field Reconnaissance

[102](1) Policies for the Electric Power Sector and Related Legal Framework

[102](2) Socioeconomic Conditions of and Development Plans for the Capital Region

[102](3) Current State of the Electric Power Industry and Field Reconnaissance of Existing Power Supply Facilities

[102](4) Other Related Matters

[102](5) Legal Framework for Environmental Protection and Restrictions

[103] Socioeconomic Survey (Power Demand and Amount Willing to Pay)

[104] Power Demand Forecast

[104](1) Analysis of the Socioeconomic Survey Results

[104](2) Review of Economic Policies, Forecast of the Population and Economic Growth Rates and Individual Development Plans

[104](3) Size and Operating Situation of Private Power Generation Units

[104](4) Power Demand Forecast

[105] Formulation of the Power Development Plan (1)

[105](1) Review of the Existing Power Development Plans

[105](2) Power Development Scenarios

[106] Examination with a View to Formulating the Distribution Grid Renewal, Reinforcement and Extension Plan (1)

[106](1) Development of Basic Data on Distribution Facilities

[106](2) Field Reconnaissance of Unelectrified Areas

[106](3) Examination of the Basic Policies for the Formulation of the Distribution, Grid Renewal, Reinforcement and Extension Plan

[107] Preparation of the Interim Report

[108] Second Workshop (Explanation of and Discussions on the Interim Report)

[201] Arrangement of the Second Field Survey Items and Formulation of the Study Plan

[301] Formulation of the Power Development Plan (2)
(1) Feasibility of the Power Development Scenarios and Evaluation of Their Economic Efficiency
(2) Formulation of the Optimal Power Development Plan

[302] Examination of the Distribution Grid Renewal, Reinforcement and Extension Plan (2)
(1) Confirmation of the Current Power Load by Area and by Substation
(2) Analysis of the Distribution System
(3) Calculation of the Required Investment for the Renewal, Reinforcement and Extension of the Distribution System
(4) Examination of the Priority Ranking of Various Plans
(5) Formulation of the Distribution Grid Renewal, Reinforcement and Extension Plans
(6) Preparation of Implementation Manuals for the Distribution Grid Renewal, Reinforcement and Extension Plans

[303] Examination of the Distribution Grid Monitoring and Operating Method
(1) Analysis of the Present State and Problems of the Distribution Grid Monitoring and Operating Method
(2) Recommendations for Measures to Improve the Distribution Grid Monitoring and Operation Method
(3) Proposal of Equipment Improvement Plan to Improve the Distribution Grid Monitoring and Operating Method and Calculation of the Investment Cost

[304] Environmental and Social Consideration
(1) Strategic Environmental Impact Assessment
(2) Recommendations Regarding Environmental

[305] Evaluation of the Business Management of the NPA

[306] Examination of the Electricity Tariff
(1) Examination of a Method to Establish the Optimal Electricity Tariff
(2) Proposal of Adequate Electricity Tariff

[307] Examination of the Human Resources Development Plan

[308] Recommendations to Consolidate the Conditions for the Introduction of Energetic Private Enterprises

[309] Economic and Financial Analyses of the Power Development Project

[401] Preparation of the Draft Final Report

[501] Third Workshop (Explanation of and Discussions on the Draft Final Report)

[502] Preparation of the Final Report

【600】 Preparation and Submission of the Final Report

Fig. 1.4-1 Formulation Process of the Master Plan

1.5 Formulation Method of the Master Plan

In Sierra Leone, basic data necessary to formulate the Master Plan are not sufficient because, 1) current power demand is suppressed due to the lack of power supply capacity, and 2) the database of distribution facilities that should include the specifications and numbers of equipment is not well organized. Therefore, the following methods are applied to collect and supplement data in this Study.

Obstacles	Countermeasures
1. Power demand, demand characteristics, etc. are not recorded at each distribution feeder in power stations and substations.	The Study Team installed compact power meters at distribution feeders in power stations and substations and measured power demand, load current, power factor, etc.
2. The database of distribution facilities that should include the specifications and numbers of equipment is not well organized.	The Study Team conducted site survey in collaboration with NPA counterpart members and prepared a distribution facilities database.
3. Due to the lack of power supply capacity, current power demand is suppressed and actual demand is unknown.	A power demand survey subcontracted to a local firm was conducted to collect data on power consumption and type, number and capacity of electric appliances by selecting interviewees through random sampling from NPA consumers. Such data were utilized to estimate power demand potential.
4. Current electricity tariff is based on such a formula that Domestic is lower and Industrial is higher and it does not always represent the economic value (preciousness) of electricity. Therefore, current tariff can not be used as it is for economic analysis in the projects (calculation of economic benefit).	Willingness-to-pay of NPA consumers for electricity was also surveyed through above mentioned survey and economic electricity tariff was calculated based on the results of the survey.

1.6 Implementation Organization of the Study

The Study Team and the NPA have jointly established the collaborative working organization in order for the smooth implementation of the Study as well as technology transfer for NPA through the Study. The following table shows the members of the organization.

JICA Study Team		Counterpart Team of NPA	
Name	Assignment	Name	Assignment
Kyoji Fujii	Team leader/ Power development planning	Dr. Zubairu Ahmed Kaloko (General Manager)	Team leader
		Ing. Abdul P. Y. Kamara (Ag. Corporate Planning Head)	Power development planning
Mitsuhisa Nishikawa	Deputy team leader/ Power demand forecast	Ing. John A. Kabia (Dep. System Planning Manager)	Power demand forecast
Hirohito Seto	Distribution system planning/ Distribution system operation	Ing. Unisa Samura (Snr Electrical Engineer)	Distribution system planning/ Distribution system operation
Takayuki Miyamoto	Distribution/Generation equipment planning	Ing. Edward Parkinson Ing. Daniel Ansumana	Distribution equipment planning
		Ing. Aiah Morseray Ing. Milton Gegbai (Senior Mechanical Engineers)	Generation equipment planning/ Generation Maintenance planning
Kazunari Nogami	Distribution/Generation equipment maintenance planning	Ing. Edward Parkinson Ing. Daniel Ansumana	Distribution equipment maintenance planning
Toru Aoyama	Financial and economic analysis/ Electricity tariff analysis	Mr. Thomas P. Tucker Ing. Michael Conteh	Financial and economic analysis/ Electricity tariff analysis
Megumi Kaneda	Environmental and social considerations	Ing. Reuben Dunn Mr. Rev Dan Palmer	Environmental and social considerations
Daisuke Akatsuka	Coordinator	Ing. John A. Kabia	Coordinator

2. Current Situation of the Electric Utility

2.1 Trend of Power Supply and Demand

In the Western Area of Sierra Leone, power supply to meet the demand is difficult because of the insufficient generating and transmission/distribution capacity. The power supply situation in the five year period from 2002 to 2007 shows that the generated electric energy peaked in 2002 when the civil war ended, followed by a continual decline as is shown in Table 2.1-1. In contrast, the GDP sharply increased from 2000. After recording an annual GDP growth rate of as high as 27.4% in 2002, the annual growth rate has been steady around 7% since 2004. These figures mean that the power supply in Western Area falls short of the demand to achieve the full potential for economic growth. This insufficient power supply has been hampering the post-civil war reconstruction and economic growth of the country.

Table 2.1-1 Power Supply Situation in Western Area

Item \ Year	2003	2004	2005	2006	2007
1. Generated Energy (MWh/year)	109,386.21	84,796.41	53,253.11	31,980.52	31,280.72
2. Generated Energy Growth Rate (%)	-11.4	-22.5	-37.2	-39.9	-2.2
3. Station use Power (MWh/year)	6,235.01	5,232.10	3,485.70	2,728.00	2,223,02
4. Station use ratio against Generated Energy (%)	5.70	6.17	6.55	8.53	7.25
5. Energy Available for sale (MWh/year)	103,151.20	79,564.31	49,767.41	29,252.52	28,431.48
6 Energy Sold (MWh/year)	68,937.47	53,151.93	33,258.64	20,889.11	17,340.96
7 Transmission/Distribution Loss (MWh/year)	34,213.73	26,412.38	16,508.77	8,363.41	11,090.52
8 Ratio of Transmission / Distribution Loss (%)	33.17	33.20	33.17	28.59	39.01
9. Load Factor	47.3%	38.3%	-	-	-

[Source] NPA

2.2 Present Situation of Power Supply and Demand

2.2.1 Present Conditions of the Generating Facilities

Generating facilities handled by the NPA comprise seven diesel engine generators, of which five units are stopped due to problems and two units are operable. The cause of stoppage is mainly due to lack of sufficient generating capacity, lack of technology and shortages of spare parts.
Currently electric power to Freetown Capital Region is supplied from Kingtom and Blackhall Road Power Stations by two private power companies with the contractual output of 15 MW and 10 MW, respectively.

In view of operation and maintenance, the generation section consists of 77 staff members including two engineers and 15 superintendents for the operation of two power stations such as Kingtom P/S and Blackhall Road P/S.

However, presently, All NPA staffs are stationed at Kingtom P/S because there are no generating units at Blackhall Road P/S.

2.2.2 Present Status of Transmission and Distribution Facilities

Transmission and distribution systems of the NPA are categorized by voltage level such as 33, 11 and 3.3 kV and Low Voltage (400/230V). Aside from this, 161 kV transmission line from Bumbuna Hydroelectric power plant to Freetown Substation is under construction and it will be completed within this year.

There is a 33 kV line between Wilberforce S/S and Regent S/S which was commissioned in March 2009. However, the line has not been energized yet, because 33 kV line from Freetown S/S to Wilberforce S/S is now under construction and is to be completed within this year.

New 33 kV lines, as a part of the rehabilitation & extension works of Freetown distribution system under the Power and Water Project financed by WB, will be completed by 2010. However, some of resettlement is not finalized and some towers may need relocation.

3.3 kV system which was installed in a mountain rural area and is not functioning will be upgraded to 11 kV system under assistance of the WB.

Low voltage system feeds electricity to consumers by three-phase four-wire lines. Some areas have terrible voltage fluctuation because of long lines without adjusting the balance of three phase connection. The annual peak demand is mostly recorded between November and February.

The Study area consists of seven power supply areas represented by power stations and substations such as Kingtom, Falcon Bridge, Blackhall Road, Congo Cross, Brookfield, Wilberforce and Wellington. Regent area will be energized within 2009 with loads branching from Wilberforce substation.

The installation, operation and maintenance work of 11 kV and Low Voltage systems in the Western Area is handled by Transmission & Distribution (T&D) division of NPA which consists of 111 staffs including five engineers and 33 superintendents.

Wellington Industrial Estate where many large and small scale factories are located is situated in the eastern part of Freetown, between Blackhall Road P/S and Wellington S/S. Falcon Bridge S/S supplies power to office areas and other areas that mainly consist of residential areas.

2.3 Account Balance and Financial Situation of the NPA

2.3.1 Account Balance

The profit and loss table of the NPA is shown in Table 2.3-1. It shows that the NPA has had continuous deficits in operation and toverall. In particular, it is a serious problem that the operation losses have increased since 2003. It corresponds to the decrease of the sales revenues since 2003. The NPA’s power supply seems so insufficient and unreliable that customers have begun to rely on their own private generators. In addition, system loss is too high and the collected charges ratio to billed charges is too low as described later.

Table 2.3-1 Profit and Loss of the NPA

(Unit: thousand Le)

Year	2002	2003	2004	2005	2006	2007
Revenue	31,130,882	41,928,807	36,295,161	31,534,729	25,006,958	19,704,469
Sales	30,028,598	39,024,527	34,038,007	25,173,087	19,656,117	15,365,574
Others	1,102,284	2,904,280	2,257,154	6,361,642	5,350,841	4,338,895
Expenditure	50,677,433	62,963,046	63,862,245	46,871,375	36,253,821	45,450,113
Fuel	21,336,517	23,770,497	21,739,166	16,827,459	14,011,102	14,447,566
Labor	6,001,600	7,423,173	7,610,214	1,512,430	1,706,633	1,994,163
Maintenance	2,277,148	2,292,679	3,163,262			
Administration	3,383,885	3,062,739	2,285,321	9,614,780	12,603,445	10,737,502
Depreciation	3,392,972	3,554,842	3,872,743	3,770,810	4,312,669	4,249,247
Financial costs	5,230,271	5,917,709	408,123	564,538	483,016	770,438
Exchange loss	9,055,040	16,941,407	24,783,416	14,581,358	3,136,956	13,251,197
Operation Loss	-6,363,524	-1,079,403	-4,632,699	-6,552,392	-12,977,732	-16,062,904
Total Loss	-19,546,551	-21,034,239	-27,567,084	-15,336,646	-11,246,863	-25,745,644
Grant	10,594,154	11,728,678	13,395,549	25,096,442	38,263,128	38,263,128
Balance	-8,952,397	-9,305,561	-14,171,535	9,759,796	27,016,265	12,517,484
Fuel cost share	58.6%	59.3%	56.2%	53.0%	42.9%	46.0%

[Note] Classification of expenditure items changed between 2004 and 2005.

[Source] NPA, Financial Statement

The losses have been covered by government grants. The fuel (diesel and marine oil) cost decreased from 2003 to 2006, but it increased a little in 2007. The proportion of the fuel cost to the operation costs shows the similar trend, but the change is greater.

2.3.2 Tariffs

Tariffs are directly related to revenues. In December 2008, the NPA raised tariffs 50%. The NPA proposed 75% increase at first, but the Ministry of Energy and Power refused it. Then, NPA submitted a 50% raise and it was approved. The new and old tariffs are shown in Table 2.3-2.

Table 2.3-2 NPA's Old and New Tariffs

Tariff Category	Units(kWh)	Tarrif		Account Deposit		Service Charge		Reconnection Fee	
		Current	New	Current	New	Current	New	Current	New
T1 Residential	0-30	373	560						
	31-150	533	800						
	Above 150	709	1,064						
	Minimum charge	11,180	16,770	90,000	135,000	5,000	7,500	28,000	42,000
T2 Small commercial	0-30	651	977						
	31-150	781	1,172						
	Above 150	846	1,269						
	Minimum charge	19,520	29,280	110,000	165,000	5,910	8,865	42,000	6,300
T3 Institutions	All units	781	1,172						
	Minimum charge	32,533	488,800	84,000	126,000	6,820	10,230	42,000	6,300
T4 Industries including large commercial	All units	941	1,412						
	Minimum charge	118,300	177,450						
	kW demand	1,448	2,172	300,000	450,000	37,240	55,860	168,000	252,000
T5 Street light	All units	792	1,188						
	Minimum charge	26,618	39,927			7,280	10,920		
T6 Temporary supply	All units	910	1,365						
	Minimum charge	11,284	16,926			7,280	10,920		
T7 Welders	All units	993	1,490						
	Minimum charge	35,490	53,235	180,000		18,200	27,300	56,000	84,000

[Source] NPA material

The past tariff was 816 leones/kWh (27.2 US cents/kWh) and the new tariff is 1,224 leones/kWh (40.8 US cents/kWh) on average. The tariff for industries including the large commercial sector was raised from 31.4 US cents/kWh to 47.1 US cents/kWh. Even the previous tariffs were very expensive compared with those of other countries.

3. Power Demand Forecast

3.1 Power Demand Forecast method

The macroscopic power demand forecast for the entire capital region will be conducted based on the econometric forecasting method. The econometric model to be used for power demand forecasting under the Study will be developed using Simple E (Expanded, V2008), an economic projection simulation software developed by the Institute of Energy Economics, Japan and used by ASEAN countries for power demand forecasting. In general, an econometric model is developed as an aggregate of many estimations as well as definitional equations and it is necessary to verify “the suitability of the model”. This verification of the power demand forecasting model developed for the Study will be conducted using the following indicators.

- Coefficient of determination (R^2): 0.85 or higher
- Durbin-Watson ratio: target range of between 1.00 and 3.00
- Sign test of coefficient: checking on the basis of correlation with economic principles
  (Example: the GDP coefficient has a positive value, the coefficient of the electricity charge has a negative value and so on)

Using the forecasting model developed for the Study, the power demand will be forecast using the following four structural equations corresponding to the four customer categories.

① Commercial customers: power demand = f (GDP of the commercial sector; actual demand in the previous year, including the institutional sectors)
② Residential customers: power demand = f (number of residential customers; actual demand in the previous year)
③ Industrial customers: power demand = f (GDP of the industrial sector; actual demand in the previous year)

Power demand forecasting will be conducted for three cases (low, base and high cases) based on the GDP growth rate forecasting results. Fig. 3.1-1 shows the flow of the power demand forecasting under the Study.

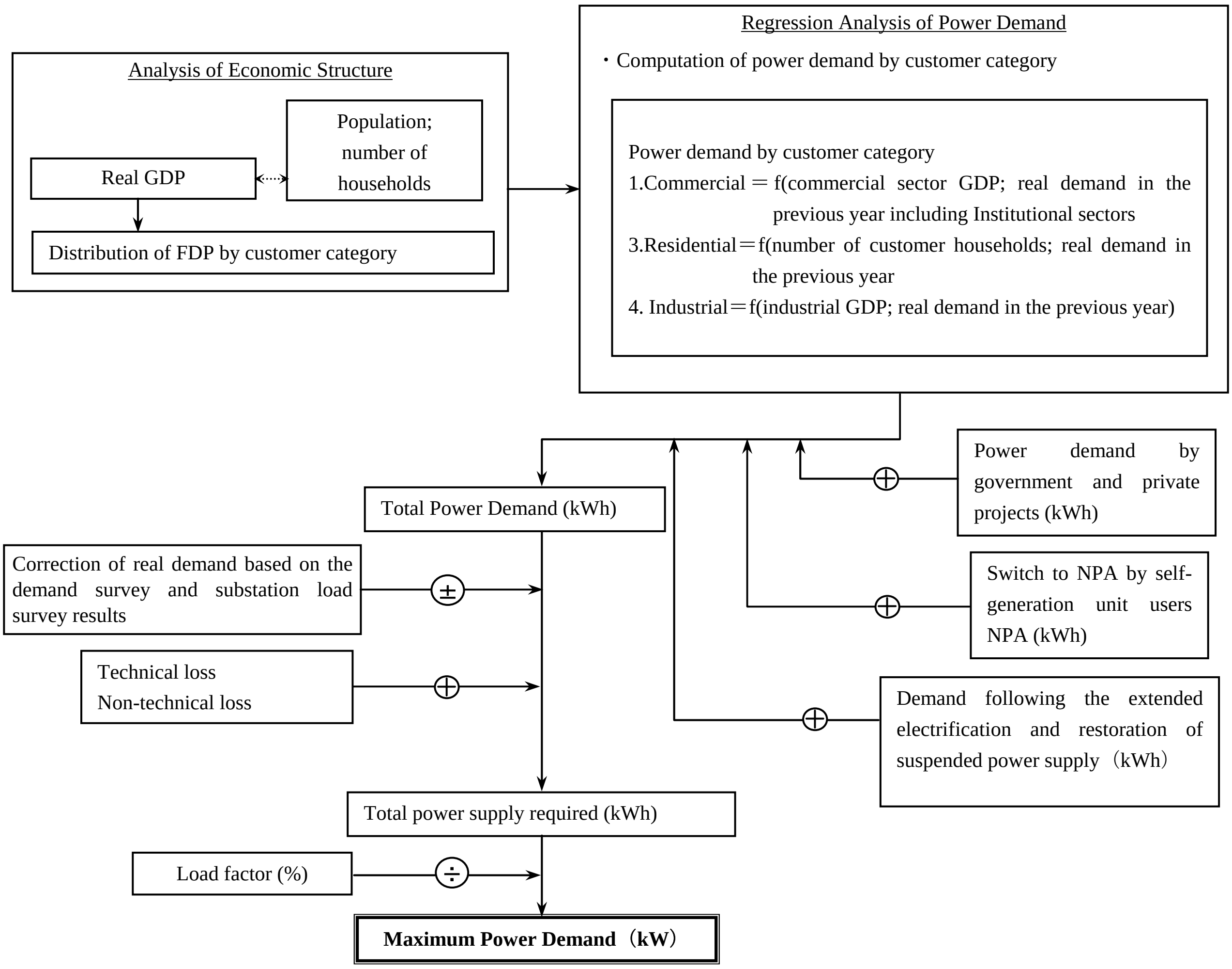


Fig. 3.1-1 Flow of Power Demand Forecasting

3.2 Review of Economic Development Policy and Economic Growth Scenario

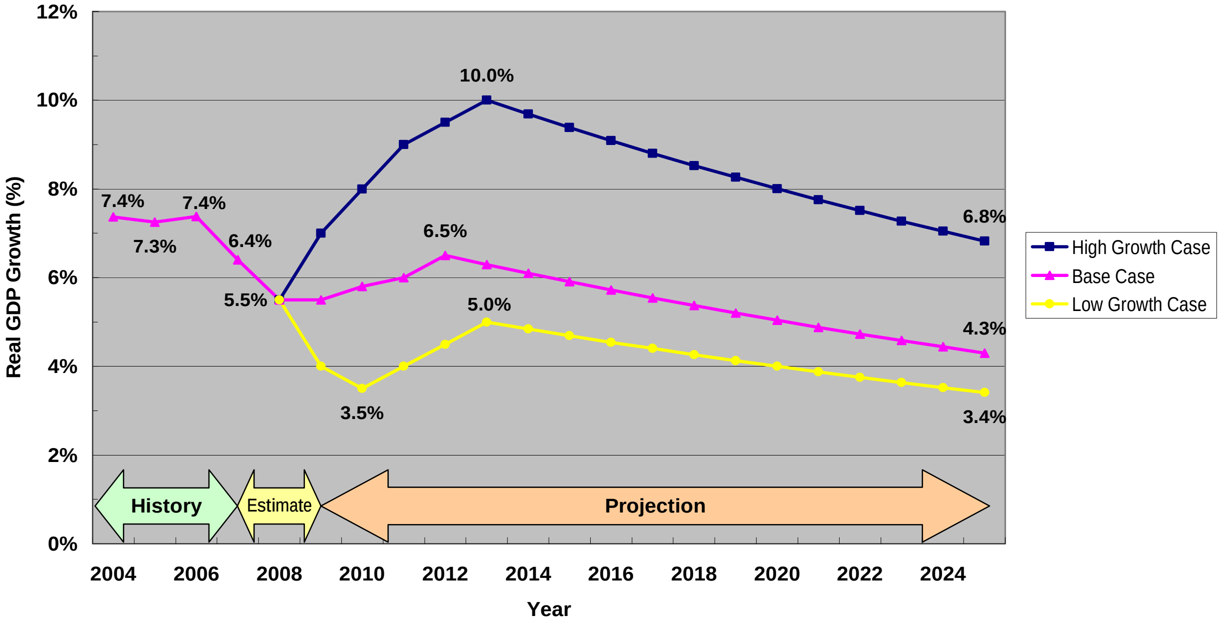
Although the Ministry of Finance and Economic Development (MoFED) has not forecast long term GDP growth, they have a medium-term (3-5 years) GDP growth forecast in Sierra Leone up to 2014 in consultation with International Monetary Fund (IMF).

Table 3.2-1 Forecast of Real GDP Growth Rate

Year Case	2009	2010	2011	2012	2013	2014
High growth	7.0 %	8.0 %	9.0 %	9.5 %	10.0 %	—
Base growth	5.5 %	5.8 %	6.0 %	6.5 %	6.3 %	6.1 %
Low growth	4.0 %	3.5 %	4.0 %	4.5 %	5.0 %	—

[Source] The Ministry of Finance and Economic Development

Based on above scenarios, the Study Team forecasted the Real GDP Growth (constant prices at year 2000) and Growth Rate (%), until year 2025, as is shown in Fig. 3.2-1.



