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

SEPTEMBER 2009

JAPAN INTERNATIONAL COOPERATION AGENCY
（JICA）

YACHIYO ENGINEERING CO., LTD.

IDD
JR
09-060

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).

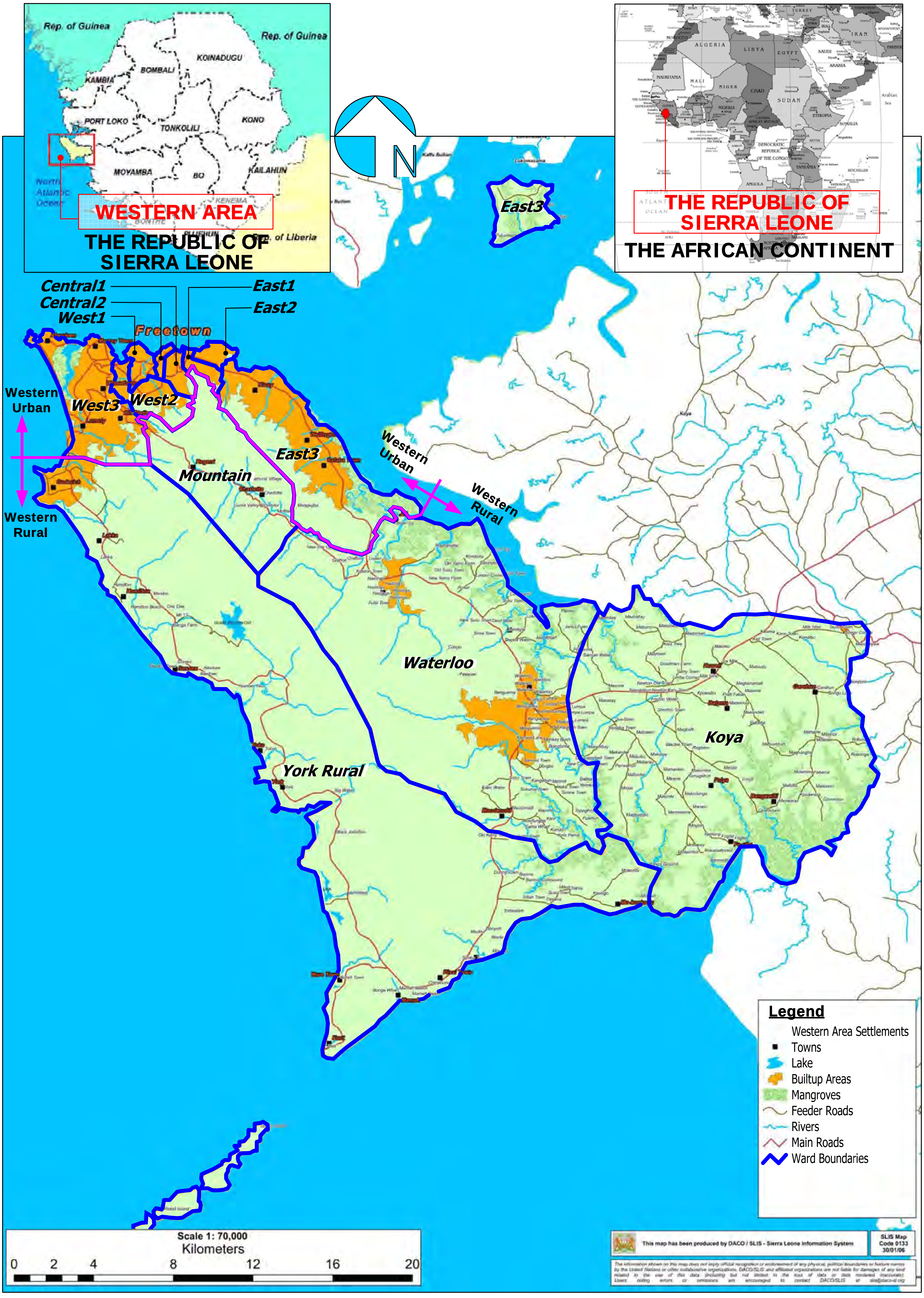
The Study Team compiled this report, which consists of the Master Plan Study on Power Supply in Western Area by 2025, including Power Development Planning, Improvement of Distribution System, Financial and Economic Analyses, Capacity Building, etc. through close consultations with officials concerned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

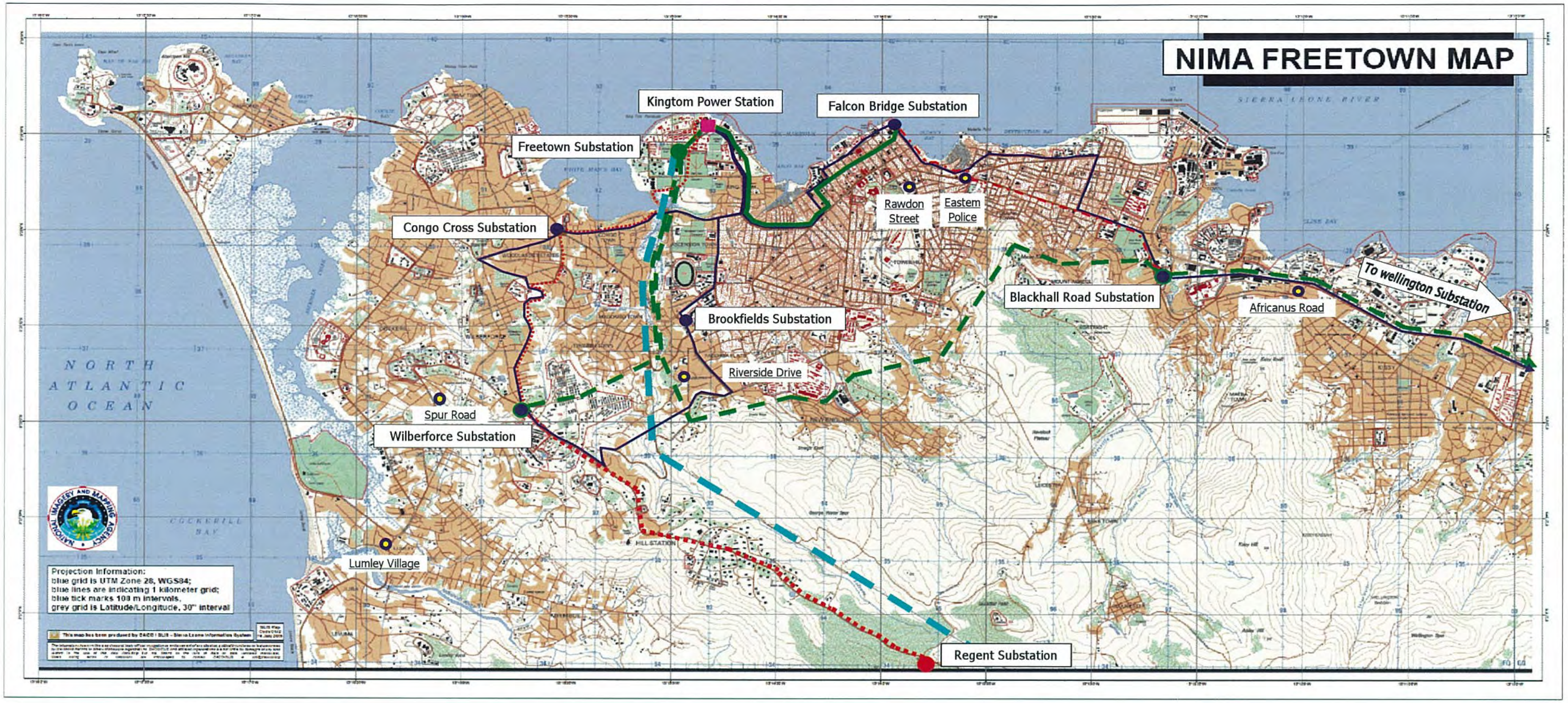
Yours faithfully,

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

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Abbreviations

AfDB	African Development Bank
BADEA	Banque Arabe pour le Developpement Economique en Afrique
BGC	Bumbuna Generating Company
BKPS	Bo-Kenema Power Services
DDR	Disarmament, Demobilisation and Reintegration
DFID	Department for International Development
ECG	Electricity Company of Ghana
ECOMOG	ECOWAS Monitoring Group
ECOWAS	Economic Community of West African States
EIA	Environmental Impact Assessment
EU	European Union
F/S	Feasibility Study
FIRR	Financial Internal Rate of Return
GDP	Gross Domestic Product
GTG	Global Trading Group
GVWC	Guma Valley Water Company
IDA	International Development Association
IDB	Islamic Development Bank
IEA	International Energy Agency
IEL	Income Electrix Limited
IMF	International Monetary Fund
IPP	Independent Power Producer
IT	Information Technology
JICA	Japan International Cooperation Agency
L/C	Letter of Credit
LF	Load Factor
MDRI	Multilateral Debt Relief Initiative
MEWR	Ministry of Energy and Water Resources
NASSIT	National Social Security & Insurance Trust
NCP	National Commission for Privatization

NGO	Non-Governmental Organizations
NPA	National Power Authority
OPEC	Organization of the Petroleum Exporting Countries
PCB	Polychlorinated Biphenyl
PPA	Power Planning Associates Ltd
PWP	Power and Water Project
RAP	Resettlement Action Plan
ROW	Right of Way
RUF	Revolutionary United Front
SALWACO	Sierra Leone Water Company
SEA	Strategic Environmental Assessment
SPC	Special Purpose Company
SWBR	Switchgear
UNAMSIL	United Nation Mission in Sierra Leone
UNDP	United Nations Development Programme
WAPF	Western Area Peninsular Forest
WAPP	West African Power Pool
WB	World Bank
WHO	World Health Organization
WSD	Water Supply Division

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.

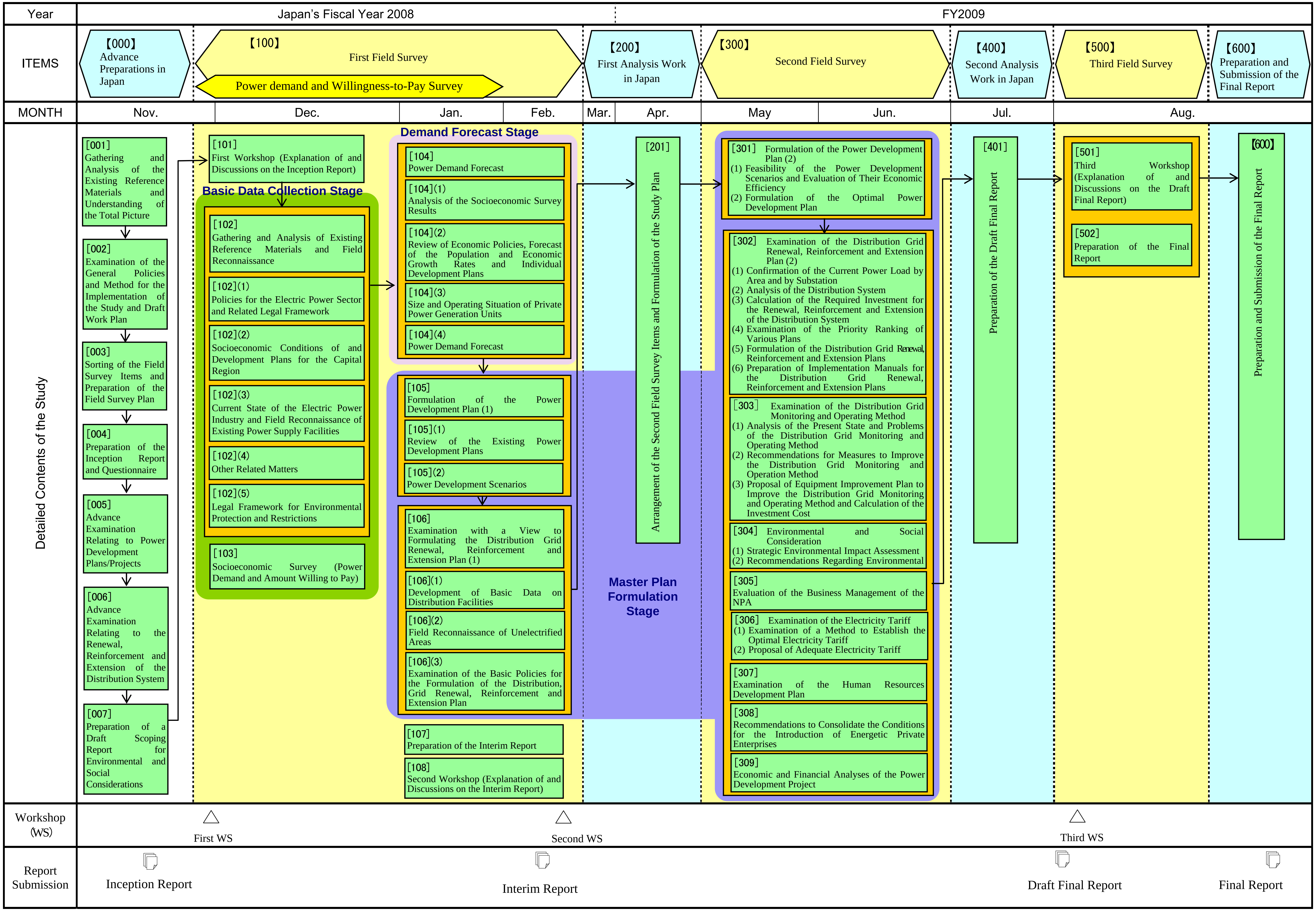


Fig. 1.4-1 Formulation Process of the Master Plan

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. Socioeconomic Conditions and Development Plan

2.1 Social Conditions

The Revolutionary United Front (RUF), an anti-government force, commenced an armed uprising in Sierra Leone, putting the country into a state of civil war. Using locally produced diamonds as the source of its finance, the RUF expanded its influence and intermittently continued its anti-government armed struggle. In February 1996, democratic presidential and parliamentary elections were held under the multi-party system, leading to the inauguration of President Kabbah in March. A military coup d'etat in May 1997 ousted President Kabbah who escaped to neighbouring Guinea and the civil war further intensified. In March 1998, the ECOMOG, a multi-lateral armed force established by the Economic Community of West African States (ECOWAS), ousted the junta and President Kabbah was reinstated.

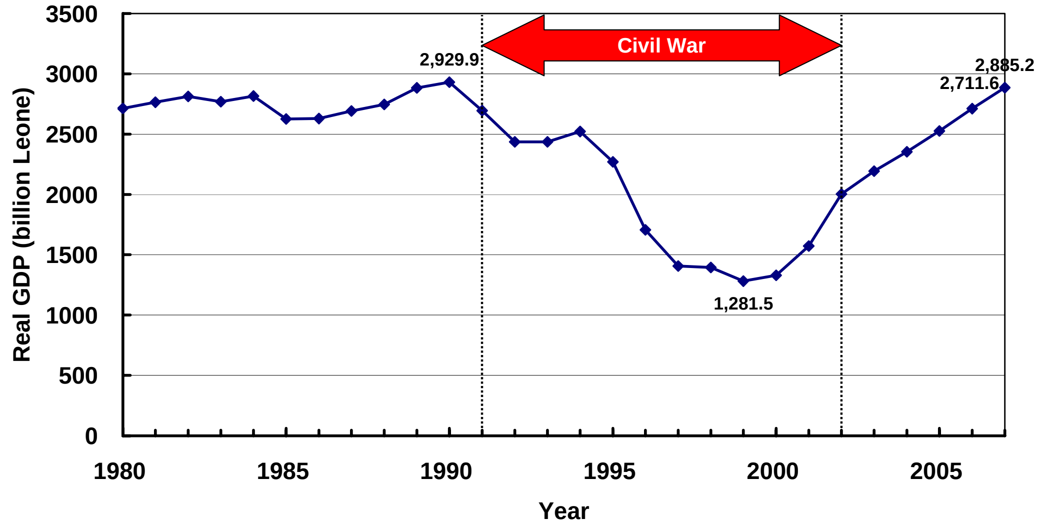
In December 1998, the RUF attacked the capital Freetown, forcing the ECOMOG to send reinforcements to deal with the renewed offensive. Meanwhile, the international community recognised the difficulty of achieving peace through military means and encouraged dialogue between President Kabbah and the RUF. In May, 1999, a ceasefire agreement was reached between President Kabbah and Sankoh, the leader of the RUF, and the agreement was duly signed in July at Lome, the capital of the Republic of Togo.

In 1999, the DDR (Disarmament, Demobilisation and Reintegration) Programme was implemented for former soldiers with the assistance of the UN Mission in Sierra Leone (UNAMSIL) and a ceasefire was agreed between the Government of Sierra Leone and the RUF in November 2000. In January 2002, President Kabbah officially declared the end of the civil war which had lasted for more than 10 years and the disarmament process. This was followed by the declaration to end the state of a national emergency in March, illustrating the concrete progress made towards peace. The subsequent presidential and parliamentary elections in May 2005 and the presidential election in August following the expiration of the presidential term of office and the parliamentary election in September 2007 have been peacefully held, suggesting the steady progress of peace and stability in Sierra Leone.

However, factors destabilising the socioeconomy of the country such as crime, a high level of unemployment, absolute poverty and the uneven distribution of resources have not yet been solved, posing many difficult tasks for the country's post-civil war reconstruction efforts. During the civil war period, some 400,000 people fled Sierra Leone to Guinea and Liberia while a further 300,000 people were displaced within Sierra Leone. Most of these people have now returned home.

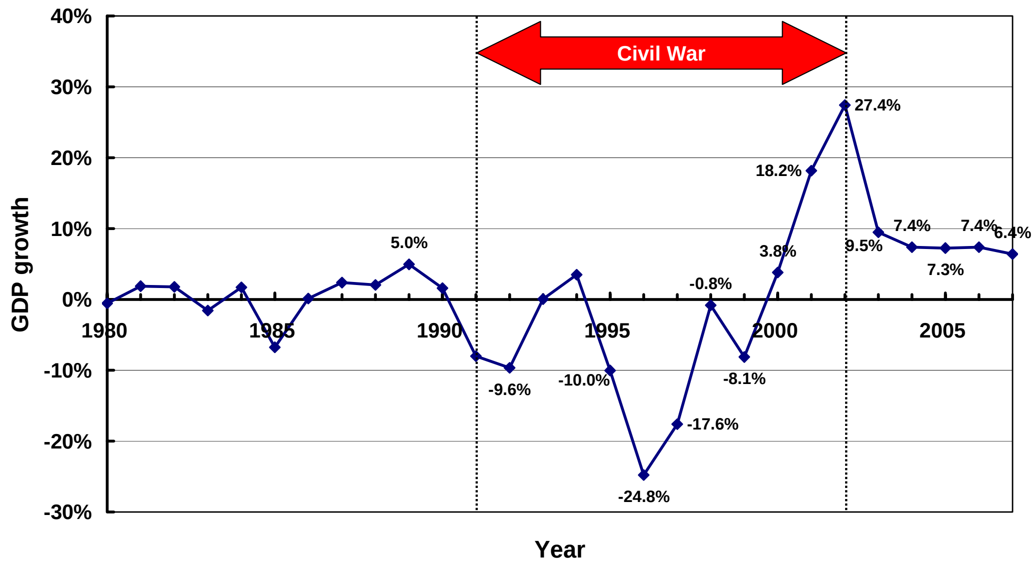
2.2 Economic Conditions

Throughout the civil war period, the economy of Sierra Leone was steadily retrenched. The real GDP which stood at 2,929.9 billion leones (approximately ¥89.7 billion) in 1990 continued to fall as the civil war intensified to 1,281.5 billion leones (approximately ¥39.2 billion) in 1999. The gradual easing of the civil war after 1999 reversed the falling trend of the national GDP and the annual GDP growth rate in 2002 was as high as 27.4%. From 2004 to 2006, the annual GDP growth rate was steady with an average figure of 7.4% and the real GDP in 2007 was almost restored to the level before the civil war. According to the IMF, the real GDP growth rate of Sierra Leone in 2007 slightly fell to 6.4% and a further fall in 2008 is expected because of the adverse impact of the worsening global economy. Fig. 2.2-1 and Fig. 2.2-2 show the historical trends of the real GDP and the real GDP growth rate respectively.



[Source] IMF (2008), "World Economic Outlook Database"

Fig. 2.2-1 Historical Changes of Real GDP

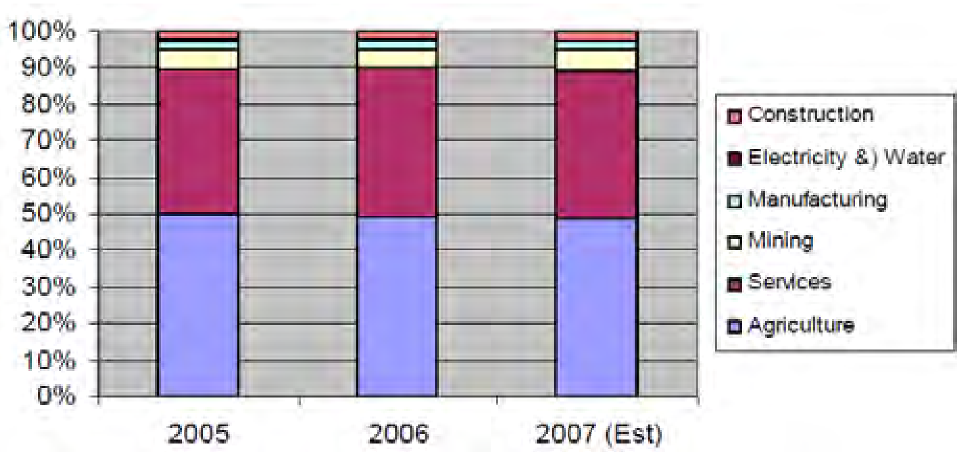


[Source] IMF (2008), "World Economic Outlook Database"

Fig. 2.2-2 Historical Changes of Real GDP Growth Rate

The breakdown of GDP by sector shows that agriculture accounted for some 50% in the period from 2005 to 2007, indicating the status of agriculture as the dominant sector. The second largest sector was services with 40% of the GDP. These two sectors accounted for approximately 90% of the country's GDP, leaving a mere 10% for mining, manufacturing, electricity & water and construction. Among these minor sectors, mining had the largest GDP share of approximately 5%. Fig. 2.2-3 shows the breakdown of the GDP by sector.

Table 2.2-1 shows the degree of contribution of each sector to GDP growth from 2005 to 2007. During this period, agriculture and services accounted for some 70 – 90% of GDP growth, clearly indicating that the economic growth of Sierra Leone in the post-civil war period was led by agriculture and services.



[Source] IMF (2008.7), “Sierra Leone: Poverty Reduction Strategy Paper—Progress Report”

Fig. 2.2-3 Breakdown of GDP by Sector

Table 2.2-1 Contribution to GDP Growth by Sector

	2005	2006	2007 (Estimate)
Agriculture	72.1%	37.4%	41.2%
Services	26.0%	57.7%	33.0%
Mining	-3.4%	0.2%	17.2%
Manufacturing	1.1%	4.2%	1.0%
Electricity & Water	-1.0%	-0.3%	-0.9%
Construction	5.1%	0.8%	8.5%

[Source] IMF (2008.7), “Sierra Leone: Poverty Reduction Strategy Paper —Progress Report”

In regard to the fiscal balance, public finance in Sierra Leone clearly relies on the financial assistance of donors. In 2007, such assistance accounted for some 75% of the total revenue although the figure is expected to be much lower at around 36% in 2008. In 2007, the fiscal balance including grants showed a surplus of 1,252.7 billion leones (approximately ¥38.3 billion). When grants are excluded, however, the fiscal balance goes into a deficit of 339.7 billion leones (approximately ¥10.4 billion). In 2008 when grants fall by 76% on the previous year, the fiscal balance including grants was expected to show a deficit of 525.7 billion leones (approximately ¥16.1 billion) as is shown in Table 2.2-2.

The international trade balance of Sierra Leone showed a deficit of US$ 163.79 million in 2006 and US$ 201.36 million in 2007, reflecting the country’s permanent state of an excess of imports. Among imported items, the share of petroleum products (mineral fuels and lubricants) is the largest at some 38% of the total value of imports (2007). Among exported items, the share of mineral exports, including diamonds, is the largest at some 89% of the total export value (2007). The second largest category of exports is agricultural products although the contribution of agricultural products to the overall export performance of Sierra Leone is rather small as is shown by the export share of 5.6% in 2007. Table 2.2-3 shows the international trade balance of Sierra Leone.

Table 2.2-2 Fiscal Balance of Sierra Leone

Unit: Billion leones

	2007 (Actual)	2008 (Estimate)	+/-
Total Revenue and Grants	**2,129.3**	**1,074.0**	**-49.6%**
Domestic Revenue	**536.9**	**692.7**	**29.0%**
Income Tax Department	146.2	196.5	34.4%
Customs and Excise Department	308.4	370.9	20.3%
Mines Department	18.6	26.2	40.9%
Other Departments	29.4	45.3	54.1%
Road User Charges	34.4	53.8	56.4%
Grants	**1,592.5**	**381.3**	**-76.1%**
Programme	168.7	222.3	31.8%
Projects	70.6	159.0	125.2%
MDRI* Assistance	1,353.2	0.0	-100.0%
Total Expenditure and Net Lending	**876.6**	**1,218.4**	39.0%
Current Expenditure	**660.9**	**887.0**	34.2%
Wages and Salaries	296.5	356.2	20.1%
Current Noninterest, Nonwage Expenditure	252.3	409.8	62.4%
Goods and Services	157.3	278.9	77.3%
Transfer to Local Councils	19.3	41.5	115.0%
Grants to Educational Institutions	27.4	27.2	-0.7%
Transfers to Road Fund	34.4	53.8	56.4%
Elections	13.8	7.5	-45.7%
Interest Payments	112.1	121.0	7.9%
Domestic	96.3	109.6	13.8%
Foreign	15.9	11.3	-28.9%
Capital Expenditure and Net Lending	**176.7**	**331.4**	87.5%
Capital Expenditure	173.8	333.3	91.8%
Net Lending	2.9	-1.9	-165.5%
Contingency Spending Related to MDRI	**39.0**	**0.0**	-100.0%
Overall Balance (Excluding Grants)	**-339.7**	**-525.7**	**54.8%**
Overall Balance (Including Grants)	**1,252.7**	**-144.4**	**-111.5%**

[Source] IMF Country Report No. 08/249

[Notes] *MDRI：Multilateral Debt Relief Initiative

1 Le=0.03060JPY

Table 2.2-3 International Trade Balance of Sierra Leone

Unit: US$'000

	2006	2007	+/-
Merchandise Imports	**394,828.6**	**446,601.0**	**13.1%**
Food	56,139.8	67,948.5	21.0%
Beverages & Tabacco	9,295.3	12,074.5	29.9%
Crude Materials	21,702.6	14,654.5	-32.5%
Mineral Fuels & Lubricants	147,080.4	168,576.5	14.6%
Animal & Vegetable Oils	3,327.1	6,205.8	86.5%
Chemicals	23,999.9	31,008.5	29.2%
Manufactured Goods	48,601.3	51,900.1	6.8%
Machinery & Transport Equipment	69,110.9	75,112.8	8.7%
Other Imports	15,571.3	19,119.8	22.8%
Merchandise Exports	**231,037.1**	**245,238.0**	**6.1%**
Mineral Exports	179,241.2	217,086.3	21.1%
Diamonds	125,041.2	142,048.5	13.6%
Bauxite	23,573.1	32,706.1	38.7%
Rutile	28,501.1	38,146.2	33.8%
Ilumenite	1,063.3	1,200.6	12.9%
Gold	1,062.5	2,984.9	180.9%
Agricultural Exports	12,761.4	13,666.6	7.1%
Coffee	1,093.4	1,854.7	69.6%
Cocoa	11,570.8	11,368.1	-1.8%
Fish and Shrimps	97.2	443.8	356.6%
Others	10,634.6	11,764.8	10.6%
Re-exports	28,399.9	2,720.3	-90.4%
Trade Balance	**-163,791.5**	**-201,363.0**	**22.9%**

[Source] Bank of Sierra Leone (2007.12) "Annual Report and Statement of Accounts"

[Note] 1US$=97.28JPY

2.3 Development Plan

2.3.1 National Development Plan

The Government of Sierra Leone formulated “Vision 2025”, a national development plan with the target year of 2025, in August 2003 and the basic concept of this national policy is outlined below.

< Three Visions >

1. United People
2. Progressive Nation
3. Attractive Country

↓

< Six Strategies >

1. How to attain a competitive private sector-led economy with effective indigenous participation;
2. How to create a high quality of life for all Sierra Leoneans;
3. How to build a well educated and enlightened society;
4. How to create a tolerant, stable, secure and well managed society based on democratic values;
5. How to ensure sustainable exploitation and effective utilization of natural resources, while maintaining a healthy environment;
6. How to become a science and technology driven nation;

↓

< Concrete Actions (Electricity Sector) >

1. Rehabilitation and maintenance of the National Power Authority’s (NPA) infrastructure and systems; establish procedures and divestiture instruments to privatise its operations
2. Promote private sector involvement in the generation and sale of electricity nationwide
3. Improve future electricity supply through the development of hydro-electricity
4. Complete civil works and distribution network of Bumbuna Hydroelectric Project to operational level and establish an institutional framework for the management of its operations

Fig. 2.3-1 Outline of the National Development Plan (Vision 2025)

Careful attention will be paid to ensuring that the Master Plan to be formulated under the Study will contribute to the achievement of the goals of Vision 2025. This Master Plan will also reflect the latest sector level policies and the capital region development plan.

2.3.2 Poverty Reduction Strategy Paper-II (PRSP-II)

At the DEPAC (Development Partnership Committee) meeting held on May 20th, 2009, H.E. President Koroma made a statement on New Poverty Reduction Strategy Paper II from year 2008 to 2012 named “Agenda for Change”. The introduction of PRSP-II was the main purpose of the DEPAC meeting and four (4) sectors, i.e. power, agriculture, road & transportation and human resources development (education and health), were selected as prioritized areas of PRSP-II. DEPAC was established in May 2007 aiming to organize the important framework of dialogue between the Government of Sierra Leone and development partners. However, the DEPAC meeting has been postponed for a couple of years since its initiation in May 2007 due to the presidential election.