[Source] The Ministry of Finance and Economic Development and JICA Study Team

Fig. 3.2-1 Real GDP Growth Projection

3.3 Potential of Power Demand at the end of December 2008

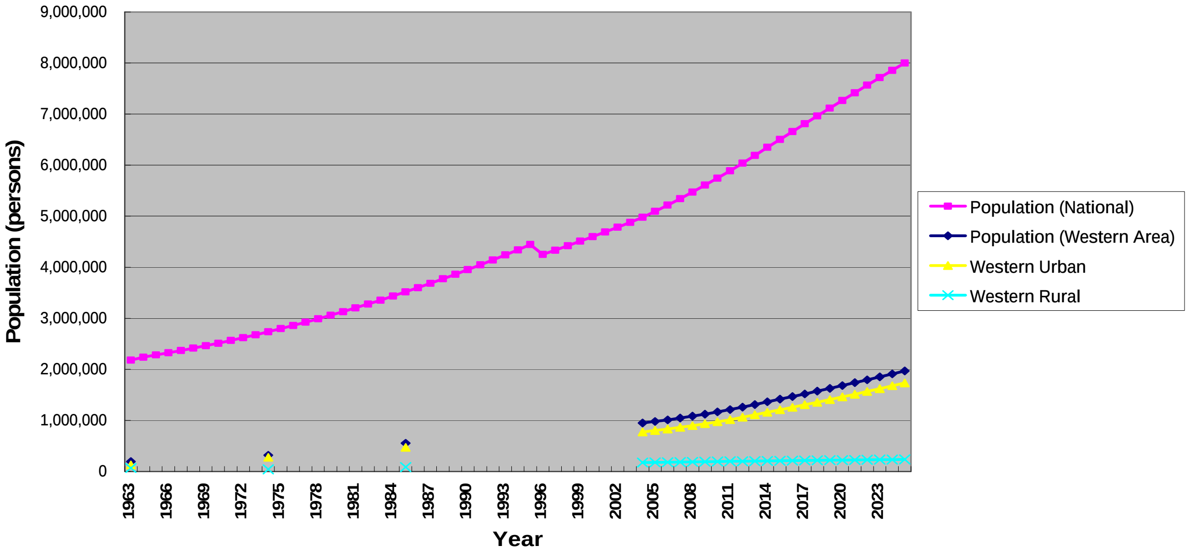
For the basis of power demand forecast, it is necessary to confirm the present actual peak demand in Freetown. Therefore, through the analysis of (1) Result of the demand survey, (2) Present power flow at the primary substations and (3) Captive generators capacity and the actual supplied capacity, the potential of power demand is estimated in the following way.

From the results of above three analyses, we concluded that the present peak demand of Freetown power system (the end of 2008) is approximately 41.0 MW (41.5 MW, 40.8 MW, and 41.0 MW) and we will calculate further power demand forecast based on this figure (41.0 MW).

3.4 Assumption of Population Growth and Electrification Rate

(1) Population Trends

Fig 3.4-1 shows population projection in Sierra Leone and Western Area prepared by the Study Team based on the projection in “2004 Census Population Projection (2005-2014)” and “Statistical Digest (year 2008)”.



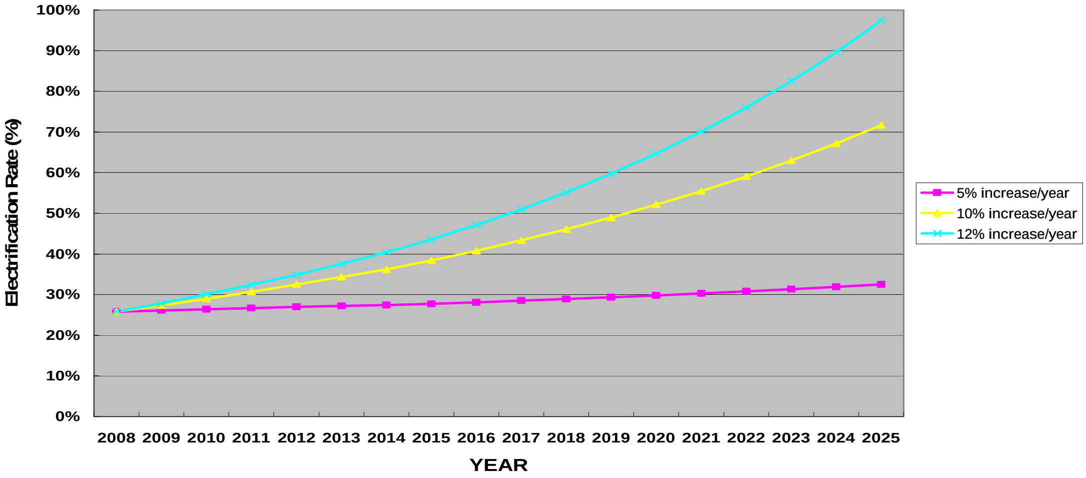
[Source] 2004 Census Population Projection and JICA study team

Fig. 3.4-1 Population in Sierra Leone (History and Projection)

(2) Rural Electrification

According to “Statement of Energy Sector Policy and Strategic Action Plan” formulated in November 2008 by the Ministry Energy and Power, the GoSL aims that at least 75 % of population can have access to electricity by year 2025, of which 100 % of urban and peri-urban population and 45 % of rural households should be electrified.

In order to achieve this target, the growth rate of electrification in household consumers should reach at least 10 % /year up to year 2025 as is shown in Fig 3.4-2. Therefore, we apply annual electrification growth rate of 10 % /year for the forecast of household electricity consumption.



[Source] JICA Study Team

Fig. 3.4-2 Annual Increase of Household Consumers and Electrification Rate in Western Area

3.5 Adjustments of Demand Forecast

3.5.1 Adjustment of Power Demand Forecast Models

The Power Demand Forecast Models formulated by regression analysis method based on the historical data from 1965-1984, and <u>the calculating formulas of household and commercial consumers are as follows;</u>

Results of Regression Analysis (Historical data: 1965-1984)

PCONH = -2.52715+0.00262627*RGDPT+0.0000909638*NOHHCON+0.867131*LAG1.PCONH
PCONC = -4.18847+0.0103346*RGDPC+0.796798*LAG1.PCONC

PCONH: Electricity consumption by **household** consumers (GWh / year) =Consumer category of NPA: T1
PCONC: Electricity consumption by **commercial** consumers (GWh / year) =Consumer category of NPA: T2&T3
RGDPT: Real GDP, total, expressed in national currency (billion leone) at 2000 price
RGDPC: Real GDP of service sector, expressed in national currency (billion leone) at 2000 price
NOHHCON: Number of household consumers
LAG1.PCONH: Electricity consumption by **household** consumers in previous year (GWh / year)
LAG1.PCONC: Electricity consumption by **commercial** consumers in previous year (GWh / year)

The peak demands of household and commercial consumers in 2008 are forecast as 8.4 MW and 6.4 MW respectively, by using above formula. However, the potential peak demands of both categories in the same year are estimated as 21.5 MW and 7.33 MW respectively. The forecast peak demands are much lower than potential peak demands.

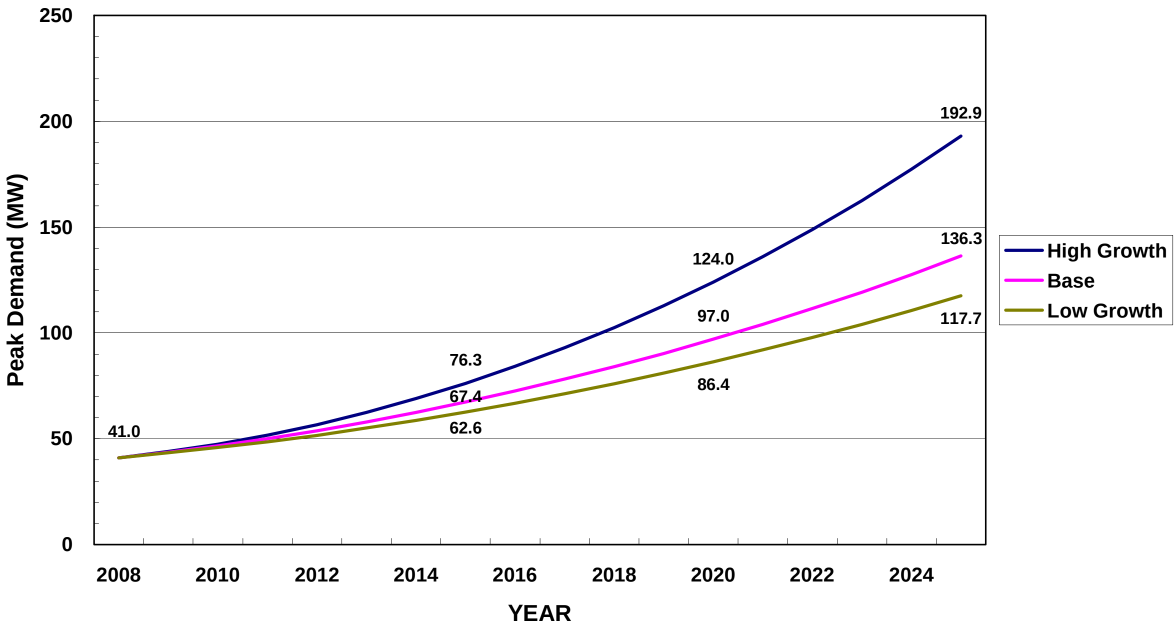
In recent years (especially, after the conflict), GDP elasticity of electricity consumption might have changed because of the transition of energy consumption pattern and the dissemination of electricity appliances. Therefore, power demand forecast models formulated through the analysis of old historical data from 1965 to 1984 should be adjusted to meet current power consumption trends.

In addition, industrial GDP has no close correlation with industrial electricity consumption. Therefore, the demand forecast model of industrial sector is formulated by using GDP elasticity of cement production.

3.5.2 Adjustment of Power Demand Forecast

The results of power demand forecast (Base Case, High Case and Low Case) adjusted to meet the estimated peak demand in 2008 are as follows;

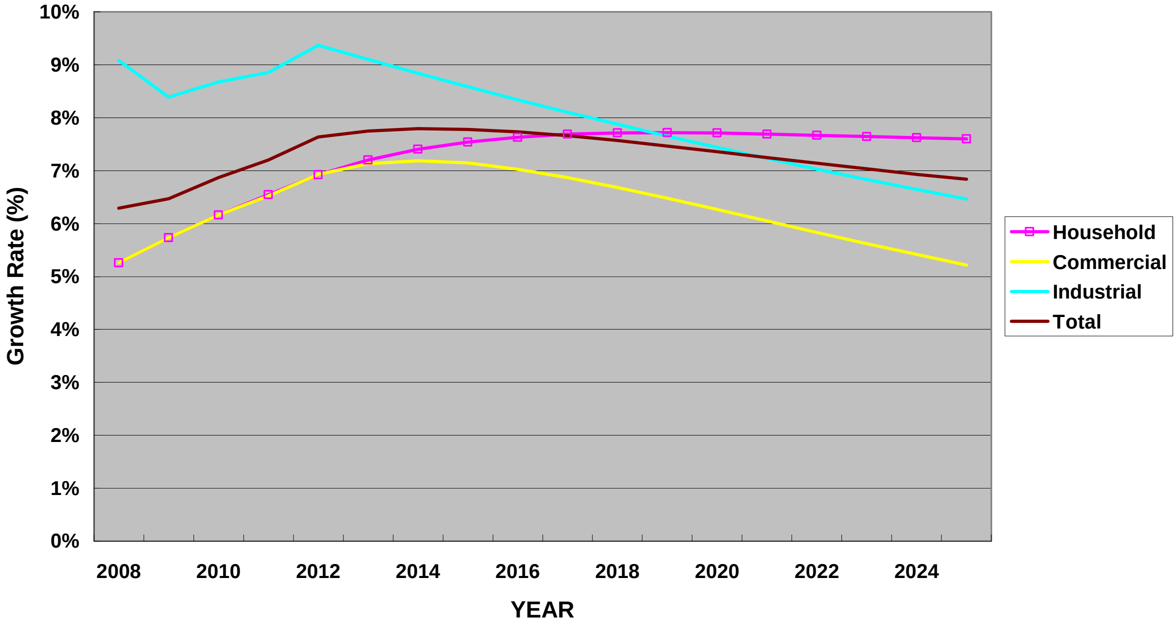
(1) Adjusted Total Power Demand Forecast Comparison (Base, High and Low Cases)



[Source] JICA Study Team

Fig. 3.5-1 Power Demand Forecast After Adjustment (comparison of growth scenario)

(2) Adjusted Base Case (Adjusted Base Case Peak Demand Growth Rate (Each Sector))



[Source] JICA Study Team

Fig. 3.5-2 Adjusted Base Case Peak Demand Growth Rate (All Sectors)

4. Power Development Planning

4.1 Setting of Power Development Scenario

From the viewpoint of long term generation cost, hydro power development should be prioritized among other candidates. However, there is a concern that some processes of hydro development such as fund procurement and environmental and social considerations including involuntary resettlement may require long period of time. Therefore, two scenarios, namely, "Thermal Dominant Scenario" where no hydro is expected until 2025, and "Hydro Dominant Scenario" where Yiben-I and II are included in the candidate plants are set.

(1) Thermal Dominant Scenario

Candidate plants of the thermal dominant scenario are HFO-fired low-speed (less than 150rpm) and middle-speed (less than 750rpm) diesel as base load middle load plants and diesel oil-fired high-speed diesel (less than 1,500rpm, package type, prime condition) for peak cut purposes.

(2) Hydro Dominant Scenario

In addition to above mentioned low, middle and high-speed diesel generators, Yiben-I and Yiben-II are listed as the candidate plants.

4.2 Least Cost Development Analysis by WASP-IV

In this study, an optimal power development planning software named WASP (Wien Automatic System Planning Package, Version 4.0.3) developed by IAEA is used to seek the least cost power development plan that is a combination of various types of plants and development patterns. In WASP, a power development plan that has the least Objective Function (see below for details) within the limitation of LOLP and reserve margin is sought through the calculation. Future price is discounted to present value by using discount rate.

$$OF = C - SV + O\&M$$

where,

OF：Objective Function
C：Construction Cost
SV：Salvage Value
O&M：Operation＆Maintenance Cost

(1) Thermal Dominant Scenario

The least cost power development plan of "Thermal Scenario" that meets the target reliability standard (LOLP＜1.918% or 7days/year) is shown in Table 4.2-1. Until 2025, 30.6 MW of high-speed diesel, 64.3 MW of middle-speed diesel and 30 MW of low-speed diesel generators are to be developed.

Table 4.2-1 Least Cost Power Development Plan (Thermal Scenario)

Year	High-speed Diesel (MW) (1.8MW/unit)	Mid-speed Diesel (MW) (8.0MW/unit)	Low-speed Diesel (MW) (15MW/unit)	Annual Total (MW)	LOLP* (%)
2010	5.4			5.4	1.584
2011		8.28		8.3	0.674
2012	1.8			1.8	1.670
2013	5.4			5.4	1.668
2014	3.6			3.6	1.788
2015	1.8	8.0		9.8	1.902
2016		8.0		8.0	1.438
2017		8.0		8.0	1.240
2018		8.0		8.0	1.159
2019	3.6			3.6	1.897
2020	1.8	8.0		9.8	1.548
2021			15.0	15.0	0.843
2022	1.8			1.8	1.910
2023	3.6	8.0		11.6	1.581
2024	1.8	8.0		9.8	1.763
2025			15.0	15.0	1.188
Total	**30.6**	**64.3**	**30.0**	**124.9**	

[Remarks]
*: LOLP= Loss of Load Probability
Target LOLP<1.918% (7days/year)

[Source] JICA Study Team

Power demand and supply balance in the development plan above are shown in Table 4.2-3.

The sum of power development cost for Thermal Dominant Scenario until 2025 reaches approximately US$213million. Annual investment cost from 2010 to 2025 is shown in Table 4.2-2. Re-investment cost of high-speed diesel generators is counted in the eleventh year after the commissioning because the economic life of those plants is 10 years.

Table 4.2-2 Power Development Cost (Thermal Dominant Scenario)

[Unit: million USD, expressed in Y2009 price]

Year	Thermal Dominant Scenario				
	High-speed Diesel (1.8MW/unit)	Mid-speed Diesel (8.0MW/unit)	Low-speed Diesel (15MW/unit)	Annual Investment Cost	Cumulative Investment Cost
2010	2.48	3.01	0.00	5.49	5.49
2011	0.00	12.03	0.00	12.03	17.52
2012	0.83	0.00	0.00	0.83	18.35
2013	2.48	0.00	0.00	2.48	20.83
2014	1.66	2.76	0.00	4.42	25.25
2015	0.83	13.80	0.00	14.63	39.87
2016	0.00	13.80	0.00	13.80	53.67
2017	0.00	13.80	0.00	13.80	67.47
2018	0.00	11.04	0.00	11.04	78.51
2019	1.66	2.76	0.00	4.42	82.93
2020	3.31	11.04	7.59	21.94	104.87
2021	0.00	0.00	30.36	30.36	135.23
2022	1.66	2.76	0.00	4.42	139.65
2023	4.14	13.80	0.00	17.94	157.59
2024	2.48	11.04	7.59	21.11	178.70
2025	0.83	2.76	30.36	33.95	212.65
Total	**22.36**	**114.39**	**75.90**	**212.65**	

[Remarks] 1US$=97.28JPY

[Source] JICA Study Team

Table 4.2-3 Power Balance in Western Area Power System (Base Case, Thermal Dominant Scenario)

	Year	Capacity	Estimate	Forecast																
	Commissioned	(MW)	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
1. Peak Demand (MW)			**41.0**	**43.7**	**46.7**	**50.0**	**53.8**	**58.0**	**62.5**	**67.4**	**72.6**	**78.2**	**84.1**	**90.4**	**97.0**	**104.0**	**111.5**	**119.3**	**127.6**	**136.3**
Growth Rate（%）				6.5%	6.9%	7.2%	7.6%	7.8%	7.8%	7.8%	7.7%	7.7%	7.6%	7.5%	7.4%	7.2%	7.1%	7.0%	6.9%	6.8%
2. Generating Capacity (MW)			**17.0**	**30.5**	**55.0**	**61.1**	**62.6**	**67.8**	**71.2**	**76.4**	**83.7**	**91.0**	**98.2**	**101.4**	**110.6**	**124.4**	**125.8**	**136.7**	**145.7**	**159.4**
2.1 Kingtom P/S			**15.0**	**11.0**	**18.9**	**18.8**	**20.5**	**25.8**	**29.3**	**27.0**	**26.9**	**26.8**	**26.6**	**30.1**	**32.0**	**31.8**	**33.6**	**37.3**	**39.1**	**39.0**
(1) Mirrlees 3	2002	6.3	(5.5)	**Retire**																
(2) Sulzer 4	1978	9.2	(7.0)	5.0	**Retire**															
(3) Sulzer 5	1980	9.2	(6.5)	5.0	**Retire**															
(4) Mitsubishi 6	1995	5.0	(3.5)	(3.5)	4.0	4.0	4.0	3.9	3.9	**Retire**										
(5) Caterpillar-1	2001	1.2	(1.0)	1.0	**Retire**															
(6) Caterpillar-2	2001	1.2	(1.0)	(1.0)	**Retire**															
(7) Mirrlees-2 (Eskom)	(2006)	6.9	0.0	**Retire**																
(8) New DEG-7 (Japan's Grant)	2010	5.0			4.8	4.7	4.7	4.7	4.7	4.6	4.6	4.6	4.6	4.5	4.5	4.5	4.5	4.5	4.4	4.4
(9) New DEG-8 (Japan's Grant)	2010	5.0			4.8	4.7	4.7	4.7	4.7	4.6	4.6	4.6	4.6	4.5	4.5	4.5	4.5	4.5	4.4	4.4
(10) Rental Power (GTG1-14)	2007	15.0	15.0																	
(11) New DEGs (high-speed)		1.8MW/unit			5.4	5.4	7.1	12.5	16.0	17.8	17.7	17.6	17.5	21.0	23.0	22.9	24.6	28.4	30.2	30.1
					1.8MWX3	1.8MWX3	1.8MWX4	1.8MWX7	1.8MWX9	1.8MWX10	1.8MWX10	1.8MWX10	1.8MWX10	1.8MWX12	1.8MWX13	1.8MWX13	1.8MWX14	1.8MWX16	1.8MWX17	1.8MWX17
2.2 Blackhall Road P/S			**2.0**	**2.0**	**18.6**	**24.8**	**24.6**	**24.5**	**24.4**	**31.9**	**39.3**	**46.7**	**54.1**	**53.8**	**53.5**	**53.3**	**53.0**	**52.7**	**52.5**	**52.2**
(1) New DEG-1 (BADEA-I)	2010	Net 8.28			8.3	8.2	8.2	8.2	8.1	8.1	8.0	8.0	8.0	7.9	7.9	7.8	7.8	7.8	7.7	7.7
(2) New DEG-2 (BADEA-II)	2010	Net 8.28			8.3	8.2	8.2	8.2	8.1	8.1	8.0	8.0	8.0	7.9	7.9	7.8	7.8	7.8	7.7	7.7
(3) IPP (Income Electrix)	2008	10.0	2.0	2.0	2.0															
(4) New DEG-3 (BADEA-III)	2011	Net 8.28				8.3	8.2	8.2	8.2	8.1	8.1	8.0	8.0	8.0	7.9	7.9	7.8	7.8	7.8	7.7
(5) New DEG-4 (mid-speed)	2015	8.0								7.6	7.6	7.5	7.5	7.4	7.4	7.4	7.3	7.3	7.3	7.2
(6) New DEG-5 (mid-speed)	2016	8.0									7.6	7.6	7.5	7.5	7.4	7.4	7.4	7.3	7.3	7.3
(7) New DEG-6 (mid-speed)	2017	8.0										7.6	7.6	7.5	7.5	7.4	7.4	7.4	7.3	7.3
(8) New DEG-7 (mid-speed)	2018	8.0											7.6	7.6	7.5	7.5	7.4	7.4	7.4	7.3
2.3 New Diesel P/S															**7.6**	**21.8**	**21.7**	**29.2**	**36.6**	**50.7**
(1) New DEG-1 (mid-speed)	2020	8.0													7.6	7.6	7.5	7.5	7.4	7.4
(2) New DEG-2 (low-speed)	2021	15.0														14.3	14.2	14.1	14.0	14.0
(3) New DEG-3 (mid-speed)	2023	8.0																7.6	7.6	7.5
(4) New DEG-4 (mid-speed)	2024	8.0																	7.6	7.6
(5) New DEG-5 (low-speed)	2025	15.0																		14.3
2.4 Bumbuna Hydroelectric P/S				**17.5**	**17.5**	**17.5**	**17.5**	**17.5**	**17.5**	**17.5**	**17.5**	**17.5**	**17.5**	**17.5**	**17.5**	**17.5**	**17.5**	**17.5**	**17.5**	**17.5**
(1) Unit 1	2009	25.0		8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8
(2) Unit 2	2009	25.0		8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8
3. Power Balance (MW)（2.－1.）			**-24.0**	**-13.2**	**8.3**	**11.0**	**8.8**	**9.8**	**8.6**	**9.0**	**11.1**	**12.8**	**14.1**	**11.0**	**13.6**	**20.4**	**14.3**	**17.4**	**18.1**	**23.1**
4. Maintenance outage（MW）			1.1	5.0	8.3	8.3	8.2	8.2	8.2	8.1	8.1	8.0	8.0	8.0	7.9	14.3	14.2	14.1	14.0	14.3
5. Firm capacity (MW) (2.－4.）			15.9	25.5	46.7	52.8	54.4	59.6	63.0	68.3	75.6	82.9	90.2	93.4	102.7	110.2	111.6	122.6	131.6	145.1
6. Reserve margine(MW)（5.- 1.）			**-25.1**	**-18.2**	**0.0**	**2.8**	**0.6**	**1.6**	**0.5**	**0.9**	**3.0**	**4.8**	**6.1**	**3.1**	**5.7**	**6.1**	**0.1**	**3.3**	**4.1**	**8.8**
7. Reserve margine(%) (6. / 1.)			**-61.2%**	**-41.6%**	**0.0%**	**5.5%**	**1.1%**	**2.8%**	**0.8%**	**1.3%**	**4.2%**	**6.1%**	**7.3%**	**3.4%**	**5.9%**	**5.9%**	**0.1%**	**2.8%**	**3.2%**	**6.5%**
8. Loss of Load Probability (%)			**N/A**	**N/A**	**1.584**	**0.674**	**1.670**	**1.668**	**1.788**	**1.902**	**1.438**	**1.240**	**1.159**	**1.897**	**1.548**	**0.843**	**1.910**	**1.581**	**1.763**	**1.188**

Source: NPA and JICA Study Team

Remarks: (1) During dry season, generating capacity of Bumbuna drops up to 17.5 MW and this number is used for calculating power balance until Yiben-I Hydro is commissioned.
(2) Derating factor of each diesel engine generator is supposed to be about 0.5 % per annum.
(3) House consumption of diesel power station is estimated to be 5%.
(4) Ex-transformer generating capacity is used in calculating power balance, i.e. house consumption is subtracted from the output at generator-end except high-speed DEGs and Blackhall Road P/S New DEG-1, 2 & 3 (net capacity).
(5) Target Number of "Loss of Load Probability" (LOLP) to be achieved in the futhre Western Area Power System is less than 1.918% (7days/year).

(2) Hydro Dominant Scenario

The least cost power development plan of “Hydro Dominant Scenario” that meets the target reliability standard (LOLP＜1.918% or 7days/year) is shown in Table 4.2-4. Until 2025, 18 MW of high-speed diesel, 40.3 MW of middle-speed diesel and Yiben-I hydro are to be developed.

After the completion of Yiben-I in 2019, the system will have plenty of reserve capacity for the time being and this situation allows high-speed diesels used for peaking capacity to be relocated to non-electrified rural areas.