In the brief overview of “Agenda for Change”, H.E. the President Koroma said that “Our current economic growth rate is around 6.5% per annum and if we maintain this growth rate, by 2018, Sierra Leone’s GDP will reach $350 per capita. However, the majority of Sierra Leoneans will still live on less than $1 per day. Therefore, to reduce poverty significantly and improve the lives of the majority of Sierra Leoneans, we need to achieve an annual growth rate of 10% or more. Our strategy to achieve this is based on a complete transformation of our economy. But, this will require substantive investment in supportive infrastructure, improved delivery of social service”.

While four (4) key sectors, i.e. power, agriculture, road & transportation and human resources development (education and health), are prioritized areas of PRSP-II, the power sector has the highest priority, with H.E. the President Koroma stating that "First, we must provide a reliable power supply to the country. This will be done through improving the management and regulation of the energy sector, strengthening revenue collection and increasing generating capacity. Provision of reliable power supply will be made possible by completing the Bumbuna Hydroelectric Project, including the connection of selected provincial towns to the power lines from Bumbuna and enhancing our transmission and distribution networks. We will also embark on the development of new sources of power throughout the country, including the competitive sourcing of private sector investment. In the medium to long term, we will focus on broadening access to electricity throughout the country, with particular hopes for mini-hydro schemes, given the topography and high rainfall in the country".

In addition, regarding fund procurement necessary for the implementation of PRSP-II, H.E. the President Koroma also stated that "The availability of adequate resources to fund programs identified in the second PRSP is critical for sustainable growth and poverty reduction in Sierra Leone. Total funding required for the successful implementation of the Agenda for Change is estimated at US$1.9billion.The Government and development partners have committed US$1.1 billion within the current Medium Term Expenditure Framework for 2009-11."

2.3.3 Planned Large Development Project and Regional Development Plan

Concrete regional development plans and planned large development projects do not exist in Western Area at present. Information regarding large scale development and regional development in Freetown and the surroundings which the Study Team has collected through field survey is as follows.

(1) Freetown Development Plan

The preliminary study of the Freetown Development Plan has already been completed under assistance of the European Union (EU). EU is planning to commence the full scale study from September 2009 in collaboration with Freetown City Council (FCC) as a counterpart. The target sectors of the plan include transportation, road development, electricity supply, telecommunications, water supply and sewage system, environmental and social considerations, etc. and the target areas of the study are Western Area and Lungi except Koya.

Unfortunately, the period of the study is planned for about four or five years. Therefore, it is impossible to incorporate the results into this Master Plan Study.

(2) Road Development

As a part of the Freetown Infrastructure Rehabilitation Plan funded by IDA, the traffic management study had been prepared and the proposal for the Freetown Ring Road was conceived in 1994. Based on this study, the GoSL and Road Authority prepared "Freetown Ring Road Proposal" in December 2008. The planned "Circular Route around Freetown" is shown in Fig. 2.3-2. However, no budget has been allocated and no donor's assistance has been committed for all the planned projects as of the end of December 2008.

Only road rehabilitation works between Lumley junctions and Toke that mainly consist of paving, widening and partial rerouting are under implementation with the financial assistance of OPEC and Kuwait funds. These construction works are originally planned to be completed by September 2008. However, problems such as contractual matters with contractors and resettlement of houses within the right of way (ROW) of the planned road hamper the progress. Therefore, the Road Authority at the moment is trying to complete the planned road by the end of May 2010. After completing this road, the road between Waterloo and Lumley (approximately 65 km) will be paved and widened. This will attract more tourism developments than present.

(3) Structure Plan for Greater Freetown

According to the Ministry of Lands, Country Planning and Environment, there are no concrete regional development plans, housing complex development plans and other related development plans. The only development plan for Freetown that is currently effective was prepared in the 1990s, namely, "Structure Plan for Greater Freetown". However, the Structure Plan has not been utilized so far. As general development philosophy for Western Area, the acting director of Country Planning Division indicated the following development concepts.

1) As general rules, the east side of the peninsular should be utilized for industrial and domestic housing areas, etc. and the west side should remain as an eco-tourism area.

2) As an idea, a new international airport should be constructed at the south of Waterloo in order for easy access to Freetown urban area and the eco-tourism area.

However, there is no concrete plan for the above ideas.

(4) Tourism Development (Ministry of Tourism and Cultural Affairs)

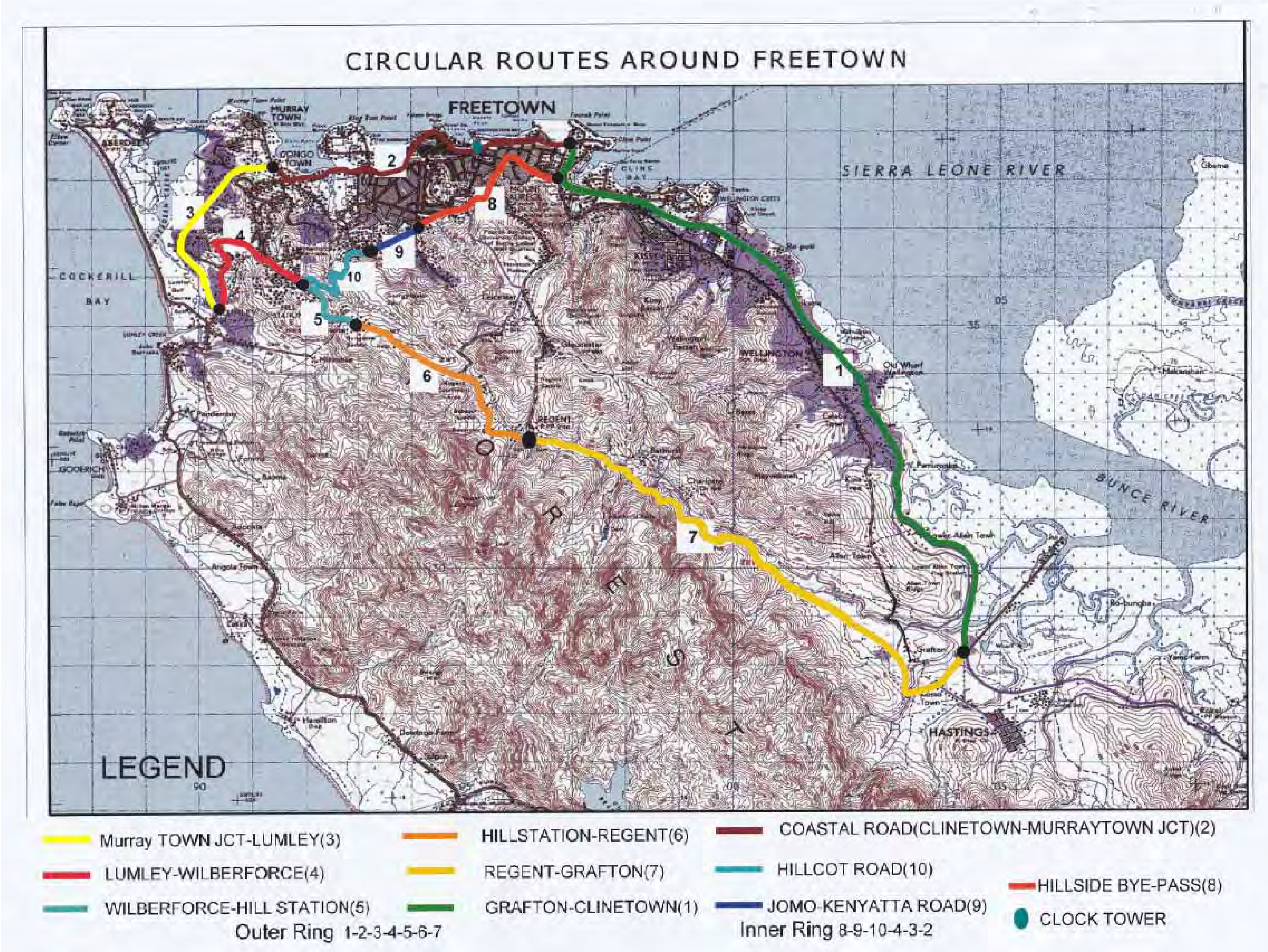
According to Ministry of Tourism and Cultural Affairs, the principal policies of tourism development for Western Area are as follows:

1) Ministry of Tourism and Cultural Affairs has eco-tourism development plans outside Freetown areas.

2) Ministry of Tourism and Cultural Affairs strongly requested the supply of electricity to Lumley beach because there is no street lighting at the moment, even though it had cleared small commercial facilities illegally located within the beach area.

(5) Housing Complex Development Plans

According to the information from "SL Housing Corporation" and "National Social Security & Insurance Trust (NASSIT)", they have housing complex development plans at Goderich, Waterloo, Hill-station, Kissy, etc. and each complex has approximately 50-150 houses only for each site. Since their development size is not so large, these developments do not affect the future power demand.



[Source] Sierra Leone Road Authority

Fig. 2.3-2 Planned “Circular Route around Freetown”

3. Current Situation of the Electric Utility

3.1 Power Sector Policy and Strategy

3.1.1 Power and Energy Policy

Sierra Leone's policy on electricity is stated in the "Energy Sector Strategy Note" published in March2007 and the "Letter of Sector Development Strategy for the Electric Power Sector" published in November 2007. Both of these identify the current problems of the electric power sector and the short, medium and long-term tasks to solve the problems, calling for the further assistance of donors.

Following the above two electric power sector strategies, the Ministry of Energy and Power formulated the "Statement of Energy sector policy & strategic action plan" in November 2008 and held a meeting on 15th January, 2009 with the participation of donors such as WB, AfDB, EU, Italian Embassy, DFID, JICA, BADEA and officials of the NPA to seek comments and opinions on the statements from the stakeholders. The contents of the statements are outlined below.

(1) Short-Term Action (Q3 2009- Q1 2011)

To sustain the donor support to the GoSL, the GoSL is committed to establishing the framework for development and growth in the sector. This framework will involve the appropriate legal, regulatory and institutional framework for full energy sector reform.

(2) Notwithstanding, this continued improvement in the NPA's management and operations will continue. Medium-Term Action (2011-2016)

Medium-term strategy shows the following main concrete measures.

1) Implementation of rural electrification policy.
   At present, only 1% of rural population has access to electricity; the goal of the GoSL is at least 15 % of access in rural areas.

2) Commencement of Bumbuna phase 2 & 3 should be implemented and planned during the medium-term to fully utilize Bumbuna's hydro potential.

3) In order to depend on renewable energy sources for 70% of power demand, biomass resources and solar energy will be utilized as much as possible. Hydro potential in the country appears the most abundant renewable resource, with prospects of generating 1,200 MW, so this will also be utilized as much as possible.

4) The GoSL strongly hopes to integrate its electricity grid through interconnection with neighbouring countries to facilitate purchase of energy from generators out of Sierra Leone through the West African Power Pool (WAPP).

(3) Long-Term Strategy (2015-2025)

The GoSL is committed, through its structural, institutional and private sector development initiatives to fully achieve and in fact surpass the ECOWAS energy access goals by 2015. In particular:

The GoSL aims that at least 75 % of the population should have access to individual electricity supplies. This translates into;

- 100 % of the urban and pre-urban population and
- 45 % of the rural population

3.1.2 Short-Term Tasks for Stable Power Supply by the NPA (additional assistance of donors is hoped for)

(1) Emergency power generating facility for 12 months

As of August 2007, the available output capacity of Kingtom Power Station belonging to the NPA was 7.8 MW, which was only 20% of the rated output capacity (some 39 MW). Therefore, almost all areas of the capital Freetown were subject to planned power cuts. To improve this situation, the Government of Sierra Leone and the NPA made an emergency power supply contract with two diesel power generating companies in December 2007 and February 2008 by use of the PWP (power and water project) budget assisted by WB, and power has since been supplied to Freetown from the Kingtom Power Station (available output of approximately 15 MW) and the Blackhall Road Power Station (available output of approximately 10 MW).

In view of the anticipated commissioning of the Bumbuna Hydroelectric Power Station, this emergency power supply is scheduled to last until December 2008. However, the Government of Sierra Leone extended the contract period until the end of 2009 to secure power supply capacity for Freetown because the commissioning of the Bumbuna Hydroelectric Power Station has been delayed. The Government of Sierra Leone had to pay the cost for the extended contract from its own finance, because the financial conditions of the Government of Sierra Leone did not improved regardless of WB's request, and the WB had decided to stop new finance loans to the Government of Sierra Leone except for the projects already decided,

However, the unit price of electricity purchased from these two companies of approximately US$ 1.0/kWh is quite high, further squeezing the finances of the NPA (the average electricity charge for domestic customers is US$ 0.3/kWh). This situation makes the early commissioning of the Bumbuna Hydroelectric Power Station (maximum output of 25 MW x 2), which has been a priority for the last 30 years, an urgent necessity for the NPA, which has been making strenuous efforts to complete the construction of this new power station as soon as possible.

(2) Rationalisation of the NPA's human resources

NPA is expecting US$ 2.5 million as retirement allowance with the assistance of DFID. However, the rationalisation of NPA's staff has not made any progress as of the end of June 2009.

(3) Improvement of the distribution grid in Freetown (US$ 25 million)

As a part of PWP, the NPA planned to construct a 33 kV distribution network with the assistance of the World Bank. The NPA signed a contract with Interserve Industrial Services, Ltd. of the UK in September 2007 for the implementation of the project. However, the actual work commencement was delayed because of the delay of relocating houses along the planned routes, the opening L/C (Letter of Credit) and negotiations of the price escalation clauses for conductor and nonferrous materials in the contract with Interserve. According to the information from WB in February 2009, all the problems were solved and the NPA and Interserve signed the supplemental agreement in March 2009, and Interserve had commenced investigation works of the construction sites and the work should be completed within thirteen (13) months from the contract date. As for relocating houses along the planned routes, the Sierra Leone side will complete work by the end of June 2009 under the assistance of a local specialized consultant.

3.1.3 Short-Term Tasks to Achieve Sustainable Development by NPA

(1) Master Plan Study for Power Supply in Western Area

Power demand study/power transmission and distribution master plan: power generation option (US$ 1.2 million);

(2) Completion of the Bumbuna Hydroelectric Power Station (US$ 47 million)

The Bumbuna Hydroelectric Project (BHP) aims at the construction of a dam type hydropower station with an output of 50 MW (25 MW x 2 units). The design documents were prepared in 1980 with the funding of the World Bank and the construction work commenced at the end of 1982. In 1988, the Italian government and the African Development Bank decided to provide loans for the civil engineering work for the dam and for the generating, transmission and transformation systems respectively to further progress the work. However, in 1993 when some 85% of the work had been completed, the Italian government announced its cancellation of the loan agreement because of the civil war, resulting in suspension of the work.

Following the end of the civil war, the World Bank played a leading role in securing total funding of US$ 91.8 million which consisted of US$ 38 million from an Italian commercial bank (loan guarantee by the IDA), US$ 3.8 million from the AfDB, US$ 19.9 million from the Italian government, US$ 0.3 million from the Dutch government, US$ 8.4 million from the OPEC Fund, US$ 12.5 million from the World Bank (IDA grant) and US$ 8.9 million from the Government of Sierra Leone.

In August, 2005, the work resumed with funding by the Italian government and this construction work has reached the final stage and is expected to be completed by the middle of 2009 including the compensation for involuntary resettlement at the dam site. Also, cabling works between Freetown substation and Kingtom power station (four (4) lines of 11 kV and one (1) line of 33 kV) was re-started at the beginning of June 2009 in order to secure power demand necessary for load test of generators.

As of the end of June 2009, it is expected that the commercial operation will be commenced by the end of year 2009. However the commissioning date is currently unclear because of unsolved problems such as difficulty of concluding power purchase agreement between NPA and Power Generation Company, etc.

(3) Construction of a back-up thermal power station (US$ 15 million)

The outline of the project is to procure and install two sets of approximately 8 MW, heavy oil-fired diesel engine generators at Blackhall Road substation with the financial assistance of BADEA. And the agreement between MEWR and the NPA and Jacobsen (Company from Norway) was concluded in May 2009 and equipment is expected to be handed over to the NPA around the end of December 2010.

(4) Power generation and distribution project in three rural provincial capitals (US$ 10 million)

(5) Improvement of distribution grid in Bo and Kenema (US$ 5 million)

(6) Interconnection to the West African Power Pool (WAPP) market: feasibility study on further hydropower development (US$ 1 million)

3.1.4 Draft National Energy Policy and Strategic Plan

Following the restructuring of the Cabinet in February 2009, the "Ministry of Energy and Power (MEP)" was reformed to "Ministry Energy and Water Resources (MEWR)" and new Minister Prof. O.R. Davidson announced to the public the "Draft National Policy and Strategic Plan" in May 2009. The outline of new energy strategy is as follows:

(1) Present Situation of Power Supply

Sierra Leone electricity supply has been characterized by poor investments in generation, transmission and distribution resulting in very low generating capacity, rising high transmission and distribution losses (about 45 % system losses in 2008), poor revenue collection and restricted distribution system in major towns. The electricity supply and service in Western Area continues to be inadequate and inefficient and installed capacity in 2008 was 39.2 MW in generation of the NPA, 25 MW by two Independent Power Producers (IPPs), and production was 138.5 GWh, which was totally inadequate, with system breakdowns frequently leading to constant load shedding. Also, the electricity tariff was one of the highest in the West Africa sub region, about US$ 45 per unit based on recent tariff revision in 2008.

The first phase of the Bumbuna Hydroelectric Project is now about 98% complete. The project has potential to make substantial positive impact on the national electricity supply. The associated transmission infrastructure will provide the link for priority provincial areas and eventually become the backbone of the national grid. The completion of first phase of Bumbuna project, which comprises 50 MW and 161 kV transmission line (250 km), will be by the end of 2009.

(2) Power Sector Reform

The power sector reform is aimed at improving the performance of the sector and increasing access to electricity. Nationwide policy measures should in the main aim at creating conditions to encourage private sector participation.

The present decentralisation of the government's functions creates possibilities and opportunities for the governance of electricity services in decentralised entities.

(3) Renewable Energy

The country has vast renewable energy potential to complement and sustain its energy needs, but there have been several barriers in the way of harnessing these resources in a productive and meaningful way. There is neither the appropriate technology nor the indigenous capacity to design, manufacture, market, distribute, install and maintain renewable energy technologies (RETs). To compound the problem, there has been insignificant investment and interest shown by both the Government and commercial operators in the advancement of RETs.

Hydropower is a major energy resource. According to the Power Sector Master Plan (1996), 27 potential hydropower sites with a total capacity of 1,513 MW have been identified. The Master Plan, however, is silent on potential resources under 2 MW. This is expected to be an area of huge potential for public-private partnerships and wider investment by the private sector.
There exists a well advanced plan for construction of one small hydro power plant (1MW) in Port Loko. The design has been completed and project implementation will start soon. It is a project funded by the Chinese Government, UNIDO and GOSL.

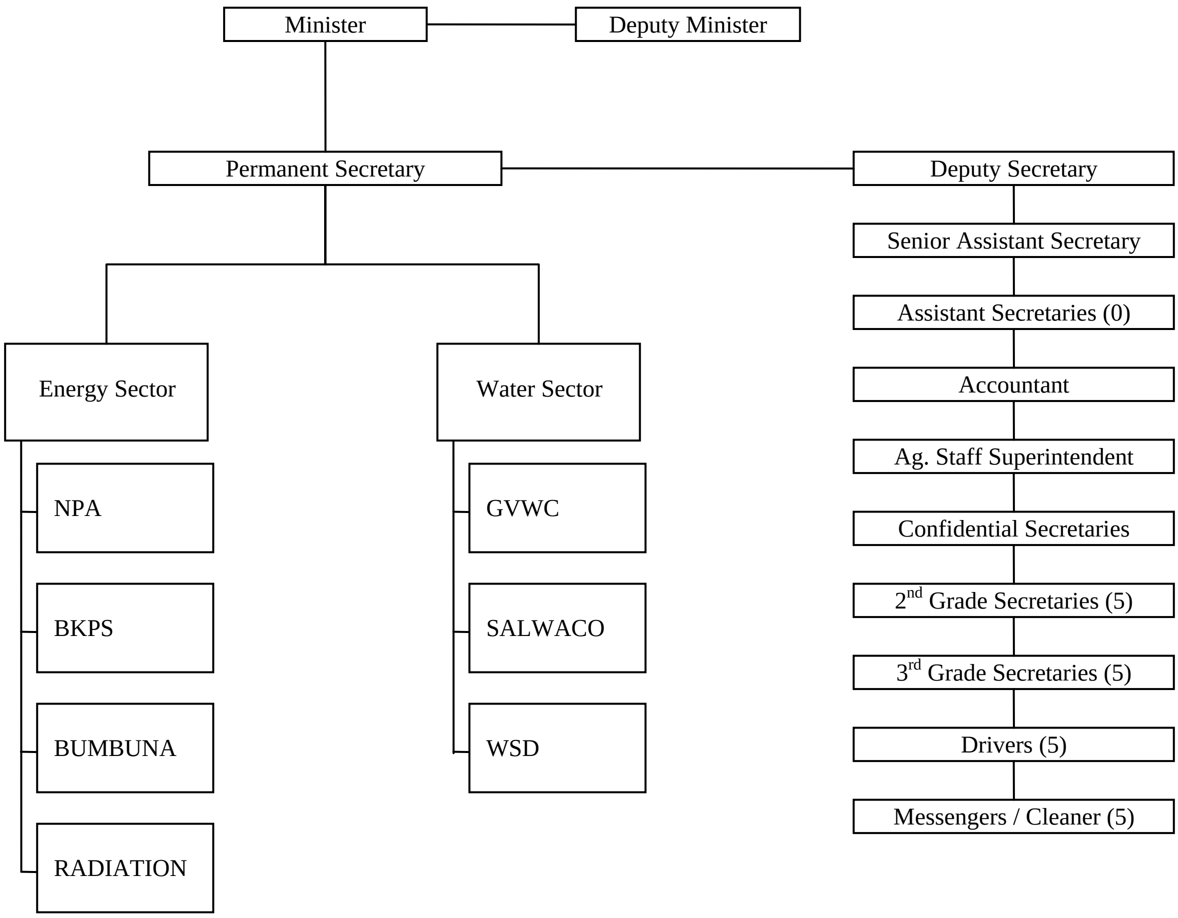
3.1.5 Trend of Power Sector Privatization

The National Commission for Privatization (NCP) was established by the National Commission for Privatization Act 2002, to privatize and reform public enterprises including the NPA. The NCP published the Revised Privatization Strategy (2004 -2010), which classifies national enterprises into two broad categories. One is suitable for early privatization and the other requires a sectoral approach and longer term planning. Although the timing difference of “early” and “longer term” is not clear, the NPA is categorized into those requiring longer term planning. As is described in 3.6, the NPA has shown continuous financial deficits and urgently requires financial improvement (accomplishing profits). Therefore, its privatization is beyond the present prospect.

3.2 Organization and Management System of the Ministry of Energy and Water Resources and the National Power Authority

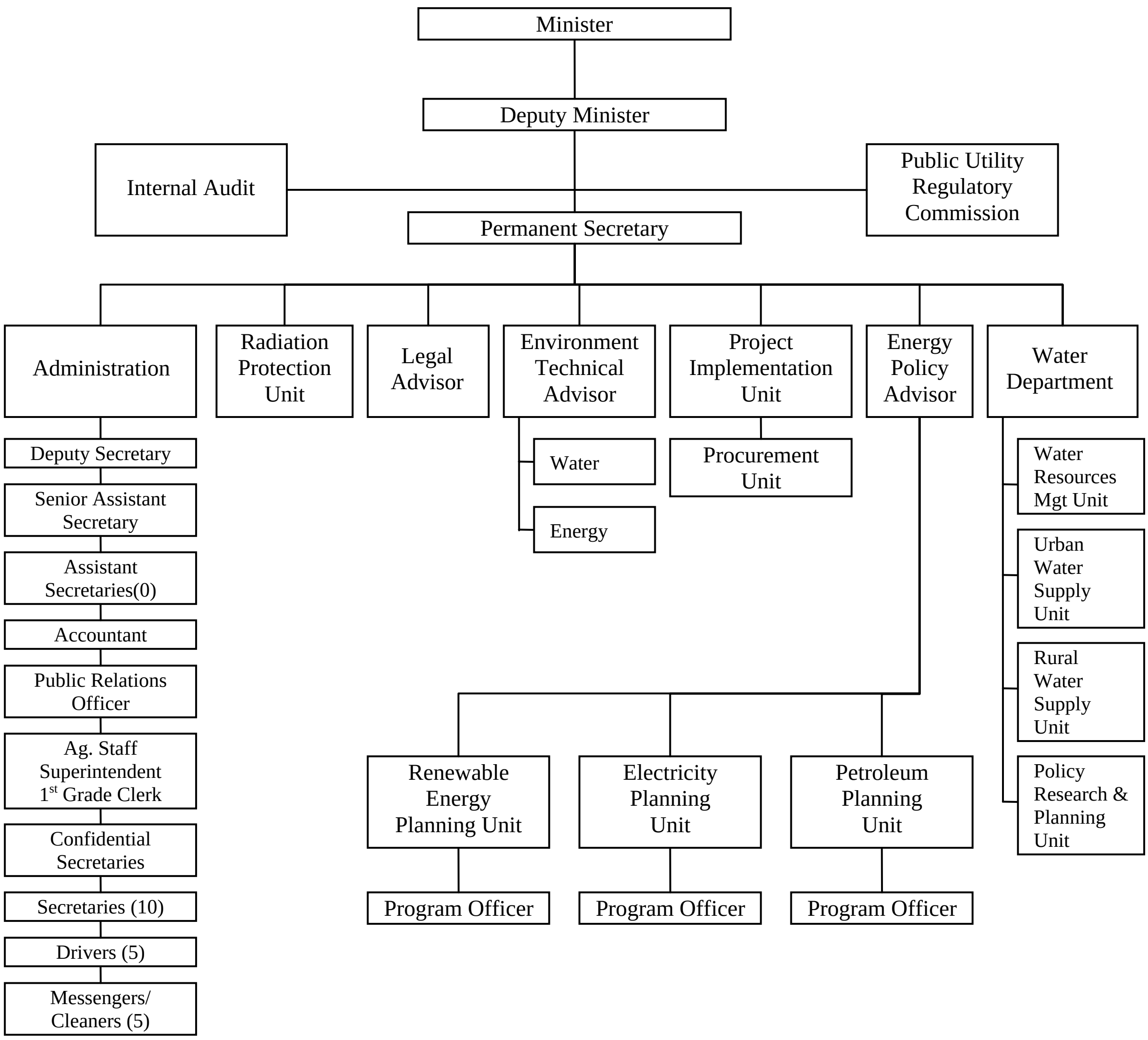
In Sierra Leone, the Ministry of Energy and Water Resources (MEWR) is responsible for energy and power policies formulation, energy and power supply planning, implementation of the policy and the supervision of public entities which are in charge of actual energy supply. Fig. 3.2-1 shows the current organizational structure of MEWR as of August 2009. Under the initiative of the new Minister inaugurated in February 2009, the Ministry's organization will be restructured as is shown in Fig. 3.2-2 by the end of 2009 in order to strengthen its policy planning and implementation capability.

As mentioned in section 3.1.5, the Government of Sierra Leone commenced the privatization of public enterprises through the establishment of the National Commission for Privatization Act (2002). The Act states that the intervention of line ministries shall be eliminated by substituting the word "Commission" for "Minister" in the National Power Authority Act (1982) thus the authority and responsibility of the Ministry on the NPA is transferred to the Commission. Consequently, the NPA comes under the jurisdiction of the NCP during the process of privatization.



[Source] Ministry of Energy and Water Resources
[Remarks] The numbers in brackets show the numbers of the staff.

Fig. 3.2-1 Present Organization of Ministry of Energy and Water Resources



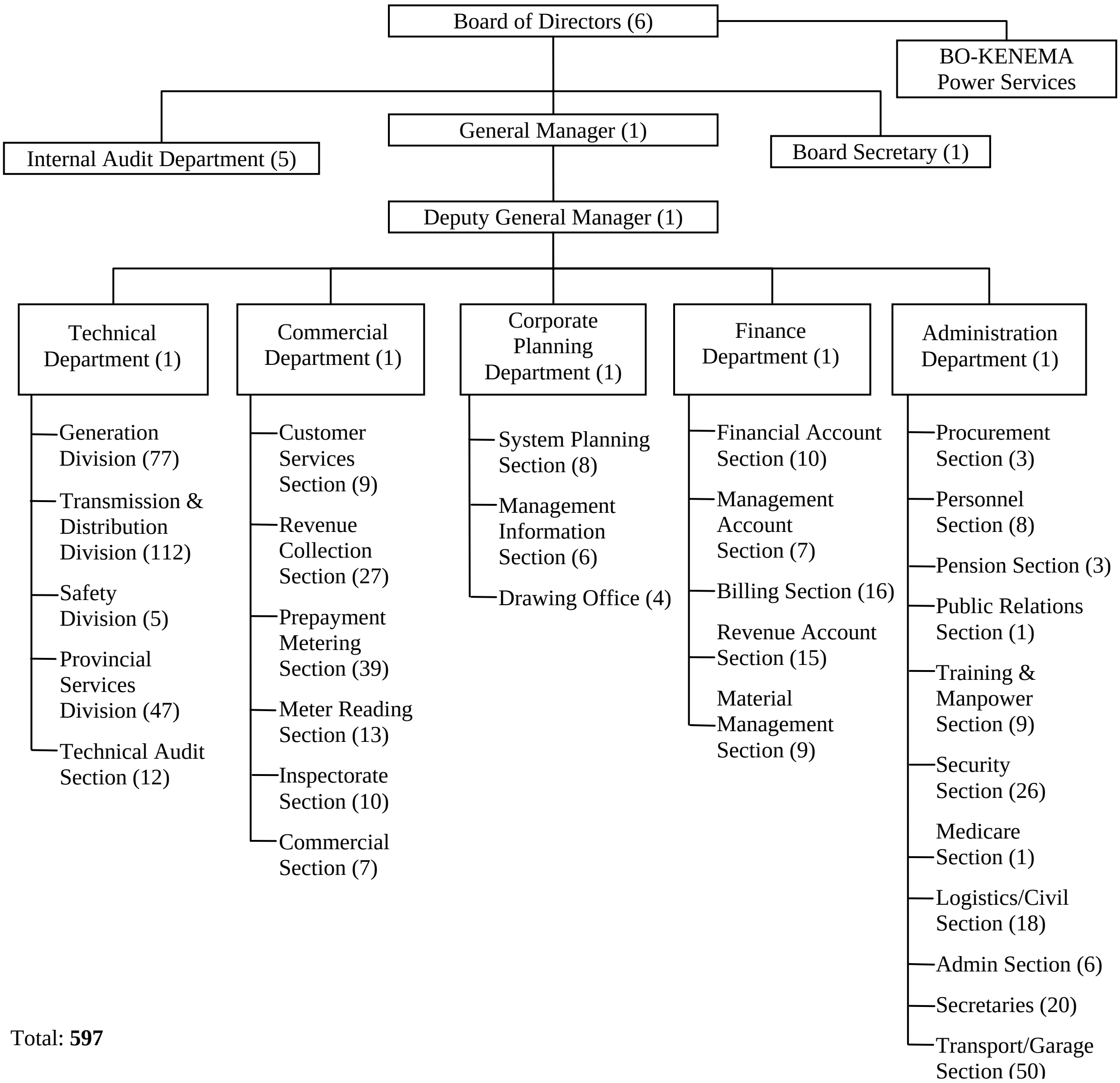
[Source] Ministry of Energy and Water Resources
[Remarks] The numbers in brackets show the number of the staff.