Table 4.2-4 Least Cost Power Development Plan (Hydro Dominant Scenario)

Year	High-speed Diesel (MW) (1.8MW/unit)	Mid-speed Diesel (MW) (8.0MW/unit)	Yiben-I Hydro (MW) (20.5MW/unit)	Annual Total (MW)	LOLP[*] (%)
2010	5.4			5.4	1.584
2011		8.28		8.3	0.674
2012	1.8			1.8	1.670
2013	5.4			5.4	1.668
2014	3.6			3.6	1.788
2015	1.8	8.0		9.8	1.902
2016		8.0		8.0	1.438
2017		8.0		8.0	1.240
2018		8.0		8.0	1.159
2019	(-18.0)		61.5	61.5	<0.0005
2020				0.0	<0.0005
2021				0.0	<0.0005
2022				0.0	<0.0005
2023				0.0	0.003
2024				0.0	0.049
2025				0.0	0.475
Total	**18.0**	**40.3**	**61.5**	**119.8**	

[Remarks]
*: LOLP= Loss of Load Probability
Target LOLP<1.918% (7days/year)

[Source] JICA Study Team

Power demand and supply balance in the case of power development above is shown in Table 4.2-6.

The sum of Power Development Cost for “Hydro Dominant Scenario” reaches approx. US$268 million, US$55 million higher than Thermal Dominant Scenario. Annual investment cost from 2010 to 2025 is shown in Table 4.2-5.

Table 4.2-5 Power Development Cost (Hydro Dominant Scenario)

[Unit: million USD, expressed in Y2009 price]

Year	Hydro Dominant Scenario				
	High-speed Diesel (1.8MW/unit)	Mid-speed Diesel (8.0MW/unit)	Yiben-I Hydro (20.5MW/unit)	Annual Investment Cost	Cumulative Investment Cost
2010	2.48	3.01		5.49	5.49
2011	0.00	12.03		12.03	17.52
2012	0.83	0.00		0.83	18.35
2013	2.48	0.00		2.48	20.83
2014	1.66	2.76		4.42	25.25
2015	0.83	13.80		14.63	39.87
2016	0.00	13.80	28.44	42.24	82.11
2017	0.00	13.80	66.35	80.15	162.26
2018	0.00	11.04	66.35	77.39	239.66
2019	0.00	0.00	28.44	28.44	268.09
2020	0.00	0.00		0.00	268.09
2021	0.00	0.00		0.00	268.09
2022	0.00	0.00		0.00	268.09
2023	0.00	0.00		0.00	268.09
2024	0.00	0.00		0.00	268.09
2025	0.00	0.00		0.00	268.09
Total	**8.28**	**70.23**	**189.58**	**268.09**	

[Remarks] 1US$=97.28JPY

[Source] JICA Study Team

Table 4.2-6 Power Balance in Western Area Power System (Base Case, Hydro Dominant Scenario)

	Year	Capacity	Estimate	Forecast																
	Commissioned	(MW)	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
1. Peak Demand (MW)			**41.0**	**43.7**	**46.7**	**50.0**	**53.8**	**58.0**	**62.5**	**67.4**	**72.6**	**78.2**	**84.1**	**90.4**	**97.0**	**104.0**	**111.5**	**119.3**	**127.6**	**136.3**
Growth Rate（%）				6.5%	6.9%	7.2%	7.6%	7.8%	7.8%	7.8%	7.7%	7.7%	7.6%	7.5%	7.4%	7.2%	7.1%	7.0%	6.9%	6.8%
2. Generating Capacity (MW)			**17.0**	**30.5**	**55.0**	**61.1**	**62.6**	**67.8**	**71.2**	**76.4**	**83.7**	**91.0**	**98.2**	**156.5**	**156.2**	**155.9**	**155.5**	**155.2**	**154.9**	**154.6**
2.1 Kingtom P/S			**15.0**	**11.0**	**18.9**	**18.8**	**20.5**	**25.8**	**29.3**	**27.0**	**26.9**	**26.8**	**26.6**	**9.1**	**9.0**	**9.0**	**8.9**	**8.9**	**8.9**	**8.8**
(1) Mirrlees 3	2002	6.3	(5.5)	**Retire**																
(2) Sulzer 4	1978	9.2	(7.0)	5.0	**Retire**															
(3) Sulzer 5	1980	9.2	(6.5)	5.0	**Retire**															
(4) Mitsubishi 6	1995	5.0	(3.5)	(3.5)	4.0	4.0	4.0	3.9	3.9	**Retire**										
(5) Caterpillar-1	2001	1.2	(1.0)	1.0	**Retire**															
(6) Caterpillar-2	2001	1.2	(1.0)	(1.0)	**Retire**															
(7) Mirrlees-2 (Eskom)	(2006)	6.9	0.0	**Retire**																
(8) New DEG-7 (Japan's Grant)	2010	5.0			4.8	4.7	4.7	4.7	4.7	4.6	4.6	4.6	4.6	4.5	4.5	4.5	4.5	4.5	4.4	4.4
(9) New DEG-8 (Japan's Grant)	2010	5.0			4.8	4.7	4.7	4.7	4.7	4.6	4.6	4.6	4.6	4.5	4.5	4.5	4.5	4.5	4.4	4.4
(10) Rental Power (GTG1-14)	2007	15.0	15.0																	
(11) New DEGs (high-speed)		1.8MW/unit			5.4	5.4	7.1	12.5	16.0	17.8	17.7	17.6	17.5	**to be relocated to rural area**						
					1.8MWX3	1.8MWX3	1.8MWX4	1.8MWX7	1.8MWX9	1.8MWX10	1.8MWX10	1.8MWX10	1.8MWX10							
2.2 Blackhall Road P/S			**2.0**	**2.0**	**18.6**	**24.8**	**24.6**	**24.5**	**24.4**	**31.9**	**39.3**	**46.7**	**54.1**	**53.8**	**53.5**	**53.3**	**53.0**	**52.7**	**52.5**	**52.2**
(1) New DEG-1 (BADEA-I)	2010	Net 8.28			8.3	8.2	8.2	8.2	8.1	8.1	8.0	8.0	8.0	7.9	7.9	7.8	7.8	7.8	7.7	7.7
(2) New DEG-2 (BADEA-II)	2010	Net 8.28			8.3	8.2	8.2	8.2	8.1	8.1	8.0	8.0	8.0	7.9	7.9	7.8	7.8	7.8	7.7	7.7
(3) IPP (Income Electrix)	2008	10.0	2.0	2.0	2.0															
(4) New DEG-3 (BADEA-III)	2011	Net 8.28				8.3	8.2	8.2	8.2	8.1	8.1	8.0	8.0	8.0	7.9	7.9	7.8	7.8	7.8	7.7
(5) New DEG-4 (mid-speed)	2015	8.0								7.6	7.6	7.5	7.5	7.4	7.4	7.4	7.3	7.3	7.3	7.2
(6) New DEG-5 (mid-speed)	2016	8.0									7.6	7.6	7.5	7.5	7.4	7.4	7.4	7.3	7.3	7.3
(7) New DEG-6 (mid-speed)	2017	8.0										7.6	7.6	7.5	7.5	7.4	7.4	7.4	7.3	7.3
(8) New DEG-7 (mid-speed)	2018	8.0											7.6	7.6	7.5	7.5	7.4	7.4	7.4	7.3
2.3 Bumbuna Hydroelectric P/S				**17.5**	**17.5**	**17.5**	**17.5**	**17.5**	**17.5**	**17.5**	**17.5**	**17.5**	**17.5**	**50.0**	**50.0**	**50.0**	**50.0**	**50.0**	**50.0**	**50.0**
(1) Unit 1	2009	25.0		8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	25.0	25.0	25.0	25.0	25.0	25.0	25.0
(2) Unit 2	2009	25.0		8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	25.0	25.0	25.0	25.0	25.0	25.0	25.0
2.4 Yiben-I Hydroelectric P/S														**43.6**	**43.6**	**43.6**	**43.6**	**43.6**	**43.6**	**43.6**
(1) Unit 1	2019	20.5												14.5	14.5	14.5	14.5	14.5	14.5	14.5
(2) Unit 2	2019	20.5												14.5	14.5	14.5	14.5	14.5	14.5	14.5
(3) Unit 3	2019	20.5												14.5	14.5	14.5	14.5	14.5	14.5	14.5
3. Power Balance (MW)（2.－1.）			**-24.0**	**-13.2**	**8.3**	**11.0**	**8.8**	**9.8**	**8.6**	**9.0**	**11.1**	**12.8**	**14.1**	**66.1**	**59.2**	**51.8**	**44.1**	**35.9**	**27.4**	**18.3**
4. Maintenance outage（MW）			1.1	5.0	8.3	8.3	8.2	8.2	8.2	8.1	8.1	8.0	8.0	8.0	7.9	7.9	7.8	7.8	7.8	7.7
5. Firm capacity (MW) (2.－4.)			15.9	25.5	46.7	52.8	54.4	59.6	63.0	68.3	75.6	82.9	90.2	148.5	148.3	148.0	147.7	147.4	147.2	146.9
6. Reserve margine（MW）（5.– 1.）			**-25.1**	**-18.2**	**0.0**	**2.8**	**0.6**	**1.6**	**0.5**	**0.9**	**3.0**	**4.8**	**6.1**	**58.2**	**51.3**	**43.9**	**36.2**	**28.1**	**19.6**	**10.6**
7. Reserve margine（%） (6. / 1.)			**-61.2%**	**-41.6%**	**0.0%**	**5.5%**	**1.1%**	**2.8%**	**0.8%**	**1.3%**	**4.2%**	**6.1%**	**7.3%**	**64.4%**	**52.8%**	**42.2%**	**32.5%**	**23.6%**	**15.4%**	**7.8%**
8. Loss of Load Probability (%)			**N/A**	**N/A**	**1.584**	**0.674**	**1.670**	**1.668**	**1.788**	**1.902**	**1.438**	**1.240**	**1.159**	**0.000**	**0.000**	**0.000**	**0.000**	**0.003**	**0.049**	**0.475**

Source: NPA and JICA Study Team

Remarks: (1) During dry season, generating capacity of Bumbuna drops up to 17.5 MW and this number is used for calculating power balance until Yiben-I Hydro is commissioned.
(2) Derating factor of each diesel engine generator is supposed to be about 0.5 % per annum.
(3) House consumption of diesel power station is estimated to be 5%.
(4) Ex-transformer generating capacity is used in calculating power balance, i.e. house consumption is subtracted from the output at generator-end except high-speed DEGs and Blackhall Road P/S New DEG-1, 2 & 3 (net capacity).
(5) Target Number of "Loss of Load Probability" (LOLP) to be achieved in the futhre Western Area Power System is less than 1.918% (7days/year).

4.3 Evaluation of Power Development Plans

The Hydro Dominant Scenario necessitates higher investment by US$55 million compared to Thermal Dominant Scenario in terms of power development cost until 2025. However, Hydro Dominant Scenario is more beneficial in terms of overall cost including operation and maintenance expenses as is shown in Table 4.3-1. If you compare the sum of Objective Function of both scenarios calculated by WASP-IV, Hydro Dominant Scenario is less expensive by US$67.5 million and more economical.

Based on the economic evaluation above, Hydro Dominant Scenario is recommended as the Base Case scenario of the future power development in Sierra Leone.

Table 4.3-1 Economic Comparison of Power Development Scenarios

Year	Thermal Dominant Scenario						Hydro Dominant Scenario					
	High-speed Diesel (MW) (1.8MW/unit)	Mid-speed Diesel (MW) (8.0MW/unit)	Low-speed Diesel (MW) (15MW/unit)	Objective*1 Function (million US$)	Cumulative Obj. Fun. (million US$)	LOLP*2 (%)	High-speed Diesel (MW) (1.8MW/unit)	Mid-speed Diesel (MW) (8.0MW/unit)	Yiben-I Hydro (MW) (20.5MW/unit)	Objective*1 Function (million US$)	Cumulative Obj. Fun. (million US$)	LOLP*2 (%)
2010	5.4			11.123	11.123	1.584	5.4			11.123	11.123	1.584
2011		8.28		9.248	20.371	0.674		8.28		9.248	20.371	0.674
2012	1.8			10.615	30.986	1.670	1.8			10.615	30.986	1.670
2013	5.4			12.643	43.629	1.668	5.4			12.643	43.629	1.668
2014	3.6			12.917	56.546	1.788	3.6			12.917	56.546	1.788
2015	1.8	8		19.843	76.389	1.902	1.8	8		19.843	76.389	1.902
2016		8		18.986	95.375	1.438		8		18.986	95.375	1.438
2017		8		18.756	114.131	1.240		8		18.756	114.131	1.240
2018		8		18.665	132.796	1.159		8		18.665	132.796	1.159
2019	3.6			15.308	148.104	1.897	(-18.0)		61.5	56.001	188.797	<0.0005
2020	1.8	8		19.085	167.189	1.548				0.611	189.408	<0.0005
2021			15	23.207	190.396	0.843				0.707	190.116	<0.0005
2022	1.8			15.899	206.295	1.910				0.985	191.101	<0.0005
2023	3.6	8		18.771	225.066	1.581				1.333	192.434	0.003
2024	1.8	8		18.407	243.473	1.763				1.674	194.108	0.049
2025			15	20.119	263.592	1.188				1.994	196.102	0.475
Total	**30.6**	**64.3**	**30.0**	**263.592**			**18.0**	**40.3**	**61.5**	**196.102**		
	124.9						**119.8**					

[Remarks]
*1: Objective Function = Construction Cost - Salvage Value + Operation and Maintenance Cost (expressed in Present Value as of year 2010)
*2: LOLP= Loss of Load Probability
WASP: **W**ien **A**utomatic **S**ystem **P**lanning Package, an optimal power development planning software developed by IAEA
Discount Rate=10%

[Remarks] 1US$=97.28JPY
[Source] JICA Study Team

5. Improvement of Distribution System

Western Area network has a lot of weak points because of not only old facilities but also insufficient planning, rehabilitation and maintenance.

Considering present situation of the system, this master plan shall be divided into three terms, i.e. the short, medium and long terms.

Especially, in the short term, the aim is the urgent rehabilitation of existing facilities and the main objectives are to secure the power supply to consumers and to improve old facilities.

① Current Situation of Distribution System (5.1)
STEP-1：Study of Current Situation
■ Data collection (specification of distribution facility, quantity, faulty condition, etc.）
■ Operation and maintenance conditions (fault and repair information of the system)
■ Demand on major distribution station (load current, voltage, power factor, etc.)
STEP-2：Preparation of Preliminary Database for Distribution Network
■ Facility Register (11/ 33 kV lines, transformer, Ring Main Unit (RMU))
■ Related documents (single line diagram of the system and S/S, location and route map)
STEP-3：Preliminary System Analysis to the end of 2008
■ Demand study at major distribution stations
■ Preparation of system diagram
■ System analysis (Voltage drop and energy losses)
■ Obstruction of weak points and countermeasures
② Basic Policy (5.2)
■ Development plan in Western Area (infrastructural, industrial, housing, etc.)
■ Consideration of countermeasure to the current system
■ Improvement of distribution system
➢ Securing of a safe and economical system
➢ Promotion of rural electrification
➢ Establishment of optimal distribution system
③ Demand Forecast and Distribution Network (5.3)
■ Demand forecast at major distribution stations
■ Preparation of preliminary system diagram and route map for 2015/2020/2025
④ System Analysis (5.4)
■ Outline of analysis and preparation of data
■ System analysis on year 2015/2020/2025
■ Results and Conclusion
⑤ Optimal Distribution System (5.5)
■ Recommendations for the system in 2015/2020/2025
■ Projects for rehabilitation, reinforcement and expansion of distribution network
■ Project cost for rehabilitation, reinforcement and expansion of distribution network

[Source] JICA Study Team

The most important work step is collection of data, which shall be the base of the planning. Thus the above flow shows the order of important procedures.

Optimal plan shall be determined with consideration of priorities. In this study, short, medium and long term shall be considered.

5.1 Analysis of Existing Network

The existing distribution system is operated with emergency conditions, i.e. shortage of power supply and temporary power supply route because of line faults. However, to find out existing weak points, preliminary system analysis shall be conducted at the end of 2008.

1) Result of Analysis:

Based on the above assumptions and measurements, analysis was conducted and highlighted as follows;

① Voltage drop at Lakka No. 2 area is beyond permissible voltage range,
② Energy losses are high, and

2) Countermeasures:

As a preliminary countermeasure, to reduce the weak points, following countermeasures shall be taken urgently;

① Increase sending voltage to 11.5 kV at power stations,
② Keep power factor more than 0.9 on all 11 kV lines,
③ Select adequate tap for distribution transformer at voltage problem area,
④ Add new trunk line to reduce line impedance,
⑤ Change some power flow to reduce power losses, and
⑥ Consider reactive power supplier at load end.

5.2 Basic Strategy and Policy

The followings shall be applied to the formulation of distribution rehabilitation, reinforcement and expansion plans in order to improve power supply quality and reliability and accessibility to electricity in Western Area.
The goal shall be upgrading of living standards.

Basic strategy is divided into three phases as follows;

- Short Term (~ 2015 year): Emergency Program,
- Medium Term (2016 ~ 2020 year): Improvement and Rural Electrification, and
- Long Term (2021 ~ 2025 year): Secure Reliability and Quality.

The contents of basic policy are selected considering present weak points on power supply network and future development plans.

＊ Secure Stable Distribution System
＊ Promote Rural Electrification
＊ Establish Optimal Distribution System

Based on site investigation, considering energy strategy of the MEWR and the NPA, the key index to be set in order to approach the goal is shown in Table 5.2-1.

Table 5.2-1 Key Index to each Phase

Index	Unit	2008	2015	2020	2025
Energy Losses	[%]	42.0	30>	20>	10>
Power Outage	[Hours]	>5,000	500>	50>	1>
No. of Fault	[Times]	981	600>	300>	100>
Electrification Rate	[%]	22.9	>40	>60	>95
New Consumers	[Houses]	3,664	>56,000	>88,000	>136,000

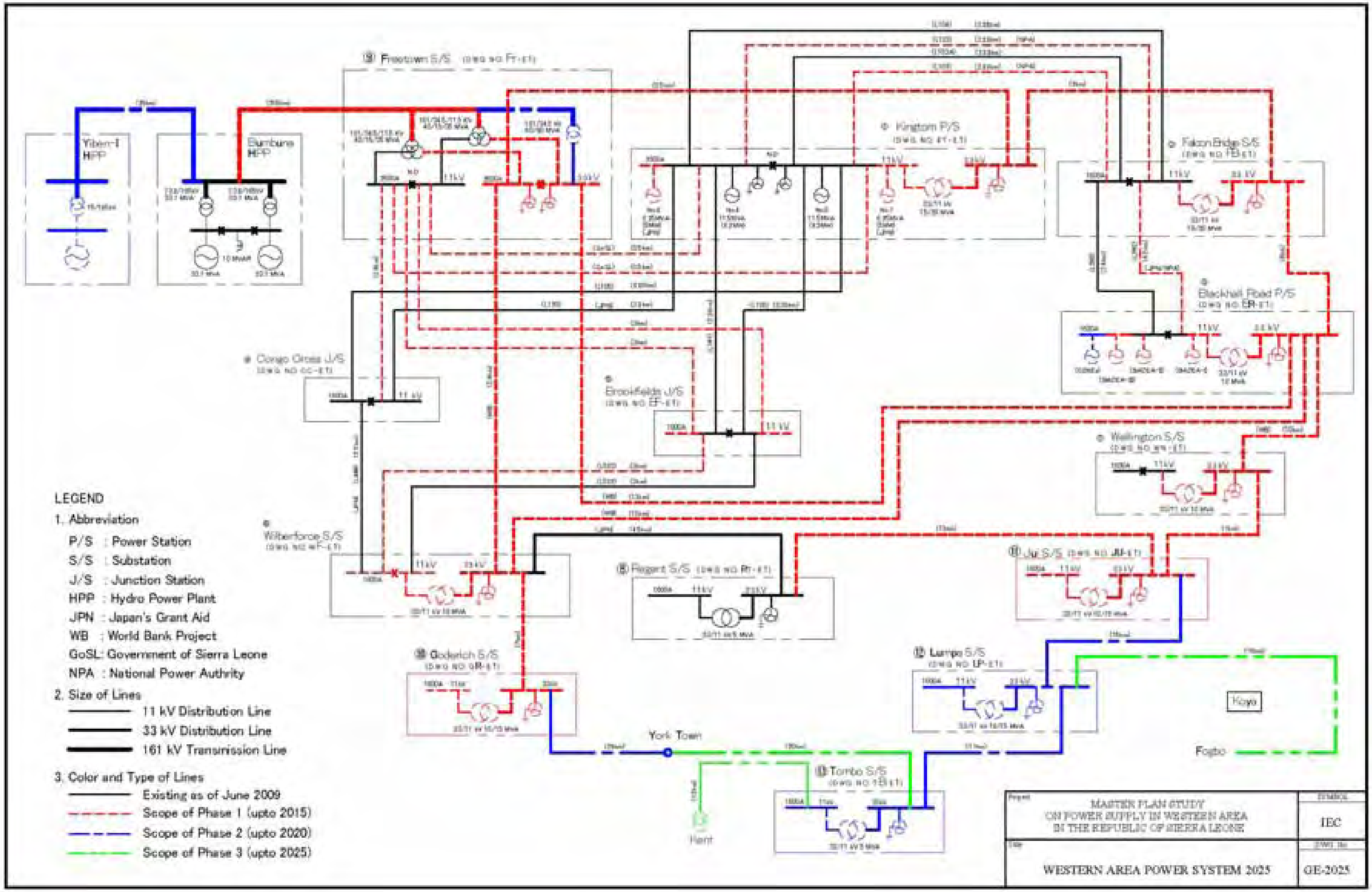
[Remarks]

1. Above key index applied Western Area only.
2. Energy losses are only for distribution network. Not including transmission line including 161 kV S/S.
3. Energy losses are including technical and non-technical losses.

[Source] JICA Study Team

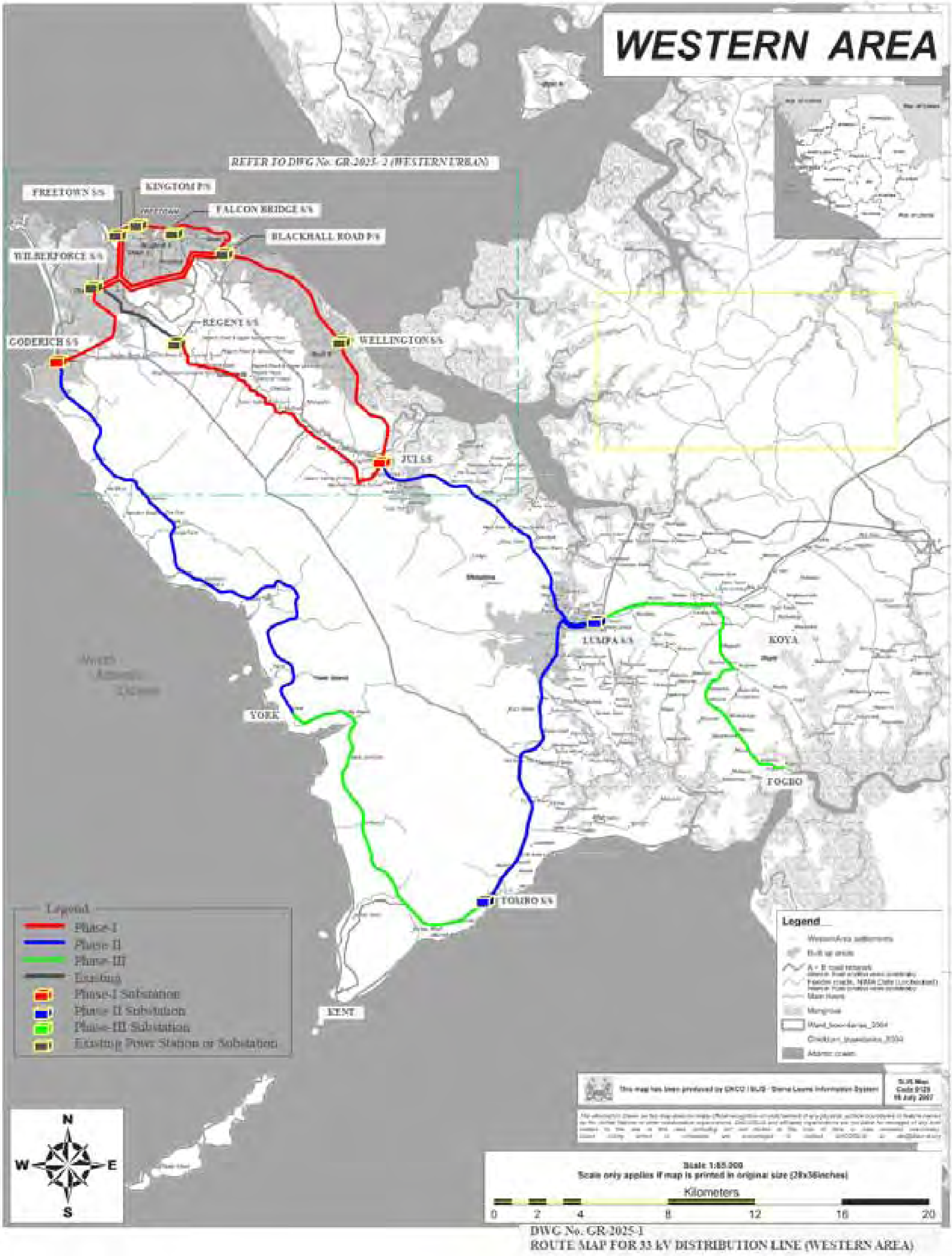
5.3 Distribution Network

Considering the above requirements, preliminary power system up to 2025 is shown in Fig. 5.3-1 and location of new substation and line route is shown in Fig. 5.3-2 and Fig. 5.3-3 respectively.



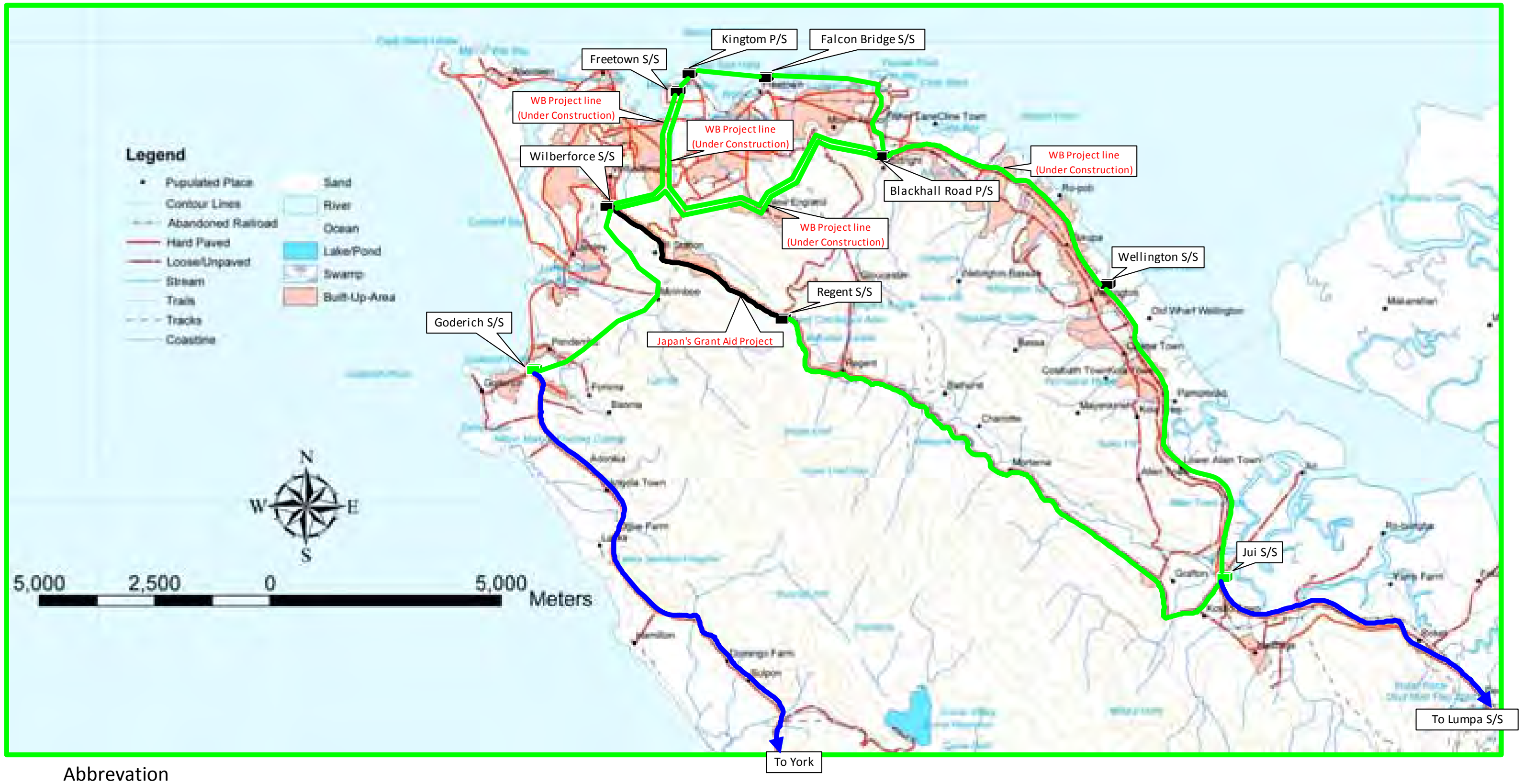
[Source] JICA Study Team

Fig. 5.3-1 Western Area Power System 2025



[Source] JICA Study Team

Fig. 5.3-2 Route Map for 33 kV Line (Western Area: 2025)



Abbreviation

P/S : Power Station

S/S : Substation

DWG No. GR-2025-2
ROUTE MAP FOR 33 kV DISTRIBUTION LINE (WESTERN URBAN)

Symbol

■ : Existing Power Station or Substatio
🟩 : Substation for phase-1
🟦 : Substation for phase-2
━ : Existing 33 kV Line
━ : 33kV Phase-1 Line
━ : 33 kV Phase-2 Line

[Source] JICA Study Team

Fig. 5.3-3 Route Map for 33 kV Line (Urban Area: 2015/ 2020)

5.4 System Analysis

In the result of system analysis, the major items on each phase is shown in Table 5.4-1, and the result of system analysis is shown in Table 5.4-2.

Table 5.4-1 Major items on each phase

Description	Unit	2015	2020	2025
Peak demand	[MW]	67.4	97.0	136.3
11 kV Lines (Except feeder)	[Lines]	18	18	18
33 kV Lines	[Lines]	11	13	14
161 kV Lines	[Lines]	1	2	2
No. of power stations	[station]	3	4	4
Total of output	[MW]	76.4	156.2	154.6
11 kV substation	[station]	2	2	2
33 kV substation	[station]	6	8	8
161 kV substation	[station]	1	1	1

[Source] JICA Study Team

Table 5.4-2 Result of system analysis

Items of analysis	Unit	2015	2020	2025
① Required capacity of SC	[MVA]	36	72	114
② Open lines for countermeasure to short circuit	[circuit]	2	5	5
③ Lines which have no adequate countermeasures	[circuit]	0	1	1
④ No. of lines less capacity to the requirement at normal conditions	[circuit]	0	3	7
⑤ Countermeasures to voltage drop in case of N-1 fault	[case]	0	1	3
⑥ Thermal capacity problem in case of N-1 fault	[case]	6	20	19
⑦ Voltage drop and/or thermal capacity problem in case of N-1 fault	[case]	6	20	21
⑧ Number of thermal faulty facility in case of N-1 fault	[No.]	2	6	15

[Source] JICA Study Team

Adequate SC capacity was studied up to 2015 which is calculated based on a lot of assumptions. And it seems that there are a lot of alternative systems to 2020 and 2025, therefore in this study, system analysis to 2020 and 2025 is omitted.

5.5 Optimal Distribution System

It is necessary to install SC as shown in Table 5.5-1 in the major distribution stations by 2015 according to increasing demand and 33 kV system configuration as a loop system.

Table 5.5-1 Proposed installation Plan of SC by year 2015

Name of station	Capacity of SC [MVA]	Target of installation
Falcon Bridge	6	By 2015
Brookfields	6	By 2015
Congo Cross	6	By 2015
Wilberforce	4	By 2015
Wellington	4	By 2015
Goderich	6	Including plan
Jui	6	Including plan

[Source] JICA Study Team

Also, it is necessary to take adequate countermeasures to solve the N-1 fault as mentioned in Table 5.5-2 such as lack of line capacity on L106 and L107, which can be solved by replacing these cables.

Table 5.5-2 Assumption of fault in 2015

No.	Facility	Faulty lines (Line No.)	Result and Remarks
1	33 kV line	Kingtom〜Falcon Bridge (L3101)	*No thermal capacity problem*
2		Kingtom〜Freetown (L3903)	*No thermal capacity problem*
3		Falcon Bridge〜Blackhall Road (L3201)	*No thermal capacity problem*
4		Blackhall Road〜Wilberforce (L3301)	*No thermal capacity problem*
5		Blackhall Road〜Wellington (L3302)	*No thermal capacity problem*
6		Blackhall Road〜Freetown (L3902)	*No thermal capacity problem*
7		Wilberforce〜Regent (L3601)	*No thermal capacity problem*
8		Wilberforce〜Freetown (L3901)	***Faulty***
9		Wilberforce〜Goderich (L3602)	Radial system
10		Wellington〜Jui (L3701)	*No thermal capacity problem*
11		Regent〜Jui (L3804･L3604)	*No thermal capacity problem*
12		Goderich〜Tombo (L31001)	York〜Tombo: not connected
13		Jui〜Lumpa (L31101)	Radial system
14		Lumpa〜Tombo (L31201)	Radial system
15	11 kV line	Kingtom(A-Bus)〜Falcon Bridge (L103)	*No thermal capacity problem*
16		Kingtom(A-Bus)〜Falcon Bridge (L104)	*No thermal capacity problem*
17		Kingtom(B-Bus)〜Falcon Bridge (L103A)	*No thermal capacity problem*
18		Kingtom(B-Bus)〜Falcon Bridge (L102)	*No thermal capacity problem*
19		Kingtom(A-Bus)〜Congo Cross (L120)	Open circuit
20		Kingtom(B-Bus)〜Congo Cross (L105)	***Faulty***
21		Kingtom(A-Bus)〜Brookfields (L107)	***Faulty***
22		Kingtom(B-Bus)〜Brookfields (L106)	***Faulty***
23		Kingtom(A-Bus)〜Freetown (L150)	*No thermal capacity problem*
24		Kingtom(B-Bus)〜Freetown (L151)	*No thermal capacity problem*
25		Falcon Bridge〜Blackhall Road (L203)	Open circuit
26		Falcon Bridge〜Blackhall Road (L202)	*No thermal capacity problem*
27		Congo Cross〜Wilberforce (L440)	*No thermal capacity problem*
28		Congo Cross〜Freetown(A-Bus) (L450)	*No thermal capacity problem*
29		Brookfields〜Wilberforce (L523)	*No thermal capacity problem*
30		Brookfields〜Wilberforce (L522)	*No thermal capacity problem*
31		Brookfields〜Freetown(A-Bus) (L550)	***Faulty***
32		Brookfields〜Freetown(B-Bus) (L551)	***Faulty***

[Source] JICA Study Team

However, before applying the above solution, following items shall be studied.

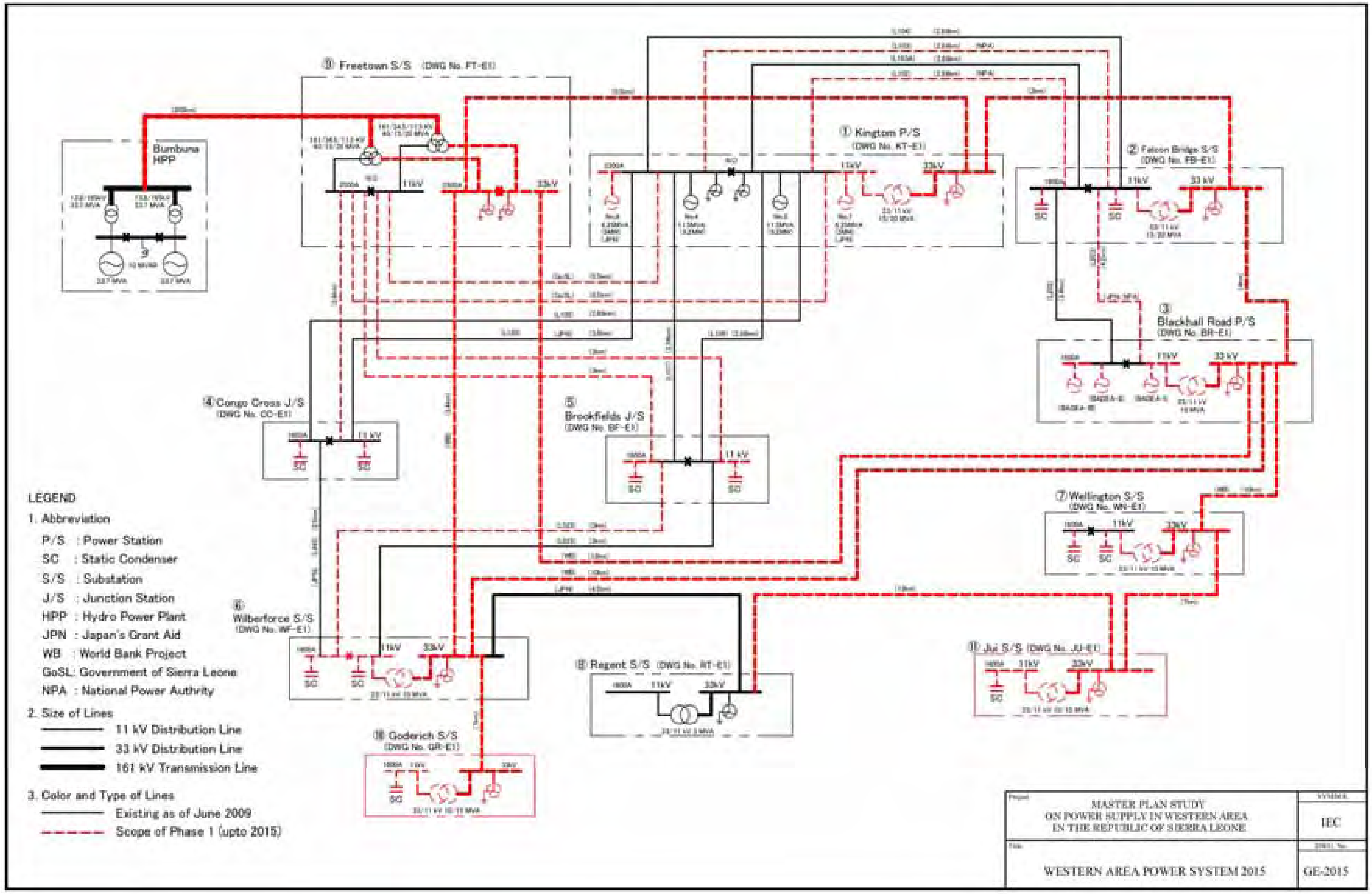
1) Review of ongoing project
   Upgrading of 11 kV lines (L550 and L551) between Freetown and Brookfields with size upgrading from 3c-185 sq to 1c-300 sq x 3

2) Re-check peak demand at Brookfields J/S
   Present open points on sub-trunk lines between Brookfields and Kingtom/Congo Cross/Wilberforce/ Falcon Bridge is decided based on experience. It shall be recommended that the open points on sub-trunk line between Brookfields and other major distribution stations shall be decided considering coverage area and minimum energy loss points based on actual power flow.

3) Data for system analysis
   There are a lot of assumed data in this analysis. These data shall be checked and actual data used as much as possible. Also, actual data to ongoing projects such as the 11 kV and 33 kV distribution systems and new generating facilities shall be used.

When 161 kV transmission line has fault, it is necessary to minimize the blackout area and prevent blackout of the capital.
It is necessary to conduct load shedding to keep the system stability. In this connection, it is strongly recommended to establish operating rules including priority order for load shedding and to install frequency relay in the 11 kV and 33 kV SWGRs.

Optimal system by 2015 is shown in Fig. 5.5-1.



[Source] JICA Study Team

Fig. 5.5-1 Western Area Power System 2015

Regarding the distribution system by 2020 and 2025, there are a lot of unclear factors including connection points of international transmission line and it is very complicated to have adequate optimal systems in each year. Therefore, preliminary system study is conducted for reference and future consideration.

As a result, it is recommendable that the 33 kV overhead line conductor for which specification is AAAC 150 sq may be upgraded to AAAC 240 sq, then the lack of line capacity problems can be solved. As for other problems in 2020 and 2025, peak demand and data shall be reviewed and also design standards including standard short circuit current should be decided as soon as possible to prevent further trouble.

There are three power sources to Western Area, i.e. Kingtom P/S, Blackhall Road P/S and Freetown S/S, which do not seem to be enough for the capital area. Lumpa S/S seems to be an adequate location as new power source which can be considered as a future Load Dispatching Center.

It is necessary to conduct new power projects to establish adequate distribution system as shown in Fig. 5.3-1 by 2025. Table 5.5-3 shows an outline of new projects with target year and project cost in each phase and objectives and results are shown in Table 5.5-4.

Table 5.5-3 Rehabilitation, Reinforcement and Expansion of Distribution System

No.	Name of Project	Outline of the Project	Cost [10^6US$]	Target Year
A.	**Phase-I：（2010～2015）**			
	1. Rehabilitation and Reinforcement of 11/33 kV systems	・Rehabilitation of 11 kV, SWGR ・Reinforcement of 33 kV facilities (Kingtom P/S, Blackhall Road P/S, Falcon Bridge S/S) ・Reinforcement of 33 kV lines (6 km)	25.6	2012
	2. Construction of 33 kV lines and S/S	・Reinforcement of 33 kV facilities (Construction of Goderich S/S, Jui S/S and 33 kV lines) ・Reinforcement of 33 kV line (20 km)	35.4	2014
	3. Rehabilitation of 11 kV facilities	・Rehabilitation of distribution transformer ・Reinforcement of LV lines	32	2015
B.	**Phase-II：（2016 ～2020）** 1. Reinforcement of 33 kV lines	・Construction of Lumpa and Tombo S/S ・Reinforcement of 33 kV lines (32 km)	33.7	2017
	2. Reinforcement and expansion of 33 kV lines	・Reinforcement of 33 kV facilities (New 161/33 kV trans. at Freetown S/S) ・Expansion of 33 kV lines (33 kV line from Goderich to York town: about 29 km)	31.4	2020
C.	**Phase-III：（2021～2025）** 1. Reinforcement and Expansion of Distribution network	・Reinforcement of 11 kV lines ・Expansion of 33 kV lines (36 km) ・Expansion of LV network	16.3	2025

[Source] JICA Study Team

Table 5.5-4 Objectives and Result

Phase	Present situation and objectives	Result
I- (1)	[Name of Project]: Rehabilitation and Reinforcement of 11/33 kV systems [Present Situations] It is urgently required to install new 33 kV system to meet increasing demand inWestern Area. Especially, Falcon Bridge, Brackhall Road, Wilberforce and Brookfields area will have serious demand increases and 33 kV system shall be established in these areas. [Objectives] In order to secure the power supply to the capital of Freetown, it is necessary to install 33 kV system from Kingtom P/S to Brackhall Road P/S through Falcon Bridge. This is because Falcon Bridge S/S is supplying power to the center of Freetown. Also, it is necessary to install 33/ 11 kV substation at Falcon Bridge. In order to minimize the fault area, it is necessary to rehabilitate existing 11 kV SWGR, such as protection and metering systems, and this will also help with providing actual records.	Secure power supply system and minimize the fault area and reduce energy losses.
I- (2)	[Name of Project]: Construction of 33 kV lines and S/S [Present situation] It is observed that the demand in Jui area will increase largely and Goderich will not have enough power supply lines. Especially, Goderich area suffers terrible voltage drop problems compared to the demand, only one 11 kV line is coming from Wilberforce S/S and many consumers cannot access the electricity. Also, this area is the base of power supply to Sussex and York town where there are a lot of development plans and demand is expected to increase. [Objectives] (1) To secure the reliability of the distribution system. Complete 33 kV loop from Kingtom, Falconbridge, Brackhall Road, Wellington, Regent, Wilberforce, Freetown (2) Construct Goderich S/S with 33 kV line from Wilberforce S/S	Secure reliability and improve quality
I- (3)	[Name of Project]: Rehabilitation of 11 kV facilities [Present Situation] There are a lot of faults because of old transformers and SWGRs. [Objectives] Replace old transformers and SWGRs which are more than 30 years old.	Secure stable power supply and reduce energy losses
II-(1)	[Name of Project]: Reinforcement of 33 kV lines [Present Situation] Present 11 kV system is connected up to Waterloo, and Koya rural does not have distribution system. Lumpa and Tombo are also not connection to the grid.	Secure reliable power supply and promote rural electrification

Phase	Present situation and objectives	Result
II-(2)	[Name of Project]: Reinforcement and expansion of 33 kV lines [Present situation] Present 33 kV capacity is not enough to cover the demand in 2025. Therefore, new 161/ 33 kV transformer needs to be installed at Freetown S/S.	Reinforce 33 kV system and secure reliable power supply
III-(1)	[Name of Project]: Reinforcement and Expansion of Distribution network [Objectives] There is no 33 kV loop from Wilberforce, Regent, Jui, Lumpa, Tombo, York and Goderich. This route shall be connected by 33 kV lines to have adequate power supply. 33 kV lines shall be installed from York to Tombo and Lumpa to Fogbo for promotion of rural electrification.	Promote rural electrification

[Source] JICA Study Team

6. Environmental and Social Considerations

6.1 Environmental and Social Considerations for Power Development Plan

This Master Plan consists of two components which need environmental and social considerations. One is the plan for power development and the other one is rehabilitation, reinforcement and extension of distribution lines.

There are several types of power generation. The environmental impacts of each type are summarized in the next table.

Table 6.1-1 Comparison of Environmental and Social Impacts of Various Power Generation Methods

		Hydropower			Thermal Power					Wind Power	Solar Power
Environmental Factors		Dam type	Flow-in type	Micro hydro	Steam-Power Generation			Internal Combustion Power Generation			
					Coal	Heavy Oil	Gas	Gas Turbine	Diesel		
Social Environment	Involuntary resettlement	A	B	C	B	B	B	B	B	B	C
	Local economy, such as employment and livelihood	A	B	C	B	B	B	C	C	C	C
	Land use and utilisation of local resources	A	B	B	B	B	B	B	B	B	B
	Social institutions, such as social infrastructure and local decision-making system	B	C	C	C	C	C	C	C	C	C
	Existing social infrastructure and services	C	C	C	C	C	C	C	C	C	C
	The poor, indigenous and ethnic people	A	B	B	B	B	B	C	C	C	C
	Erroneous communication of interests	C	C	C	C	C	C	C	C	C	C
	Cultural heritage	B	C	C	B	B	B	C	C	C	C
	Local conflict of interests	B	C	C	C	C	C	C	C	C	C
	Water usage or water rights and rights in common	A	B	C	B	B	B	C	C	C	C
	Public hygiene	B	C	C	C	C	C	C	C	C	C
	Infectious diseases	B	C	C	C	C	C	C	C	C	C
Natural Environment	Topography and geographical features	A	B	C	C	C	C	C	C	C	C
	Soil erosion	B	C	C	B	B	B	B	B	C	C
	Groundwater	C	C	C	C	C	C	C	C	C	C
	Hydrogical conditions	A	B	C	C	C	C	C	C	C	C
	Coastal zone	C	C	C	C	C	C	C	C	C	C
	Flora, fauna and biodiversity	A	B	C	B	B	B	B	B	B	C
	Meteorology	C	C	C	C	C	C	C	C	C	C
	Landscape	A	B	C	B	B	B	B	B	B	B
	Global warming	C	C	C	A	B	B	B	B	C	C
Pollution	Air pollution	C	C	C	A	B	B	B	B	C	C
	Water pollution	A	B	C	A	A	A	C	C	C	C
	Soil contamination	C	C	C	B	B	B	B	B	C	C
	Waste	B	B	C	B	B	C	B	B	C	C
	Noise and vibration	B	B	C	B	B	B	B	B	B	C
	Ground subsidence	C	C	C	C	C	C	C	C	C	C
	Offensive odour	C	C	C	C	C	C	C	C	C	C
	Bottom sediment	A	B	C	C	C	C	C	C	C	C
	Accident	B	B	C	B	B	B	B	B	C	C
Rating		**A** : Serious impact is expected **B** : Some impact is expected **C** : No or minimal impact is expected									

[Source] JICA Study Team

Power generation by clean energy such as solar and wind can minimize impacts on the environment. However, solar or wind power is dependent on the weather. For the time being, solar and wind energy is not an optimal option for the Western Area which is facing serious power shortages. Stable and reliable supply of electricity is necessary in this emergency stage. Thus, the Study Team suggests two types of power generation, that is, hydro power and thermal power in this Master Plan.

6.1.1 Thermal Power Development

If the above five types of thermal power generation methods are compared, it can be said that the environmental impact of diesel generator is smaller than the others'. In addition, diesel power generation is the easiest to operate and maintain. Since NPA has only experience of operating diesel engine generators, it is considered the diesel power generation method is the optimal option. Therefore, the diesel power generation method is recommended. In this Master Plan, it is proposed to use the Blackhall Road sub-station as a new power plant as well as the Kingtom power station to avoid adverse environmental impact by developing a new power plant at a new site. However, if the "Thermal Dominant Scenario" is chosen, it is required to construct another new power plant.