Fig. 3.2-2 Proposed Organization of Water Resources

The National Power Authority (NPA), which was established by National Power Authority Act (1982), commenced the power supply business upon inheriting business operations, assets and personnel from the former Sierra Leone Electricity Corporation. According to the NPA Act, the NPA is responsible for nation wide power generation, transmission and distribution but currently it only engages in power supply to the Freetown Capital Region. In local cities, such as Bo and Kenema, Bo-Kenema Power Services (BKPS), which is an independent company in the NPA Group, supplies power to customers. Before the conflict, there were independent power supply systems equipped with diesel generators at major district capitals but they were vandalized and/or deteriorated and are not functioning. The NPA Act was revised in April 2004 and the construction and operation of Bumbuna Hydroelectric Power Plant by private SPC (Special Purpose Company) and the conclusion of power purchase agreement between the NPA and SPC has been legally approved.

As of June 2009, the NPA is said to have slightly less than 600 staff members. The number of engineers is small at only three in the generating department and five in the transmission and distribution department as most technical staff members are of the skilled worker class.

The staffing level, i.e. the number of staff members per unit power sales (person/kWh), of the NPA is high, making rationalisation of the surplus manpower a pending task to achieve an improvement of the NPA's business performance. However, this rationalisation has not progressed as hoped for because of the lack of funding to pay the discharge allowances.



[Source] Personnel Section, NPA
[Remarks] The numbers in brackets show the number of the staff.

Fig. 3.2-3 Organization of NPA

3.3 Present Situation of Power Supply and Demand

3.3.1 Trend of Power Supply and Demand

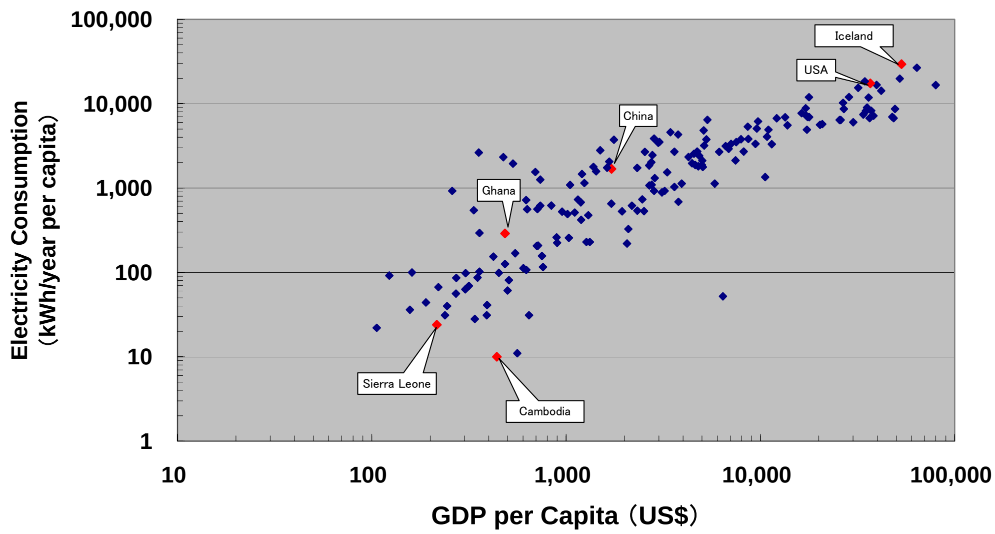
In the Western Area of Sierra Leone, power supply to meet the demand is difficult because of the insufficient generating and transmission/distribution capacity. The power supply situation in the five year period from 2002 to 2007 shows that the generated electric energy peaked in 2002 when the civil war ended, followed by a continual decline as is shown in Table 3.3-1. In contrast, the GDP sharply increased from 2000 as is shown in Fig. 2.2-1 and Fig 2.2-2. 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 3.3-1 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

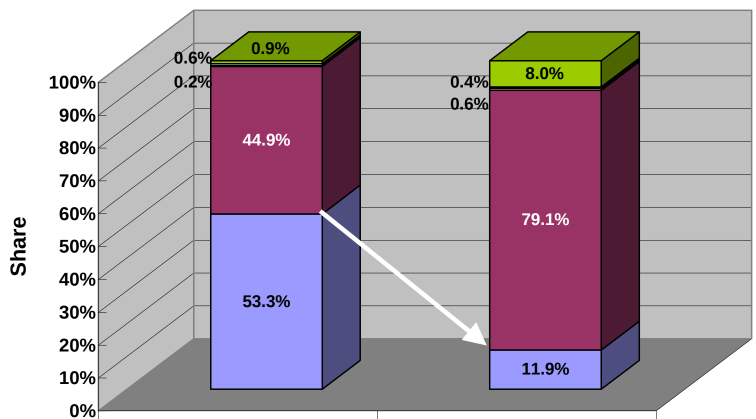
The power consumption per capita in the Western Area (urban areas) in 2006 was 23 kWh /person /year which was one of the lowest figures in the world. Fig 3.3-1 charts the correlation between the GDP per capita and the power consumption per capita of 170 countries in the world based on the Human Development Report 2007/2008 published by the UNDP.



[Source] UNDP, “Human Development Report 2007/2008”

Fig. 3.3-1 GDP per Capita and Power Consumption per Capita

Fig. 3.3-2 shows the changes in the energy sources used for residential lighting in urban areas of the Western Area. In 1985, electricity was used as the energy source for lighting by 53.3% of households but this fell to as low as 11.9% in 2004. During this period, the population in the areas in question increased by some 65%. Even if such a population increase is taken into consideration, a general deterioration of the power supply in the Western Area can be observed.



	1985	2004
Others	0.9%	8.0%
Wood	0.6%	0.4%
Gas	0.2%	0.6%
Kerosine	44.9%	79.1%
Electricity	53.3%	11.9%

[Source] Statistics Sierra Leone (2006.11), “2004 Population and Housing Census, Analytical Report on Housing Situation and Characteristics”

Fig. 3.3-2 Energy Sources for Residential Lighting in Urban Western Area

3.3.2 Transmission and Distribution Loss

As is shown in Table 3.3-1, the transmission and distribution loss in Western Area is some 35%, which is a huge value.

The distribution system in the Freetown Capital Region consists of 11 kV underground/overhead distribution lines, distribution substations and 415/240 low voltage distribution lines. Most of these are quite deteriorated and the shortage of funding as well as manpower means a lack of adequate maintenance, resulting in operation which falls far below the original functional capability. Accordingly, the available distribution capacity is approximately 20 – 25 MW which is far below the approximate potential demand of some 40 – 45 MW in the capital region and the power supply in the capital region substantially falls short of the demand. This is the main reason for the huge transmission and distribution loss.

The low voltage distribution lines also has huge losses, because of the disorderly and dangerous installation manner, the non-existence of design standards and partly because of illegal connections or power theft which is prompted by the population concentration in the capital region in the post-civil war period.

The lack of adequate consideration of the load distribution and sharing has led to the piling up of serious problems, including overloading of the distribution transformers, increase of the power loss and decline of the power supply reliability. Therefore, NPA staffs of T/D section are preoccupied with responses to such matters/problems tirelessly. All of these problems are damaging not only proper operation and maintenance but also safety.

According to the latest data of transmission and distribution losses, it seems to be getting worse and worse. Transmission and distribution losses in year 2008 that consisted of technical and non-technical losses are shown in Table 3.3-2.

Table 3.3-2 Transmission and distribution loss of 2008

Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	July	Aug.	Sep.	Oct.	Nov.	Dec.	Ave.
Losses (%)	52	38	50	47	45	41	37	51	37	43	47	37	44

[Source] NPA

3.3.3 Present Situation of Captive Power Generation Units

Because of insufficient generating and transmission/distribution capacity of the NPA, most of the large power users such as factories, hotels, hospitals and household consumers prefer to own and operate their captive generators without relying on unstable and unreliable power from the NPA. These generators must be registered to the NPA for safety reasons. The number of captive generators registered to the NPA accounts for 910 units with a total rated output of 40 MW (50.8MVA) as at the end of 2008. Since captive generators are mainly used for stand-by purposes, the owners are likely to switch to the NPA’s power once the power supply from the NPA becomes reliable. They are, therefore, regarded as potential customers of the NPA. The capacity and location of these generators and the business types of the owners were surveyed by using the generator registration list in order to assess current potential power demand.
Table 3.3-4 shows the summary of captive power generators registered to the NPA as of the end of year 2008.

In addition, according to demand survey conducted by local consultant, many domestic consumers (some 60% of domestic consumers living in Freetown capital area) also have their own generators (capacity from 0.4 kW to 4.4 kW), as is shown in Table 8.1-3, although most of them do not register with the NPA.

Table 3.3-3 Representative Examples of Captive Generators

Owener's name	Capacity/Unit [kVA]	Capacity/Unit Numbers of Units	Total capacity [kVA]	Notes
1. Leocem	1,437	4	5,750	
	total		5,750	
2. Shankerdas	200	2	400	
	250	2	500	
	275	1	275	
	500	2	1,000	
	625	1	625	
	total		2,800	
3. Sierra Leone Brewery Ltd.	100	1	100	
	750	1	750	
	total		850	
Grand total			9,400	

[Source] NPA

Table 3.3-4 Outline of Captive Generators Registered to NPA (as of the end of 2008)

	Total（Commercial + Domestic)	Commercial Only	Domestic only
1.1 Total numbers of generator	912.0	809.0	103.0
1.2 Total output capacity（kVA)	50,837.0	49,079.7	1,757.3
1.3 Average output capacity of one generator (kVA)	55.7	60.7	17.1
2.1 Number of generators with output capacity of 100kVA or more	107.0	107.0	0.0
2.2 Total output of generators with output capacity of 100kVA or more (kVA)	31,516.9	31,516.9	0.0
2.3 Average output of one generator with output capacity of 100kVA or more (kVA)	294.6	294.6	0.0
3.1 Number of generators with output capacity of 50kVA or more	223.0	220.0	3.0
3.2 Total output of generators with output capacity of 50kVA or more (kVA)	38,725.4	38,545.4	180.0
3.3 Average output of one generator with output capacity of 50kVA or more (kVA)	173.7	175.2	60.0

Notes;
(1) Above table is prepared based on NPA's Private Generator register notes
(2) Commercial includes Industry, Commercial, Institute, etc. other than domestic housing.
(3) According to interview with factories, companies, organizations, etc., most private generators are used as emergency purposes. Therefore, actual generation by private generators is 50.84MVA x 50
(4) On the other hand, not all private generators are registered to NPA. Here, we assume that 70 % of private generators are registered.

[Source] NPA

3.4 Present Situation of Power Supply and Demand

3.4.1 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.

(1) Generating Facilities

Table 3.4-1 shows the outline of generating facilities that supply electricity to Western Area including Bumbuna Hydro Power Plant (HPP), which is located at Tonkolili district, Northern Province.

Table 3.4-1 Outline of Generating Facilities (as of the End of June 2009)

Name of Unit	Operability	Manufactured Year	Output (MW)		Conditions
			Rated	Available	
1. Kingtom P/S					
Mirrlees 2	No	1974	6.9	0	Cylinder head cracked
Mirrlees 3	No	1998	6.3	0	Engine broken (piston rod, body, etc)
Sulzer 4	Yes	1977	9.2	5.6	Trial operation during week end
Sulzer 5	No	1980	9.2	0	Operation suspended
Mitsubishi 6	No	1995	5.0	0	Crank shaft damaged
Caterpillar 1	No	2000	1.28	0	Engine burnt
Caterpillar 2	Yes	2000	1.28	1.0	Operable
Niigata 7	-	2009	5.0	0	Under construction (Japan's Grant Aid)
Niigata 8	-	2009	5.0	0	Under construction (Japan's Grant Aid)
IPP (14 units)	Yes	-	17.5	12	
2. Blackhall Road P/S					
IPP (8 units)	Yes	-	12	2.4	Not enough fuel supplied
New Generators	-	-	17.52	0	Under construction by BADEA
3. Bumbuna HPP					
No. 1	-	-	25/9*	0	Under construction
No. 2	-	-	25/9*	0	Under construction
Total				**21.0**	

[Remarks] * Total output of Bumbuna hydro drops up to 18 MW during dry season.
[Source] NPA

The present generating output by the private power company at Kingtom P/S is about 12 MW at the end of July 2009, because of generating facilities are high speed machines and de-rating factor is affected by the total output.

The present available capacity of Blackhall Road Power Station operated by private power company is limited to between 2 to 3 MW due to the shortage of fuel oil supply by the NPA.

The no-load test of No. 2 unit of Bumbuna Hydro Power Station was conducted at the end of July 2009 with energizing of 161 kV system. However, the complete commissioning may be finished by the end of 2009. In this connection, the period of contract with the private power company shall be extended until stable power supply is secured from Bumbuna power station to prevent blackout of Freetown in Western Area.

The detailed conditions of generating facilities of the NPA at Kingtom Power Station are as follows;

Mirrlees-2:
The engine was installed by the South African Power Company (ESCOM) and pre-commissioned in July 2006. During this pre-commissioning it was found that the cooling system was not functioning properly. Because of the problem, the commissioning was stopped until a cooling tower was installed. After the installation of the cooling tower, commissioning was re-started in early 2007.

However, all sixteen cylinder heads of the unit were damaged due to similar problems in August 2007. Since then, the operation of this unit has been suspended.

Mirrlees-3
The engine was installed by CEMMAT for the GoSL in 2001.
The two connecting rods and engine body were damaged because of inadequate regular maintenance. Because of this, the operation of Mirrlees No. 3 has been suspended.

Sulzer-4:
The overhaul work of Sulzer 4 was started in November 2006 with the assistance of Morocco.
However, the generator caught fire during test run for commissioning.

The rehabilitation of the generator stator windings was completed in Morocco in February 2009 with the assistance of Morocco.

Currently, the NPA carries out trial operation only during weekends with the condition of stand-alone operation.

During trial operation on June 13 conducted from 11 am to 6 pm, maximum output reached 5.6 MW and total generated energy was 31.6 MWh.

At the same time, Cat-2 was also operated for the black start of No. 4 unit and the generated energy was 414 kWh. The operation period of this unit is limited only to Saturday and Sunday because it can not conduct parallel operation with the private power company.

Sulzer-5:
Electric heater for heavy fuel oil has been damaged. This unit can be operational after the arrival of electric heater to be replaced.

Mitsubishi-6:
This engine stopped on September 2, 2006 because of damage to the crankshaft, etc.
The cause of the damage seems to be the malfunction of the lubricating system, especially lube oil purifier. The operation of this unit has been suspended.

Caterpillar-1
The connecting rod of engine was damaged because of inadequate regular maintenance.
The operation of this unit has been suspended.

Caterpillar-2
This unit is operable and used for black start of Sulzer-4 which is operating Saturday and Sunday.

Common Facilities
The oil/ water separation system of the Kingtom P/S is not functioning properly and needs rehabilitation.

The generated energy by No. 4 unit and Cat-2 at Kingtom P/S until July 21, 2009 is shown in Table 3.4-2. No. 4 unit is operating by heavy fuel oil including start and stop.

Table 3.4-2 Generated Energy at Kingtom P/S by July 2009

No	Description	Unit	Jan.	Feb	Mar.	Apr.	May	Jun.	Jul.	Remarks
1	IPP	MWh	9,913	8,456	8,642	8,967	8,925	7,545	7,824	
2	NPA's	MWh	0	0	67	0	18	83	309	
Total		MWh	9,913	8,456	8,709	8,967	8,943	7,628	8,133	

[Source] NPA

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) Generated Energy

Generated energy in 2008 is about 137 GWh, sold energy is about 79 GWh (58%), energy consumption by NPA is about 0.8 GWh (0.6%) and energy losses is about 58 GWh (42%) which is including technical and non-technical for Western Area.

Detail records are shown in Table 3.4-3.

Table 3.4-3 Energy Balance in Western Area: 2008

No.	Description	Unit	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1	**Generated Energy**	[MWh]													
	1) Kingtom IPP		9,576	8,648	9,880	9,953	10,038	8,890	10,385	10,196	8,488	9,990	10,411	10,395	116,851
	2) Blackhall Road IPP		0	864	1,584	1,663	2,572	2,363	2,218	1,963	2,089	1,712	1,664	1,879	20,571
	Total		9,576	9,512	11,464	11,616	12,610	11,253	12,604	12,159	10,577	11,701	12,075	12,274	**137,422**
2	**NPA's Consumption**	[kWh]													
	1) Kingtom P/S		4,540	21,880	25,770	49,766	18,095	32,190	18,280	20,280	30,237	20,470	18,390	19,963	279,861
	2) Falcon Bridge S/S		4,398	5,309	3,211	1,067	0	115,066	24,036	3,002	2,020	596	1,451	2,016	162,172
	3) Blackhall Road P/S		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	4) Congo Cross J/S		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	5) Brookfield J/S		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	6) Wilberforce S/S		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	7) Wellington S/S		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	8) Electricity House		34,632	44,496	40,224	41,040	41,856	36,120	34,128	13,128	13,128	35,688	35,232	29,280	398,952
	Total		43,570	71,685	69,205	91,873	59,951	183,376	76,444	36,410	45,385	56,754	55,073	51,259	**840,985**
		[%]	0.45	0.75	0.60	0.79	0.48	1.63	0.61	0.30	0.43	0.49	0.46	0.42	**0.61**
3	**Energy Sold**	[MWh]													
	T1: Domestic/Diplomat		1,983	2,517	3,676	2,776	3,607	3,367	3,491	3,328	3,469	3,359	2,876	2,856	37,306
	T2: Small Commercial		302	1,302	513	506	405	671	550	1,054	541	541	512	472	7,369
	T3: Holy place/Institute		203	324	294	308	354	296	318	247	223	194	268	231	3,262
	T4: Large Com./Government		2,441	2,844	2,513	2,634	2,460	2,845	3,182	1,728	2,403	2,256	2,680	2,486	30,472
	T5: City council, Street Light		40	19	14	14	12	46	57	18	15	18	16	18	287
	T6: Temporary supply		0	0	0	0	0	0	0	35	0	15	0	0	50
	T7: Welders		5	7	3	11	5	9	17	36	11	8	8	0	120
	Total		4,973	7,012	7,014	6,249	6,842	7,234	7,616	6,446	6,663	6,391	6,360	6,064	**78,866**
4	**Energy Losses**	[MWh]	4,559	2,428	4,381	5,275	5,708	3,836	4,911	5,677	3,868	5,253	5,660	6,159	**57,715**
		[%]	47.6	25.5	38.2	45.4	45.3	34.1	39.0	46.7	36.6	44.9	46.9	50.2	**42.0**
5	**Customers**	[No.]													
	T1: Domestic/Diplomat		39,125	39,497	39,088	40,003	40,368	40,874	41,490	42,015	42,398	42,489	42,655	43,078	-----
	T2: Small Commercial		5,797	5,835	5,844	5,904	5,931	5,983	6,151	6,220	6,270	6,286	6,299	6,369	-----
	T3: Holy place/Institute		780	779	779	781	783	788	797	800	803	805	805	47	-----
	T4: Large Com./Government		284	284	286	290	293	295	302	300	300	302	306	306	-----
	T5: City council, Street Light		11	11	11	11	14	14	14	14	14	14	14	14	-----
	T6: Temporary supply		7	7	7	7	7	7	8	8	8	8	8	0	-----
	T7: Welders		146	148	150	151	135	158	162	165	169	170	171	0	-----
	Total		46,150	46,561	46,165	47,147	47,531	48,119	48,924	49,522	49,962	50,074	50,258	**49,814**	-----
6	**Index**		Increasing of;	**3,664**	[Customers]						**Residential (T1)**				[%]
	1) No. of people to be able to access;			**248,500**	[Head]		5.77	[Head/House]			1) Electrified [Houses]			**43,080**	**22.9**
	2) Not access to power supply;			**835,200**	[Head]		**165**	[W/Head] to the Peak			2) Not Electrified			144,820	77.1
	Total			**1,083,700**		Estimated Peak	41	[MW]			Total			**187,900**	100.0

[Source] NPA

3.4.2 Present Status of Transmission and Distribution Facilities

(1) General

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 middle of 2010. However, some of resettlement is not finalized and some towers may need relocation.

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.

Fig. 3.4-1 shows the distribution system with main distribution lines at the end of 2008, in which red line means normal operation and blue line means faulty line. Details are shown in item 3: Drawing List of Appendices.

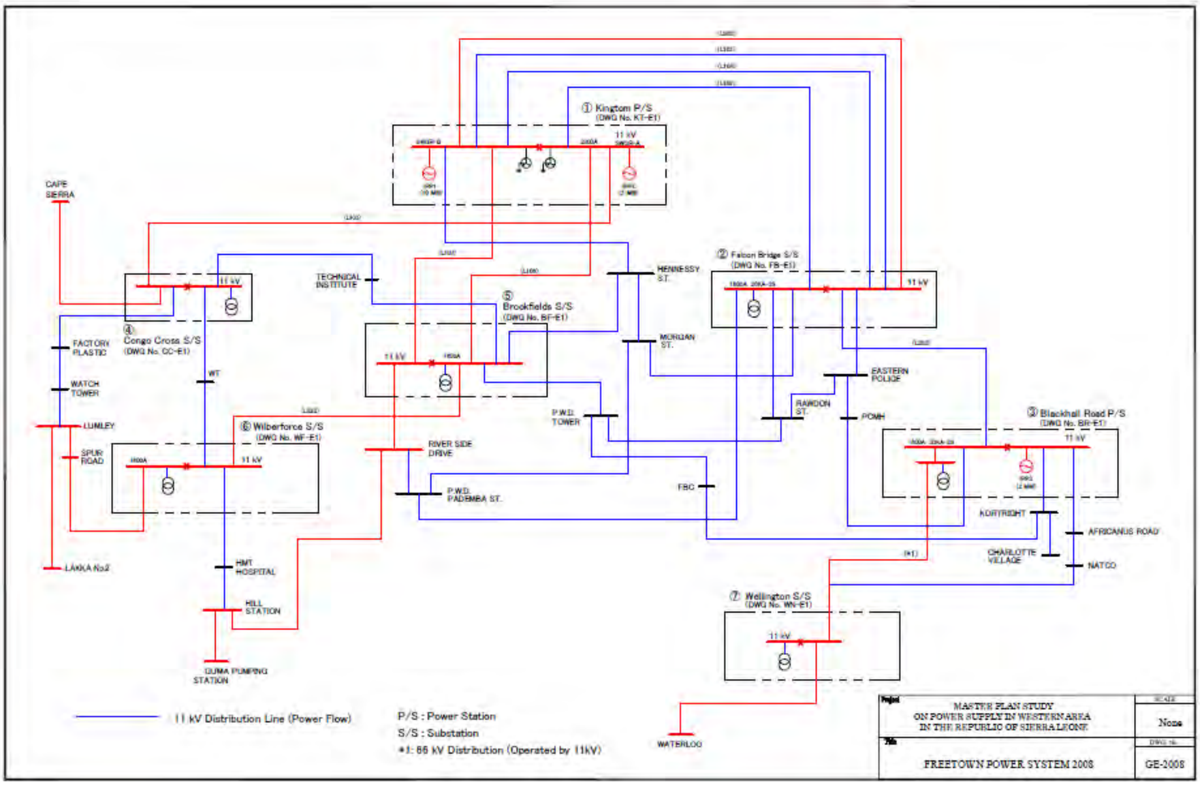


Fig. 3.4-1 Main 11 kV Distribution System at the End of 2008

Main P/S and S/S are connected by 11 kV trunk line and/or sub-trunk lines making flexible power supply in the above figure. The power supply to the Wilberforce area comes through Brookfields J/S because the 11 kV line between Congo Cross J/S and Wilberforce S/S is faulty and this causes low reliability and additional distribution losses. Table 3.4-4 shows operating conditions of these main lines.

Table 3.4-4 Operating conditions of main lines at the end of 2008

No.	Main 11 kV lines		No.	Conditions
	From	To		
1.	Kingtom P/S	Falcon Bridge S/S	4 (3)	Three lines are faulty
2.	Kingtom P/S	Congo Cross J/S	2 (1)	One line is faulty
3.	Kingtom P/S	Brookfields J/S	2	
4.	Kingtom P/S	Congo Cross J/S	2 (1)	One line is faulty
5.	Congo Cross J/S	Brookfields J/S	1	
6.	Congo Cross J/S	Wilber Force S/S	1 (1)	One line is faulty
7.	Brookfields J/S	Wilber Force S/S	1	
8.	Falcon Bridge S/S	Blackhall Road P/S	2 (2)	Two lines are faulty
9.	Blackhall Road P/S	Wellington S/S	1	With temporary connection
	Total		16 (8)	

[Source] NPA

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 is 400/ 230 V, three-phase four-wire method and feeds electricity to consumers. Some areas have terrible voltage fluctuation because of long lines without adjusting the balance of three phase connection.

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.

Outline of the major system is as follows;

(2) Transmission System (HV system)

A transmission line between Bumbuna Hydro Power Plant (HPP) and Freetown Substation (S/S) having the specification of 161 kV, one circuit- 400 mm^2 ACSR (Aluminum Cable Steel Reinforced), about 205 km long is now under construction and will be put into operation within 2009.The operation and maintenance for these HV facilities shall be done by a third company.

33 kV system is adapted to the overhead grounding wire on the 161 kV transmission line which requires careful operation. The 33 kV overhead grounding wire is not grounded on the Freetown S/S side although it is necessary to ground before energizing of the line.

(3) Distribution System

1) 11/ 33 kV System (MV system)

Present situation of 11 kV and 33 kV systems is as follows;

(a) 33 kV system

There are five main substations that are already equipped with 33/11 kV step-down transformers.

However, these transformers have not been connected to the grid and will not be operational until the completion of commissioning works.

Outline of the step-down transformers and 33 kV facilities is shown in Table 3.4-5 and 3.4-6, respectively.

Table 3.4-5 List of 33/ 11 kV Step-down Transformer

Name of substation	Capacity [MVA]	No.	Remarks
1. Kingtom P/S	15/20	1	ONAN/ONAF
2. Blackhall Road P/S	10	1	
3. Wilberforce S/S	10	1	
4. Wellington S/S	10	1	
5. Regent S/S	5	1	Completed

[Source] NPA

Table 3.4-6 Outline of 33 kV Facilities

Description	Unit	Present	Remarks
1. Transformer 1)Total capacity	[MVA]	50	ONAN base
2) No. of transformers	[Sets]	5	
2. Overhead (OH) lines	[km]	14	Under construction
3. Underground (UG) cables	[km]	3	

[Source] NPA

Some 33 kV facilities of on-going projects, such as SWGRs, transformer protection panels and LV boards are stored at the Blackhall Road P/S.

(b) 11 kV system

The 11 kV system is used as main system and distributes electricity from power stations to distribution transformers. Main distribution stations are connected by 16 main lines of which eight lines are faulty. The 11 kV system consists of overhead and underground distribution and some operated lines are jointed with different types of cables such as XLPE (Cross Linked Polyethylene) and PILC (Paper Insulated Lead Sheathed Cable) for temporary solution.

Most protection and metering systems of switchgears (SWGR) in main substations are not properly functioning. Because of this, the generator circuit breaker at Kingtom P/S shall be tripped because of earth fault at the end of the 11 kV line and this will cause the overall system black-out. Moreover, since most measuring instruments are not functioning properly, actual demand, etc. cannot be recorded.

Most high voltage panels (Ring Main Unit: RMU) are not functioning properly because they are too old and it is difficult to have adequate spare parts. Some RMUs for transformer feeder use copper wire instead of fuse which is same as no transformer protection and is a very dangerous condition. Also, insulation for load isolators is deteriorated which is again dangerous.

Distribution transformers at some places are connected to a lot of consumers with long LV lines which cause voltage problems, unbalance of the loads and overload of transformers at the end of 11 kV lines. Lumley area is one of the areas not considered to be a transformer coverage area, such as 200 m for high density area and 600 m for low density area. Present coverage in Lumley area is shown in item 3: Drawings of Appendices.

The drawings and technical information of distribution facilities are missing or not well organized and broken-down maintenance is usually implemented due to lack of facilities, spare parts and instruments.

The outline of current 11 kV equipment and lines is shown in Table 3.4-7 and 3.4-8 respectively.

Table 3.4-7 Outline of 11 kV Equipment

Name of Facility	Unit	Number	Remarks
1. Transformer 1) Total capacity	[MVA]	About 91	About 10 transformers are over loaded
2) No. of transformers	[sets]	About 210	
2. Ring Main Unit (RMU)	[sets]	About 180	RMUs are too old & have no name plate

[Source] NPA

Table 3.4-8 Outline of 11 kV Lines

Name of Load Area	Length [km]			Remarks
	O/H	U/G	Total	
1. Kingtom area	3	24	27	
2. Falcon Bridge area	1	30	31	
3. Blackhall Road area	16	29	45	
4. Congo Cross area	20	2	22	
5. Brookfield area	2	22	24	
6. Wilberforce area	23	39	62	
7. Wellington area	36	40	76	
Total [%]	101 [35]	186 [65]	287 [100]	

[Source] NPA

Distribution line between Blackhall Road P/S and Wellington S/S is operating at 11 kV instead of 33 kV which is the design voltage. There is 11 kV SWGR in the seven main distribution station and these stations are connected by main lines.

70 % of 11 kV line faults happen on underground cables and are caused by straight joints. This may be because the old cable and jointing materials are unsuitable.

Table 3.4-9 shows the number of faults occurring on underground cables and overhead lines during 2008.

Table 3.4-9 Number of 11 kV Line Faults in 2008

Type of line	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total	
													No.	[%]
Underground	12	13	8	13	10	10	9	13	8	19	16	12	**143**	**67**
Overhead	7	7	2	5	6	9	3	4	7	9	7	5	**71**	**33**
Total	**19**	**20**	**10**	**18**	**16**	**19**	**12**	**17**	**15**	**28**	**23**	**17**	**214**	**100**

[Source] NPA

Some areas have no power supply because of conflict. However these areas may be rehabilitated by the assistance of WB by 2010. Major areas are as follows;

- Lakka to Sussex village in York Rural
- Leicester to Charlotte village in Mountain Rural
- Some villages around Waterloo and Koya Rural

The 11 kV distribution system with operable distribution transformers is shown in DWG No. GE-2008-1 and GE-2008-2 in section 3 of Appendices.

Recently, Lumley and Goderich areas located west of Western Area have a terrible voltage drop problem which may be caused by lack of distribution capacity from Wilberforce and inadequate location of distribution transformers. Coverage area of these transformers is shown on DWG No. CA-LV0 of drawings in section 3 of Appendices.

2) Low Voltage System (LV system)

LV systems distribute electricity to end-users by overhead lines and/or underground cables. There are a lot of temporary connections in these systems because of lack of adequate materials, tools and instruments. These temporary connections have caused fires, increasing technical losses (high impedance) and further faults.

LV line length in some places is longer than one (1) km and unbalanced loading exists. Recently, ABC (Aerial Bundled Cable) is used for LV line.

Table 3.4-10 and 3.4-11 show the number of faults occurring on main LV lines in 2008.

Table 3.4-10 Numbers of Faults on Main LV Lines in 2008

Description	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Underground	4	3	3	6	6	5	5	5	8	9	8	7	**69**
Overhead	10	10	11	8	9	9	5	10	5	7	7	6	**97**
Total	**14**	**13**	**14**	**14**	**15**	**14**	**10**	**15**	**13**	**16**	**15**	**13**	**166**

[Source] NPA

Table 3.4-11 Numbers of Faults on Branch LV Lines in 2008

Description	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Fault	514	373	384	366	586	416	439	458	387	500	501	502	**5,426**
Repaired	481	323	356	333	514	337	398	415	356	459	424	389	**4,825**
Pending	33	50	28	33	72	39	41	43	31	41	77	113	**601**

[Source] NPA

New connections work is handled by T&D section except for procurement, installation and calibration of energy meters which is handled by the commercial section of financial division.

Prepaid meters have recently been introduced around the west area of Freetown by the NPA. Major specification is AC 220 V +/- 35 V, frequency is 50 Hz +/- 0.5 Hz and harmonic is based on BS.

There is no calibration certificate. Current installed prepaid meter is shown in Table 3.4-12.

Table 3.4-12 Setting Number of Prepaid Meter (As of End of July 2009)

No.	**Manufacturer**	**Country**	**Type of Prepaid Meter**			
			Single	**Three**	**Total**	**Remarks**
1	Elsewedy	Egypt	1,500	348	1,848	Smart Card
2	Apator	Poland	5,464	466	5,930	Token
3	Xj/Guoji	China	418	28	446	Smart Card
Total			**7,382**	**842**	**8,224**	

[Source] NPA

New applicants have to pay for the cost of materials for new connection. T&D section issues cost estimation to the new applicants. However actual new connections were about 26 % in 2008.
Requests and actual connections made in 2008 are shown in Table 3.4-13.

Table 3.4-13 Numbers of New Connections in 2008

Description	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Request	561	350	386	403	478	413	323	485	196	171	201	230	4,197
Connection	254	54	82	58	46	40	34	73	79	100	125	150	1,095

[Source] NPA

(4) Other Status

1) Operation Conditions of Distribution Network

Present distribution network is power from two generating sources, i.e. Kingtom P/S and Blackhall Road P/S, and terrible shortages of power supply occur. Because of this, 25 of 111 staffs of T&D division engage in load sharing.

Power factor on 11 kV feeders at Blackhall Road P/S that was measured during the field survey was 0.79 and the value is considerably low. Low power factor induces negative effect on power system such as energy losses and harmonic component which is harmful to electronic devices.

Delivery voltage at 11 kV SWGR is between 10 kV to 10.5 kV at Kingtom P/S and this low voltage causes increasing of energy losses.

Most existing cables are laid without installation standards and this causes not only energy losses and the reduction of distribution capacity but also faults resulting from other problems.

Most rated short circuit current of 11 kV equipment is 20 kA. However some of them are 12.5 kA which may be replaced in the future because there are no technical standards.

The protection systems mounted on the 11 kV SWGRs are almost not functioning properly and this seems to be the cause of overall black out of the system even when feeder faults occur on the tail end of 11 kV lines. And most of the meters mounted on the 11 kV SWGRs are also not functioning properly.

Some single core cables are put in the single steel conduits and this causes not only the damage of cable but also is dangerous to residential users, especially to the children because of the heat.

There are not sufficient instruments and equipments to maintain the network adequately, such as oil purifier for transformer insulation oil, measurement of load conditions, grounding resister, etc. including IT facilities and communication equipments.

Some areas do not have power supply because of damaged systems and equipment. These facilities are scattered in York and Koya Rural.

Most end users who are located far from power sources suffer from voltage fluctuation problems, especially, during night time. They cannot use fluorescent lamps and other electronics devices with such unstable voltage.

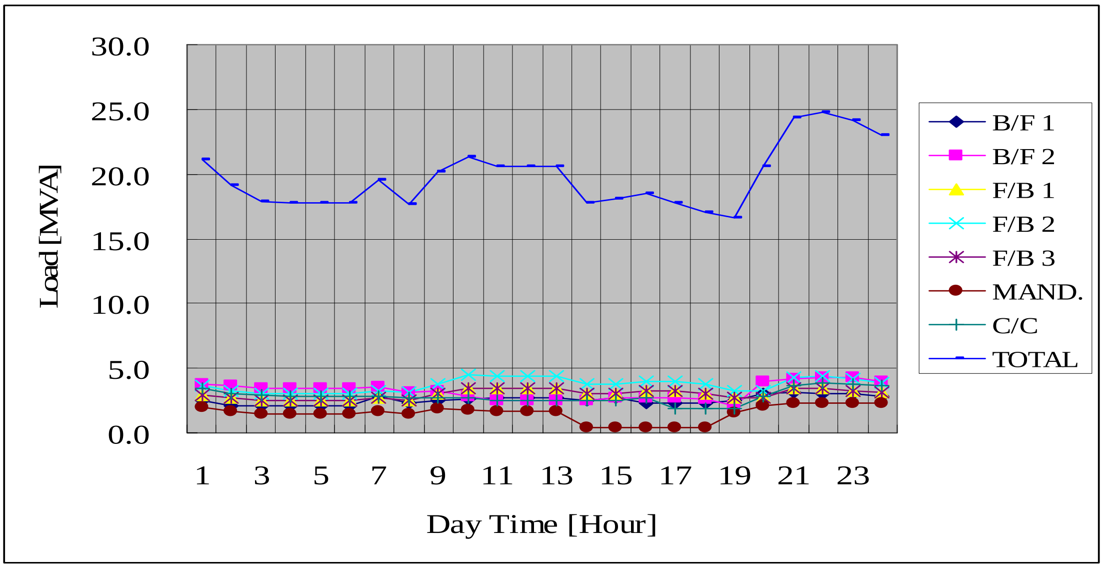
Energy consumption of the NPA itself is not recorded satisfactorily. Some of the station consumption is not checked.

There are two types of categories, i.e. T1 to T7 and industrial, commercial/domestic which causes the difficulties in checking the energy balance.

There are neither minimum spare parts nor materials which are obliged to execute temporary solutions to the several faults. Therefore, there is no control list to them.

2) Peak Demand

Typical daily load curve is shown in Fig. 3.4-2 which was recorded on the 11 kV SWGR at Kingtom P/S on September 13, 2002. At that time, four generating units were operated. Peak demand was recorded at 10 pm which was 4 MVA larger than day time peak. The highest peak generation in 2002 was recorded as 26.5 MW at 11:30 pm on December 5, 2002 when some generators were not operated during day time.



[Source] NPA

Fig. 3.4-2 Typical Daily Load Curve at Kingtom P/S in 2002

3) Energy Losses

Energy losses in 2008 were extremely high because of temporary power flows and connections. In 2007, energy losses were about 71 % and these high losses were caused by temporary power supply route which makes long power supply lines. Table 3.4-14 shows energy losses from 1999 to 2007.

Table 3.4-14 Energy Losses in Western Area (from 1999 to 2007)

No.	Unit	1999	2000	2001	2002	2003	2004	2005	2006	2007	Remarks
1 Peak Demand	[MW]			20.2	26.5	26.4	25.3	13.8	14.5	12.5	
2 Generated Energy	[MWh]	52,905	61,386	106,312	123,499	109,386	84,816	53,253	31,980	31,281	
3 NPA Use	[kWh]	4,171	3,609	5,708	6,472	6,128	5,293	3,486	2,728	2,524	
4 Energy Sold											
1) Industrial	[MWh]	12,615	16,528	22,033	25,548	27,802	23,062	16,326	10,586	5,053	
2) Commercial	[MWh]	3,799	4,955	10,237	11,933	10,772	7,129	3,470	2,281	1,194	
3) Domestic	[MWh]	16,842	16,639	30,494	35,606	30,363	23,002	13,557	7,177	2,821	
Total		33,256	38,122	62,764	73,087	68,937	53,193	33,353	20,044	9,068	
1) Industrial	[%]	38	43	35	35	40	43	49	53	56	
2) Commercial	[%]	11	13	16	16	16	13	10	11	13	
3) Domestic	[%]	51	44	49	49	44	43	41	36	31	
Total		100	100	100	100	100	100	100	100	100	
5 Energy Losses											
1) Losses	[MWh]	19,645	23,260	43,542	50,406	40,443	31,618	19,897	11,933	22,210	
2) Percentage	[%]	37.1	37.9	41.0	40.8	37.0	37.3	37.4	37.3	71.0	

Remarks: 1) Industrial= T4+T5
2) Commercial=T2+T3+T6+T7
3) Domestic=T1

[Source] NPA

4) Electrification Rate

The electrification rate in Western area is about 23 % based on the census of 2004. However, registered residential population in Freetown is about 70,000 which is less than estimated. It seems that there is a lot of population inflow to Freetown.

Most customers in rural areas cannot access power supply because of damaged distribution systems and load sharing as is shown in item-5) below.

Table 3.4-15 shows electrification rate of urban and rural areas in Western Area

Table 3.4-15 Electrification Rate in Western Area in 2008

Districts	Population	No. of Household			Electrification Rate [%]
		Electrified	Not electrified	Total	
1. Urban	896,700	41,800	112,900	154,700	**27.0**
2. Rural	187,000	1,280	31,120	32,400	**4.0**
Total	**1,083,700**	**43,080**	**144,020**	**187,100**	**22.9**

[Source] JICA Study Team

Populations of the major towns by the end of 2008 are shown in Table 3.4-16.

Table 3.4-16 Population of major towns in 2008

No.	Name of town	Population		
		Male	Female	Total
1	Jui	1,981	2,200	4,181
2	Waterloo	5,684	6,174	11,858
3	Lumpa	11,853	13,625	25,478
4	Tombo	9,626	10,312	19,938
5	York	1,401	1,280	2,681
6	Goderich	17,009	16,847	33,856
7	Koya Rural Area	11,850	12,976	24,826

[Source] Statistics Sierra Leone

5) Load Sharing

Every day, load sharing is adopted because of lack of generating output. Table 3.4-17 shows load sharing switching programme in Western Area that is planned considering current available output.

Table 3.4-17 Loads Sharing for Switching Programme

No.	Category	Available Power [MW]	Duration of power supply [Hours]
A: Kingtom Switching: Available: 15 [MW]			
1	Essential services	-----	24
2	Hotels	3	24
3	Banks	3.5	12 (7 am to 7 pm: Monday to Friday)
4	Major MDI's	4	12 (7 am to 7 pm: Everyday)
5	Commercial business district	5	12 (Day time)
6	Security areas	1	12 (6 pm to 6 am (Daily))
7	Radio station	2	24 (6 pm to 6 am (Daily))
8	Night domestic customers transformer stations: 1 day supply and 2 days out every 3 days rotational operation		
	1) Zone-1	10	West: (7 pm to 7 am)
	2) Zone-2	10	East/ Central (7 pm to 7 am)
	3) Zone-3	10	Central/ West (7 pm to 7 am)
B: Blackhall Road Switching: Available: 2 [MW]			
1	Day-1	Local (West feeder), Kortright, Kennedy Street, etc.	
2	Day-2	PWD, Africanus road, Fisheries, Local, etc.	
3	Day-3	Natco, Foamaco, Congo water, Old soap, etc.	
4	Day-4	Clarke street, Thunder hill, Ropoti, Clay factory, etc.	
5	Day-5	Police barracks, Low cost housing, Kissy village, etc.	
6	Daily Switching industries	Milla group, Dockyard, Hotel, etc.	

[Source] NPA

3.5 Present Progress of Rehabilitation and Improvement Plan on Power Supply System

3.5.1 Rehabilitation Plan of Generating Facilities at Kingtom Power Station

It seems that it is not feasible to rehabilitate Unit No. 2 and No. 3 DEGs considering manufacturing year, damage conditions and availability of spare parts.

The Unit No. 4 generator was repaired in February 2009 with the assistance of Morocco. However, the commissioning of generating system is still ongoing. It is notable that this No. 4 unit shall be synchronized to the existing system.

Unit No. 5 DEG is now waiting arrival of heater for fuel oil supply system which is expected to finalize by the end of this year.

Unit No. 6 DEG is now under consideration for repair work.

3.5.2 Improvement Plan of Generating Facilities at Power Stations

The procurement and installation of new two DEGs (5 MW x 2) at Kingtom power station is in progress under Japan's grant aid. The project will be completed by the end of March 2010.
The project title is "Urgent Improvement of Electric Power Supply System in Freetown".

Installation of new DEG sets (8.28 MW x 2) at Blackhall Road Power Station is now ongoing with the assistance of BADEA/ SFD and is expected to be completed by 2011. The project title is "Western Area Power Generation Project".

The name of project is "Rural Electrification: Mini-Hydro Projects" with the assistance of China. These are projects on the verge of being implemented and/or in the feasibility study stage. This project includes Charlotte: 2.2 MW Mini hydro power station which is located between Regent and Jui in the Western Area.

3.5.3 Rehabilitation Plan of Distribution Facilities

(1) Japan

Improvement of 33 kV distribution systems from Wilberforce S/S to new Regent S/S was completed in March 2009 under Japan's grant aid. Outline of the project is shown in Table 3.5-1.

Table 3.5-1 Outline of the Project

No.	Description
A.	**Material supply and installation**
1.	Construction of Regent S/S 1) 5 MVA, 33/11 kV transformer 2) 33 and 11 kV switchgear 3) 630 kVA station transformer (including power supply to the customers) 4) Ancillary facilities with building
2.	33 kV Line between Wilberforce S/S and Regent S/S
3.	Construction of 11 kV lines from; 1) Kingtom P/S to Congo Cross S/S 2) Congo Cross S/S to Wilberforce S/S
B.	**Material supply (Installation by NPA)**
1.	11 kV line between Falconbridge S/S and Blackhall Road P/S
2.	11 kV distribution transformers and RMUs for the electrification around Regent S/S

[Source] JICA Study Team

[Remarks]

1. Above 33 kV system was the first experience for the NPA which required capacity building not only for operation & maintenance but also for engineering such as interlocking, protection system, etc. to maintain the system adequately.

2. Improvement of 11 kV trunk line between Falcon Bridge and Blackhall Road P/S is now ongoing with materials supplied by Japan and installation/commissioning executed by the NPA. This work will be completed by the middle of 2009.

(2) The World Bank

The repair work and construction of 33 kV distribution lines is now ongoing under the "Repair and Construction of Western Area T&D (33 kV) Network" project which costs US$ 7.08 million and is expected to be completed in 13 months, i.e., by the end of April 2010.

Major components are as follows;

1) Construction of 33 kV overhead line between;
    a) Freetown S/S and Wilberforce S/S
    b) Freetown S/S and Blackhall Road P/S
    c) Wilberforce S/S and Blackhall Road P/S
    d) Blackhall Road P/S and Wellington S/S
2) Installation of new 11 kV underground cable from Blackhall Road P/S to Leocem,
3) Reconstruction of 11 kV overhead line from Tower Hill to FBC,
4) Supply and installation of five 4-way 11 kV RMU,
5) Supply and installation of two 315 kVA and one 630 kVA package substation,
6) Supply of cable fault location and test equipment, spare circuit breakers for substation and some electricians, linesmen and cable jointer tool kits,
7) Supply of 500 wood poles for low voltage lines,
8) Rehabilitation of the cable test van equipment, and
9) Supply and installation of 28 distribution transformers.

(3) OPEC Fund

The completion of 161 kV transmission line between Bumbuna HPP and Freetown S/S is financed by OPEC Fund. This project will be completed by the end 2009.

Major items are as follows;

1) Construction of 161 kV transmission line from Bumbuna HPP to Freetown S/S
2) Construction of 161/33/11 kV Freetown S/S
3) Installation of two circuits of 11 kV lines from Freetown S/S to Kingtom P/S

(4) West African Power Pool

The main objective is to increase access to electricity supply in ECOWAS member states. This would require the development of power plants, hydro resources like the Bengonkor and Bumbuna to provide the energy for sustainable power supply. This project is just started recently.

3.6 Account Balance and Financial Situation of the NPA

3.6.1 Account Balance

The profit and loss table of the NPA is shown in Table 3.6-1. 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 3.6-1 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.

3.6.2 Balance Sheet

The balance sheet of NPA is shown in Table 3.6-2.

Table 3.6-2 NPA's Balance Sheet

(Unit: thousand Le)

Year	2002	2003	2004	2005	2006	2007
Fixed Assets	37,393,252	36,100,912	37,408,287	46,677,940	42,680,413	38,697,855
Tangible fixed assets	37,393,242	36,100,902	37,408,277	46,677,930	42,680,403	38,697,845
Investment	10	10	10	10	10	10
Current Assets	18,795,523	22,747,633	22,933,970	31,593,476	32,809,173	34,924,170
Inventories	10,179,059	10,727,505	8,884,896	9,273,486	8,548,934	8,057,985
Trade receivables	7,510,634	10,924,821	13,316,934	21,224,711	23,516,120	25,939,005
Other receivables	327,381	375,386	590,102	593,908	617,957	530,920
Cash & bank balances	778,449	719,921	142,038	501,371	126,162	396,260
Total Assets	56,188,775	58,848,545	60,342,257	78,271,416	75,489,586	73,622,025
Liabilities	131,724,912	154,284,397	181,678,322	203,243,234	198,580,813	222,458,896
Amount due within 1 year	71,392,710	89,677,281	111,322,150	128,009,353	80,192,484	91,555,614
Amount due after 1 year	60,332,202	64,607,116	70,356,172	75,233,881	118,388,329	130,903,282
Capital	2,000	2,000	2,000	2,000	2,000	2,000
Accumulated Surplus/Loss	-75,538,137	-95,437,852	-121,338,065	-124,973,818	-123,093,227	-148,838,871
Total Liabilities & Capital	56,188,775	58,848,545	60,342,257	78,271,416	75,489,586	73,622,025

[Note] The balance sheet of NPA is a little different from usual style and so it is revised.
[Source] Revised from NPA Financial Statement

The share of fixed assets to the total assets decreased from 66.5% in 2002 to 52.6% in 2007 and the share of trade receivables has increased from 13.4% in 2002 to 35.2% in 2007. Capital is very small and liabilities are huge compared with total assets and accumulated losses are also great.
The profit and loss table and balance sheet show the terrible financial situation of the NPA.

3.6.3 Substantial Operation Revenues and Expenditures

Department of Managing Accounts, Finance Division, NPA, is analyzing substantial performance of the NPA. Summary of the key performance indicators is shown in Table 3.6-3.

Table 3.6-3 Summary of NPA's Key Performance

Description Year	2003	2004	2005	2006	2007
Energy Generated (kWh)	109,386,209	84,796,409	53,253,105	31,980,520	30,681,499
Station Use (kWh)	6,235,014	5,232,096	3,485,700	2,728,000	2,223,023
Station Use (%)	5.70%	6.17%	6.55%	8.53%	7.25%
Energy Available for Sales (kWh)	103,151,195	79,564,313	49,767,405	29,252,520	28,431,476
Energy Sold (kWh)	68,937,466	53,151,932	33,258,635	20,889,113	17,340,958
System Losses (%)	33.2%	33.2%	33.2%	28.6%	39.0%
Sales Billed (Le Million)	38,350	33,648	27,675	22,071	17,965
Revuenue Collected (Le Million)	35,707	33,400	24,890	16,841	14,324
% Revunue Collected to Billed	93.1%	99.3%	89.9%	76.3%	79.7%
Total Debtors (Le Million)	10,578	9,334	10,107	12,276	13,666
Debtors Expressed As Month of Sales	3	3	0.4	0.6	0.8
Cost of Sales (Le Million)	28,370	29,498	32,347	23,553	24,960
Cost of Sales/kWh Generated (Le Million)	259	348	607	736	814
Cost of Sales/kWh Sold (Le)	412	555	973	1,128	1,439
Sales Cost/kWh Sold (USc/kWh)	13.7	18.5	32.4	37.6	48.0
Sales billed /kWh Sold (USc/kWh)	18.5	21.1	27.7	35.2	34.5
Revenue collected/kWh Sold (USc/kWh)	17.3	20.9	24.9	26.9	27.5

[Note] Cost of Sales does not include depreciation and so on and is different from those in Financial Statement.
US cent amount data (exchange rate: US$=3000 Le) are added.
[Source] Added from NPA material

Energy sold (kWh) has decreased every year and so the income must have decreased. The first problem is high system losses. 33% is relatively high and in particular, 39% in 2007 is very high. The second problem is that the rates of collected charges to billed charges have decreased. Although the rate is 99.3% in 2004, other year rates are approximately 90% in 2003 and 2005 and less than 80% recently.

Cost and Sales in Le are not easy to compare internationally and so amounts per sold energy (kWh) are converted to US cents using exchange rate of 3000 Le per US$. At first, Sales billed per kWh are increasing and too high recently (34.5 c/kWh in 2007). Sales cost /kWh sold have increased more than Sales billed /kWh sold and Revenue collected /kWh sold. Therefore, Sales billed /kWh sold and Revenue collected /kWh sold exceed Sales cost /kWh sold from 2003 to 2004 (profits), but it is reversed from 2005 (losses). (However, it should be taken into consideration that Sales cost does not include depreciation and so on and so the profit is not real.) The loss has been increasing every year since 2005.

From December 2007, Global Trading Group (GTG) (the World Bank support) generation started. NPA stopped its own generation in January 2008 and from next month, February, Income Electrix: (IEL) started generation by NPA's own decision. Both of GTG and IEL are called IPP, but actually they are emergency rental power. Anyway, the NPA's generation situation changed in 2007. Recent actual cash flow for one year starting from December 2007 to November 2008 is shown in Table 3.6-4.

Table 3.6-4 Cashflow for one year from December 2007

Item	Cashflow (Dec. 07 to Nov. 08)	Remarks
Receipts		
Electricity sales	38,264,427,897	
Other income	4,075,266,548	
Total generation revenue	42,339,694,445	
Govet. Grants- GTG	96,195,040,650	
Total Receipts	138,534,735,095	
Payments		
Direct costs	20,141,472,235	
Salary/Pension	9,658,659,156	
Administrative & other costs	7,988,903,206	
Provincial expenses	202,399,300	
Total payment excluding GTG	37,991,433,897	
GTG-fuel and C&E charges	96,195,040,650	
Total payments	134,186,474,547	
Net receipt	4,348,260,548	
Electricity sales(US$)/kWh	0.1775	Net base
Generation (IPP) costs (US$/kWh)	0.2476	Gross base
Generation (IPP) costs (US$/kWh)	0.4463	Net base
Billed amount (US$) /kWh	0.2841	Net base

[Note] Net base is billed kWh. Gross base is generated kWh.
US cent amount data (exchange rate: US$=3000 Le) are added.
[Source] Calculated from NPA materials

IPP costs are covered by government grant. Therefore, the revenue minus expenditure shows a profit of approximately 4.34 billion leones. However, this does not reflect depreciation and non-operation expenditures such as financial costs and exchange losses. In addition, the generation costs are covered by the government grant. The IPP cost per kWh is 24.8 US cents/kWh generated and it seems appropriate from the viewpoint of diesel generation average in the high oil price situation of 2008. However, if the IPP unit cost is expressed in kWh billed, it is 44.6 US cents/kWh. System loss of NPA inside (44.5%) causes this unit cost increase. Electricity sales (charge collected income) per kWh billed is 17.8 US cents and cannot cover the IPP unit cost, 44.6 US cents. Even the billed amount/ kWh, 28.4 US cents, cannot cover the IPP unit cost, 44.6 US cents, either.

The difference between the billed amount per kWh (28.4 US cents) and electricity sales per kWh (17.8 US cent) is caused by arrears. Monthly performance in 2008 is shown in Table 3.6-5.

Table 3.6-5 NPA's Key Performance in 2008

Month	Quantity Generated	Quantity Available	Quantity Billed	% Billed to Genarated	% Billed to Available	Station Losses	System Losses
	kWh	kWh	kWh				%
Jan.	9,771,148	9,725,708	4,709,376	48.2%	48.4%	0.5%	51.6
Feb.	9,512,124	9,490,244	5,927,796	62.3%	62.5%	0.2%	37.5
Mar.	11,464,155	11,438,385	5,677,734	49.5%	49.6%	0.2%	50.4
Apr.	11,616,212	11,566,446	6,167,625	53.1%	53.3%	0.4%	46.7
May	12,610,215	12,592,120	6,896,533	54.7%	54.8%	0.1%	45.2
Jun.	12,253,455	12,221,265	7,243,623	59.1%	59.3%	0.3%	40.7
Jul.	12,603,635	12,585,355	7,879,895	62.5%	62.6%	0.1%	37.4
Aug.	12,158,964	12,138,684	5,912,876	48.6%	48.7%	0.2%	51.3
Sep.	10,577,036	10,546,799	6,621,376	62.6%	62.8%	0.3%	37.2
Oct.	11,701,486	11,681,016	6,633,544	56.7%	56.8%	0.2%	43.2
Nov.	11,978,888	11,960,498	6,361,664	53.1%	53.2%	0.2%	46.8
Dec.	12,290,632	12,270,669	7,738,424	63.0%	63.1%	0.2%	36.9
Total	138,537,950	138,217,189	77,770,466	56.1%	56.3%	0.2%	43.7%

Month	Amount Sold	Amount Collected	% Rev. Coll to Sales	Total Cost	Cost per Unit
	Le	Le	%	Le	Le
Jan.	4,066,493,481	2,361,687,539	58.1	1,724,562,740	366.20
Feb.	4,800,425,433	2,732,216,921	56.9	2,395,449,620	404.10
Mar.	4,361,840,831	2,655,318,003	60.9	3,213,827,010	566.04
Apr.	5,125,540,501	4,213,080,467	82.2	2,823,120,754	457.73
May	5,589,114,989	3,966,844,998	71.0	3,941,565,169	571.53
Jun.	5,890,179,093	3,941,129,171	66.9	3,980,905,795	549.57
Jul.	6,925,120,711	4,275,199,690	61.7	3,965,118,502	503.19
Aug.	4,079,487,656	3,431,086,572	84.1	4,148,341,610	701.58
Sep.	6,635,451,818	4,386,127,852	66.1	3,639,398,064	549.64
Oct.	6,860,059,634	4,385,602,209	63.9	3,926,067,009	591.85
Nov.	6,774,240,072	4,614,355,992	68.1	2,849,648,132	447.94
Dec.	5,187,387,340	4,693,227,118	90.5	3,532,474,788	456.49
Total	66,295,341,559	45,655,876,532	68.9%	40,140,479,193	516.14

[Source] NPA material

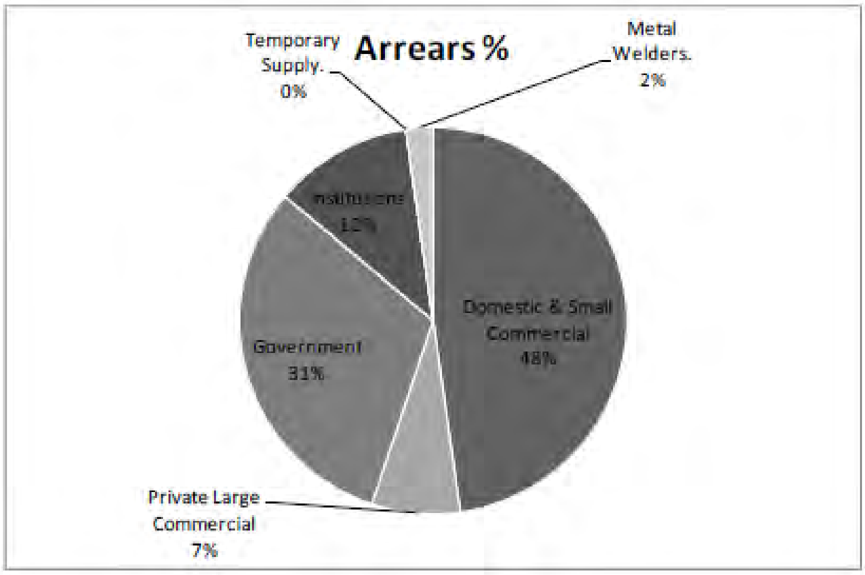
Station loss becomes less than 1%, because most of generated power comes from IPP. System loss on average is 44% and increased from that in the previous years. The rate of collected charges to billed charges on average is 69% and decreased from 80% in 2007. Therefore, the system loss and arrears worsened.