(1) Adverse Environmental and Social Impact Identified

Adverse environmental and social impacts identified for the thermal plant development are summarized in the next table. The natural and social environment in the target area and the condition of the existing power plan was taken into consideration to identify the impacts.

Table 6.1-2 Assessment of Adverse Environmental and Social Impacts of Thermal Plant (Diesel Generation)

Evaluation Items		Assessment Results			Expected Environmental and Social Impact
		General	Construction Stage	Operating Stage	
Social Environment	Involuntary Resettlement	**B**	**B**	**C**	Construction of a new power plant may require land acquisition.
	Local Economy, Employment and Livelihood	**C**	**C**	**C**	
	Use of Land and Other Local Resources	**B**	**B**	**C**	It may be necessary to acquire land for a new power plant and change the use of land.
	Social Institutions such as Social Infrastructure and Local Decision-Making Institutions	**C**	**C**	**C**	
	Existing Social Infrastructure/Services	**C**	**C**	**C**	
	The Poor, Indigenous of Ethnic People	**C**	**C**	**C**	
	Misdistribution of Benefit and Damage	**C**	**C**	**C**	
	Cultural Heritage	**C**	**C**	**C**	Although there are cultural heritages in Western Area, most of them are small monuments.
	Conflict of Local Interests	**C**	**C**	**C**	
	Water Rights and Rights of Common	**C**	**C**	**C**	
	Public Health	**C**	**C**	**C**	
	Infectious Diseases	**C**	**C**	**C**	

Evaluation Items		Assessment Results			Expected Environmental and Social Impact
		General	Construction Stage	Operating Stage	
Natural Environment	Topographical and Geographical Features	C	C	C	
	Soil Erosion	B	B	C	Construction of a power plant and installation of generators may cause soil erosion caused by site preparation.
	Groundwater	C	C	C	
	Hydro geological Conditions	C	C	C	
	Coastal Zone	B	B	B	If a power plant is located near the coast or mangrove swamp, it carries risk of polluting the areas without necessary auxiliary facilities.
	Flora, Fauna and Bio-Diversity	B	B	B	If a power plant is located near the important protected sites, it may give impact to the flora and fauna.
	Meteorology	C	C	C	
	Landscape	B	B	B	A power plant may not be in harmony with the surrounding environment.
	Global Warming	B	C	B	New diesel engine generators will discharge CO^{2}.
Pollution	Air Pollution	B	C	B	New diesel engine generators will discharge NOx and SOx.
	Water Pollution	B	C	B	New diesel engine generators may pollute water without necessary auxiliary facilities
	Soil Contamination	B	C	B	New diesel engine generators may contaminate soil by oil leak without necessary auxiliary facilities.
	Waste	B	B	B	Increase of the capacity of power supply by adding diesel-engine generators increases the amount of waste oil.
	Noise and Vibration	B	B	B	New diesel-engine generators will discharge noise and cause vibration. Construction noise and vibration are usually observed.
	Ground Subsidence	C	C	C	
	Bad Odour	C	C	C	
	Benthic Sediment	C	C	C	
	Accidents	B	C	B	There is a risk of fire.

Rating
A: serious impact is expected
B: some impact is expected
C: minimum or hardly any impact is expected
[Source] JICA Study Team

(2) Mitigation Measures

To mitigate the expected impacts in the table above, the following measures are recommended.

1) Involuntary Resettlement

Careful consideration of the location of a new power plant can avoid or minimize involuntary resettlement.

2) Use of Land and Other Local Resources

To choose a site which does not change the use of land widely as much as possible or to avoid a site where people depend on their lives is necessary.

3) Soil Erosion

Before site preparation of a new diesel engine generator or a power plant, survey of geological condition should be conducted to take necessary measures to avoid soil erosion.

4) Coastal Zone

It is better to avoid constructing a new plant near the Sierra Leone River Estuary and Yawri Bay area in order not to cut mangrove forests and give adverse impact on the environment. When a new generator is installed in the Kingtom Power station, it is a must to install necessary auxiliary facilities not to pollute the sea around the power station or give impacts on marine animals and plants, because effluent from the power plant used to be discharged to the sea.

5) Flora, Fauna and Bio-Diversity

Threatened species of flora and fauna can be observed in Western Area. The location of a new plant has to be decided carefully to avoid interference to threatened species of animals and plants in particularly in WAPF and the Sierra Leone River Estuary.

6) Landscape

Planting trees in a power plant and designing a power plant in harmony with the surrounding environment is necessary.

7) Global Warming

New diesel engine generators to be installed should have high thermal efficiency and keep the emissions of CO^2 low.

8) Air Pollution

An exhaust gas system, which meets the international standards for the emissions of NOx, SOx and dust, for the generators and an engine with low NOx emissions should be installed. Installing a higher stack is also effective.

9) Water Pollution

A new diesel generator should have a sludge treatment system to meet the international standards for oil content emission to avoid water pollution.

Water containing waste oil used to be discharged to the ocean in the Kingtom Power Station when the generators were operating, as the sludge treatment system was not working. Currently, the Moroccan government is trying to fix one of the broken down generators in the Kingtom power station. If the generator operates again, it is recommended to install a new sludge treatment system or at least clean up the pond of the existing sludge treatment system to boost efficiency.

10) Soil Contamination

Oil stains by lubricant or oil leaks from the waste oil tanks or from the sludge treatment system are observed on the ground and in the drains of Kingtom Power Station. When the Sulzer 4 is fixed by Morocco and starts operation again, the present sludge treatment system in the Kingtom Power Satiation, which is not working properly, should be changed to a new one, and proper maintenance system should be introduced. Not only for the sludge treatment system, but proper operation and maintenance of generators and other facilities and equipment should be introduced to avoid oil leak.
Oil retaining bunds should be installed around waste oil tanks. And the ground surface should be covered by concrete to avoid penetration of oil to the ground.

11) Waste

Oil is one of the major wastes generated from a power plant, and it has a risk to pollute the environment. The NPA used to give waste oil to an oil treatment company for reuse. It was reported that oil spill was observed everywhere in the treatment facility. Since this company stopped its business and the NPA is not generating electricity by their generators, waste oil has been kept in waste oil tanks in the Kingtom power plant. If an oil treatment facility which operates in an environment-friendly manner cannot be found, it will be necessary to install an incinerator to burn waste oil when a new generator is installed.

There is no separate waste collection system in Sierra Leone. Wastes are not separated in two dump sites in Freetown either. A separate waste collection system for normal solid waste, hazardous waste and recyclable should be established in the NPA. No landfill or treatment facilities for hazardous waste are available in Sierra Leone. The NPA, as a generator of wastes, should be responsible for all types of wastes. If there is no landfill to dump hazardous wastes such as oil or chemicals, the NPA should separate them and secure a safe place to keep them as a temporary solution.

12) Noise and Vibration

A new diesel engine generator and a power house should be designed to reduce noise and vibration by choosing a low noise level type generator or installing necessary auxiliary facilities and equipment such as sound proof walls. And generators should be installed in a powerhouse with strong platform, roof and walls with certain distance from the surrounding houses.

13) Accidents

Currently no training for fire fighting is held for NPA workers in the power plant. And there are not enough fire extinguishers in good condition. Procedures in case of fire should be taught to NPA workers and the power plants need to equip necessary fire extinguishers.

6.1.2 Hydro Power Development

(1) Adverse Environmental and Social Impact Identified

As there are not enough data for Yiben, general adverse environmental and social impacts of hydro power are mainly identified as below.

Table 6.1-3 Assessment of Adverse Environmental and Social Impact of Hydro Power Generation

Evaluation Items		Assessment Results			Expected Environmental and Social Impact
		General	Construction Stage	Operating Stage	
Social Environment	Involuntary Resettlement	**A**	**A**	**C**	Construction of a hydro dam requires acquiring land. The people have their houses and farmlands in the area and have to be resettled.
	Local Economy, Employment and Livelihood	**A**	**A**	**A**	Resettlement or change of land use may mean changing or losing means of livelihood (farming, fishing, collection of fire woods or non timber forest products in forest) of project affected persons.
	Use of Land and Other Local Resources	**A**	**A**	**B**	Forests or farmlands will be lost.
	Social Institutions such as Social Infrastructure and Local Decision-Making Institutions	**B**	**B**	**B**	Resettlement may divide one community into two or more. Or a whole community may be resettled in a host community. This may affect the role of existing social institutions.
	Existing Social Infrastructure/Services	**C**	**C**	**C**	It is thought that no adequate social services such as education or health are provided in provinces, in particular remote areas.
	The Poor, Indigenous of Ethnic People	**B**	**B**	**B**	The poor or the vulnerable (eg the old or widow) have more difficulties to restore their lives in a resettled site.
	Misdistribution of Benefit and Damage	**C**	**C**	**C**	
	Cultural Heritage	**B**	**B**	**C**	Cultural heritage may be submerged. There is no cultural heritage in the Yiben area. But there are sacred sites in villages.
	Conflict of Local Interests	**B**	**C**	**B**	Host communities of project affected persons (PAPs) sometimes feel unfairness because PAPs receive generous supports.
	Water Rights and Rights of Common	**A**	**B**	**A**	The change of water flow and volume may have some impacts.
	Public Health	**B**	**B**	**B**	The influx of construction workers and newcomers seeking an economic opportunity after the completion of a dam will raise the risk of the spread of infectious diseases such as sexual transmission diseases, AIDS/HIV. A reservoir will be a good breeding site for mosquitoes and raise a risk of spread of infectious diseases by mosquitoes.
	Infectious Diseases	**B**	**B**	**B**	

Evaluation Items		Assessment Results			Expected Environmental and Social Impact
		General	Construction Stage	Operating Stage	
Natural Environment	Topographical and Geographical Features	**A**	**A**	**C**	Construction work of a dam may change topographical and geographical features in the area.
	Soil Erosion	**B**	**B**	**B**	Landslide or earth fall might happen by making a reservoir and change of water level.
	Groundwater	**C**	**C**	**C**	
	Hydrogeological Conditions	**A**	**A**	**A**	A dam might have impact on hydro geological conditions.
	Coastal Zone	**C**	**C**	**C**	
	Flora, Fauna and Bio-Diversity	**A**	**A**	**A**	Habitats of animals and plants will be lost by construction of a dam. Even though there is no protected area nearby Yiben, animals and plants occurring in the dam area will lose their habitats.
	Meteorology	**C**	**C**	**C**	
	Landscape	**A**	**A**	**A**	A dam type hydro power generation leads to a big scale construction. This causes loss of the environment in the surrounding area and drastic change in landscape.
	Global Warming	**C**	**C**	**C**	
Pollution	Air Pollution	**C**	**C**	**C**	
	Water Pollution	**A**	**B**	**A**	Eutrophication in the reservoir and decayed plants under reservoir may cause water pollution. Construction works and mishandling of wastes may pollute water.
	Soil Contamination	**C**	**C**	**C**	
	Waste	**B**	**B**	**C**	Excavated earth of sand and construction wastes will be discharged.
	Noise and Vibration	**B**	**B**	**C**	Construction noise and vibration are usually observed.
	Ground Subsidence	**C**	**C**	**C**	
	Bad Odour	**C**	**C**	**C**	
	Benthic Sediment	**A**	**B**	**A**	Sedimentation may happen in the reservoir. The level of riverbed in the upstream of the river may be increased.
	Accidents	**B**	**B**	**B**	Accidents in the construction site may happen. There is a risk of accident in the downstream of the dam caused by discharged water.

Rating
A: serious impact is expected
B: some impact is expected
C: minimum or hardly any impact is expected
[Source] JICA Study Team

(2) Mitigation Measures

To mitigate the expected impacts in the table above, the following measures are recommended.

1) Involuntary Resettlement

To change the location of a dam slightly or to lower the full supply water level of the reservoir could minimize involuntary resettlement.

2) Local Economy, Employment and Livelihood

Livelihood assistance project or income generation projects for example agriculture extension services to teach the skills to produce new agricultural products, vocational training, micro finance service and so on should be implemented to assist projected affected people during and after the construction period.

3) Use of Land and Other Local Resources

During and after the construction of a dam, a project of the watershed management should be implemented to conserve the environment.

4) Social Institutions such as Social Infrastructure and Local Decision-Making Institutions

Consultation with communities and households should be held with host communities to discuss how to keep or modify the existing institutions in a resettled site.

5) The Poor, Indigenous and Ethnic People

It is necessary to identify the vulnerable groups by economic and social survey, and special assistance should be given to them.

6) Cultural Heritage

To avoid cultural heritages in deciding the location of a dam is required. If it is difficult, heritages should be moved to another site. Communities sometimes have sacred sites in a community. The Bumbuna dam project relocated these sacred sites after consultation with the communities and organizing a ceremony. It is necessary to give such consideration.

7) Conflicts of Local Interests

A supporting program which will benefit host communities, such as construction of footpath, community center, school, health center should be implemented too.

8) Water Rights and Rights of Common

A survey of water use and water rights should be conducted in advance to take countermeasures.

9) Public Health and Infectious Diseases

Health education to construction workers during the construction period and to communities and new comers during and after the construction period should be held.

10) Soil Erosion

To conduct a comprehensible geological survey is required to avoid the landslide or earth fall-prone areas. Planting trees around the area is a measure to retain soil.

11) Hydro geological Conditions

A hydro geological survey should be conducted in advance to take countermeasures.

12) Flora, Fauna and Bio-Diversity

To change the location of a dam slightly or to lower the full supply water level of a reservoir could minimize the impacts on flora and fauna.

If endangered species or endemic species are found in the planned site, to create a protected area in near places or other habitats, then to conduct careful monitoring is required. Education programs for the community in the area should be organized to raise their awareness to protect the biodiversity.

13) Landscape

It is necessary to design in harmony with the surrounding environment and to plant trees in the area.

14) Water Pollution

Plants should be removed before impoundment to avoid water pollution caused by decayed plants.

It is necessary to provide necessary sanitation facilities to construction workers and to implement waste management to avoid pollution caused by waste generated during the construction period

After the construction period, to install a fraction fence or aerator to avoid eutrophication in the reservoir can be effective. And to do monitoring of water quality and take necessary measures to avoid water pollution, which may affect the ecosystem in watershed areas and water use of people living in the downstream area, is necessary.

15) Waste

Waste management should be undertaken for waste generated during the construction period such as construction wastes.

16) Noise and Vibration

To give information regarding noise and vibration caused by construction work to the neighboring community to gain understanding is necessary.

17) Benthic Sediment

In the design stage, the amount of expected sediment should be considered to provide enough capacity of a reservoir. If necessary, sand discharge facilities should be installed.

18) Accidents

Contractors should be responsible for occupational health and safety of construction workers.

After a power plant starts operation, to raise awareness of people who live in the downstream about the danger of discharged water and how to act is necessary. And to build an alarm system with sirens or speakers to give notice of discharge schedule is also necessary.

6.2 Environmental and Social Considerations for Substations, Transmission and Distribution Lines

6.2.1 Strategic Environmental Assessment (SEA) for the Renewal, Reinforcement and Extension of the Distribution Line

Considering the natural and social environment in Western Area, it is required in this Master Plan to conduct SEA regarding the renewal, reinforcement and extension of the distribution lines.

(1) Options for Distribution Network Route in Western Area

Firstly, three options will be compared to determine the route of distribution lines for renewal, reinforcement and extension in the whole Western Area.

1) Without Option

2) Only North to East Part of the Peninsula Option

The second option is to renew, reinforce and extend the distribution lines only in the north-east part of the peninsula.

3) Around the Peninsula Option (Ring Trunk Network)

This option is to renew, reinforce and extend the distribution lines around the peninsula.

The Study Team proposes the third “Around the Peninsula Option (Ring Trunk Network)” among the three options, because the third option is in accordance with the policy of the government, it can contribute to economic development of the country and improve life of people, and build a ring distribution network which is able to easily back up in cases of accidents. Also it is possible mitigate expected adverse impacts by taking proper mitigation measures.

(2) Options for Distribution Network in Freetown City

Secondly, two options will be compared to determine the route in Freetown.

1) Rehabilitate Only the Lines which Need Emergency Rehabilitation Option

This option can avoid resettlement at minimum. But even now, the fragility of the network increases the workload of NPA workers because the weak network system causes many accidents. And hundreds people are always on the waiting lists to be connected.

2) Ring Trunk Network Option

This option is to develop a ring network in Freetown to increase the reliability of power supply. This option can contribute to meet the target set by the government, 100% electrification rate in urban area by 2025.

There is a possibility of occurrence of involuntary resettlement, as the city is very congested. Necessary mitigation measures should be considered. There are several mitigation measures. One measure is to use high towers instead of normal electric poles for distribution lines and stretch the lines over the crowded area.

Secondary, careful determination of location of each pole can decrease the number of affected people. The next option is to use marine cable along the coastal line. This can avoid involuntary resettlement especially in the most congested area along the northern coastal line.

The Study Team proposes the second option "Ring Trunk Network Option" between the two options. The current distribution network is so old that many accidents happen. To make matters worse, the response to such accidents is temporary repairs and this has resulted in high distribution loss. The distribution loss is one of the reasons for the NPA's bad financial condition. This is the reason we propose a ring trunk network, which is able to back up in case of accidents and to increase electrification ratio. Regarding involuntary resettlement, it is considered that mitigation is possible if necessary measures explained above are taken.

6.2.2 Plan for Rehabilitation, Reinforcement and Extension of Distribution Lines

(1) Adverse Environmental and Social Impact Identified

Adverse environmental and social impacts identified for the planned substations, transmission and distribution lines can be summarized in the next table. The natural and social environment in the target area and the current conditions of the existing substations and distribution lines were considered to identify the impacts. Regarding the transmission line from a new hydro dam to Western Area, the route is not determined in this Master Plan. Therefore, general impacts are assessed.

Table 6.2-1 Assessment of Adverse Environmental and Social Impact for Substations, Transmission and Distribution Lines

Evaluation Items		Assessment Results			Expected Environmental and Social Impact
		General	Construction Stage	Operating Stage	
Social Environment	Involuntary Resettlement	**B**	**B**	**C**	Construction of a substation (50m×50m) and transmission and distribution lines require land acquisition. The congestion and existence of big slums in Freetown and encroachment in ROW of roads in the whole Western Area raise a concern of involuntary resettlement.
	Local Economy, Employment and Livelihood	**B**	**B**	**C**	There are many small shops along the streets in Freetown. The construction of distribution lines may require them to relocate or affect their livelihood.
	Use of Land and Other Local Resources	**B**	**B**	**C**	It is necessary to acquire land for substations and transmission and distribution lines.
	Social Institutions such as Social Infrastructure and Local Decision-Making Institutions	**C**	**C**	**C**	
	Existing Social Infrastructure/Services	**C**	**C**	**C**	
	The Poor, Indigenous of Ethnic People	**C**	**C**	**C**	
	Misdistribution of Benefit and Damage	**C**	**C**	**C**	
	Cultural Heritage	**C**	**C**	**C**	
	Conflict of Local Interests	**B**	**C**	**B**	There is a possibility of conflict of local interests between electrified and non-electrified areas.
	Water Rights and Rights of Common	**C**	**C**	**C**	

Evaluation Items		Assessment Results			Expected Environmental and Social Impact
		General	Construction Stage	Operating Stage	
	Public Health	C	C	C	
	Infectious Diseases	C	C	C	
Natural Environment	Topographical and Geographical Features	C	C	C	
	Soil Erosion	B	B	C	Construction of substations and transmission and distribution lines may cause soil erosion by site preparation and cutting tree.
	Groundwater	C	C	C	
	Hydrogeological Conditions	C	C	C	
	Coastal Zone	B	B	B	Sierra Leone River Estuary, a wetland registered in the Ramsar Convention is located in north-east of the peninsula. The extension of distribution lines in this area may give some impact.
	Flora, Fauna and Bio-Diversity	B	B	B	Distribution lines run near Western Area Peninsular Forest Reserve and Sierra Leone River Estuary, which may give some impact on flora, fauna and biodiversity. Transmission lines from a new hydro dam might pass through forests.
	Meteorology	C	C	C	
	Landscape	B	C	B	Transmission/distribution lines may not harmonize with the scenery.
	Global Warming	C	C	C	
Pollution	Air Pollution	C	C	C	
	Water Pollution	C	C	C	
	Soil Contamination	B	C	B	Oil leak from transformers at sub stations may happen.
	Waste	B	B	B	Insulating oil in old transformers may contain Poly Chlorinated Biphenyl (PCB).
	Noise and Vibration	C	C	C	
	Ground Subsidence	C	C	C	
	Bad Odour	C	C	C	
	Benthic Sediment	C	C	C	
	Accidents	B	C	B	There are many structures under the unused existing power distribution lines. There is a risk of accidents to the public if electricity is turned on. Safety rules and maintenance methods are not usually observed at NPA. There is a risk of accidents to NPA workers and the general public.
	Electromagnetic field	C	C	C	

Rating
A: serious impact is expected
B: some impact is expected
C: minimum or hardly any impact is expected
[Source] JICA Study Team

(2) Mitigation Measures

To mitigate the expected impacts in the table above, the following measures are recommended to take.

1) Involuntary Resettlement

Routes of transmission and distribution lines and location of each electric tower (pylon) and pole should be carefully determined to avoid unnecessary involuntary resettlement when overhead line is used. High towers for the distribution lines should be used in the crowded areas in Freetown to minimize resettlement.

It is ideal to secure ROW of transmission and distribution lines, and to have no structures under the line. But to avoid involuntary resettlement, the safety clearances limit, i.e. “the distance from the lowest conductor to a roof top of a structure,” has been adapted in Sierra Leone by the World Bank assisting projects. This is 7m for 161kV line, and 5m for 33kV line which is consistent with European and American safety standards. If it is possible, ROW should be secured. But if it is difficult, this safety clearance limit can be applied.

2) Local Economy, Employment and Livelihood

Many people in Freetown are engaged in the service sector, in particular, petty trading. So along the streets, many small shops can be seen. If relocation of those small shops is needed, compensation should be paid or assistance for income generation should be given to them.

3) Use of Land and Other Local Resources

In case the NPA needs to acquire land, it should choose land which has least impact and avoid acquiring land inside the protected areas in consultation with the Ministry of Lands, Country Planning and the Environment.

4) Conflict of Local Interests

The government and the NPA should disclose the electrification plan to the public to gain their understanding.

5) Soil Erosion

As for the distribution lines, if the lines go along the existing roads, there will be minimum tree cutting. For site preparation of substations or electric towers, survey of geological condition should be conducted to take necessary measures to avoid soil erosion.

6) Coastal Zone

As far as the new distribution lines run along the existing road, which run with certain distance from the wetland, there will be minimum adverse impact. For the future secondary distribution lines to the new points, the lines should also along the existing roads not to cut down mangrove trees or any other plants in the future.
A substation should be constructed away from the mangrove swamp.

7) Flora, Fauna and Bio-Diversity

To avoid interference to threatened species of animals and plants in WAPF and the Sierra Leone River Estuary, substations will not be constructed inside WAPF and in Sierra Leone River Estuary. The distribution line should be along the existing roads to avoid going deeper in the protected areas.

According to the Forestry Division, it is acceptable to extend the distribution lines along the existing road although one part of the road passes inside the original boundary of WAPF, unless the line goes across WAPF without following the existing roads. The existing roads run along the foot of hills, so they will not have serious adverse impact on flora and fauna.

However, as overhead transmission/distribution facilities (lines, poles and conductors) give negative impact on birds, such as electrocution and collision, necessary measures should be taken.

8) Landscape

Transmission/distribution lines should be designed in an environmental conscious manner.

9) Soil Contamination

Oil leaks can be observed in the existing substations. Oil retaining bands or pits should be installed around transformers. And the earth surface should be covered by concrete to avoid penetration of oil to the ground. Then, an adequate operation and maintenance system for substations should be established.

10) Waste

There is no regulation on PCB disposal or treatment facilities in Sierra Leone. Thus, the NPA, as a generator of waster, should safely store the old transformers in a properly controlled storage for the time being as a temporary solution, and establish a safety handling procedures to protect NPA staff. And it is desirable to establish a recycling system as recyclable waste will be discharged after renewing the distribution line.

11) Accidents

To avoid electrocution or fires caused by distribution facilities, to keep minimal safety clearance between the line and structures is needed. Also to enhance safety factors of distribution line is needed.

The current safety rules should be followed by the NPA. The NPA should raise awareness of people on potential accidents.

7. Financial and Economic Analyses

7.1 Comparison of Own Generation Costs and Corresponding NPA Charges

Willingness-to-pay survey was conducted from November to December in 2008 by Peninsular Group of Companies with support of JICA Team.