3.6.4 System Losses

System losses consist of technical losses such as deterioration of lines and transformers and non-technical losses such as theft. According to the report of PPA study, power loss of NPA was 40.8% and non-technical loss was 21.9% in 2002. There are not only thefts but also cases that invoices are not sent because access to some household consumers is too difficult (information from the counterpart). According to the subcontract study of willingness to pay conducted in December 2008, there are a few percents that consumers did not receive invoices. The causes of system losses should be clarified and appropriate countermeasures should be taken.

3.6.5 Arrears

Arrears have deteriorated recently. According to the JICA preparatory study, arrears share by customer category is shown in Fig. 3.6-1 (New data are being prepared by the NPA).



[Source] NPA material 2008

Fig. 3.6-1 Arrears by Customer Category

According to the NPA, these arrears are caused by refusal of payment or other situations. Invoices are sent to consumers two months later and if consumers do not pay, their meters are removed and the lines cut. Electricity bills had to be paid within 10 days, but it was shortened to 3 days. Recently, some consumers close their doors and do not show the meters when the meter reading persons visit their houses.

In those cases, the consumed power is reported zero. As a countermeasure for this, financial division people organized three urgent taskforce teams responsible for Eastern, Central and Western areas in Freetown and visited these consumers and when they closed their doors, the teams cut the line using ladders. There are some cases such as moving, redevelopment and missing addresses. Some consumers whose lines have been cut move to other houses and apply for new line connections using false names.

The NPA started to switch meters to new prepaid meters. Approximately 1250 Apator (Polish manufacturer) prepaid meters were set already. The NPA has approximately 5000 prepaid meters of Apator and Gouji (Chinese manufacturer) at present. The NPA made contracts to purchase 20,500 prepaid meters in total. Remaining approximately 15,000 prepaid meters will come gradually by paying the money earned by the prepaid meter setting. However, the number of prepaid meters is limited (a half of consumers) and it will take time. Since they are mainly for household users, arrears of government facilities and institutions should be solved.

3.6.6 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. However, a 28% raise in June 2009 and later 25% raise proposal was not decided, because Bumbuna hydropower is supposed to start in June 2009 and the result of the JICA study should be taken into consideration. Actually, invoices based on the new tariffs were sent in February 2009. The new and old tariffs are shown in Table 3.6-6.

Table 3.6-6 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. Interviews with industrial and business people conducted by this JICA team raised concern about the tariff increase. Most members of Chamber of Commerce complained about the tariff increase. The largest power consumer cement manufacturer said that the high electricity tariff makes Sierra Leone cement products uncompetitive internationally and it loses an opportunity to export to countries such as Liberia where there is great demand. Now the cement factories depend on their own generators and the cost is 35 – 40 US cents/kWh and cheaper than the new NPA tariff for industries. Therefore, the tariff raise may make these customers continue to rely on their own generators.

The tariff for industries is more expensive than that for households, but industrial consumers use higher voltage and purchase their own transformers. Therefore, their tariff should reflect cheaper investment and operation and maintenance costs than those of households. Since average people in Sierra Leone are poor, the NPA might set higher tariffs for industries and heavy users to get revenues reliably. However, this is a kind of cross-subsidy and not beneficial to industries. In addition, the high power tariffs impede export of Sierra Leone or weaken the competitiveness. Therefore, the tariffs by category should be changed gradually to reflect the costs in the future.

Above all, the new tariffs are too expensive internationally and heavy users would get away from the expensive NPA's power. Thus, the sales of NPA may decrease rather than increase. The vicious circle of NPA might deteriorate more.

In order to attain cheap tariffs and stop the vicious circle, there are mainly four directions as follows.

1) To improve the system losses
2) To improve arrears
3) To supply enough power reliably
4) To get cheaper power resources

If system losses are improved, supplied power will increase and the revenues will increase.
If the arrears are improved, the revenues will increase certainly.

Assuming that the system loss rate is improved from 43.7% to 25% and the rate of collected charges to billed charges is improved from 68.9% to 95%, the sales income becomes:

45.66 billion leones/ (1-0.437) x (1-0.25)/ 0.689 x 0.95 = 83.87 billion leones. However, 83.87 billion leones is not more than even IPP or rental power generation payment, 96.2 billion leones.

3) and 4) relate to new power supply, that is, Bumbuna hydropower.

The Republic of Sierra Leone will enter into a Concession Agreement the pursuant to the BGC obtaining concessionary and exclusive rights and the responsibility for the operation, maintenance and management of the Bumbuna hydropower project. BGC was established by an Italian construction company and the Government of Sierra Leone. The purchase price of NPA from BGC is under negotiation now. But according to the World Bank, the price is 20 US cents/kWh. It is said that the price might be 12 US cents/kWh. According to the AfDB material (Sierra Leone Appraisal Report, Supplementary Loan, Bumbuna Hydroelectric Project, March 2008, http://www.afdb.org/pls/portal/docs/PAGE/ADB_ADMIN_PG/DOCUMENTS/OPERATIONSINFORMATION/SIERRA%20LEONE-%20BUMBUNA%20SUP%20LOAN%20ENG.PDF), the selling price of Bumbuna hydropower is assumed 11 US cents per kWh and FIRR is estimated 17%. However, FIRR 17% is too high. It is usually 12%. Usually, hydropower cost is 7 or 8 US cents/kWh at the highest level. Therefore, 20 or 11 US cents/kWh is too high. Since the construction costs were covered by the World Bank, AfDB and other donors, BGC takes only operation and maintenance and depreciation into consideration. Thus, NPA should negotiate with the BGC to attain purchase price as cheap as possible. If the price is lower, it will contribute to improve the financial situation of NPA in greater extent, because the present rental power diesel generation costs are high. Therefore, the negotiation at present is very important and the result may decide the NPA's future.

Assuming the purchase price is 7 US cents per kWh, the generation costs will be less than one third of 96 billion leones, that is, 32 billion leones and the NPA can get a great profit in the case of the past tariffs (before the tariff raise).

Revenue 96.2 billion leones (system loss 25% and collection rate 95%) – generation costs 32 billion leones – other costs 30 billion leones = 34.2 billion leones.

However, the problems of liabilities repayments and Income Electrix payments will remain.

3.6.7 NPA Organization in Charge of Finance

Financial Division of NPA consists of four departments as follows.

1) Management Account Department
   To collect and analyze substantial data for management

2) Revenue Account Department
   To collect revenues and manage revenue accounts

3) Finance Department
   To prepare financial statement and service shareholders

4) Billing Department
   To prepare and send invoices and manage billing information

The information sharing among these departments seems good. For example, thick revenue account computer printouts by each customer grouped by district are delivered and daily incomes by commercial bank (payments from customers) are reported. However, IT should be improved. Then information sharing and analyses can be facilitated and promoted.

Although organizational issues are not analyzed in detail, the problem might be lack of early problem recognition, preparation of countermeasures and establishment of implementation task force. The arrears problem was responded to by the recent task force team implementation. But it is too slow. The problem should have been responded to earlier. In addition, it is not clear how the arrears of government facilities are to be responded to. At first, precise analyses of arrears, grasp of situation and effective planning of measures, quick implementation, review of the results and the following repetition cycle process are necessary. Causes of the technical and non-technical system losses have not been analyzed precisely and it seems efforts to resolve the problem have not been made.

4. Power Demand Forecast

4.1 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. [104](4)-1 shows the flow of the power demand forecasting under the Study.

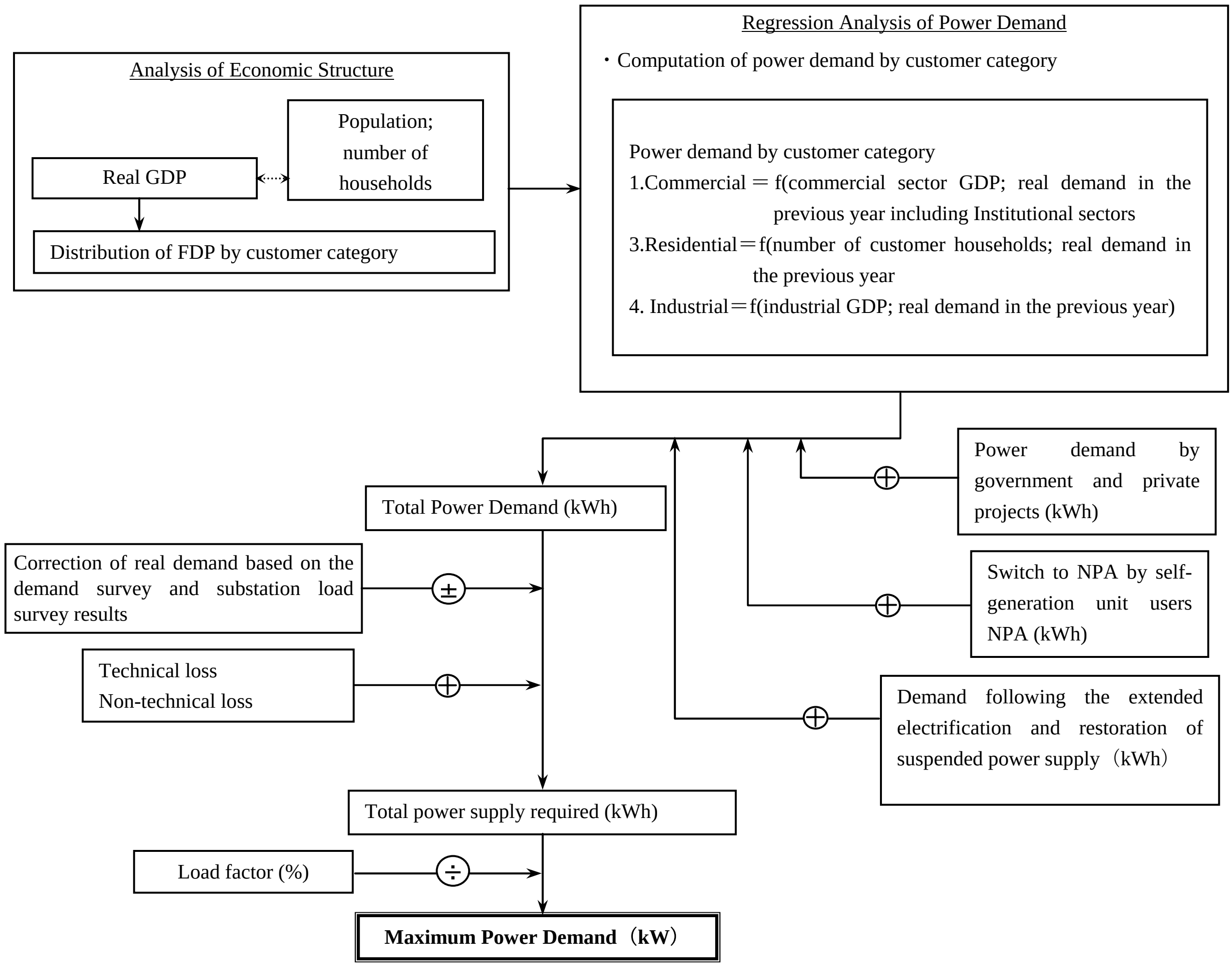


Fig. 4.1-1 Flow of Power Demand Forecasting

4.2 Review of Economic Development Policy and Economic Growth Scenario

(1) Real GDP Growth Rate forecasted by MoFED

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 4.2-1 Forecast of Real GDP Growth Rate

Case \ Year	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

The Ministry of Finance and Economic Development suggested the Study Team that annual GDP growth rate after 2015 might continue to drop until it reaches between 5.0 % and 4.5 %.

(2) Trend of Economic situation

Throughout the civil war period, the economy of Sierra Leone was steadily retrenched. The real GDP which stood at 2,929.9 billion leones (approximately ¥106.5 billion) in 1990 continued to fall as the civil war intensified to 1,281.5 leones (approximately ¥46.6 billion) in 1999. The gradual easing of the civil war after 1999 reversed the falling trend of the national GDP and the annual GDP growth rate in 2002 was as high as 27.4%. From 2004 to 2006, the annual GDP growth rate was steady with an average figure of 7.4% and the real GDP in 2007 was almost restored to the level before the civil war. According to the IMF, the real GDP growth rate of Sierra Leone in 2007 slightly fell to 6.4% and a further fall in 2008 is expected because of the adverse impact of the worsening global economy.

(3) Forecast of Economic Growth

Agriculture sector has the largest proportion in the total Sierra Leonean GDP and is expected to grow continuously in the medium-term due to financial assistance from GoSL and donors. The mining sector also accounts for a large proportion of GDP growth thanks to re-commissioning and new development of mining industries such as iron ore (London Mining and African Minerals), gold (Kimberlite Mining company), diamond, bauxite, titanium dioxide (rutile), etc. These mining industries are expected to back up the economic development for the medium term. Although manufacturing and service industries have potential to attract foreign investments, it seems difficult to realize these investments at the moment because they solely depend on the progress of infrastructure developments such as road, water supply, electricity supply, etc. and.

(4) Economic Growth Scenarios

As the scenarios of economic growth that are utilized for power demand forecast, three scenarios of high, base and low growth are set. Both high and low cases reflect the following economic situations.

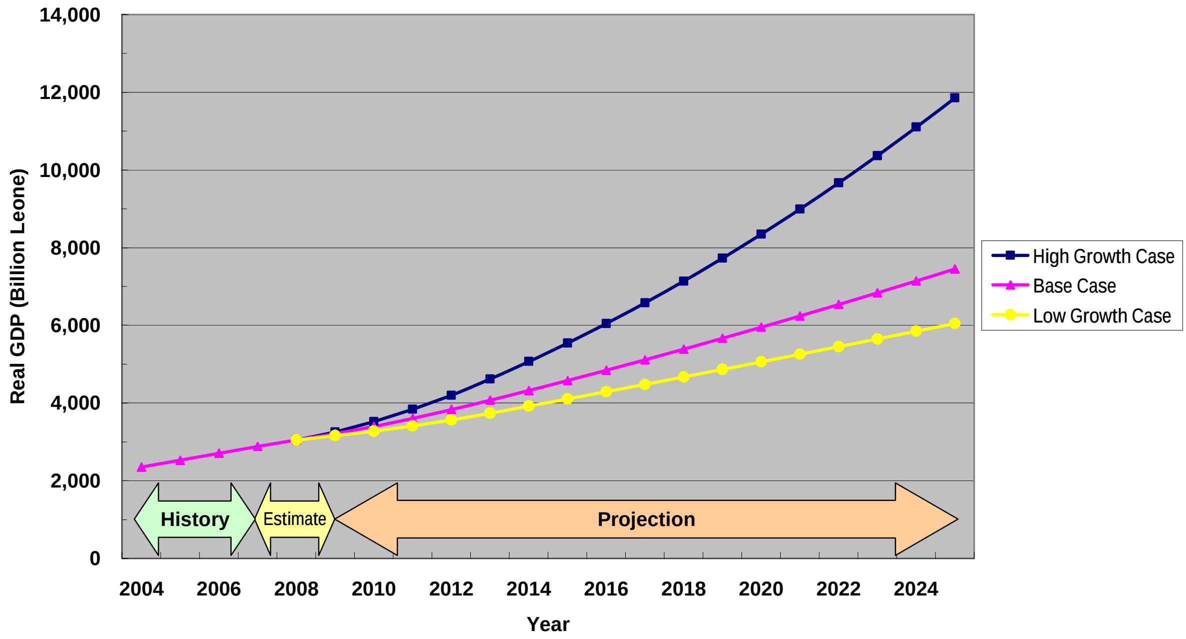
1) Scenario of high economic growth

If all the planned donor's assistances shown in PRSP are realized, high economic growth in the country will be achieved. Statement at Gleneagles Summit committed that donor countries will triplicate development assistance for African countries. In case the commitment is materialized, the development assistances for Sierra Leone will account for 7.4% of GDP at 2008 and 22% GDP at 2010.

2) Scenario of low economic growth

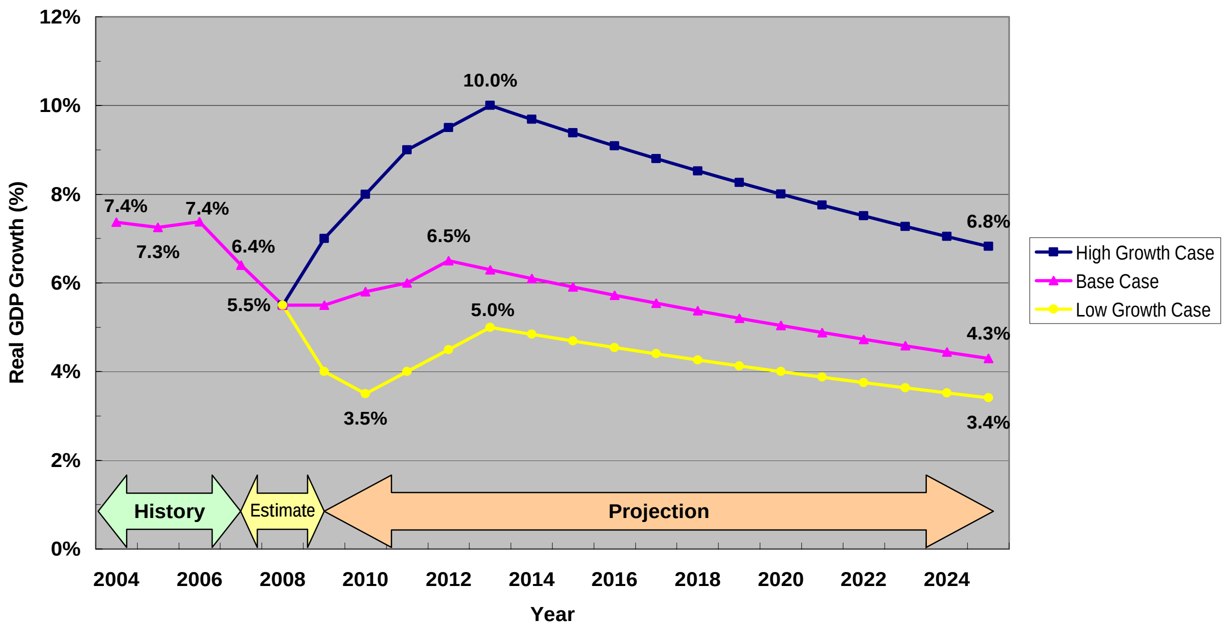
In case that the world economic recession and further oil price inflation is continued, economic growth will be low.

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. 4.2-1 and Fig. 4.2-2.



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

Fig. 4.2-1 GDP Growth Projection (Constant Price at Y2000)



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

Fig. 4.2-2 Real GDP Growth Projection

4.3 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.

(1) Power demand potential calculated by the results of the demand survey

The socioeconomic survey (Power demand and Amount willing to pay) was conducted from 1st week of December 2008 to 4th week of January 2009. 260 NPA consumers were selected by random sampling (Mother population 48,081 consumers as of September 2008), as samples and were interviewed. Trough the result of the demand survey, the potential peak demand is shown in Table 4.3-1 below (Estimated peak demand as of the end of year 2008 is **41.4 MW at the end of 2008**).
Item (1) ～(5) shown in Table 4.3-1 is the sorted results of the socio economic survey and item (6) is the projected results of concurrence use ratio by the Study Team.

The projected results of concurrence use ratio (Domestic consumers: example)

1) Domestic consumer paid some 108,000 leones/month (US$ 34/month) to the NPA on average, as is shown in Annex-4 of Appendix 4 (Domestic consumer (T1)).
2) The NPA supplied electricity some 8.7 hours/day on average.
3) Therefore, average electricity consumption/house/hour is 0.47 kWh (US$ 34 ÷30 days÷8.7 hour/day ÷US$0.28/kWh: unit price)
4) Beside, shown in annex-4 of Appendices-4 (Domestic consumer (T1)), average electric capacity of electric apparatus is 1.81 kW/house. Therefore, 0.47 kW is approximately 26 % of it (0.47 ÷ 1.81). This 26 % is average concurrence use ratio.
5) Here, we evaluate that, maximum concurrence use ratio for domestic consumers is 30 % (20 % higher than average one)

Table 4.3-1 Peak Demand Estimation based on Power Demand Survey (as of the end of 2008)

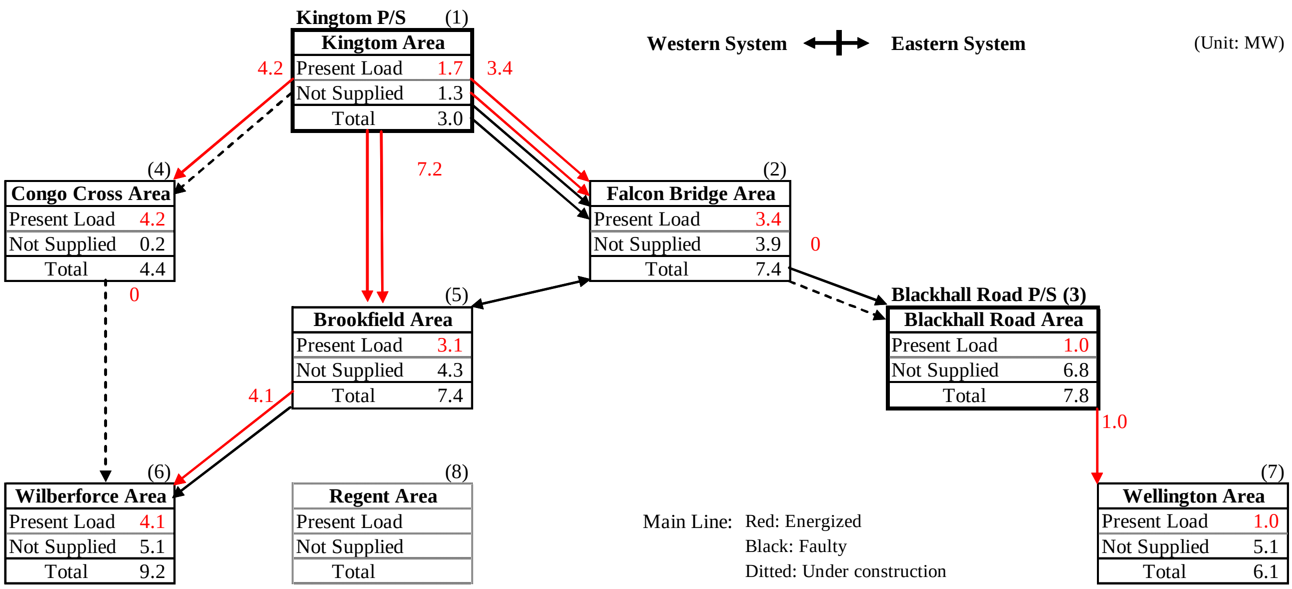
Consumer Category	No. of*1 Consumers	No. of Samples	Capacity of Electrical Appliances/Machines (kW)			Concurrence Use Ratio*2	Estimated Peak Demand (kW)
	(1)	(2)	Total of Samples (3)	Average of Samples (4)=(3)/(2)	Total Capacity of Consumers (5)=(4)x(1)	(6)	(7)=(5)x(6)
T1 Domestic	41,001	70	126.75	1.81	**74,240**	0.3	**22,272**
T2 small commercial	6,460	70	193.20	2.76	**17,830**	0.35	**6,240**
T3 Institutional	306	65	780.00	12.00	**3,672**	0.3	**1,102**
T4 Industrial	314	55	6,882.24	125.13	**39,291**	0.3	**11,787**
Total	**48,081**	**260**	**7,982.19**		**135,033**		**41,401**

[Remarks] *1: as of September 2008
*2: "Concurrence Use Ratio" means ratio of electrical appliances/machines that are expected to operate concurrently
Concurrence Use Ratio = Number of appliances in operation / Total Number of appliances

[Source] JICA Study Team

(2) Power demand potential calculated by the actual power flow

Actual power flow at primary substations of Freetown distribution system is shown in Fig. 4.3-1. This power flow shows that maximum demand of each primary substation and its total is 45.3 MW. However, we evaluated that the peak demand of each substation does not occur at same time and its concurrence ratio is approximately 90 %. Therefore, the peak demand of Freetown power system is estimated as **40.8 MW** (45.3 x 90 %).



(Preliminary Study)

Remarks: 1) Estimated Power Factor: 0.90
2) Not Supply: **26.7** [MW]
3) Total Load: **45.3** [MW]
4) Arrow shows power flow and No. of 11 kV main line which capacity is about 5 MW.
5) Red numerical values are present peak load on each area. Therefore, time difference shall be considered for the study of actual demand.
6) Black numerical value shows the power which can not supply because of load sharing.

[Source] JICA Study Team

Fig. 4.3-1 Present Power Flow of Freetown Distribution System (As of the end of 2008)

(3) Potential power demand calculated by the capacity of the captive generators

According to “Table 3.3-4 Present situation of captive power generation units”, total captive generator registered to the NPA is 50.8 MVA.

However, the NPA has only a handwritten generator list and cannot confirm what percentage of generators are registered to the NPA. Therefore, through consultation with the persons in charge from the NPA counterparts and the interview with factories, companies, organizations etc through demand survey, the Study Team assumed that the rate of registration is 85 %. As result, total captive generator capacity is estimated as approximately 59.8 MVA.

Beside, actual operating ratio of captive generators is assumed to be 50% and power demand supplied from captive generators is estimated to be 59.8 MVA x 50% ≒ 29.9 MVA (23.9 MW). Therefore, it seems that captive generators account for approximately 24 MW of total peak demand in Freetown power system.

<u>The operating ratio (50%) is assumed by the following reasons,</u>

1) According to Annex-4 of Appendix 4 (Industrial consumer (T4)), average fuel (diesel oil) consumption of one (1) factory is some 794 gallon/month (3,700 liters/month) and average generator capacity is 180 kW
2) According to the interview with factories, most factories operate generators on some 80 % load.
3) Therefore, average operation hour of generator is 100 hours/month (3,700 liters/month ÷37 liters (fuel consumption/hour))
4) When the average factory operating time is 200 hours/month (25 days/month x 8 hours/day), operating ratio of 100 hour/month is 50% (half of 200 hours)

In addition, two IPP generation companies (Global Trading Group and Income Electrix) are supplying approximately 17.0 MW to Freetown power system. Therefore, peak demand in Freetown power system is estimated to be 41.0 MW (24.0 + 17.0 = 41.0 MW) in total.

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).

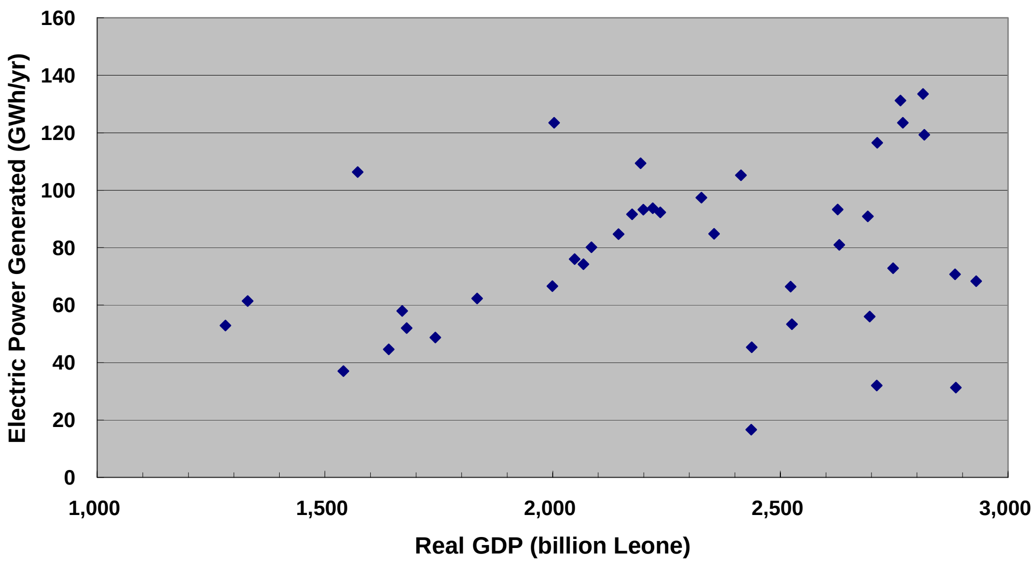
4.4 Power Demand Forecast by Econometric Approach

4.4.1 Analysis of Past Demand & Supply Situation and Socio-Economic Data

(1) Economic Growth and Power Demand

In general, the power demand is said to be related to the GDP, industrial production index, electricity charge, electrification rate and population size. As energies, including electric energy, are considered to be intermediate goods of production activities, power consumption is inferred to have a strong correlation to the GDP.

In Sierra Leone, the available socioeconomic indices are not complete. In addition, the power demand itself may well be restrained due to supply constraints caused by generator breakdown and other reasons. Because of this, any analysis of the correlation between the GDP and power demand in the past has had to be very careful regarding the socioeconomic conditions and power supply situation. Fig. 4.4-1 shows the correlation between the real GDP and electric energy generated in Western Africa in the period from 1963 to 2007. Fig. 4.4-1 does not appear to indicate a strong correlation between the GDP and the electric energy generated. This is contrary to the principle of the economic system described earlier and the statistical analysis data appears to have been affected by socioeconomic factors, constrained power supply and others.

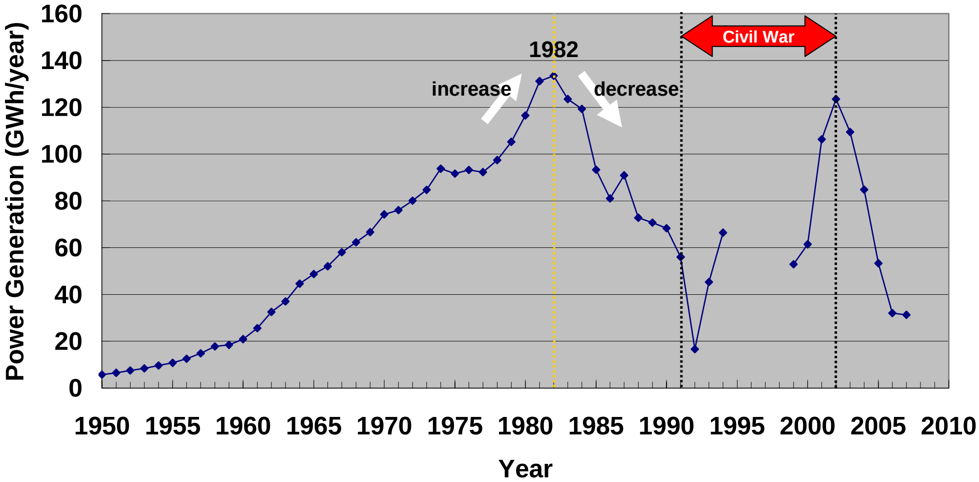


[Source] GDP（1963～1979）: Lahmeyer International (1996), ”Power Sector Master Plan, Sierra Leone”
GDP（1980～2007）: International Monetary Fund (2008), “World Economic Outlook Database”
Electric energy generated（1963～1994）: Lahmeyer International (1996), ”Power Sector Master Plan, Sierra Leone”
Electric energy generated（1999～2007）: National Power Authority
[Remarks]The real GDP figures are based on 2000 prices.
1Le=0.03060JPY

Fig. 4.4-1 Real GDP and Electric Energy Generated in the Western Area (1963 – 2007)

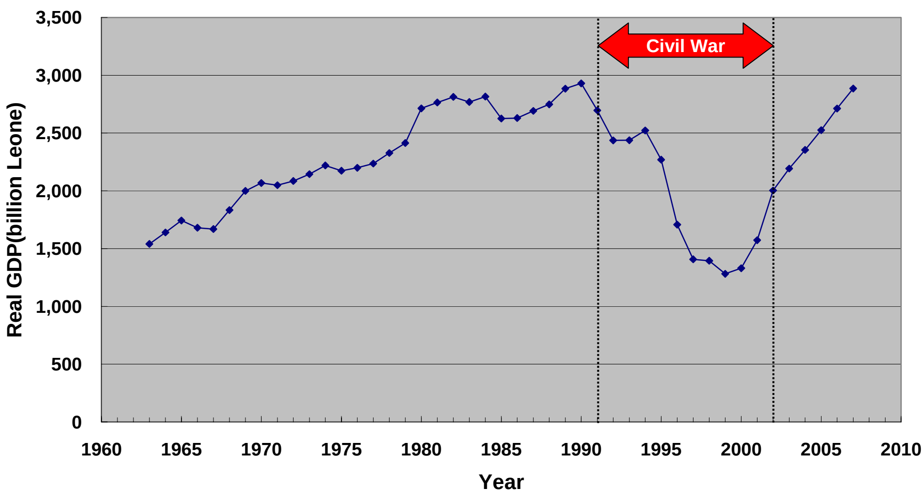
According to Fig. 4.4-2, the electric energy generated in the Western Area steadily increased from

1950 to 1982, followed by a sharp decline thereafter. In contrast, the GDP continued to grow until 1990, one year before the outbreak of the civil war, even though there were minor fluctuations as is shown in Fig. 4.4-3. Fig. 4.4-4 shows the annual GDP growth rate and the annual growth rate of the electric energy generated. Both rates showed similar movement from 1964 to 1984. From 1985 onwards, however, the growth rate of the electric energy generated showed huge fluctuations irrespective of the GDP performance. It is inferred that the statistical data from 1985 onwards does not properly reflect the actual growth rate of the electric energy generated as the power supply has been restricted by the breakdown of the generating units and other reasons. Based on this inference, the scatter diagram shown in Fig. 4.4-5 indicates the relationship between the GDP growth rate and the growth rate of the electric energy generated, excluding data from 1985 onwards.



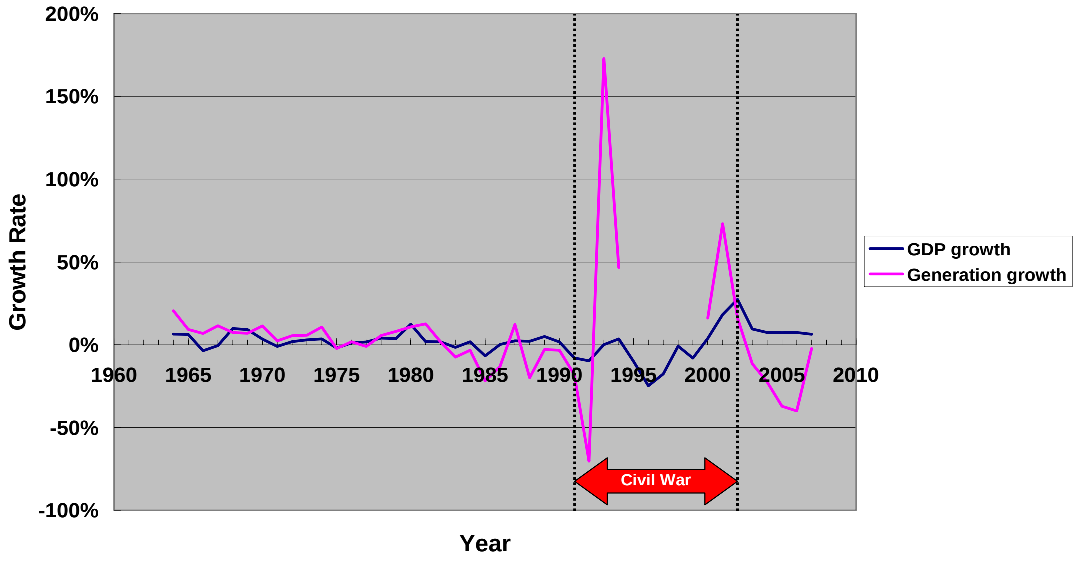
[Source] Same as those for Fig. 4.4-1

Fig. 4.4-2 Historical Changes of the Electric Energy Generated in Sierra Leone (1950 – 2007)



[Remarks] 1Le=0.03060 JPY
[Source] Same as those for Fig. 4.4-1

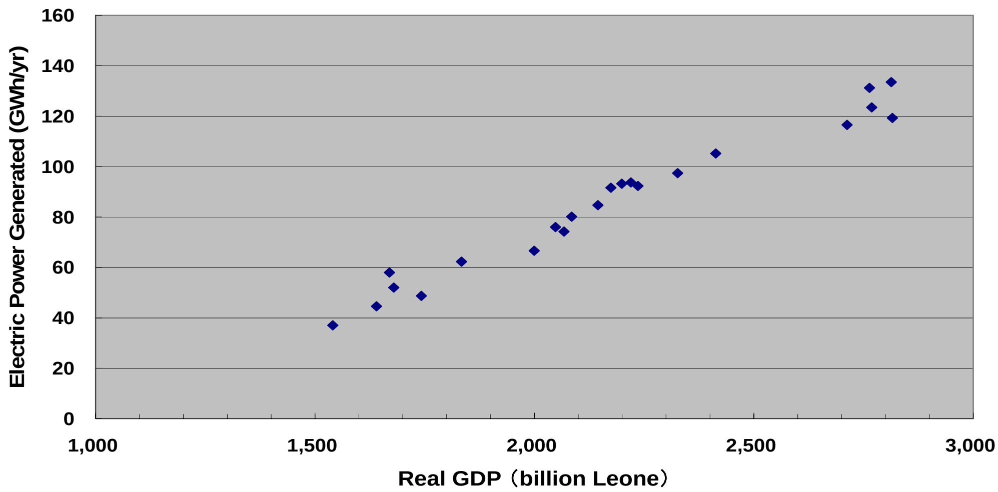
Fig. 4.4-3 Historical Changes of the Real GDP of Sierra Leone (1963 – 2007)



[Source] Same as those for Fig. 4.4-1

Fig. 4.4-4 GDP Growth Rate and Growth Rate of the Electric Energy Generated

As is shown in Fig. 4.4-5, there is a strong correlation between the real GDP and the electric energy generated. A linear approximation of Y = 0.06926 x – 65.253 (R^2 = 0.07) is obtained by the linear regression analysis where the real GDP (billion Leones) and electric energy generated (GWh/year) are considered to be the explaining variable (X) and the explained variable (Y) respectively.



[Remarks] 1Le=0.03060 JPY
[Source] Same as those for Fig. 4.4-1

Fig. 4.4-5 Real GDP and Electric Energy Generated in the Western Area

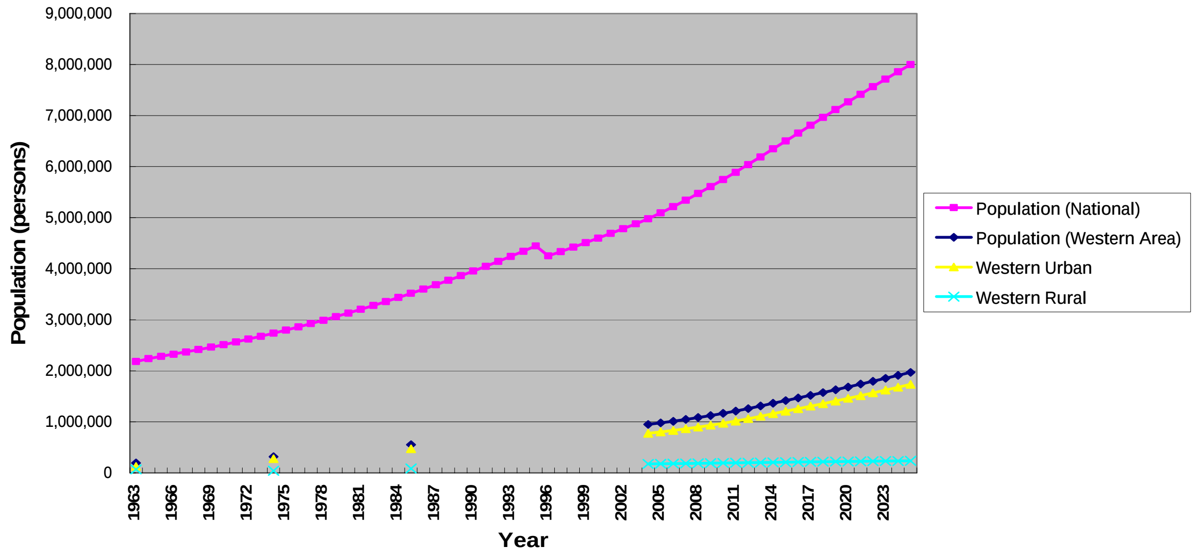
Based on the analysis described above, it seems possible to formulate a power demand forecast model through a regression analysis on historical socio-economic indicators and power demand between 1963 and 1984.

4.4.2 Assumption of Population Growth and Electrification Rate

(1) Population Trends

According to the results of the Population and Housing Census which has been conducted numerous times in the past, the population of Sierra Leone increased from 2.18 million in 1963 to 4.97 million in 2004.

By province, the population growth rate in Western Area of 75.22% for the 11 year period from 1974 to 1985 (5.23%/year) and 70.89% for the 19 year period from 1985 to 2004 (2.86%/year) was far higher than that of the other three provinces. During these two periods, the national population growth rate was 28.54% (2.31%/year) in the first period and 41.56% (1.85%/year) in the second period. This rapid population increase in the Western Area is attributed to the inflow of internally displaced people due to the civil war and also to the inflow of migrant workers from other provinces. Fig 4.4-6 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)”.



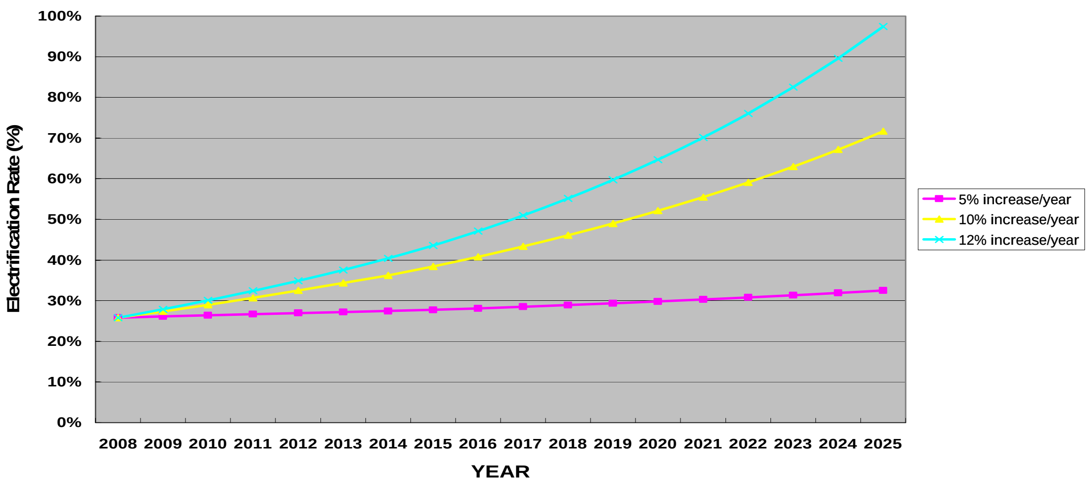
[Source] 2004 Census Population Projection and JICA study team

Fig. 4.4-6 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 4.4-7. Therefore, we apply annual electrification growth rate of 10 % /year for the forecast of household electricity consumption.



[Source] JICA Study Team

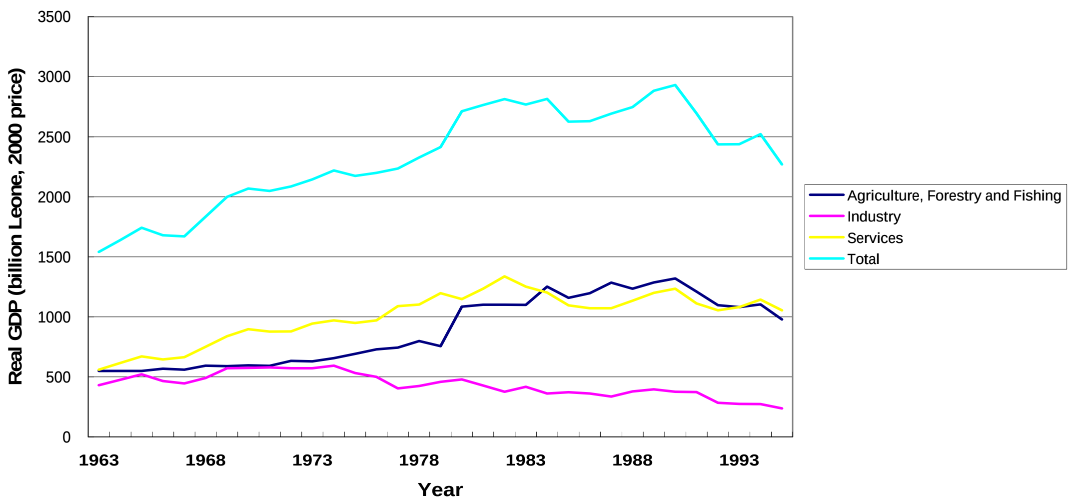
Fig. 4.4-7 Annual Increase of Household Consumers and Electrification Rate in Western Area

4.4.3 Formulation of Econometric Model

Since analytical results in clause 4.4.1 indicate that there is close correlation between the real GDP (Fig. 4.4-8) and electricity consumption by consumer categories (Fig. 4.4-9), econometric model used for power demand forecast has been formulated based on such correlations.
The correlations between GDP and electricity consumption by consumer category is shown in Fig 4.4.10～12. As observed in the figures, the electricity consumption of domestic sector and commercial sector has close correlation with GDP. Therefore, it is possible to obtain demand forecast formulae through regression analysis on those data.

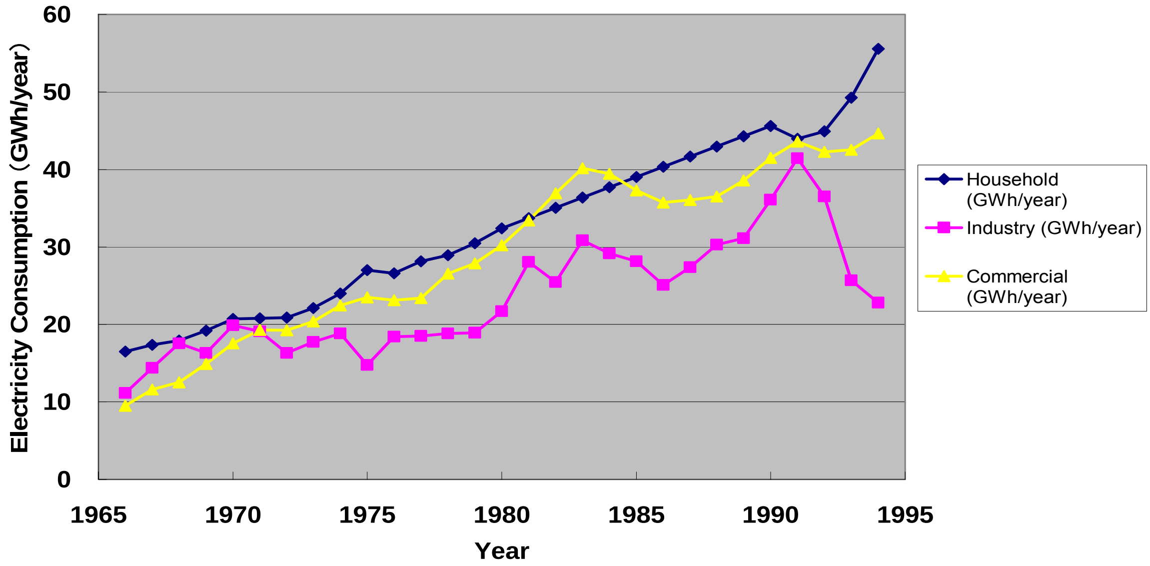
However, it seems that industrial power consumption does not have any close correlation with industrial GDP. Because, most of industrial consumers depend on captive generators for their operation and the industrial power demand of the NPA is not necessarily the actual industrial demand.

Therefore, industrial power consumption will be calculated by utilizing GDP elasticity of cement production as an indicator that represents all industrial production. Fig. 4.4-13 shows "Comparison of Industrial GDP and Projected Cement Production". According to the information from cement factories, the specific power consumption of cement production is 40 kWh/ton and cement production and electricity consumption have linear correlation. Also, as is shown in Fig 4.4-13, the growth of cement production closely follows the trend of industrial GDP growth. Therefore, it is possible to formulate an industrial demand forecast model by utilizing this methodology.



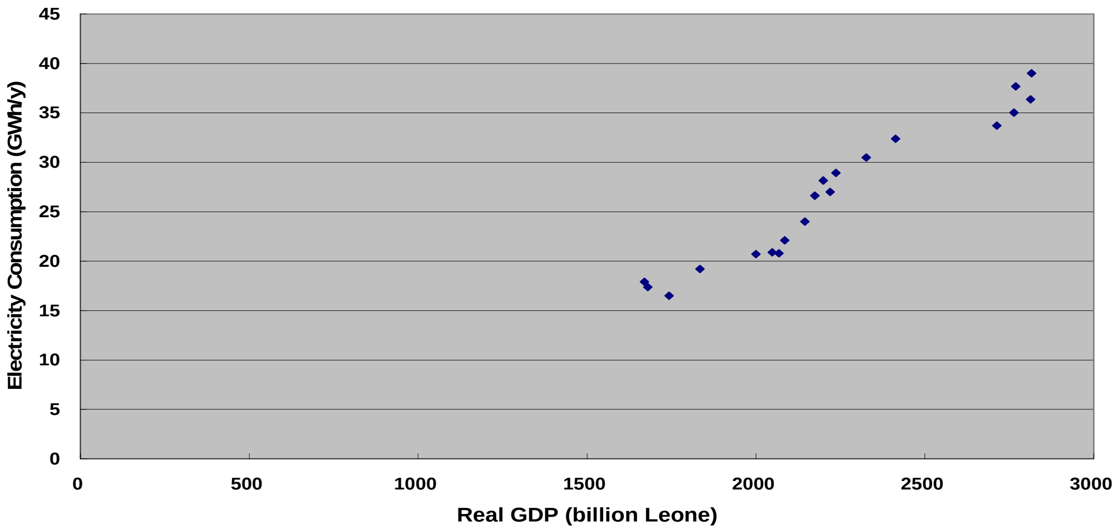
[Remarks] 1Le=0.03060 JPY
[Source] JICA Study Team

Fig. 4.4-8 Historical Change of Real GDP (1963- 2007) by Sector



[Source] JICA Study Team

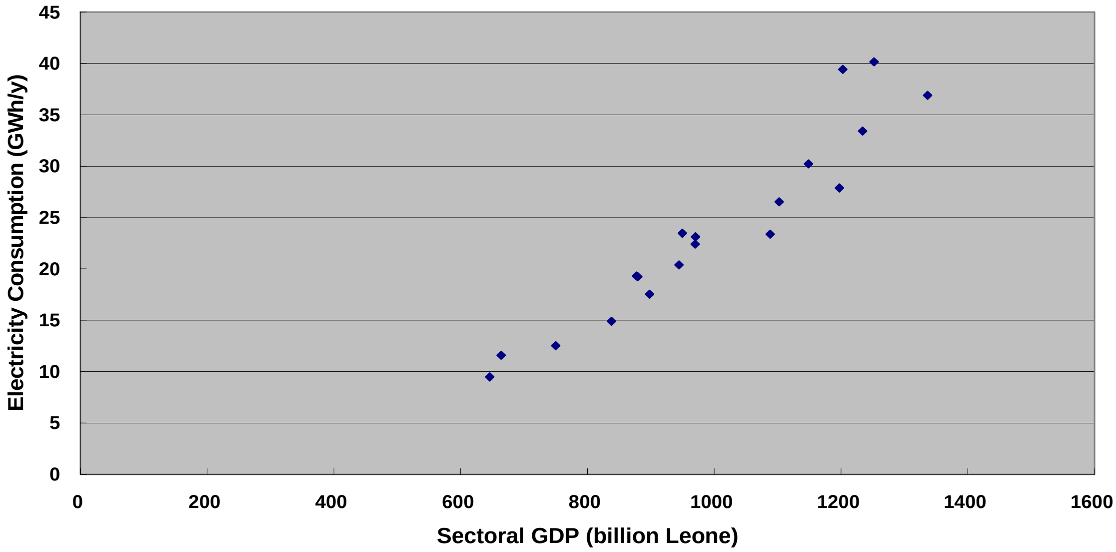
Fig. 4.4-9 Historical Electricity Consumption by Consumer Categories (1966-1994)



[Remarks] 1Le=0.03060 JPY

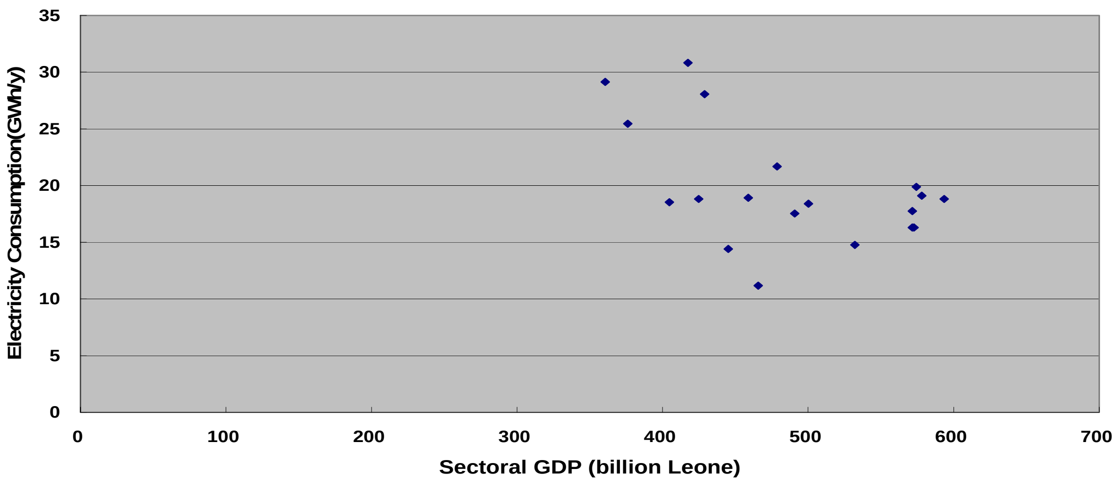
[Source] JICA Study Team

Fig. 4.4-10 GDP (total) vs. Household Electricity Consumption (1963-1984)



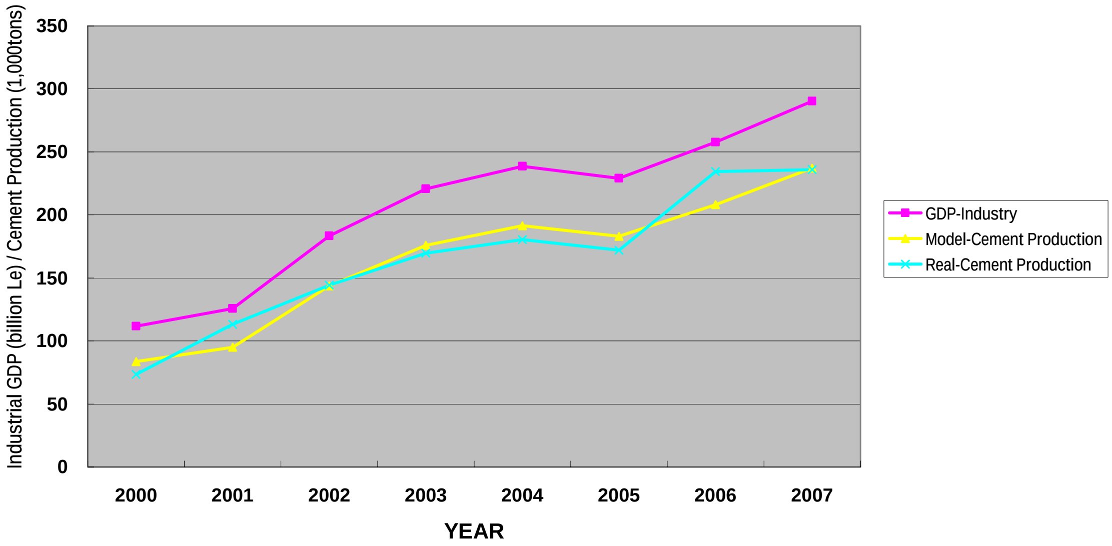
[Remarks] 1Le=0.03060 JPY
[Source] JICA Study Team

Fig. 4.4-11 Sectoral GDP (Commercial) vs. Commercial Electricity consumption (1963-1984)



[Remarks] 1Le=0.03060 JPY
[Source] JICA Study Team

Fig. 4.4-12 Sectoral GDP (Industry) vs. Industrial Electricity Consumption (1963-1984)



[Remarks] 1Le=0.03060 JPY
[Source] JICA Study Team

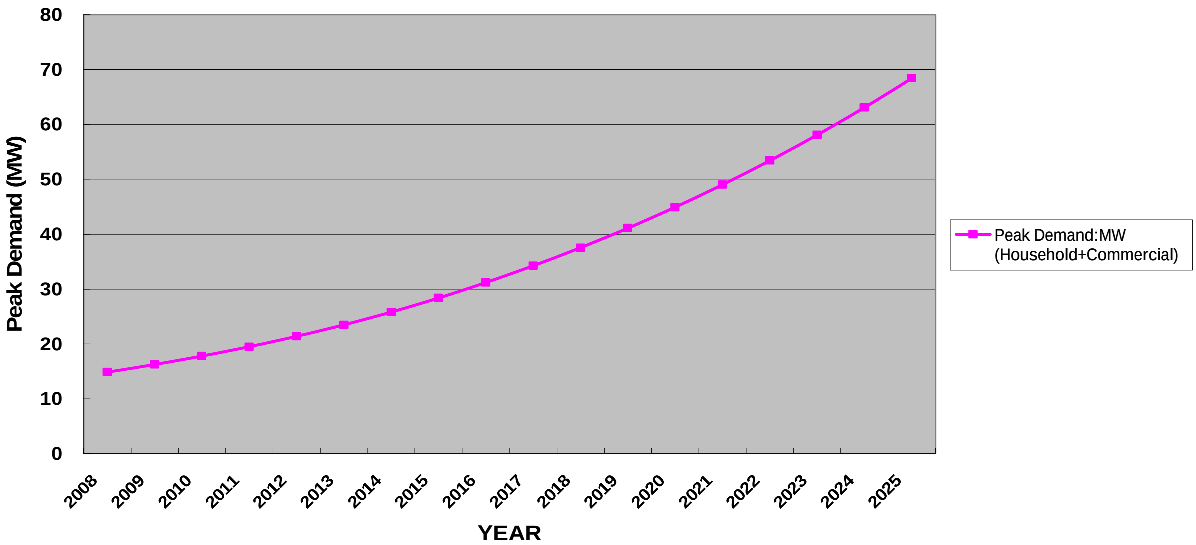
Fig. 4.4-13 Comparison of Industrial GDP and Projected Cement Production

4.4.4 Power Demand Forecast

Results of the power demand forecast (Base Case, High Case and Low Case) calculated by regression analysis method based on the historical data from 1965-1984 are as follows. Here, only the power demand of household and commercial consumers is calculated because demand forecast formula of these categories can be formulated through the regression analysis on historical GDP and electricity consumption.