Based on the results of the survey, consumers' own generation costs are compared with the NPA's tariffs as follows.

The survey result shows the average monthly fuel cost of each category consumer and assuming 30 US cents/kWh as general generation cost, own generator demand (kWh/month) can be calculated. Then, the average generator investment cost can be exchanged to US dollars and annuitized using the following formula.

$$\frac{\text{Investment cost X Discount Rate (10\%) X (1+ Discount rate)}^{\text{Economic Life (year)}}}{\text{(1+ Discount Rate)}^{\text{Economic Life (year)}}\ -1}$$

The annuitized investment cost can be divided by 12 and monthly costs can be calculated. The average operation and maintenance cost (including fuel cost) obtained from the survey is added and monthly total own-generator cost can be calculated.

The old and new tariffs of the NPA are applied to each category consumer's average monthly used electricity volume of own generation calculated above and compared with the own generation cost. The result is shown in Table 7.1-1.

Own generation cost is more than NPA charges for domestic, commercial and institutional consumers. However, industrial consumers' own generation cost is less than the NPA charges, even old charges. Therefore, they may use their own generators rather than NPA power as long as the tariff of the NPA for industry is as expensive as the old tariff. The new tariff is, needless to say. The factors other than cost may be noise, air pollution and operation and maintenance work.

Table 7.1-1 Comparison of Own Generation Costs and Corresponding NPA Charges

Category	Fuel Cost	Fuel Cost	Demand	Investment	Annuitized	O&M	Cost	NPA(old)	NPA(new)
	Le/M	UScents/M	kWh/M	US$/Y	US$/M	US$/M	US$/M	US$/M	US$/M
Household	179,018	5,631	188	129	10.7	64.8	75.5	32.1	48.2
Commercial	1,019,575	32,072	1,069	451	37.6	410	447	280	420
Institution	2,441,223	76,790	2,560	6,231	519	872	1,391	629	943
Industry	10,917,750	343,426	11,448	21,645	1,804	4110	5,914	6323	9484

[Remarks] 1Le=0.03060JPY, 1US$=97.28JPY

[Source] JICA Study Team

7.2 Long-run Marginal Cost Calculation

7.2.1 Concept of Long-run Marginal Cost

According to the JBIC's "Power Tariff Theory and Analysis Handbook" (only Japanese version) published in February 2000, since the electrical market is a natural monopoly and there is no competitive pressure, it is necessary to set tariff at the price equal to "marginal cost" politically in order to attain efficient resource allocation. Long-run marginal cost is marginal cost (necessary cost to attain production increase per unit) in the long term as the capital (facility investment) changes (increases and decreases) (in the case of electricity, usually 20 years).

The guideline indicates the causes bringing about the difference of marginal cost as follows.

- Voltage class
  Marginal cost is calculated depending on cost necessary to increase electrical supply and so the marginal cost differs depending on the voltage class at which each user receives electricity. Long-run marginal cost of high voltage users such as factories is cheaper than that of low voltage user households. Generally, different tariffs are imposed on voltage classes based on the marginal costs.

- Peak and off-peak
  Marginal costs at peak and off-peak times differ. In particular, demand increase at peak time causes not only energy cost increase but also facility cost increase because of additional generation facility capacity need and it is the main cause of marginal cost difference between peak and off-peak times. Generally, introduction of tariffs based on the marginal cost difference between 1) peak and off-peak in a day (night time off-peak tariff) and 2) seasonal peak and off-peak in a year (such as summer tariff) is examined.

- Area
  Marginal costs of a densely populated area and a rural dispersed area or areas with very different distances from the generation station differ because necessary facilities differ. If the marginal costs by areas differ very much, it is efficient to impose different tariffs by each area. However, there is a case that a nation adopts a policy to impose national uniform tariffs from the viewpoint of equity and if the uniform tariff policy is prioritized, a cross-subsidy happens.

The calculation methods of long-run marginal cost are different between generation and transmission & distribution. Marginal cost of generation includes energy cost, but that of transmission & distribution is only facility cost excluding loss. Long-run marginal cost is regarded as long-run average increment cost obtained from dividing the least facility investment cost of original investment plan by annual demand increase based on the existing demand forecast. The calculation method is described as follows.

(1) Find A= (Present value sum of investment and O&M costs during a certain period) / (Present value sum of annual peak demand increase during the same period)

(2) Convert A ($/kW) resulting from (1) above to annual value, namely annuitize
$A \times i \times (1+i)^n / ((1+i)^n -1) = B$ $/kW/year

(3) Convert B in $/kW/year resulting from (2) above to value in $/kWh
B/ 365days/ 24hours / Load Factor (0.65)

Long-run marginal cost of generation requires addition of fuel and variable costs calculation.
It is said that the power industry is one of the plant industries and so initial investment cost is high and past accumulated investment cost becomes great. Therefore, tariffs of power operators to maintain their sound financial balance may tend to be higher than those to cover the future cost (Long-run

marginal cost). In this case, it is necessary to set tariffs higher than Long-run Marginal Cost in order to continue their business.

7.2.2 Application of Long-run Marginal Cost to This Project

An example table to calculate long-run marginal cost is applied to the JICA Study using the power development plan with investment and NPA's existing financial data.

Long-run marginal costs of generation, transmission (actually, HV&MV in the case of NPA) and distribution are summarized as follows.

Generation (Base Case: Hydro Main):	13.5	US cents/kWh
HV&MV:	3.17	US cents/kWh
Distribution:	0.48	US cents/kWh
Total:	17.2	US cents/kWh
Generation (Alternative: Thermal Main):	15.5	US cents/kWh
HV&MV:	3.17	US cents/kWh
Distribution:	0.48	US cents/kWh
Total:	19.2	US cents/kWh

7.3 Financial Estimate Based on Power Development Plan

7.3.1 Estimate Model Structure

Based on the power development plan, a financial estimate model of the NPA for the future is prepared. It starts from 2009 and continues until 2030. The revenue of the NPA in 2009 is estimated from the sale data from January to April except February. The other income is assumed to be 10% of sale based on the past data. The expenditure is estimated based on the past data, too. Bumbuna hydropower is assumed to begin supply power from December, 2009. The purchase price is set at 7 US cents/kWh, but it can be changed in the model calculation. In addition, the currency used is US dollar. The exchange rate is 3,179.07 Le/US$ according to the rate of Bank of Sierra Leone as of June 3, 2009. The other assumptions are as follows.

- Revenue
  The past tariff (before the raise in December, 2008) of the NPA is set, but increase rate (e.g. 120% shows 120% of the past tariff) can be changed (e.g. 100% is the same as the past tariff). The tariff is multiplied by demand in each consumer category based on the demand forecast except industrial consumer category for which 93.5% is set because the industrial tariff is necessary to be competitive with own generation based on the willingness to pay survey result. Furthermore, institution users are included in commercial users. However, it is assumed that the rates of system loss and collection (namely arrears) are 40% and 70% in 2009 and would be improved to 15% and 95% in 2025 (transmission and distribution investment completion), respectively, improving proportionately between 2009 and 2025.

- Expenditure
  General administration and payroll costs are supposed to change proportionately to the revenue. Operation and maintenance costs for new facilities and fuel cost are based on the power development plan. Income electric generation (payment) will continue until February 2011 and capacity charge (US$ 100,000 per month) will be paid to Income Electric until accumulated monthly payment becomes US$ 12 million

- Depreciation

The existing asset depreciation is calculated based on the NPA asset data. Lifetimes are as follows.

Building: 50 or 30 years
Diesel generator (middle-speed): 20 years
Transmission and distribution facility: 20 years
General and office equipment and furniture: 5 years
Vehicle: 4 years

Lifetimes of the new investment facilities are as follows.
Low-speed generator: 30 years
High-speed generator: 10 years
Hydropower facilities: 50 years

Scrap value is null and depreciation is linear.

- Long-term liability

The existing long-term liabilities such as EU's and IDA's have not been repaid because the NPA has had deficits. When the NPA gets profits, interest payment and repayment of the existing long-term liabilities would be started at once. The conditions are as follows.

EU: 15 years for repayment and 2% as interest rate
IDA: 20 years for repayment with 5 years grace period and 7.75% as interest rate
BADEA and Saudi Fund: 30 years for repayment with 10 years grace period and 1% as interest rate

New investment in the power development plan of this study is assumed to be funded as follows based on the Bumbuna Hydroelectric Company loan by the AfDB and other donors and Power and Water project loan of the IDA.

Yiben Hydroelectric Generation: 40 years repayment with 10 years grace period and 2% interest rate
Other investment (diesel and distribution): 20 years repayment with 5 years grace period and 5% interest rate

- After profit

Corporate tax is 28%. Dividend is 10%. Commercial bank interests for lending and saving are 15% and 4%, respectively.

The power development plan shows two cases. One is Hydro Dominant Case and the other is Thermal Dominant Case. Therefore, the financial estimate models are prepared for these two cases with the assumptions above. In addition, another model is prepared in the case that Yiben I and II would be constructed and operated by Bumbuna Hydropower Company and their generated power would be purchased by the NPA at the same price of Bumbuna's (Yiben IPP Case).

7.3.2 Model Calculation Results

Those financial estimate model calculation results can be summarized in Table 7.3-1.

Table 7.3-1 Financial Estimate Model Calculation Results

Case	Bumbuna price	System loss 09	Collection rate 09	Long-term liability	Tariff					NPV (10%) Mill. US$	DSCR
					Increase	Average	Domestic	Commercial	Industrial		
Hydro main	7 c/kWh	40%	70%	Existing	130%	27 c/kWh	23 c/kWh	34 c/kWh	28 c/kWh	41	0.25~116
	10 c/kWh	40%	70%	Existing	165%	31 c/kWh	29 c/kWh	43 c/kWh	28 c/kWh	74	0.21~62
	20 c/kWh	40%	70%	Existing	280%	48 c/kWh	49 c/kWh	73 c/kWh	28 c/kWh	180	0.14~8.3
	7 c/kWh	15%	95%	Existing	80%	19 c/kWh	14 c/kWh	21 c/kWh	28 c/kWh	5	0.38~16
	7 c/kWh	40%	70%	Transferred	115%	25 c/kWh	20 c/kWh	30 c/kWh	28 c/kWh	1	0~1.03
Thermal	7 c/kWh	40%	70%	Existing	155%	30 c/kWh	27 c/kWh	41 c/kWh	28 c/kWh	9	0.43~2.0
Yiben IPP	7 c/kWh	40%	70%	Existing	135%	27 c/kWh	24 c/kWh	35 c/kWh	28 c/kWh	54	0.26~11.6

[Remarks] 1US$=97.28JPY [Source] JICA Study Team

Thus, the Base Case is most desirable from the financial viewpoint. However, if Yiben is to be developed as IPP and purchase price can be as cheap as possible, Yiben IPP Case can be considered although tariff is 135% up and NPV (10%) is US$ 54 million.

7.3.3 Consideration of Long-run Marginal Cost

Long-run marginal costs of this project described above are much less than NPA tariffs which enable NPA to continue to manage financially as estimated above. Therefore, long-run marginal cost is different from financial needs. However, most industrial consumers use higher voltage than other consumers and industrial tariffs should reflect the less cost for high and middle voltage users than other users who should bear the distribution costs in long-run marginal cost calculation. (But, this is not necessarily concluded through calculation of long-run marginal cost.) However, the domestic users are poor in Sierra Leone and so the tariff structure is shifted to industrial consumers. Therefore, it is desirable that in the future industrial tariffs should be equal to or less than domestic user’s although industrial tariffs are more expensive than other user’s at present. In addition, recent study of the World Bank insists that the government subsidy to the NPA for households (NPA’s deficits are covered by the government and so it is a kind of subsidy) is not necessarily useful for poor households but rich domestic users who use more electricity receive benefits.

7.4 Financial and Economic Analyses of Distribution Projects

The impacts of power development plan on NPA’s finance were analyzed in relation to the tariffs in 7.3, but this section focuses on the distribution projects to which donors will pay attention instead of the whole power development plan and financial and economic effects are analyzed for each of the packaged projects of distribution development as follows.

7.4.1 Financial Analysis of Distribution Projects

The distribution projects are limited part of NPA projects and financial analysis separating generation has only limited meaning because it is not entire profit and loss. The entire account was analyzed in 7.3 previously and so financial analysis in this section shows the profit and loss extent of distribution projects, in particular, packaged projects in the total accounts.

The revenues of distribution are calculated multiplying the total revenues by distribution cost share (50.7%)[1] which can be derived from tentative calculation in the model and sharing the total

---

[1] Bumbuna power purchase cost is calculated on the generation side in the long-run marginal cost calculation, but it is calculated on the distribution side in this section.

distribution revenues among the projects with the shares of project power demand to the whole demand. Concerning costs, O&M costs are supposed to be 3% of initial investment costs and others such as administration costs of distribution in the model are divided with the shares of project power demand to the whole demand.

Construction time period of each project is supposed to be one year and cash flow is calculated for 20 years from the construction year so that IRR (Internal Rate of Return) can be obtained. Since the account is partial, it may be minus (loss) or IRR cannot be calculated. In addition, 20 years may be beyond 2030 which is the final year of the model depending on the construction year. In that case, increase rates of 2030 are used to extend the revenues and expenditures.

The average tariff, 27 cents/kWh (22.6 cents/kWh for household, 34.1 cents/kWh for commercial users and 27.7 cents/kWh for industrial users), that is 130% increase of the old tariffs, in the standard hydro main case with 7cents/kWh as purchase price from Bumbuna hydro power is used as income.
Based on these conditions, the calculated results are shown in Table 7.4-2. Cash flows of all the distribution projects are minus and IRRs cannot be obtained.

Table 7.4-1 Energy Consumption by Project

No.	Title of the Project	Major Components	Funded by	Target Year	Cost (10^6US$)	Expected Energy Consumption at Target Year [GWh]
A:	**Phase-I (from 2010 to 2015)**					
1	Rehabilitation of 11 kV and Improvement of 33 kV System	1) Improvement of 33 kV system of Kingtom P/S 2) Improvement of 33 kV system from Kingtom to Blackhall Road P/S 3) Construction of Falconbridge S/S 4) Rehabilitation of 11 kV system		2012	25.6	**28.7**
2	Improvement of 33 kV System in Goderich and Jui Area	1) Installation of 33 kV line (about 20 km) 2) Construction of Goderich and Jui S/S 3) Improvement of 11 kV existing lines		2014	35.4	**9.4**
3	Improvement of 11 kV Distribution Facil	1) Replacement of 11 kV transformer more than 40 years 2) Replacement of 11 kV transformers more than 30 years 3) Rehabilitation of existing 11 kV system 4) Electrification around Goderich and Jui S/S		2015	32.0	**2.3**
3		**Sub-total**			**93.0**	
B:	**Phase-II (from 2016 to 2020)**					
1	Improvement of 33 kV System	1) Construction of 33 kV line (about 32 km) 2) Construction of Lumpa and Tombo S/S 3) Rural electrification around Lumpa and Tombo S/S		2017	33.7	**7.2**
2	Expansion of 33 kV System and Improvement of Network	1) 1-161/33 kV Trf. (60/80 MVA, OLTC with AVR) 2) 33 kV line from Goderich S/S to York town (29 km) 3) Rehabilitation of trunk lines and rural electrification		2020	31.4	**4.1**
2		**Sub-total**			**65.1**	
C:	**Phase-III (from 2021 to 2025)**					
1	Improvement of Distribution Network	1) Expansion of 33 kV system 2) Rural electrification 3) Power Purchase Agreement to the neighboring country		2025	16.3	**0.9**
1		**Sub-total**			**16.3**	
		Grand Total			**174.4**	

Table 7.4-2 Financial Analysis Result of Distribution Projects

(Unit: US$ 1,000)

Phase I-1	Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
	Investment cost	25,600																			
	Revenue		2,036	2,295	2,584	2,906	3,264	3,659	4,095	4,574	5,100	5,675	6,304	6,990	7,737	8,550	9,113	9,706	10,328	10,982	11,671
	Expenditure		2,963	3,106	3,262	3,429	3,609	3,795	3,981	3,759	4,244	4,734	5,080	5,442	5,827	6,162	6,562	6,882	7,189	7,478	6,415
	Cash flow	-25,600	-927	-811	-678	-523	-346	-135	114	815	856	941	1,223	1,547	1,909	2,387	2,551	2,824	3,140	3,504	5,256
	IRR	-																			
Phase I-2	Year	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
	Investment cost	35,400																			
	Revenue		729	820	920	1,032	1,155	1,290	1,438	1,600	1,778	1,971	2,182	2,411	2,570	2,737	2,912	3,097	3,291	3,497	3,717
	Expenditure		1,765	1,812	1,863	1,915	1,968	1,905	2,042	2,180	2,278	2,380	2,489	2,583	2,696	2,786	2,873	2,954	2,654	2,730	2,808
	Cash flow	-35,400	-1,037	-993	-943	-884	-813	-616	-604	-580	-500	-409	-307	-172	-126	-49	40	143	637	767	909
	IRR	-																			
Phase I-3	Year	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
	Investment cost	32,000																			
	Revenue		186	209	234	262	293	326	363	404	447	495	547	583	621	661	703	747	794	844	897
	Expenditure		1,130	1,142	1,154	1,166	1,151	1,183	1,214	1,236	1,259	1,284	1,305	1,331	1,351	1,371	1,390	1,322	1,339	1,358	1,376
	Cash flow	-32,000	-944	-933	-920	-904	-859	-856	-851	-833	-812	-789	-758	-748	-730	-710	-686	-574	-545	-514	-479
	IRR	-																			
Phase II-1	Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
	Investment cost	33,700																			
	Revenue		632	708	790	881	981	1,089	1,208	1,337	1,477	1,575	1,677	1,784	1,898	2,016	2,143	2,277	2,420	2,572	2,733
	Expenditure		1,534	1,566	1,528	1,612	1,696	1,756	1,819	1,885	1,943	2,012	2,067	2,120	2,170	1,987	2,034	2,082	2,131	2,181	2,232
	Cash flow	-33,700	-902	-859	-737	-730	-716	-667	-611	-548	-466	-438	-390	-336	-273	30	109	196	289	391	500
	IRR	-																			
Phase II-2	Year	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
	Investment cost	31,400																			
	Revenue		404	450	500	554	613	678	722	769	819	871	925	983	1,045	1,110	1,180	1,254	1,332	1,416	1,505
	Expenditure		1,218	1,256	1,284	1,313	1,343	1,370	1,401	1,427	1,451	1,474	1,390	1,412	1,434	1,457	1,480	1,503	1,527	1,551	1,576
	Cash flow	-31,400	-813	-807	-784	-758	-730	-692	-679	-657	-632	-603	-464	-428	-389	-346	-300	-249	-194	-135	-71
	IRR	-																			
Phase III	Year	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043
	Investment cost	16,300																			
	Revenue		106	113	120	128	136	145	154	163	173	184	196	208	221	235	250	265	282	300	319
	Expenditure		556	561	565	569	572	559	562	566	570	573	577	580	584	588	591	595	599	603	607
	Cash flow	-16,300	-450	-448	-445	-441	-436	-414	-409	-403	-396	-389	-381	-372	-363	-353	-342	-330	-317	-303	-288
	IRR	-																			

7.4.2 Economic Analysis of Distribution Projects

While the costs in the benefit/ cost analysis of each distribution project are the same as those in 8.5.2, namely investment cost and expenditures, the benefits are not revenues but economic benefits. Considering what the economic benefit of distribution project is, it is defined as satisfaction or utility of users obtaining electricity in this section. Concretely, the benefit is considered to be the cost which users pay actually or think reasonable to pay for obtaining electricity.

The willingness-to-pay survey from November to December in 2008 clarifies payments which users will pay and actual costs of their own generation. There is a method to calculate benefits by clarifying economic tariff based on amounts which users pay for alternative electricity actually or intended to pay and calculating benefits.[2] It is explained as follows.

The part "ABFC" shown in Fig. 7.4-1 is called consumer's surplus and calculated by the following formula.

$(ABFC)= (P'_E-P_E) \times Q_E \times R$ ----------- (1)

Here, the definitions are as follows.

P_E: existing electricity tariff, P'_E: upper limit of willing-to-pay
P''_E: economic electricity tariff
Q_E: electricity demand at electricity price P_E
R: ratio of area ABFC to area of rectangle (ABO'C)

P''_E is electricity tariff P_E converted from consumer surplus and so area of rectangle (ADO"C) is equal to area of ABFC. Therefore, ABFC is expressed in the following formula.

$(ABFC) = (ADO''C) = (P''_E-PE) \times Q_E$ ----------- (2)

Based on (1) and (2) formulae,

$(P'_E - P_E) \times Q_E \times R= (P''_E-P_E) \times Q_E$
$P''_E = P_E + (P'_E - P_E) \times R$

---

[2] Desai, N., Economic Analysis of Power Projects: Asian Development Bank Economic Staff Paper No.24, Asian Development Bank, 1985

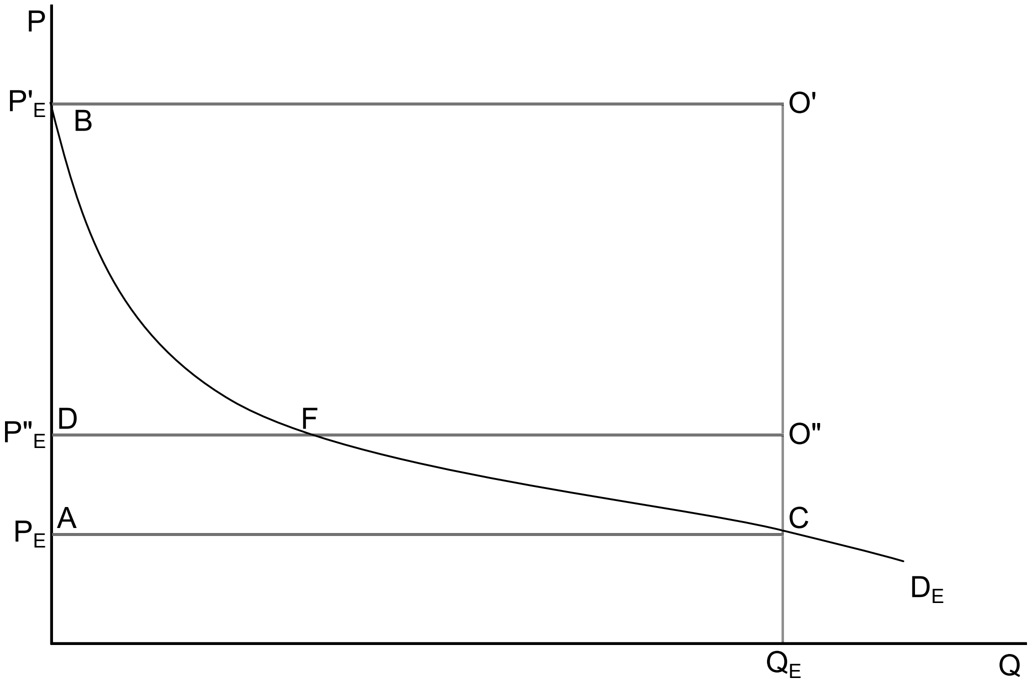


Fig. 7.4-1 Demand Curve

Both the willingness-to pay amounts and own independent generation costs are surveyed in the willingness-to-pay survey of this Master Plan Study and the result shows that the own generation cost is more expensive than the willing-to-pay amount. Therefore, the own generation cost is used. The survey was conducted for three categories: household, commercial and industrial users. Concerning household and commercial users, the tariff units, which are costs divided by electricity volumes, of own generation are more expensive than the tariffs of the NPA. However, it is the contrary concerning industrial users and the industrial own generation unit cost is used as economic tariff. Concerning household and commercial users, economic tariffs are calculated by the method above. Those economic tariffs including generation are separated to distribution by use of the distribution cost share in the financial analysis model. The resultant economic distribution tariffs for household, commercial and industrial users are multiplied by the total electricity demands of household, commercial and industrial users, respectively. Then, the three multiplied numbers are summed up and distribution project share of electricity demand is used to obtain the project benefit. In addition, system loss improvement effects by the distribution projects are considered using total economic tariffs because it is effective to not only distribution but also generation.

For example, the household economic tariff is calculated as follows.
Using monthly fuel volumes and costs for own generation and monthly investment costs which result from dividing annuitized investment costs with five years lifetime and 10% discount rate by 12 according to the household samples of the willingness-to pay survey, own generation costs per kWh can be calculated dividing the monthly costs by monthly own generated electricity in kWh. The generation maintenance cost data exceeding 1,000 leones/kWh are supposed to have required a lot of repair costs and excluded from the calculation. In addition, generation facilities with very low use rates (less than 3%) are also excluded similarly because fixed cost shares in own generation costs are too many. The resultant own generation costs per kWh of the samples are assumed distribution of demand curve and 2,819 leones/kWh, the maximum among them, is defined as P'_E.