(1) Base Case

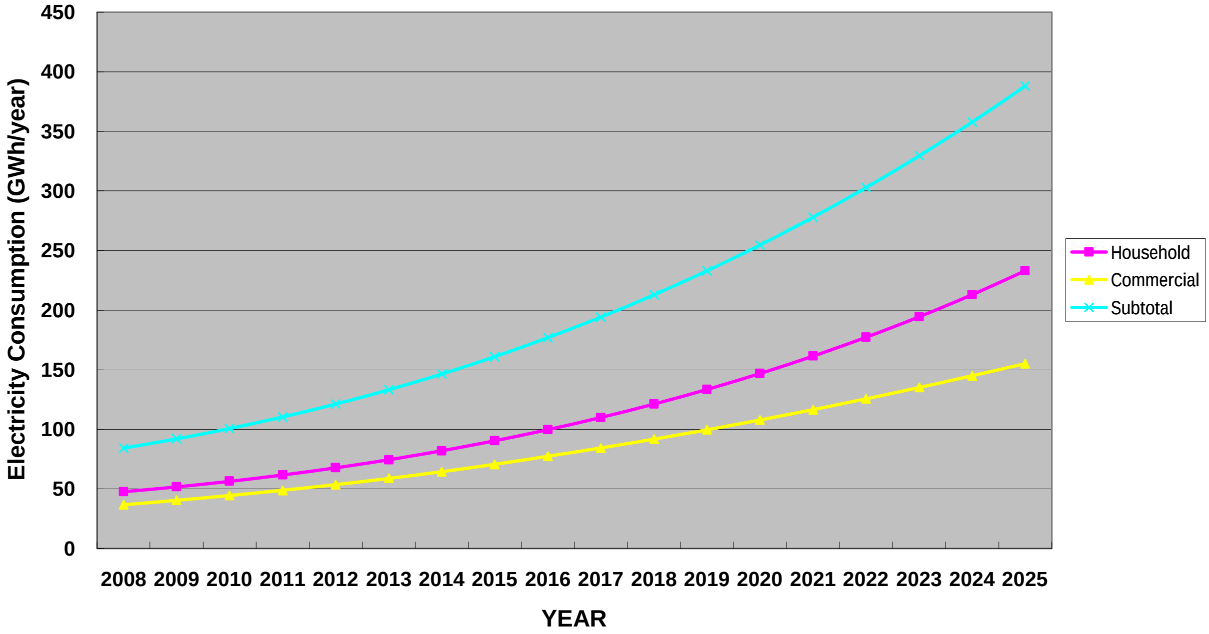
1) Peak Demand (MW)



[Source] JICA Study Team

Fig. 4.4-14 Base Case Power Demand Forecast (Household + Commercial)

2) Electricity Consumption (GWh/Year)

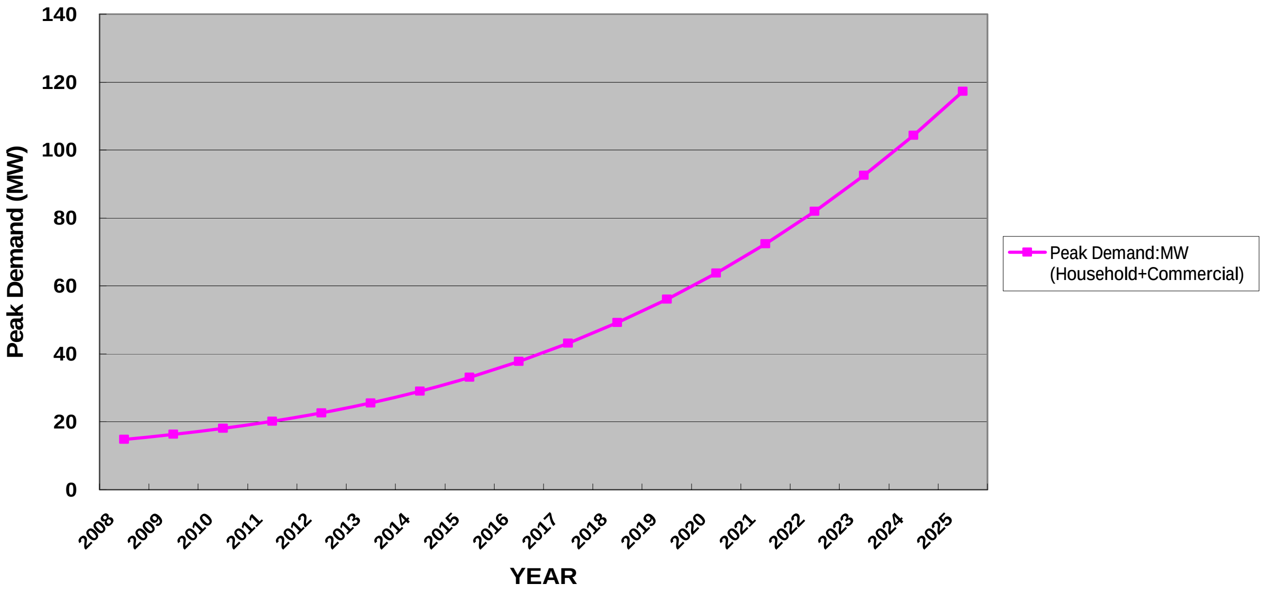


[Source] JICA Study Team

Fig. 4.4-15 Base Case Power Demand Forecast (Household + Commercial)

(2) High Case

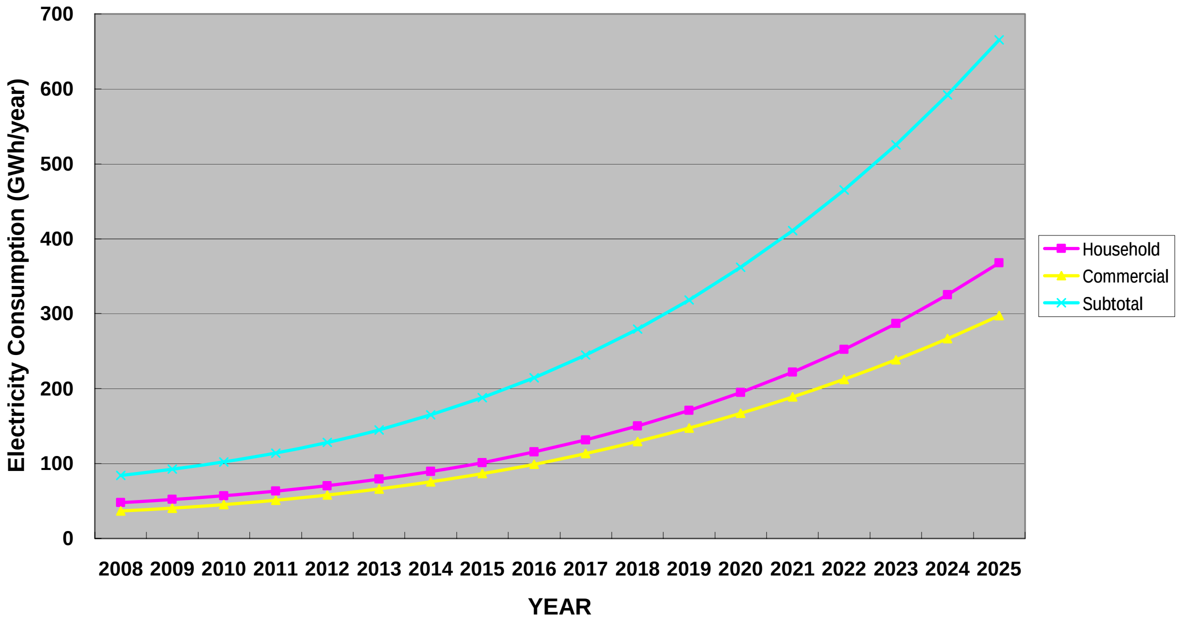
1) Peak Demand (MW)



[Source] JICA Study Team

Fig. 4.4-16 High Case Power Demand Forecast (Household + Commercial, LF= 0.6476)

2) Electricity Consumption (GWh/Year)

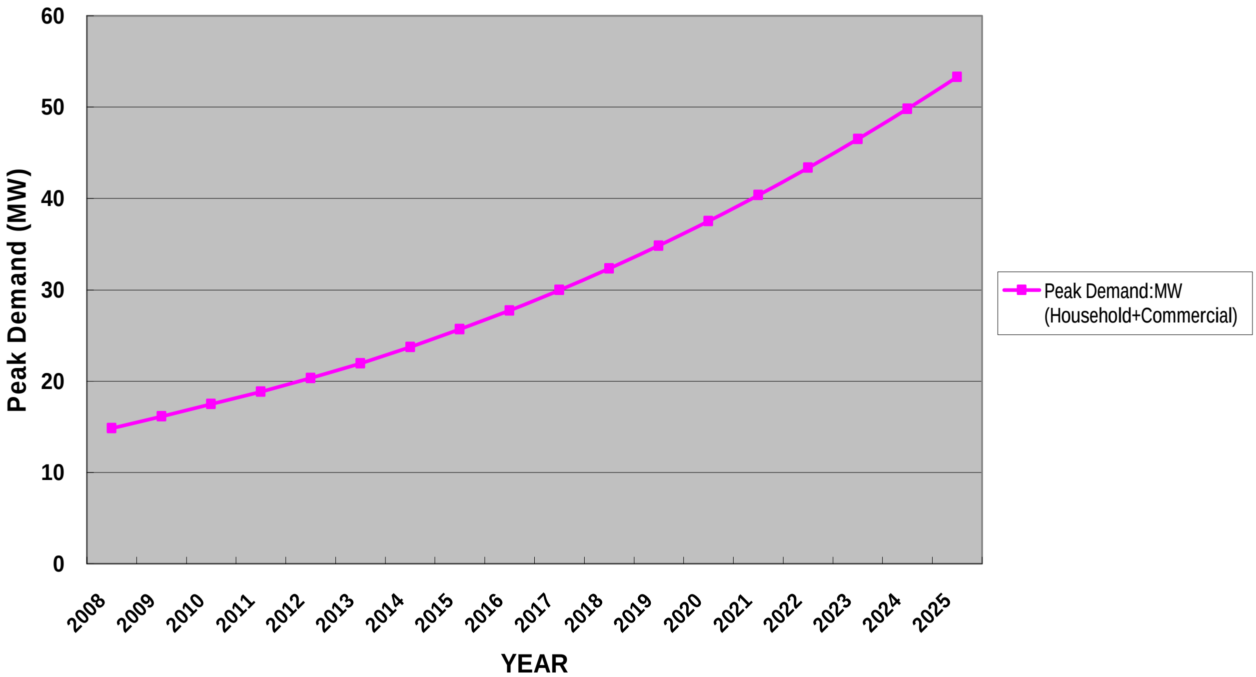


[Source] JICA Study Team

Fig. 4.4-17 High Case Power Demand Forecast (Household + Commercial)

(3) Low Case

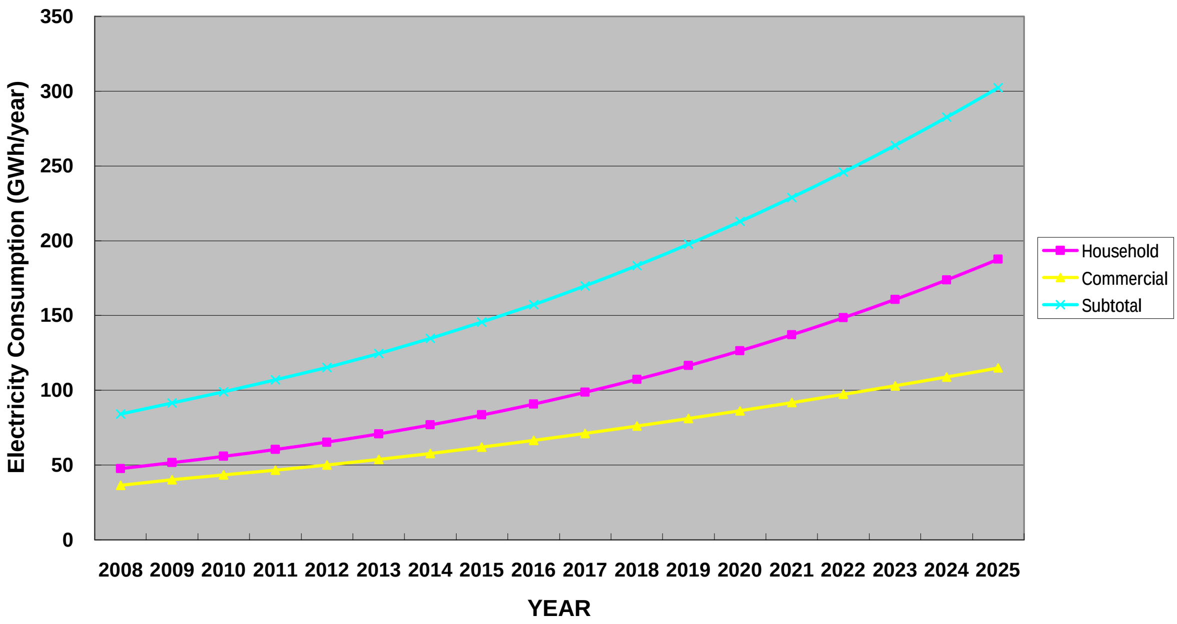
1) Peak Demand (MW)



[Source] JICA Study Team

Fig. 4.4-18 Low Case Power Demand Forecast (Household + Commercial, LF=0.6476)

2) Electricity Consumption (GWh/Year)



[Source] JICA Study Team

Fig. 4.4-19 Low Case Power Demand Forecast (Household + Commercial)

4.5 Adjustments of Demand Forecast

4.5.1 Adjustment of Power Demand Forecast Models

The Power Demand Forecast Models formulated by regression analysis method based on the historical data from 1965-1984 are shown in clause 4.4.4, and the calculating formulas of household and commercial consumers are as follows;

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, as is shown in Table 4.5-1. 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. Fig. 4.4-13 shows "Comparison of Industrial GDP and Projected Cement Production". It is assumed that cement production represents the industrial activities in Sierra Leone because the cement factories used to be the biggest electricity consumer of the NPA and cement production is controlled to meet demand in the construction sector.

Here, the models of power demand forecast shown above are adjusted to meet the estimated peak demand in 2008 (shown in Table 4.5-1 below).

Table 4.5-1 Estimated Peak Demand Potential in 2008 (MW)

T1 (Household)	21.50	(P1)
T2 (Small Commercial)	7.33	(P2)
T3 (Institutional)	0.82	(P3)
T4 (Industrial)	11.35	(P4)
Load Factor	0.65	(LF)

[Source] JICA Study Team

(1) Adjustment of power demand forecast models for domestic consumers:

1) Household electricity consumption in 2008 = P1xLFx8760h x1/1000 = 122.42 GWh/year

2) A_{HH} ; Adjustment coefficient for household electricity consumption

3) PCONH=-2.52715+A_{HH}*(0.00262627*RGDPT+0.0000909638*NOHHCON+0.867131*LAG1.PCONH

4) Here, assume ; LAG1, PCONH/PCONH=0.95

5) A_{HH}=(PCONH+2.52715-0.867131*LAG1.PCONH)/(0.00262627*RGDPT+0.0000909638*NOHHCON)
= 1.94376

(2) Adjustment of power demand forecast models for commercial consumers:

1) Commercial electricity consumption in 2008 = (P2+P3)xLFx8760hx1/1000=122.42 GWh/year

2) A_C ; Adjustment coefficient for commercial electricity consumption

3) PCONH=-4.18847+ A_C *0.0103346*RGDPC+0.796798*LAG1.PCONC

4) Here, assume ; LAG1, PCONC/PCONC = 0.95

5) A_C= (PCONC +4.18847-0.796798*LAG1.PCONC/(0.0103346*RGDPC)
= 1.08023

(3) Adjustment of power demand forecast models for industrial consumers:

1) PCEM = EXP(-0.720742)*(RGDPI)^1.09152
Hence; RGDPI: Real GDP by industrial sector at year2000 price, billion Leones
PCEM: Cement production, 1000 metric tons

Logarithmic transformation of equation

2) in (PCEM) = -0.720742 + 1.09152*In (RGDPI)

Here, it is assumed that GDP elasticity of cement production is similar to GDP elasticity of industrial electricity consumption and

3) in (PCONI) = A1 + 1.09152*In (RGDPI)

Here, PCONI; Industrial electricity consumption (GWh/year)

4) Industrial electricity consumption in 2008 = (P4) x LF x 8760h x 1/1000 = 64.63 GWh/year

5) A_{I}; Adjustment coefficient for industrial electricity consumption

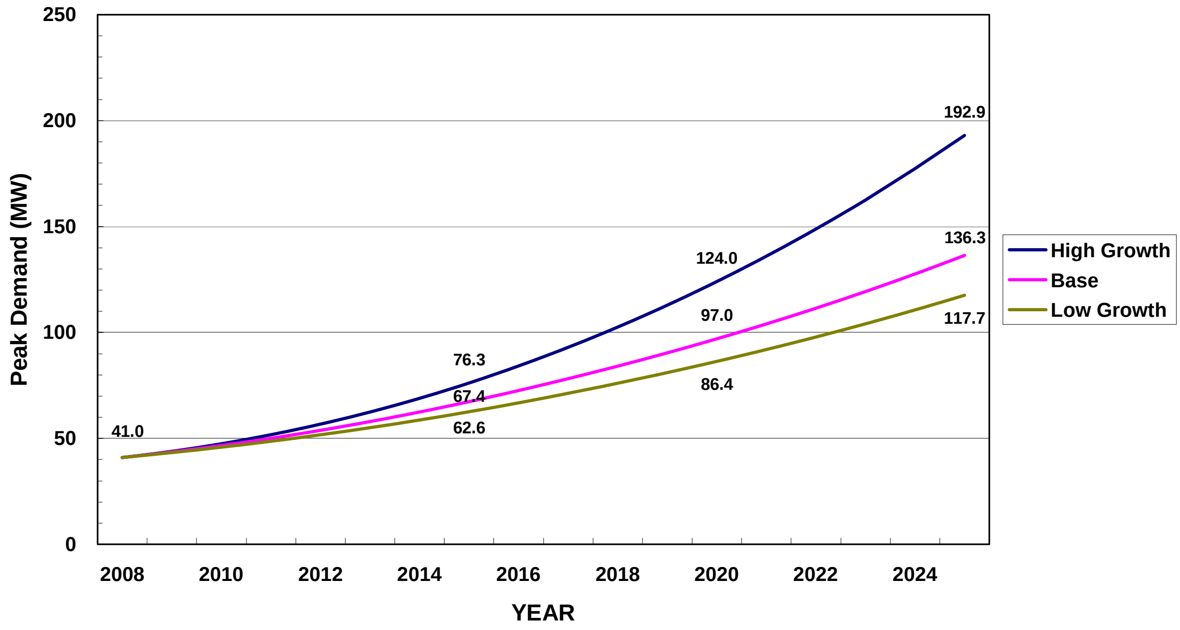
6) A_{I} = in (PCONI) – 1.09152*In (RGDPI) = -2.108

7) PCONI = EXP(A)*RGDPI^1.09152

4.5.2 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)

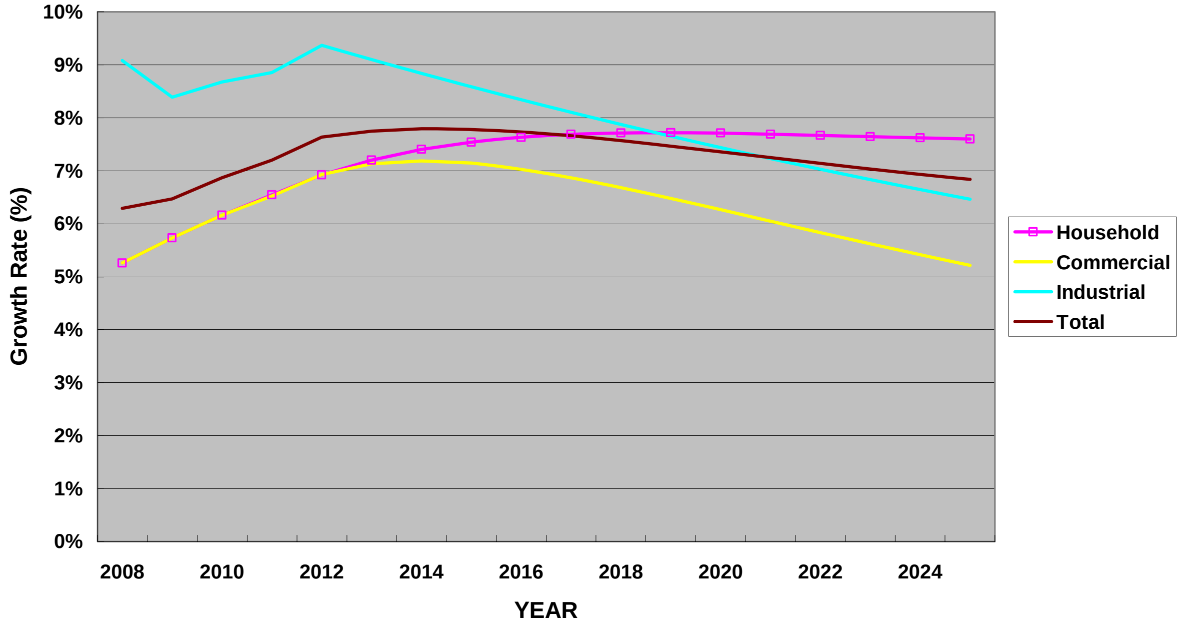


[Source] JICA Study Team

Fig. 4.5-1 Power Demand Forecast After Adjustment (comparison of growth scenario)

(2) Adjusted Base Case

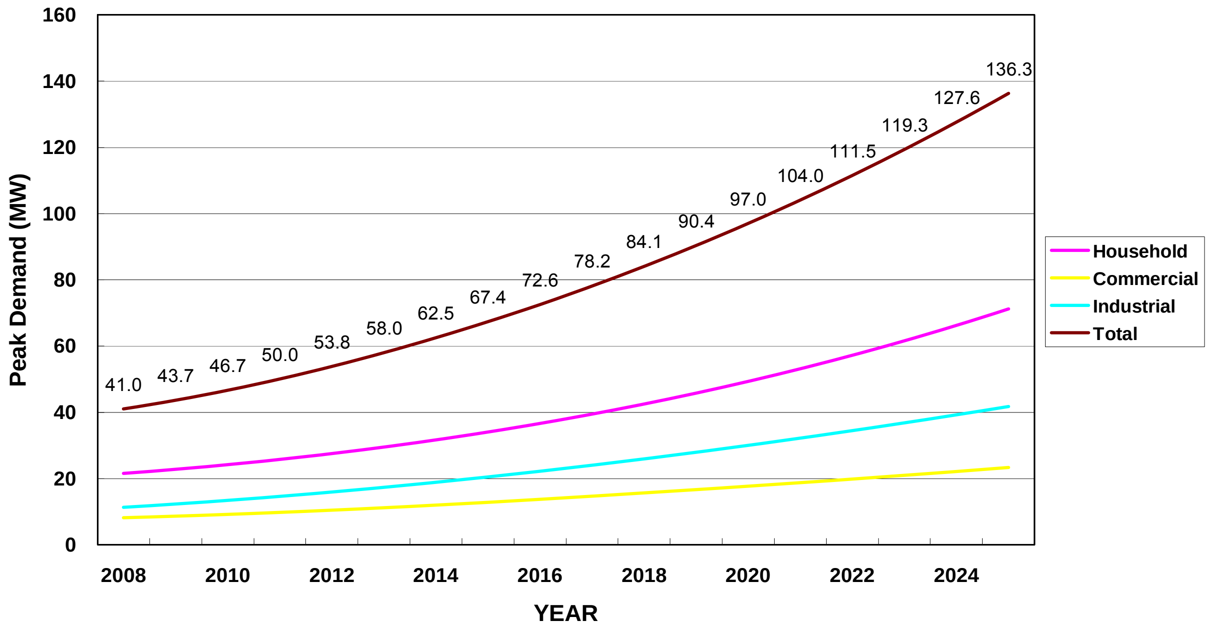
1) Adjusted Base Case Peak Demand Growth Rate (Each Sector)



[Source] JICA Study Team

Fig. 4.5-2 Adjusted Base Case Peak Demand Growth Rate (All Sectors)

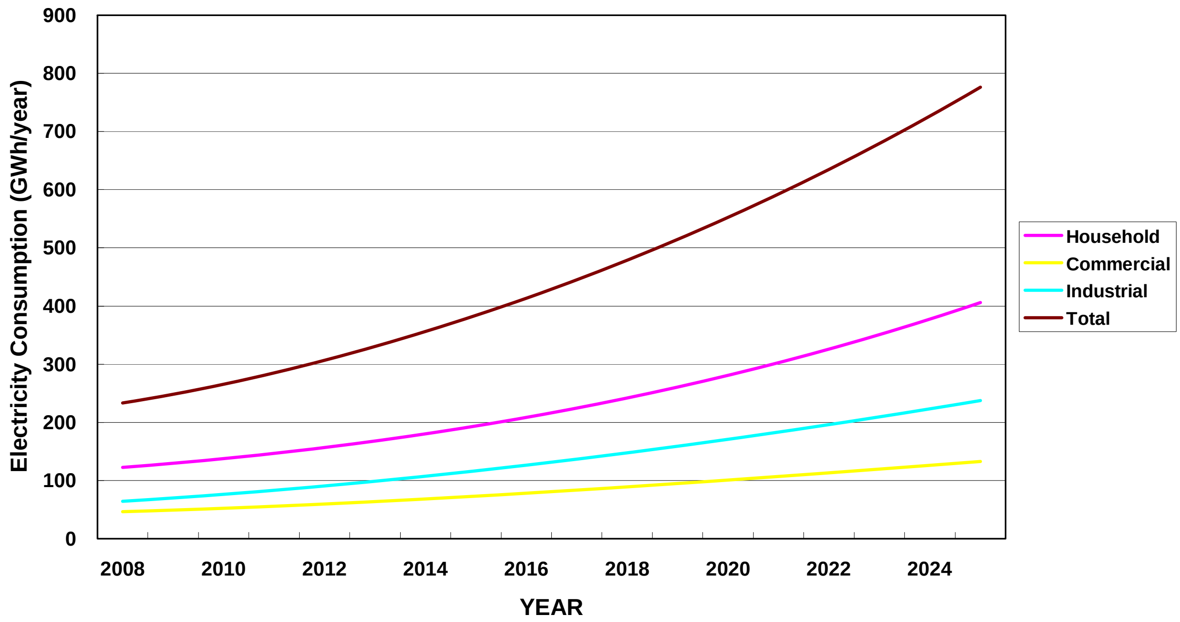
2) Adjusted Base Case Peak Demand (MW) of Each Sector



[Source] JICA Study Team

Fig. 4.5-3 Base Case Adjusted Peak Demand Forecast (MW) of All Sectors

3) Adjusted Base Case Electricity Consumption (GWh/year) of Each Sector

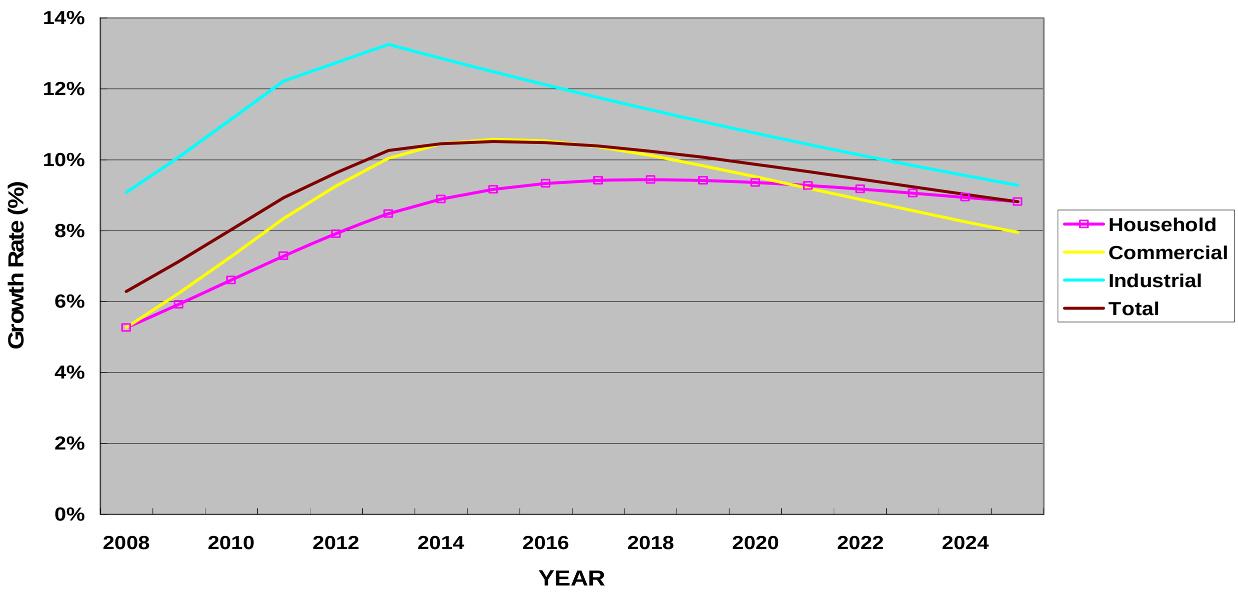


[Source] JICA Study Team

Fig. 4.5-4 Base Case Adjusted Electricity Consumption (GWh/year) of All Sectors

(3) Adjusted High Case

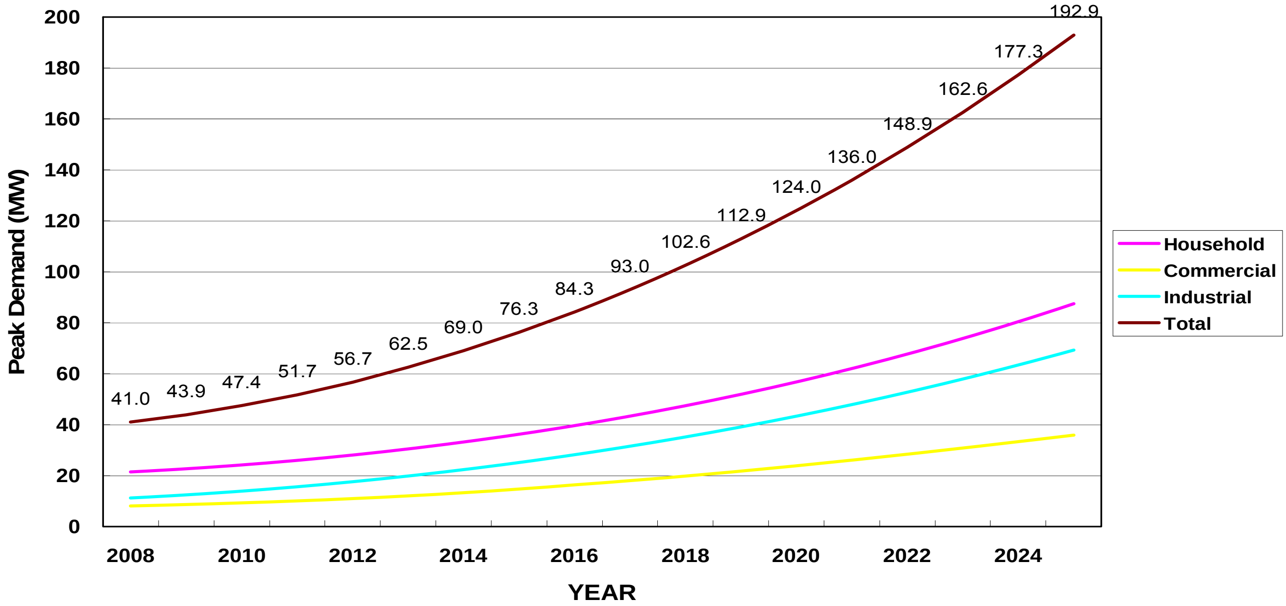
1) Adjusted High Case Peak Demand Growth Rate (Each Sectors)