On the other hand, the NPA's tariffs at the survey time are as shown in Table 7.4-3. Using these and 0.73 as standard conversion factor (SCF)[3] derived from export and import and others in Sierra Leone

---

[3] SCF: used to exclude national policy effects distorting economic efficiency concerning investment costs and estimate to convert the costs from market prices to economic costs (border costs)

$$SCF = (M + X) / ((M + Tm) + (X – Tx – SB))$$

Where M: import (CIF), Tm: import duty, X: export (FOB), Tx: export tax, SB: export subsidy and assumed consumer surplus 25%, the economic electricity tariff is shown in Table 7.4-4.

Table 7.4-3 NPA's Tariffs for Household

Old Tariff	Le/kWh	cents/kWh
0-30 kWh	373	11.7
31-150 kWh	533	16.8
above 150 kWh	709	22.3

Note: 1USD=3,179Le

Table 7.4-4 Economic Tariffs for Household

Economic Tariff	Le/kWh	cents/kWh
0-30 kWh	**719**	**22.6**
31-150 kWh	**806**	**25.4**
above 150 kWh	**903**	**28.4**

According to the willingness-to pay survey, general household's average monthly NPA and own generation electricity demands are 228.8kWh and 107.2 kWh, respectively, and the sum is 336 kWh. This is applied to the economic tariffs and 22.6 × 30 + 120 × 25.4 + 186 x 28.4 = US$9,008.4. The average is 9,008.4 / 336 = 26.8 cents/kWh. The distribution part is its 50.7% and it is multiplied by annual household power demand and the benefit is obtained.

Similarly the commercial user benefits are calculated. The commercial users' economic tariffs calculated are shown in Table 7.4-6. Commercial user's average monthly NPA and own generation electricity demands are 214.5 kWh and 341.35 kWh, respectively, according to the willingness-to pay survey and the sum is 555.85 kWh. This is applied to the economic tariffs and the average is 16,666.8 / 555.85 = 30.0 cents/kWh.

Table 7.4-5 NPA's Tariffs for Commercial Users

Old Tariff	Le/kWh
0-30 kWh	651
31-150 kWh	781
above 150 kWh	846

Table 7.4-6 Economic Tariffs for Commercial Users

Economic Tariff	Le/kWh	cents/kWh
0-30 kWh	**861**	**27.1**
31-150 kWh	**932**	**29.3**
above 150 kWh	**968**	**30.4**

Concerning industrial users, own generation unit cost, 27.7 cent/kWh, is multiplied by SCF
27.7 × 0.73 = 20.2 cent/kWh and it is used as economic tariff.

The results of benefit / cost analyses are shown in Table 7.4-7. IRR of Phase I-1 is 6.7%, but cash flows of the other projects are minus and so IRR cannot be calculated.

Table 7.4-7 Benefit/ Cost Analysis Result of Distribution Projects

(Unit: US$ 1,000)

Phase I-1	Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
	Investment cost	25,600																			
	Benefit		3,852	4,146	4,466	4,810	5,178	5,572	5,991	6,437	6,908	7,407	7,935	8,492	9,079	9,700	10,354	11,045	11,774	12,544	13,358
	Expenditure		2,963	3,106	3,262	3,429	3,609	3,795	3,981	3,759	4,244	4,734	5,080	5,442	5,827	6,162	6,562	6,882	7,189	7,478	6,415
	Cash flow	-25,600	890	1,040	1,204	1,380	1,569	1,778	2,010	2,678	2,664	2,673	2,854	3,049	3,252	3,537	3,792	4,163	4,586	5,066	6,943
	IRR	6.7%																			
Phase I-2	Year	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
	Investment cost	35,400																			
	Benefit		1,463	1,575	1,696	1,825	1,962	2,108	2,263	2,426	2,599	2,781	2,974	3,177	3,391	3,618	3,856	4,109	4,375	4,659	4,961
	Expenditure		1,765	1,812	1,863	1,915	1,968	1,905	2,042	2,180	2,278	2,380	2,489	2,583	2,696	2,786	2,873	2,954	2,654	2,730	2,808
	Cash flow	-35,400	-303	-237	-167	-90	-6	203	220	246	321	401	485	594	695	832	984	1,154	1,721	1,929	2,154
	IRR	-																			
Phase I-3	Year	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
	Investment cost	32,000																			
	Benefit		385	415	447	480	516	554	594	636	681	728	777	830	885	944	1,005	1,071	1,140	1,214	1,293
	Expenditure		1,130	1,142	1,154	1,166	1,151	1,183	1,214	1,236	1,259	1,284	1,305	1,331	1,351	1,371	1,390	1,322	1,339	1,358	1,376
	Cash flow	-32,000	-745	-727	-707	-686	-636	-629	-620	-600	-579	-556	-528	-501	-466	-427	-384	-251	-199	-144	-83
	IRR	-																			
Phase II-1	Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
	Investment cost	33,700																			
	Benefit		1,398	1,503	1,615	1,733	1,858	1,991	2,130	2,278	2,433	2,598	2,771	2,954	3,147	3,351	3,569	3,800	4,047	4,309	4,589
	Expenditure		1,534	1,566	1,528	1,612	1,696	1,756	1,819	1,885	1,943	2,012	2,067	2,120	2,170	1,987	2,034	2,082	2,131	2,181	2,232
	Cash flow	-33,700	-136	-63	87	122	162	234	312	393	490	585	704	833	977	1,365	1,535	1,719	1,916	2,128	2,357
	IRR	-																			
Phase II-2	Year	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
	Investment cost	31,400																			
	Benefit		987	1,058	1,134	1,213	1,297	1,386	1,479	1,578	1,682	1,792	1,908	2,032	2,164	2,304	2,454	2,613	2,783	2,963	3,156
	Expenditure		1,218	1,256	1,284	1,313	1,343	1,370	1,401	1,427	1,451	1,474	1,390	1,412	1,434	1,457	1,480	1,503	1,527	1,551	1,576
	Cash flow	-31,400	-231	-198	-150	-99	-46	16	78	151	231	318	519	621	730	848	974	1,110	1,256	1,412	1,580
	IRR	-																			
Phase III	Year	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043
	Investment cost	16,300																			
	Benefit		304	325	346	369	393	419	446	475	506	539	574	611	651	693	738	786	837	891	949
	Expenditure		556	561	565	569	572	559	562	566	570	573	577	580	584	588	591	595	599	603	607
	Cash flow	-16,300	-252	-236	-218	-199	-179	-140	-116	-91	-64	-34	-3	30	66	105	146	190	238	288	342
	IRR	-																			

7.4.3 Consideration of Financial and Economic Analyses of Distribution Projects

Financial analyses of the distribution projects result in worse account than the whole electricity development plan including generation. This shows that revenues of the distribution projects are smaller and cannot cover the costs. It means that the demand increase by the distribution project implementation is smaller proportionally to the whole plan and the revenues cannot cover the investment and expenditures and so the other existing demand contributes much more financially.

Economic analyses are similar, but barely IRR of Phase I-1 is 6.7% and the other distribution projects show that the benefits cannot cover the costs (including investment). This is also because of small proportion of demand increase by the distribution project implementation to the whole. As the phases progress, distribution network is extended to the areas with low demand density and demand increase by the project implementation is smaller so that financial and economic balances become worse.

However, the whole plan can avoid financial loss and so the projects can be implemented. After Bumbuna hydro power begins to generate and expansion of Kingtom generation station and construction of Blackhall Road are completed, generation capacity responding to the most urgent demand can be ensured. Nevertheless, power supply situation in Western Area cannot be improved unless the transmission and distribution network supplying power to the end users is improved. Namely, effects of generation facility investment cannot be realized. Networking of distribution brings about effects which cannot be calculated and included in the economic benefits such as stabilization of power supply. They become the existing user's benefits, too. In addition, the Hydro Dominant Case has economic effects on greenhouse gas reduction which are not included in the benefits. Furthermore, the projects have effects on reduction of air pollution and noise caused by own generation. These economic effects are difficult to quantify so that they are not calculated, but they exist absolutely.

Since there are benefits which cannot be expressed simply in numbers such as IRR above and an electricity supply system has characteristics that it functions as a total system and if part of it is missing, electricity supply is impeded, implementation of the distribution projects in this Master Plan is meaningful enough to improve electricity supply in Western Area.

8. Capacity Building

8.1 Technical Items to be Transferred

Technical staffs in the Generation Division do not have the experience of systematic technical training programs. In addition, from the end of 2006, the practice of operation and maintenance of generation facilities stopped. Therefore, there is concern that technical works shown in Operation and Maintenance Guidelines shall be transferred from the basic steps for development of certain capacity. As diesel engines are operated in such severe conditions as high pressure, high temperature and high speed, early breakdown of engine cannot be avoided without appropriate operation and maintenance. Based on Operation and Maintenance Guidelines for Diesel Engine Generators, technical items to be transferred are shown in Table 8.1-1.

Table 8.1-1 Capacity Development for Lead Engineers of Generation Facility Operation and Maintenance

Section	Items to be trained	Contents
Operation	Operation	Start-up/Stop Procedure
		Mechanical Protection System of Diesel Engine
		Fitting and Adjustment Operation
		Emergency Shutdown and the conditions
		Preparation for Dormant State
		Operation Management of Engine
		Operation Management of Fuel Oil System
		Operation Management of Lubricating Oil System
		Operation Management of Cooling Water System
		Operation Management of Start-up Air System
		Operation Management of Waste Oil Disporsal Facility
	Management of Operation Data	Preparation of Check Lists and Reports
	Management of Recirculating Flow	Management of Fuel Oil, Lubricating Oil and Cooling Water
		Stock Management
		Management of Discharged Water, and Waste (Residual Ash)
	Combustion Management	Adjustment of Injection Timing
		Adjustment of Fuel Injection Pump Rack
	Preparation of Operation Manuals	Preparation of Manuals
	Preparation of Waste Management Manuals	Preparation of Manuals
	Trouble Shooting for Failures	Trouble Shooting Procedures
	Budgetary Planning for Operation	Estimation Procedure of Budget
Maintenance and Planning	Planning and Implementation of Periodical Overhauls	Planning and Implementation Procedures of Periodical Overhauls
	Arrangement/Rearrangement Works for Periodical Overhauls	B Overhaul
		D1 Overhaul
		D2 Overhaul
		D3 Overhaul
		E2 Overhaul
		Stock Management of Spare Parts Management
	Implementation Procedures for Periodical Overhauls	Fitting and Inspection Procedure of Intake/Exhaust Valve
		Overhaul Procedures of Fuel Injection Valve and Pump
		Inspection Procedure of Cylinder Liner
		Disassembling and Inspection Procedure of Piston and Connection Rod
		Disassembling and Inspection Procedure of Rocker Arm and Cam Function
		Replacement Procedure of Main Bearing
		Inspection Procedure of Crank Shaft

Section	Items to be trained	Contents
		Inspection Procedure of Gears
		Overhaul Procedure of Turbocharger
		Overhaul Procedure of Torsion Vibration Damper
		Overhaul Procedure of Governor
		Overhaul Procedure of Other Accessory Equipment
	Overhaul Procedures of Auxiliary Equipment	Overhaul Procedures of Filtering Equipment
		Overhaul Procedures of Purifiers
		Overhaul Procedures of Pumps
		Overhaul Procedure of Compressor
		Overhaul Procedures of Measurement Instruments
	Preparation of Overhaul Manuals of Engine	Preparation of Manuals
	Preparation of Overhaul Manuals of Auxiliary Equipment	Preparation of Manuals
	Budgetary Planning for Maintenance	Estimation Procedure of Budget
	Trouble Shooting for Failures	Trouble Shooting Procedures
Common Item for、Operation, Maintenance and Planning	Theory	Theory of Diesel Cycle
		Sequence Control System
		Preventive Maintenance
		Non-Destructive Inspection
		Automatic Control of Generation Facilities
		Control Systems of Generation Facilities
	Others	Structure and Function of Governor
		Principle of Function of Purifiers
Electrical Facility	Theory	Voltage and Frequency Management
		Sequence Control System
		Protection Coordination and Setting
		Automatic Voltage Regulator
	Operation Management	Sequence Control of Generation Facilities
		Control Systems of Generation Facilities
		Protection Relays and Setting of Generation Facilities
		Synchronous Running of Generation Facilities
		Operation Management of Generation Facilities
		Voltage and Frequency Management
	Management of Operation Data	Preparation of Check Lists and Reports
	Maintenance Management	Overhaul Procedure of Synchronous Generator
		Overhaul Procedure of Switchgears
		Overhaul Procedure of Control Panel and Synchronizing Panel
		Overhaul Procedure of Station Transformers
		Overhaul Procedure of MCC
		Overhaul Procedure of DC Supply Panel
		Performance Test of Protection Relays
	Trouble Shooting for Failures	Trouble Shooting Procedures
	Applications of Tools and Instruments	Purpose and Method of Usage
	Others	Structure and Operation of Governor
Common	Outline of Generation Facility	Outline of Engine
		Outline of Fuel System
		Outline of Lubricating Oil System
		Outline of Cooling Water System
		Outline of Start-up Air System

[Source] JICA Study Team

Technical staff in the Transmission and Distribution Division also do not have the experience of systematic technical training programs. Therefore, there is concern that the technical works shown in Operation and Maintenance Guidelines shall be transferred from the basic steps for development of certain capacity. After the commissioning of Bumbuna Hydraulic Power Plant, such policies as protection coordination and demand and supply planning shall fundamentally be revised. In addition, as the Transmission and Distribution Division is forced to conduct a huge number of repair works for faults, the appropriate and efficient procedures for repair work shall also be transferred. Based on Operation and Maintenance Guidelines, technical items to be transferred are shown in Table 8.1-2.

Table 8.1-2 Capacity Development for Lead Engineers of Power Distribution Facility Operation and Maintenance

Section	Items to be trained	Contents
Operation	Operation Management	Formulation of Observation Framework
		Start-up/Stop/Switching Operation Procedures of Power System
		Emergency Operation Procedures at Failures
		Commissioning/Recommissioning Procedures of Power System
		Improvement of Power Factor
		Load Shedding
	Protections of Power System	Main and Back-up Protections
		Protection Coordination and Setting
		Performance Tests of Protection Relays
		Functional Tests of Switchgears
	Management of Operation Data	Preparation of Check Lists and Reports
	Planning of Demand and Supply	Analysis of Operation Data
		Analysis of Time Schedule Periodical Overhauls
		Analysis of Reservoir Utilization Plan
	Management of Power System	Voltage and Frequency Management
		Improvement of Power Factor
	Preparation of Operation Manuals	Preparation of Manuals
	Trouble Shooting for Failures	Trouble Shooting Procedures
	Applications of Tools and Instruments	Purpose and Method of Usage
Maintenance and Planning	Maintenance Management	Overhaul Procedure of Transformer
		Inspection of Overhead Lines
		Inspection of Underground Cables
		Overhaul Procedure of Switchgears
		Overhaul Procedure of DC Supply Panels
		Performance Test of Protection Relays
		Overhaul Procedure of Auto Reclosers
		Overhaul Procedure of Arresters
	Repair Work	Overhead Lines
		Underground Cables
	Patrol and Inspection Procedure	Overhead Lines
		Underground Cables
		Transformation Equipment
		Preparation of Patrol and Inspection Check List
	Budgetary Planning for Operation and Maintennce	Estimation Procedure of Budget
	Trouble Shooting for Failures	Trouble Shooting Procedures
Common	Theory	Voltage and Frequency Management
		Sequence Control Systems
		Calculation for Failures
		Protection Coordination and Setting
		Automatic Voltage Regulator
		Power System and Stability
	Applications of Tools and Instruments	Purpose and Method of Usage

[Source] JICA Study Team

Though services concerning the power system planning are conducted in the System Planning Section of the Corporate Planning Department presently, the NPA depends on assistance from the foreign donors and the staff capable of planning the future system do not exist in the NPA. Even in case of reception of assistances from foreign donors, the NPA shall be able to coordinate consistency of each project from technical viewpoints. In the near future, system planning engineers who can plan and evaluate power system development projects shall be secured in the NPA. Especially, concerning the low voltage distribution network, essential problems for stable and reliable power supply are caused not only by lack of knowledge and skills for operation and maintenance in technical staff but also deterioration and overload of equipment. As the distribution network is composed of huge numbers of equipment, it is difficult for foreign donors to assist improvement of the distribution networkt in limited term projects. From this viewpoint, the existence of system planning engineers is necessary. Technical items to be transferred for power system planning are shown in Table 8.1-3.

Table 8.1-3 Capacity Development for Lead Engineers of Power System Planning

Section	Items to be trained	Contents
Power Distribution Facility Planning	Present Data Analysis	Preparation of Single-Line Diagram for 11kV Distribution Line
		Preparation of Single-Line Diagram for Low Voltage Distribution Line
		Preparation of Route Map for 11kV Distribution Line
		Preparation of Route Map for Low Voltage Distribution Line
		Analysis of Load Characteristic
		Analysis of Operation Data
		Analysis of Voltage Drop and Power Loss
		Confirmation of Projects by Foreign Donors
	Demand Forecast	Macro Demand Forecast
		Micro Demand Forecast
	Distribution Network Planning	Planning for Renewal of Distribution Line
		Planning for Empowerment of Distribution Line
		Planning for Extension of Distribution Line
		Designing Procedure for Distribution Network
		Evaluation of Profitability of Projects
		Planning for Reduction of Voltage Drop and Power Loss
		Planning for Introduction of Power Factor Improvement Equipment
	Power System Analysis	Calculation of Power Flow
		Calculation of Short-circuit Capacity
		Calculation for Failures
		Evaluation of Stability of Power System
Power Development Planning	Analysis of Existing Generation Facility	Evaluation of Current Performance and Life Duration of Existing Generation Facility
		Analysis of Load Characteristic
		Confirmation of Projects by Foreign Donors
	Demand Forecast	Macro Demand Forecast
	Evaluation for Potential of Power Development	Feasibility Study for Hydroelectric Power Plant
		Feasibility Study for Thermal Power Plant
		Analysis of Characteristics of each Power Source Type
	Formulate and Evaluation of Power Development Planning	Evaluation of Initial Costs and Running Costs of Each Development Plan
		Study for Best Mix of Power Development (Screening Method)
		Evaluation of Flexibility for Operation

Section	Items to be trained	Contents
		Study for Optimal Layout of Power Source
		Study for Construction Period
		Evaluation of Flexibility of Development Plan

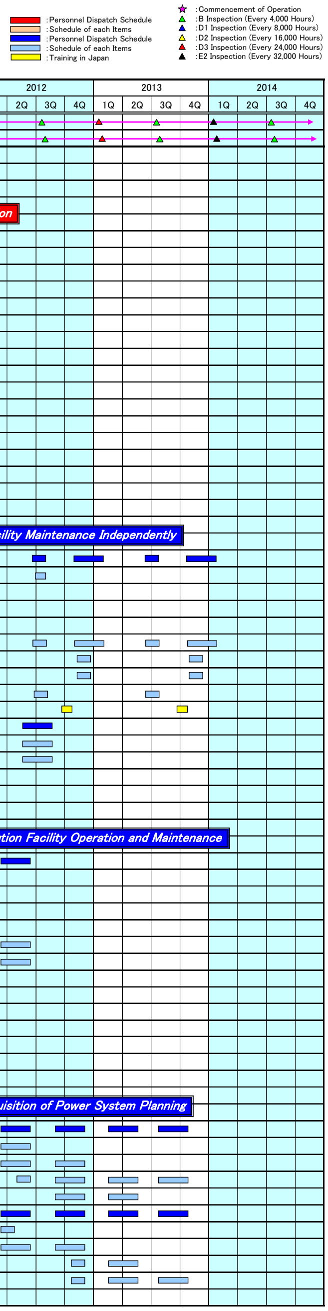
[Source] JICA Study Team

8.2 Schedule of Capacity Development

Though i the capacity for operation and maintenance of generation facilities has declined since the practice stopped from the end of 2006, the new facilities will be commissioned from 2010. Therefore, the capacity for operation and maintenance for the facilities shall be developed as soon as possible. On the other hand, it is necessary to develop synthetically such basic capacity for independently and continuously reliable power supply as operation, maintenance and planning of power generation facilities and power system.

In consideration of these situations, the Capacity Development Plan for the NPA is scheduled shown in Table 8.2-1.

Table 8.2-1 Capacity Development Plan for the NPA



[Source] JICA Study Team

9. Conclusions and Recommendations

9.1 Conclusions

In order to meet the growing power demand in the future and to supply stable and reliable power in Western Area, the power supply system rehabilitation and expansion projects described in the following section 9.1.1 and 9.1.2 are recommended to be completed by 2025. Revision of electricity tariff explained in section 9.1.3 is recommended in order for the NPA to manage investment for the development of power supply system and to be an independent and sustainable entity.

9.1.1 Power Development Planning

High-speed and middle-speed diesel engine generators and Yiben-I hydroelectric power plant are to be developed in line with the schedule indicating completion year and capacity as shown in Table 9.1-1. Investment cost for such power development is described in Table 9.1-2 and total investment requires approximately US$268 million.

Table 9.1-1 Power Development Plan
(Hydro Dominant Scenario)

Unit: MW

Year	High-speed Diesel (MW) (1.8MW/unit)	Mid-speed Diesel (MW) (8.0MW/unit)	Yiben-I Hydro (MW) (20.5MW/unit)	Annual Total (MW)
2010	5.4			5.4
2011		8.28		8.3
2012	1.8			1.8
2013	5.4			5.4
2014	3.6			3.6
2015	1.8	8.0		9.8
2016		8.0		8.0
2017		8.0		8.0
2018		8.0		8.0
2019	(-18.0)		61.5	61.5
2020				0.0
2021				0.0
2022				0.0
2023				0.0
2024				0.0
2025				0.0
Total	**18.0**	**40.3**	**61.5**	**119.8**

Table 9.1-2 Investment for Power Development

Unit：US$million, expressed in Y2009 price

Year	High-speed Diesel (1.8MW/unit)	Mid-speed Diesel (8.0MW/unit)	Yiben-I Hydro (20.5MW/unit)	Annual Investment Cost	Cumulative Investment Cost
2010	2.48	3.01		5.49	5.49
2011	0.00	12.03		12.03	17.52
2012	0.83	0.00		0.83	18.35
2013	2.48	0.00		2.48	20.83
2014	1.66	2.76		4.42	25.25
2015	0.83	13.80		14.63	39.87
2016	0.00	13.80	28.44	42.24	82.11
2017	0.00	13.80	66.35	80.15	162.26
2018	0.00	11.04	66.35	77.39	239.66
2019	0.00	0.00	28.44	28.44	268.09
2020	0.00	0.00		0.00	268.09
2021	0.00	0.00		0.00	268.09
2022	0.00	0.00		0.00	268.09
2023	0.00	0.00		0.00	268.09
2024	0.00	0.00		0.00	268.09
2025	0.00	0.00		0.00	268.09
Total	**8.28**	**70.23**	**189.58**	**268.09**	

9.1.2 Improvement of Distribution System

Rehabilitation, enhancement and expansion of distribution network until 2025 as shown in Table 9.1-3 shall be implemented by dividing the planning period by 5 year-windows. The total investment costs approximately US$172 million. Even though this Master Plan does not take interconnection of WAPP and national grid into consideration, in case when these transmission lines are realized and connected to the Western Area power system, the following distribution rehabilitation, enhancement and expansion projects should be reviewed and revised based on power system analysis on new network configuration.

Table 9.1-3 Distribution Rehabilitation, Enhancement and Expansion Plans

No.	Project Packages	Major Components	Target Year	Cost (10^6US\$)
Phase-I (from 2010 to 2015)				
	1 Rehabilitation of 11 kV and Improvement of 33 kV System	1) Improvement of 33 kV system at Kingtom P/S	2012	25.6
		2) Construction of 33 kV line from Kingtom to Falcon Bridge S/S (about 2 km)		
		3) Construction of 33 kV line from Kingtom to Blackhall Road P/S (about 4 km)		
		4) Construction of 11/33kV Substation at Falconbridge S/S		
		5) Rehabilitation of 11 kV switchgears		
	2 Construction of 33 kV System in Goderich and Jui Area	1) Construction of 33 kV line from Wilberforce S/S to Goderich S/S (about 7 km)	2014	35.4
		2) Construction of 33 kV line from Wellington S/S to Jui S/S (about 13 km)		
		3) Construction of Goderich and Jui S/S		
		4) Improvement of 11 kV lines and extension of LV system		
	3 Improvement of 11 kV Distribution Facilities	1) Replacement of old 11 kV transformers (more than 40 years)	2015	30.0
		2) Replacement of old 11 kV transformers (more than 30 years)		
		3) Rehabilitation of existing 11 kV facilities		
		4) Promote new customer connections around Goderich and Jui S/S		
		Sub-total		**91.0**
Phase-II (from 2016 to 2020)				
	1 Construction of 33 kV System in Lumpa and Tombo Area	1) Construction of Lumpa S/S and 33 kV line from Jui S/S to Lumpa S/S (about 15 km)	2017	33.7
		2) Construction of Tombo S/S and 33 kV line from Lumpa to Tombo S/S (about 17 km)		
		3) Electrification around Lumpa and Tombo S/S		
	2 Expansion of 33 kV System and Improvement of Network	1) Installation of 161/33 kV transformer (60/80 MVA, OLTC with AVR) at Freetown S/S	2020	31.4
		2) Construction of 33 kV line from Goderich S/S to York town (29 km)		
		3) Rehabilitation of 11kV trunk lines and electrification		
		Sub-total		**65.1**
Phase-III (from 2021 to 2025)				
	1 Expansion of Distribution Network	1) Construction of 33 kV line from Lumpa S/S to Fogbo town (about 16 km)	2025	16.3
		2) Construction of 33 kV lines from York S/S to Tombo S/S (about 20 km)		
		3) Extension of 11kV lines and electrification		
		Sub-total		**16.3**
		Grand Total		**172.4**

9.1.3 Revision of Electricity Tariffs

In the case where the power development scenario is the hydro dominant case and the Bumbuna hydro power purchase price is 7 cents/kWh, it is necessary for the NPA to set the average tariff at 27 cents/kWh shown in Table 9.1-4 for the purpose of enabling the NPA to sustain financially with investment of facilities planned by the Master Plan.

Table 9.1-4 Revised Tariff Plan

Category	Subcategory	Old tariff (before Dec. 2008)		Proposed tariff
		Le/kWh	US cents/kWh	US cents/kWh
Household	0-30 kWh	373	11.7	23
	31-150 kWh	533	16.8	
	Above 150 kWh	709	22.3	
Commercial	0-30 kWh	651	20.5	34
	31-150 kWh	781	24.6	
	Above 150 kWh	846	26.6	
Industrial	All units	941	29.6	28
Average	—	816	25.7	27

[Note] US$1 = 3,179 Le

Preconditions of proposed tariff calculation

- Power development scenario: hydro main case
- Power purchase price from Bumbuna: 7 cents/kWh
- System loss: improved from 40% in 2009 to 15% in 2025
- Collection rate: improved from 70% in 2009 to 95% in 2025
- Long-term liability: repayment by the NPA supposed to continue

9.2 Recommendations

9.2.1 Recommendations concerning PPP (Public-Private Partnership) Introduction into Power Development

It is difficult for the Government of Sierra Leone with financial difficulties to give funds to power facility investment even if facilities belong to the electricity sector with high priority. In addition, donor support is not sufficient to invest in the power sector in which demand is increasing. Furthermore, there are no funds and time for the NPA to attain worldwide levels of technical knowhow and efficient management quickly. Therefore, it is very necessary to introduce private activities in order to realize the power development plan in this Master Plan. Concretely, private entry including foreign companies is a theme on the occasion of IPP introduction and NPA participation. However, the NPA is suffering from chronic deficiency and needs the government support and technical capacity building so that it has a lot of issues to solve before the privatization which seems a long way off in the future although the privatization of the NPA is included in the long-term strategy of NCP.

While private generation companies have participated in urgent generation (rental power) already, it is necessary to introduce private company activities from now on. It requires establishment of the following conditions to introduce private activities in future Sierra Leone smoothly.

- Establishment of legal institutions
  It is necessary to establish laws and regulations arranging investment conditions to introduce the private sector without problems so that the private sector can participate without anxiety. Undoubtedly, since it will be a problem only if the situation changes from public monopoly to private monopoly, the laws and regulations of the process below based on the competition policies are necessary. Contracts, implementation, penalties, etc. are prescribed.
- Establishment of transparent and fair introduction process
  It is necessary to establish transparent processes such as public participation invitation and tender which can ensure fair competition. In addition, it is essential to establish an independent regulating organization to monitor and supervise these processes.
- Clarification of roles and risks born by the public and private sectors
  Share of the roles, in particular, risks, between the government and private sector should be designed appropriately in order to complete the project successfully without cancellation or

suspension. Treating the private sector too well may cause too much government burden, whereas pushing too many risks onto the private sector may cause no entry so that balance is necessary. Study on the past best practices and suitable adviser's consultation are necessary.

- Investment promotion policies
  Private investment promotion policies such as government's guarantee of power projects which the private sector enters, incentive tax systems and abolition of foreign investment restriction should be implemented. Since Sierra Leone Investment and Export Promotion Agency (SLIEPA) established in May 2007 is attracting investors and doing publicity work in Sierra Leone, it is desirable that the Ministry of Finance and Economic Development, Ministry of Energy and Water Resources and SLIEPA cooperate to promote investment in the power sector much more.

A standard process of PPP introduction as an example of private introduction into public works is shown in Fig. 9.2-1.

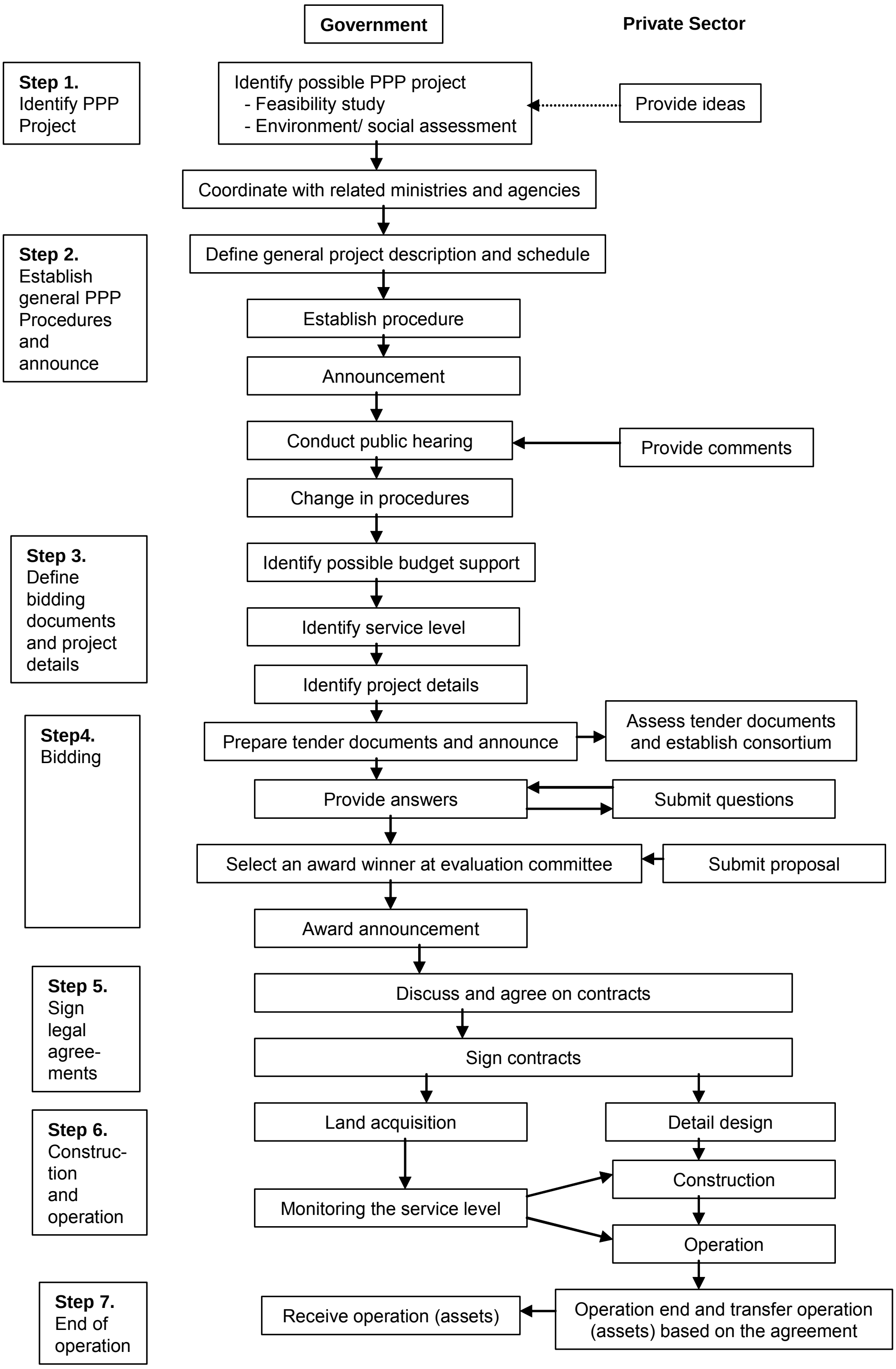
On the other hand, private introduction requires attention. There has already been an example where rental power introduction brought about high costs because of the free contract. Therefore, the competitive process described above is necessary. Indonesia and the Philippines had problems after IPP introduction. For instance, the government introduced IPP responding to lack of power supply in the 1990s in the Philippines. However, high price agreements have made the National Power Corporation (NPC) and later the liquidation organization (Power Sector Assets and Liabilities Management Corporation established by the government to dispose NPC's stranded liabilities and stranded IPP contract costs before the unbundling and privatization of NPC) suffer from huge liabilities and annual adverse income/costs of IPP are still continuing now. Therefore, universal charge imposed on electricity consumers may be increased so that the burden is transferred to the consumers.

In the case of a project close to a monopoly such as electricity supply business, there is a case where tariff negotiation between the government and electricity company is decided with the following formula.

Tariff increase rate = CPI (Consumer Price Index) – alpha

Here, alpha is a productivity improvement goal which is negotiated between the government and operator so that appropriate tariffs can be attained.

Privatization of the NPA is a long-term future matter and it is necessary to attain profits financially and train the staff so that they can operate and maintain technically before the privatization. After the NPA becomes an independent public corporation, it will be necessary to re-examine the privatization and unbundling. At present, NCP has a long-term strategy to unbundle the NPA to generation, transmission and distribution and privatize each, but it should reconsider how to privatize the NPA when it can become independent. It will be necessary to examine desirable aspects of power sector in Sierra Leone because international competitiveness may be necessary when West Africa Power Pool (WAPP) is established. There are some examples of electricity companies without unbundling in the world and it is not necessary to decide how to privatize the NPA at present in a hasty way.



[Source] JICA, "Public-private Partnership (PPP) Program for Cairo Urban Toll Expressway Network Development," March 2006

Fig. 9.2-1 Standard PPP Introduction Process

9.2.2 Recommendations concerning Transmission and Distribution System

(1) 161 kV Bumbuna Transmission Line

In the future, power supply to Western Area will largely depend on hydroelectric power plants such as Bumbuna, Yiben, etc. However, the only transmission line that sends electricity from those hydro power plants to the capital region is 161kV-single circuit Bumbuna line. Therefore, system load must be reduced to the level that is equal to diesel generators' capacity connected to the Kingtom's bus bar on that occasion if an accident occurs on the Bumbuna line, as explained in section 6.4 6) power frequency calculation and 7) stability analysis. The Bumbuna line has the length of approximately 205 km and there is a high possibility of line accident and shut down. If such situation happens, the functions of the capital region will be heavily impeded. In order to avoid such catastrophe, it is highly recommended to implement the following countermeasures.

1) The Western Area power system should be interconnected with cross-border transmission link. The desirable location of new substation will be such that;
   - Power supply is hampered when the existing 161 kV line is out,
   - A load dispatch center can be easily constructed in the future, and
   - No negative impact on the environment is anticipated.

   One of the recommended nominal 230 kV transmission line routes is Mano-Kenema-Bo-Makongo-Lumpa but final decision shall be made through the comprehensive examination on future road plan, demand forecast and conservation areas.

2) Diesel generators which are connected to the Western Area power system might be disconnected if fast load cut back is impossible in case of Bumbuna line outage. This will lead to the collapse of whole Western Area power system. In order to minimize blackout area, it is necessary to cut back system load as soon as possible. To do so, preliminary system flow monitoring, transmission of accident information on Bumbuna line, calculation of the amount of load cut back after an accident happens, and automated load cut back systems should be equipped. In addition, prioritization of feeders at each substation should be defined beforehand.

(2) Operation of Loop System

In the Western Area power system, system configuration that is suitable for loop system operation is preferred and actually the system is composed of complicated multi-loops. A loop system has an advantage in that blackout can be avoided by sending power from a normal path in case an N-1 accident happens. On the other hand, a loop system has the disadvantage that it is difficult to monitor power flow and system operators and planners are required to have higher skills compared with radius network.

In order to maximize the advantages of loop system, it is necessary to establish a distribution network which can cater to change of power flow in case of an accident. Careful system analyses on trunk distribution lines and the selection of configuration of network which will meet various load patterns should be conducted in advance. In addition, loop system operation should be accompanied with the modification of the existing system (adoption of frequency relays, etc.). Furthermore, training for system operators and planners and the introduction of supporting system on system operation and planning would be necessary.

9.2.3 Recommendation for Environmental and Social Considerations in the Future

9.2.3.1 Important Points in the Next Step of Feasibility Study or Project Implementation

This Master Plan presents the plans of power development and renewal, enforcement and extension of distribution lines from now on. To implement the Master Plan, in the next step, feasibility study or project implementation, it is necessary to consider the following points.

(1) To Avoid Involuntary Resettlement

Involuntary resettlement has to be avoided as much as possible since the financial capacity of the government to pay such costs is very weak. Thus, routes or height and position of pylons and poles for distribution lines need to be carefully considered, and the location of a power plant and dam is also carefully considered.

(2) To Conduct Environmental Survey

There are the forest reserves and mangrove swamps in Western Area, and the possibility that endangered species live there is very high. It is necessary to conduct survey on the protected areas and their ecosystems, and then consider mitigation measures again after the current conditions become clear. As for a new dam, it is necessary to start field survey at an early stage and collect basic information as there is no data on the environment in rural areas.

(3) To Have Enough Time and Budget for Study

Unfortunately, there are few reliable data in Sierra Leone. It is not realistic to depend on only the existing data. As with the population data or accurate maps for resettlement, the information on protected areas and ecosystem for environmental protection are necessary. Therefore, it is required to have enough time and budget to conduct field survey and collect necessary data.

(4) To Work with the Forestry Division, NGOs, etc. in a Coordinated Manner

The Forestry Division under the Ministry of Agriculture and Food Security is implementing the project to protect WAPF assisted by a donor, and there is a forestation plan in some areas in WAPF. It is necessary to obtain update information before the start of projects in Western Area. Local environmental NGOs have more detailed information on protected areas and ecosystems through their activities than the government. It is worth cooperating with them.

9.2.3.2 Recommendations to NPA on Environmental and Social Considerations

(1) Current System of Environmental and Social Considerations in NPA

NPA does not have an organizational and institutional framework for environmental and social considerations, which are needed before the NPA starts a new project. Nor does the NPA have an environmental management system to monitor and manage activities. There is no department or section to deal with environmental and social issues. A safety specialist under the safety division of the technical department is also assigned as an environmental officer. An acting commercial director under the customer services section of the commercial department is assigned as a social/resettlement officer. Except for these two officers, no one has been involved in environmental and social considerations.

There is no environmental department or division. So when the officers in charge have some problems, they consult with the deputy general manager.

As there is no formal organizational structure to deal with environmental and social issues, no budget is available. When they need budget for their work, they request to the general manager, but the weak financial standing of the NPA hinders allocation of money.

The two officers do not have enough formal background in the field of the environment and social considerations. No training has been organized in the NPA. Therefore, they have been learning through their works and acquire necessary knowledge from practical experiences

As for the environmental officer, he helped an environmental audit study of the Kingtom Power Station done by a German consulting company funded by the World Bank in 2004, which was his first experience. Then he participated in a study to prepare EIA for 33 kV line done by a Ghanaian consultant company under the power and water project of the World Bank in 2004. He prepared a simple EIA for a mini hydro dam in 2008. That’s all his experience as an environmental officer

As for the social/resettlement officer, he had the first experience when the RAP for 33 kV line under the power and water project of the World Bank were prepared in 2004. This was led by the World Bank and international consultants were hired to conduct the study. The RAP was revised and updated in 2007, and he was also involved in the study. And he is now supervising the implementation of the RAP.

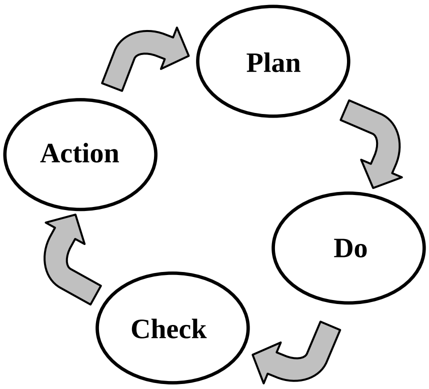
Even though the two of them participated in the projects above, the role of them was still limited. Because, it was not the NPA that took initiative but it was the World Bank and the consultants. The two officers think their knowledge and capacity are not adequate enough to carry out their work. The workload of their main posts makes it difficult for them to concentrate on their secondary posts of the environmental and social/resettlement officers.

In the first place, there are no environmental regulations or standards in Sierra Leone which regulate the activities of the NPA. The NPA does not have an environmental management system or plan. Consequently, environmental monitoring has never been conducted at the only Kingtom power station. No monitoring equipment or budget has been available.

In addition, waste management and cleaning of the power station or substations are not carried out. Waste management has not properly been handled, and a harmful waste such as waste oil is discharged without proper treatment to the sea. All kinds of wastes are discharged to the landfills, which have no facilities to separate wastes. The ground of the power plant is contaminated by waste oil or leaked oil. Substations are also contaminated by leaked transformer oil and several types of waste are scattered in the substations.

(2) Recommendation

It is recommended that NPA introduce an environmental management system. The “Plan, Do, Check and Act management cycle” is often used.



[Source] JICA Study Team

Fig. 9.2-2 PDCA Cycle

Table 9.2-1 PDCA Cycle

Plan	To develop environmental policy, set environmental targets and prepare an environmental management plan
Do	To implement the plan to protect the environment
Check	To monitor and evaluate the results of actions regularly
Act	Review the original plan for improvement

[Source] JICA Study Team

To operate this management system, following steps will be needed.

1) Establish an environmental unit

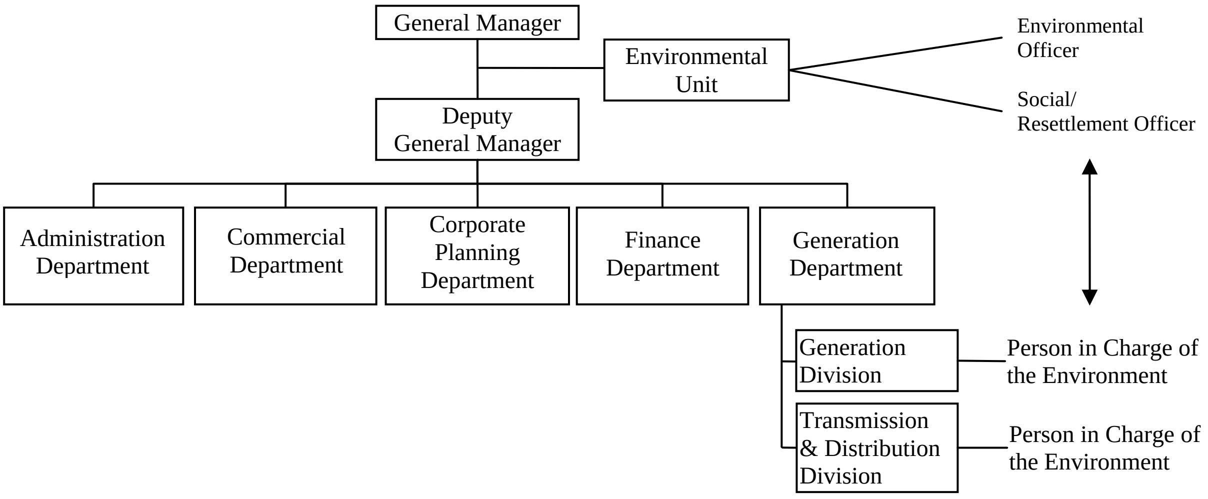
It is ideal to have an environmental department consisting of several qualified staff in the future. But it is not feasible to create this kind of environmental department from the current condition of the NPA. As a first step, it is recommended to create an environmental unit under the direct supervision of the general manager in order to deal with the environmental and social issues seriously as an authority. This unit consists of at least two environmental officers and two social/ resettlement officers. They work with all the other concerned departments. The TOR of the officers is as follows. It is encouraged to hire new staff members who have basic knowledge and qualifications.

Table 9.2-2 TOR of Officers

	TOR
Environmental officer	・Develop an environmental policy ・Set internal environmental targets ・Prepare an environmental management plan ・Conduct EIA or contract out EIA and supervise it ・Organize training for NPA staff ・Conduct the environmental monitoring ・Analyze the results of the environmental monitoring ・Report the results to the management ・Take necessary counter measures ・Coordinate with concerned ministries and agencies ・Supervise activities of and coordinate with other departments, especially the Generation Division and Transmission & Distribution Division
Social and resettlement officer	・Develop a land acquisition and resettlement policy ・Conduct EIA or contract out EIA and supervise it ・Prepare a resettlement action plan or contract out the plan to consultants and supervise them ・Coordinate with donors ・Coordinate with concerned ministries and agencies for land acquisition and resettlement ・Give information to the public and negotiate with project affected people ・Report the progress of land acquisition and implementation of a resettlement action plan to the management

[Source] JICA Study Team

One officer each in the Transmission and Distribution Division, Generation Division and the power stations should be assigned as the person in charge of the environment and supervise their activities in each office.



[Source] JICA Study Team

Fig. 9.2-3 Organization Chart of the NPA

2) Develop environmental policy and management plan

The environmental officers with collaboration with the management are expected to develop an environmental policy of the NPA. Then minimal environmental targets will be set and management plan will be developed. Although no national environmental standards are available, the NPA should develop an internal reference by referring to environmental standards of international organizations, developed counties or neighboring countries. It is important to set the feasible targets to the NPA, which has no experience of environmental considerations and monitoring.

The environmental management plan should include environmental pollution control measures for and monitoring plan of power plants, environmental and social monitoring plan for distribution lines, waste management plan and chemical control plan. In the future when the NPA has a hydro plant, it is expected to monitor environmental and social impacts of the hydro plant.

Harmful wastes, such as oil or chemicals, should be collected separately and discharged in a proper manner. Since no landfill or treatment facilities for industrial wastes exist in Sierra Leone, the NPA as a generator of wastes should take adequate measures.

In addition, development of an EIA guideline to help the NPA officers assess environmental and social impacts of a new project is highly needed since the NPA will implement many new projects in the coming years. It is believed that donors will fund those projects. Thus, it is required to study the guidelines of donors and explain them in the NPA EIA guideline. In particular, the standards of donors' for resettlement are more effective for protecting affected people than the national law. This NPA guideline for EIA should include a part for resettlement.

3) Allocate necessary budget

A budget to take actions for the environmental protection needs to be secured. The budget includes not only recurrent cost of the environmental unit, but also the procurement costs of necessary equipment, costs of environmental monitoring and so on.

As the NPA's financial status is very weak, it is difficult to allocate budgets. But this is necessary costs that the NPA should bear to protect the environment.

4) Procure monitoring equipment

The NPA does not have any monitoring equipment. So it is recommended to procure monitoring equipment as follows for the thermal plant.

- Gas emission monitoring equipment (NOx, SOx, dust)
- Noise emission monitoring equipment
- Vibration monitoring equipment
- Water quality monitoring equipment

And a laboratory at each power plan is expected to be created for the monitoring purpose. When the NPA has a hydro power plant, it will be necessary to buy additional monitoring equipment.

5) Participate and organize training

It is required to give a chance to take technical training for the environmental officers and social/ resettlement officers to equip advanced knowledge. A seminar or training on EIA or environmental monitoring is recommended for environmental officers. A seminar or training to learn other cases of resettlement, EIA or social-economic survey is recommended for social/resettlement officers. And environmental education training to all the NPA staffs to raise their awareness should be conducted.

The current environmental disaster in the power plants is caused partly by poor operation and maintenance practices. To train the workers how to operate and maintain the generating facilities and incidental facilities is also needed.

6) Monitoring, reporting and evaluation

Monitoring according to the environmental management plan should be conducted and reported to the management regularly. Monitoring should cover:

1. Gas emissions
2. Noise emissions
3. Vibration
4. Water quality
5. Waste
6. Soil contamination
7. Ecosystem

In case of a project which needs involuntary resettlement of people, monitoring of the progress of rebuilding of lives of project-affected people after the construction stage is needed.

The results of the monitoring are compared to the targets set by the environmental management plan and evaluated. If the results are not satisfactory, necessary measures should be taken.

Introduction of this environmental management system will improve the operation structure of the NPA in order to take environmental and social issues into consideration.