[Source] JICA Study Team

Fig. 4.5-5 Adjusted High Case Peak Demand Growth Rate (All Sectors)

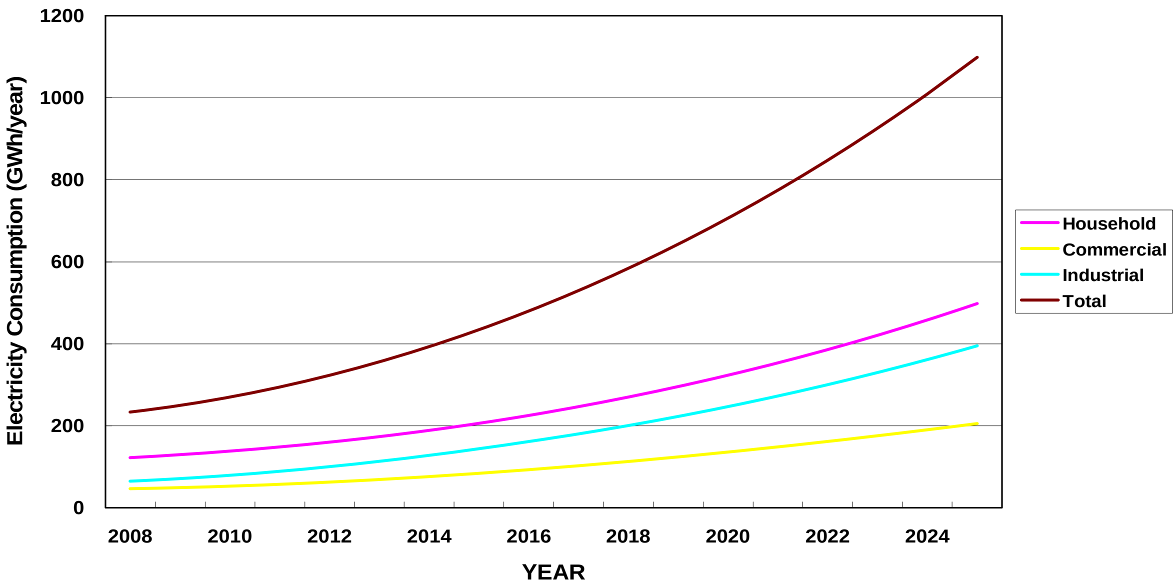
2) Adjusted High Case Peak Demand (MW) of All Sectors



[Source] JICA Study Team

Fig. 4.5-6 Adjusted High Case Peak Demand (MW) of All Sectors

3) Adjusted High Case Electricity Consumption (GWh/year) of All Sectors

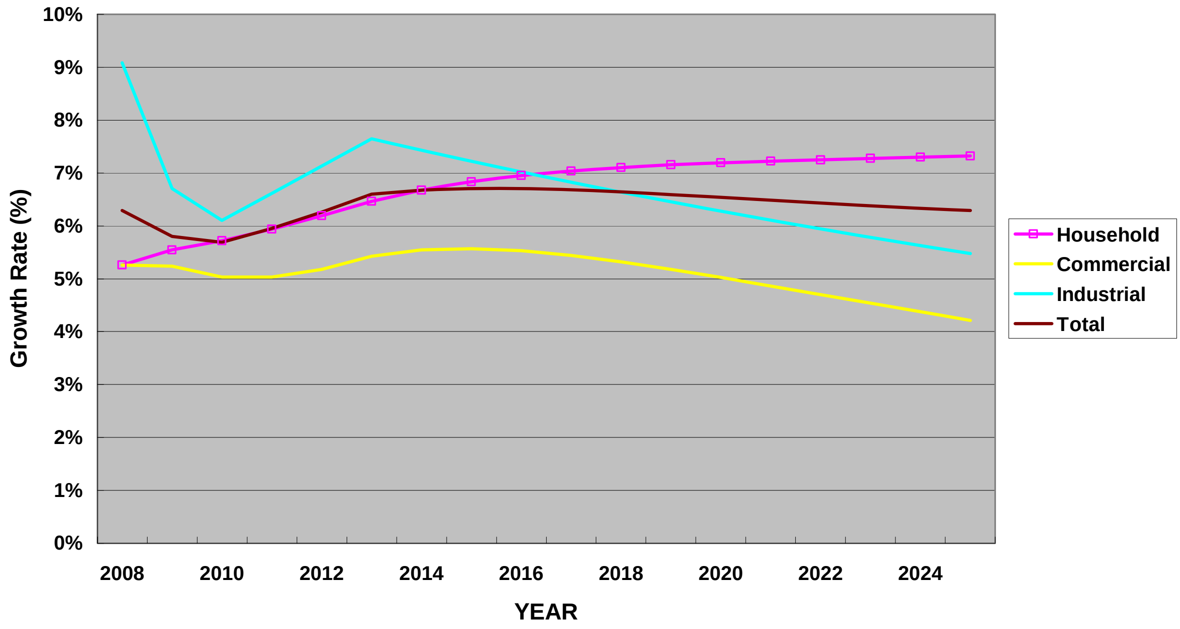


[Source] JICA Study Team

Fig. 4.5-7 Adjusted High Case Electricity Consumption (MWh/year) of All Sectors

(4) Adjusted Low Case

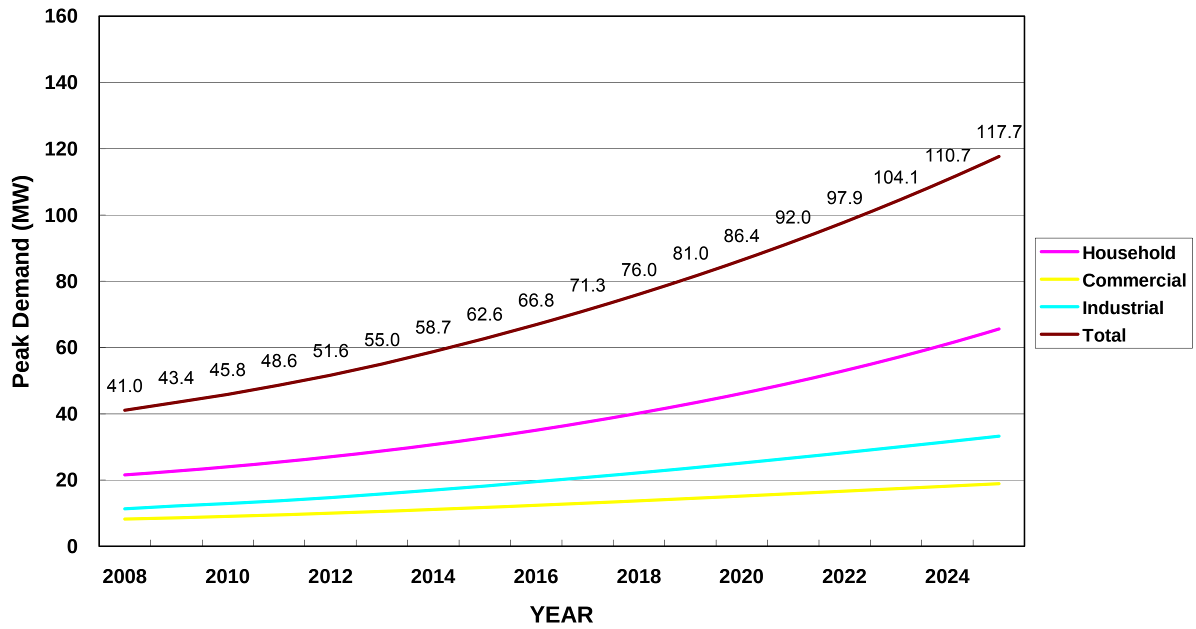
1) Adjusted Low Case Peak Demand Growth Rate (Each Sectors)



[Source] JICA Study Team

Fig. 4.5-8 Adjusted Low Case Peak Demand Growth Rate (All Sectors)

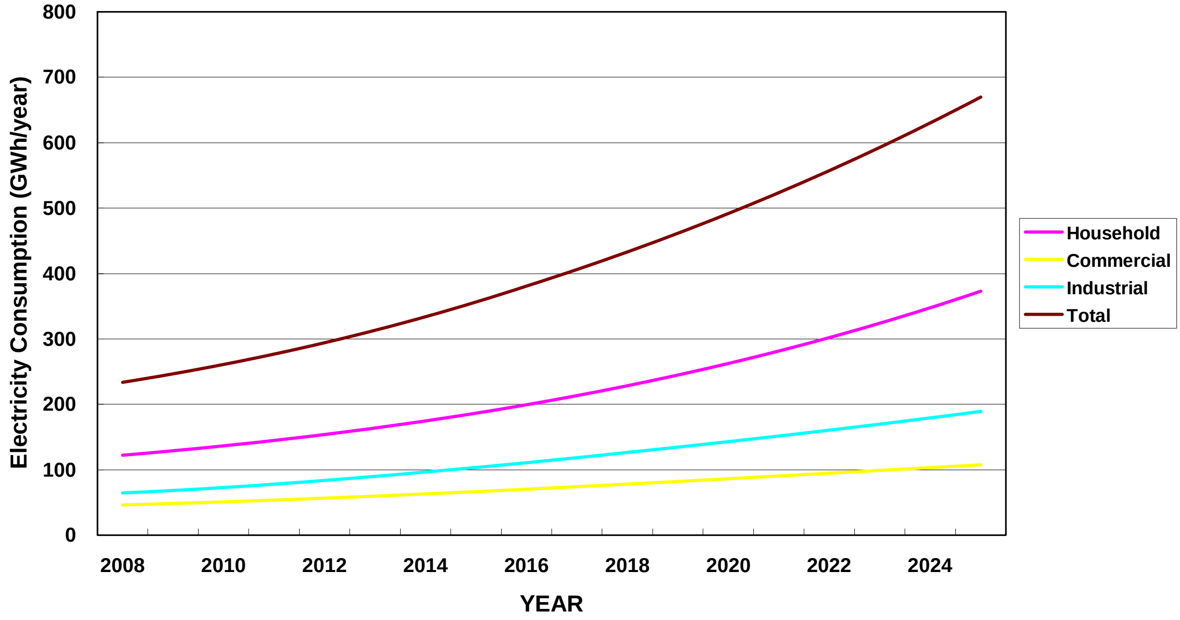
2) Adjusted Low Case Peak Demand (MW)



[Source] JICA Study Team

Fig. 4.5-9 Adjusted Low Case Peak Demand (MW)

3) Adjusted Low Case Electricity Consumption (GWh/year)



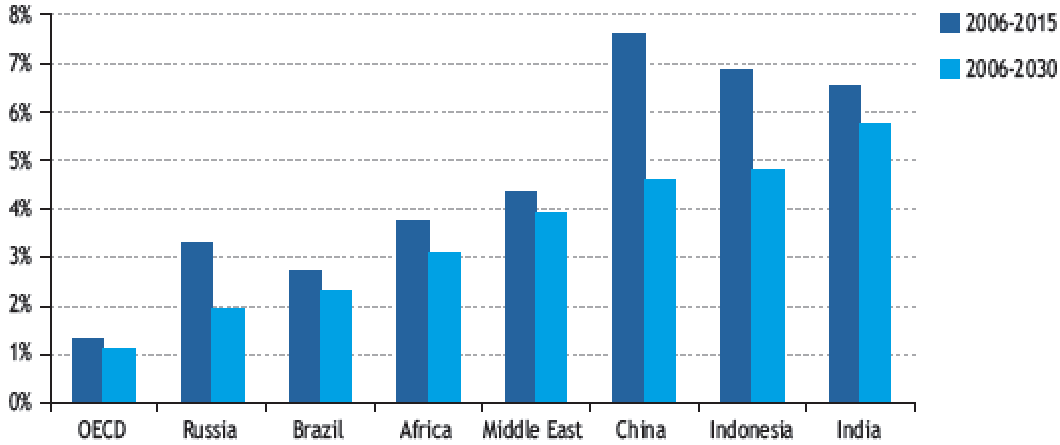
[Source] JICA Study Team

Fig. 4.5-10 Adjusted Low Case Electricity Consumption (MWh/year)

4.6 Verification of Results of Power Demand Forecast

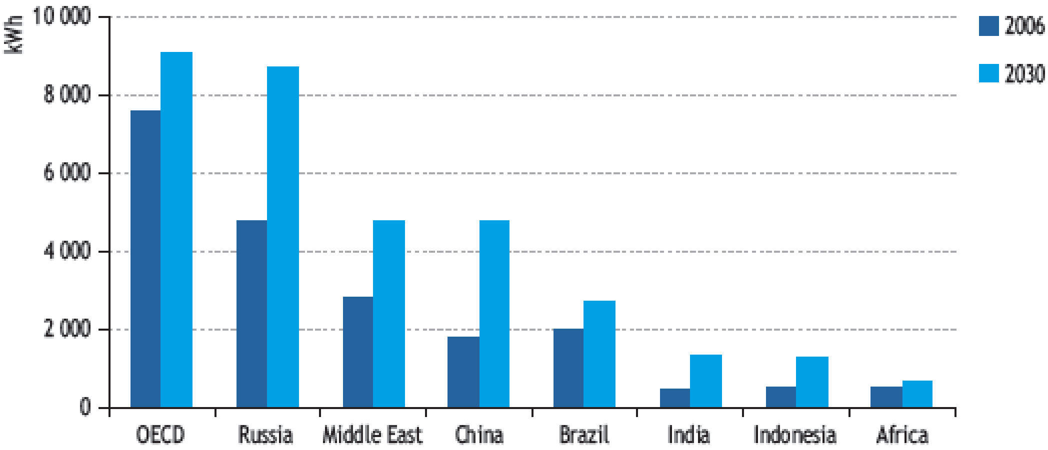
4.6.1 Comparison with World Energy Outlook

In order to verify the results of power demand forecast shown above, the forecast numbers are compared with demand growth rate (Fig. 4.6-1) and per-capita electricity consumption (Fig. 4.6-2) from 2006 to 2030 which are shown in "World Energy Outlook 2008" compiled by IEA (International Energy Agency).



[Source] IEA "World Energy Outlook 2008"

Fig. 4.6-1 Electricity demand growth rates by region



[Source] IEA "World Energy Outlook 2008"

Fig. 4.6-2 Per-capita electricity demand by selected region

As is indicated in Fig. 4.6-1, power demand growth rate in Western Area in 2025 calculated by the Study Team is 6.9% which is substantially higher than the growth rate in African region (3.1%) in 2030 estimated by IEA.

On the contrary, per-capita electricity demand in Western Area in 2025 is estimated to be 394 kWh/person by dividing forecast electricity consumption of 790GWh/year by projected population (approx.2 million), which is absolutely lower (only 58.7%) than the number in African region in 2030 (671 kWh/person).

Therefore, power demand forecast in Western Area calculated by the Study Team is evaluated as reasonable, even if the growth rate of power demand is higher than that of the African region (3.1%) because per-capita electricity consumption in Western Area is absolutely lower than that of the African region.

4.6.2 Comparison with WAPP Master Plan

In the West African Power Pool (WAPP) Master Plan report (July, 2004), the power demand forecast in Sierra Leone up to year 2020 is indicated. The comparison of the power demand forecast up to 2020 prepared by JICA Study Team and WAPP Master Plan is shown in Table 4.6-1.

Table 4.6-1 Comparison of Power Demand Forecast

(Unit: MW)

Year / Case	2007	2008	2011	2015	2020
JICA Study Team (Base case)	-	41.0	50.0	67.4	97.0
WAPP Master Plan Report	45.0	-	57.0	72.0	97.0

[Source] JICA Study Team, and Nexant Inc. (2004.7) "West Africa Regional Transmission Stability Study, Volume 2: Master Plan"

According to Table 4.6-1, the results of power demand forecast prepared by JICA Study Team (Base case) and WAPP Master Plan do not show much difference, although small differences are observed up to 2015.

5. Power Development Planning

5.1 Existing Power Development Plan

5.1.1 Long Term Power Development Plan in Sierra Leone

Long term power development plan in Sierra Leone is mentioned in the medium to long term energy policy of the Ministry of Energy and Water Resources, "Energy Sector Policy and Strategic Action Plan" (November 2008). In this, the construction of Bumbuna phase -2 and 3 is one of the targets of medium-term action plans from 2011 to 2015 and the construction of Bumbuna phase -4 and 5 is also envisaged as a target for long term action plans from 2015 to 2025. Bekongor is also considered as one of the most prominent large scale hydro developments after Bumbuna in terms of economics. However, the actual target completion year, priority among the candidate projects, implementation plans and financial plans have not been clarified yet.

5.1.2 Committed Power Development Projects

(1) Bumbuna Hydroelectric Power Project

Bumbuna is designed as a rockfill-dam type hydro electric power plant and the construction works of power plant and the transmission lines as well as dry and wet tests were completed by the end of May 2009. Bumbuna is expected to commence the commercial operation by the end of 2009 if remaining load testing is completed smoothly. Therefore, Bumbuna is deemed as a power supply source in 2009 in considering power balance. The following Table 5.1-1 shows the outline of Bumbuna Hydroelectric Power Station. As is shown in Fig. 5.2-2, the available output of Bumbuna largely fluctuates according to its seasonal water availability. It can be operated at the rated output of 50 MW only for four months between August and November; the output drops to 17.5 MW during dry season.

Table 5.1-1 Outline of Bumbuna Hydroelectric Power Plant

Province/District	North / Bumbuna
Catchment	Seli River
Reservoir Surface Area	21km^2
Dam Type	Rockfill Dam
Max/Min Head	80/47 m
Turbines	2 Francis, 25MW each
Plant capacity (ex-transformer)	50 MW
Guaranteed Continuous Power	17.5 MW
Average Annual Generation	315 GWh
HV Feeder Line	161kV, 200km

［Source］Studio Ing. G. Pietrangeli s. r. l., "Completion of Bumbuna Falls Hydroelectric Project-Data sheet "

(2) Extension of Kingtom Power Station

The extension of Kingtom Power Station has been implemented under the Japan's grant aid by installing new units No.7 and No.8, heavy oil-fired and medium speed diesel engine generators with the single output capacity of 5 MW each (5 MW x 2) within the premises of the existing Kingtom Power Station. Since the work has progressed on schedule and will be completed by February 2010, it is deemed as a power supply source in 2010 in the power development planning.

(3) Construction of Blackhall Road Power Station

Blackhall Road Power Station is planned as heavy fuel oil-fired and medium speed diesel engine generators with the single output capacity of 8.28 MW each (8.28 MW x 2) within the premises of the existing Blaskhall Road substation. BADEA and SFD (Saudi Fund for Development) provide financial assistance to the project and the contract with Jacobsen, the contractor, was concluded in May 2009. According to the contract, the construction work shall be completed within 18 months from the contract signing. Currently, the work has been accelerated to complete it by August 2010. Thus, this power plan is deemed as a power supply source in year 2010.

5.2 Pre-conditions of Power Development Planning

5.2.1 Power Demand Forecast to be used for Power Development Planning

Power demand forecast to be a basis for the power development planning is the “Base Case” power demand forecasted by this Master Plan Study. Annual peak demand (MW) and electricity consumption (GWh) are shown in the following Table 5.2-1. Power demand forecast in this Master Plan Study forecasts power demand at primary substations and distribution losses are included in the forecasted demand.

Table 5.2-1 Power Demand Forecast in Western Area Power System

	Year	Peak Demand (MW)	Electricity Consumption (GWh/year)
Estimate	2008	41.0	233.5
Forecast	2009	43.7	248.6
	2010	46.7	265.6
	2011	50.0	284.8
	2012	53.8	306.5
	2013	58.0	330.3
	2014	62.5	356.0
	2015	67.4	383.7
	2016	72.6	413.4
	2017	78.2	445.0
	2018	84.1	478.7
	2019	90.4	514.5
	2020	97.0	552.3
	2021	104.0	592.4
	2022	111.5	634.7
	2023	119.3	679.3
	2024	127.6	726.4
	2025	136.3	776.1

［Source］ JICA Study Team

5.2.2 Evaluation on the Existing Generators Owned by the NPA

All of the generating units owned by the NPA are diesel engine generators and are installed at the Kingtom Power Station. Currently, two out of seven units are operable, however, they are rather old and deteriorated and some units such as Mirrlees -2 and Mirrlees -3 are severely damaged. Therefore, these generating units cannot be depended on as power supply sources for medium to long term period. At the moment, Sulzer – 4 is operable but it cannot endure for long period of operation due to the following reasons; (1) it has been operated for almost 30 years and is deteriorated, (2) the output is limited due to insufficient cooling water system, and (3) difficulty of procuring spare parts. Considering the situation above, it is highly recommended that these generating units should be demolished soon after the completion of Bumbuna, the extension of the Kingtom Power Station and Blackhall Road Power Station.

Only Mitsubishi-6 might be repaired with a possible follow-up grant aid from the Government of Japan. JICA has decided to dispatch Mitsubishi engineers to Kingtom around the middle of 2009 to check the conditions of the engine and examine the methods of repair. Therefore, Mitsubishi-6 is expected as a short term power supply source from 2010 to 2014 in considering power balance. Current conditions and proposed demolishing schedule of NPA owned generators are shown in Table 5.2-2.

Table 5.2-2 Status of Generating Plants owned by the NPA (Kingtom Power Station)

Unit No.	Year commissioned	Rated output (MW)	Available capacity (MW)	Current status	Expected decommissioning year
Mirrlees 2	Not yet commissioned	6.9	(6.9)	Not operational: Cylinder head cracked	2009
Mirrlees 3	2002	6.3	(6.3)	Not operational: Crankshaft, connecting rod and lower engine casing damaged	2009
Sulzer 4	1978	9.2	5.6	Operational	2010
Sulzer 5	1980	9.2	(5.6)	Not Operational	2010
Mitsubishi 6	1995	5.0	(3.5)	Not operational: Crank shaft and bearing damaged	2015
Caterpillar 1	2001	1.28	(1.0)	Not operational: Cylinder head damaged	2010
Caterpillar 2	2001	1.28	1.0	Operational	2010
Total		**39.16**	**6.6**		

［Source］NPA and JICA Study Team

5.2.3 Candidate Types of Power Generation

The types of power generation to be considered as candidates for power development planning are thermal power and hydro power as described below.

(1) Thermal Power

The only thermal power currently introduced in Sierra Leone is diesel engine generating system. Conventional (boiler and steam turbine), gas turbine and combined cycle power plants are not introduced. There used to be steam turbine generators at the premises of Blackhall Road substation, however, the engineers at that time had left the NPA and the technology to operate and maintain steam turbines had not been transferred. Steam turbines and gas turbines that are operated at high rotation speed, high temperature and high pressure require advanced technology in operating and maintaining the machines. Therefore, it will take long time for engineers in Sierra Leone to be familiarized with such thermal plants. Based on this circumstance, it is judged that diesel engine generation is the only type of thermal power plant that can be applicable to Sierra Leone at the moment.

Heavy fuel oil-fired low-speed (less than 150 rpm) and middle-speed (less than 750 rpm) diesel engine generators will be considered as base and middle load power plants and package type, diesel oil-fired high-speed diesel engine generators (less than 1,500 rpm, prime condition) will be selected for peaking plants as candidates of thermal power plants in power development plan.

(2) Hydro Power

It was reported in the 1996 Lahmeyer International’s Master Plan Report of Sierra Leone that there is hydro development potential of more than 1,200 MW in Sierra Leone scattered around 27 sites as is shown in Table 5.2-3. The development of these sites could cover the growth in energy demand for the future much more economically than any other type of power sources. Fig.5.2-1 shows the locations of potential hydro power development sites identified by the previous Master Plan Study. As is shown in Table 5.2-3, Yiben proves to be the most promising option for the future hydro power development among the candidate sites in terms of generating cost. Bekongor -III also has an attractive generating cost but its available capacity sharply drops from 85.5 MW to 5MW in dry season. This huge fluctuation of seasonal output and its distant location from Freetown and existing transmission lines (from Bumbuna to Freetown) makes Bekongor-III less attractive.

Table 5.2-3 Candidate Sites for Hydroelectric Power Generation in Sierra Leone

Site	River System	Rated Output (MW)	Utilization Rate (%)	Electric Energy Generated (GWh/yr)	Construction Cost (million US$)	Unit Generating Cost (US ¢ /kWh)
Benkongor I	Sewa River	34.8	69.6	237.2	102.0	7.19
Benkongor II	Sewa River	80.0	55.5	413.7	116.3	6.77
Benkongor III	Sewa River	85.5	70.9	513.1	77.4	3.72
Mange I	Little Scarcies	35.2	75.3	244.1	84.8	5.72
Mange II	Little Scarcies	12.8	84.5	108.6	51.8	7.15
Tendata	Little Scarcies	28.6	77.5	211.4	95.4	6.45
Kuse I	Little Scarcies	28.0	37.8	99.3	123.2	32.14
Kuse II	Little Scarcies	91.8	83.1	679.7	298.0	5.90
Maka	Little Scarcies	21.0	55.4	113.5	77.2	11.65
Kumba	Little Scarcies	48.9	64.3	302.8	166.7	8.14
Kambatimbo	Little Scarcies	65.7	56.1	322.1	81.2	4.93
Kabata Falls	Seli River	2.4	43.0	7.6	9.0	29.35
Rokon	Seli River	31.8	47.4	136.5	72.0	14.09
Bumbuna Falls	Seli River	26.8	80.0	205.8	75.8	5.70
Yiben I	Seli River	61.5	78.9	442.9	90.6	2.89
Yiben II	Seli River	62.1	75.8	430.2	122.4	3.94
Komoia	Seli River	10.8	59.9	61.6	41.5	11.97
Betmai I	Pampana River	52.5	57.7	268.5	69.0	5.88
Betmai II	Pampana River	60.0	50.8	269.9	89.5	8.10
Betmai III	Pampana River	36.6	72.4	249.5	84.5	4.92
Titama	Taia River	22.2	47.1	95.9	52.0	13.06
Levuma	Sewa River	7.8	91.0	59.0	49.4	14.96
Banda Karafaia	Sewa River	7.8	75.3	54.1	34.9	8.57
Goma	Sewa River	9.8	59.4	49.6	21.0	10.43
Baraka	Moa River	39.6	65.2	233.8	87.5	8.26
Nyandehun	Moa River	6.4	98.2	49.4	22.9	7.42
Moyamba	Gbangbaia River	4.4	51.5	21.8	20.4	19.50
Total	—	**974.8**	—	**5,881.6**	**2,216.4**	—

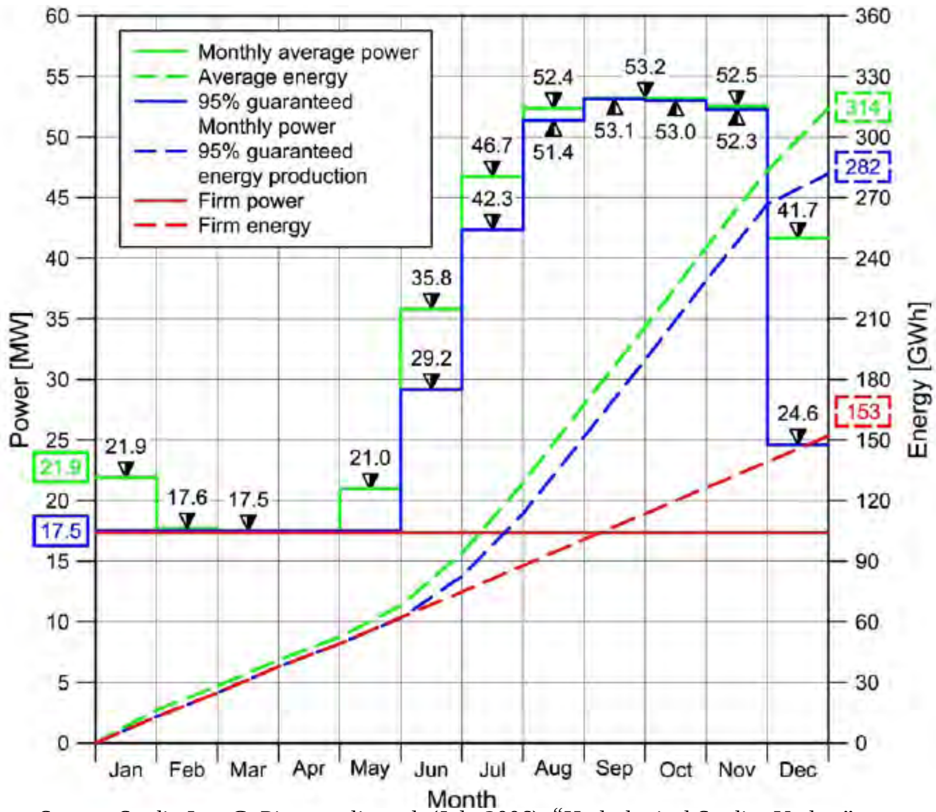
[Source] Lahmeyer International (1995.11), "Power Sector Master Plan, Sierra Leone"

[Note] (yellow) Promising site (unit generating cost of US ¢ 6/kWh or less (cyan) Already developed site

［Source］Lahmeyer International (1995.11), "Power Sector Master Plan, Sierra Leone"

Fig. 5.2-1 Locations of potential hydro power development sites

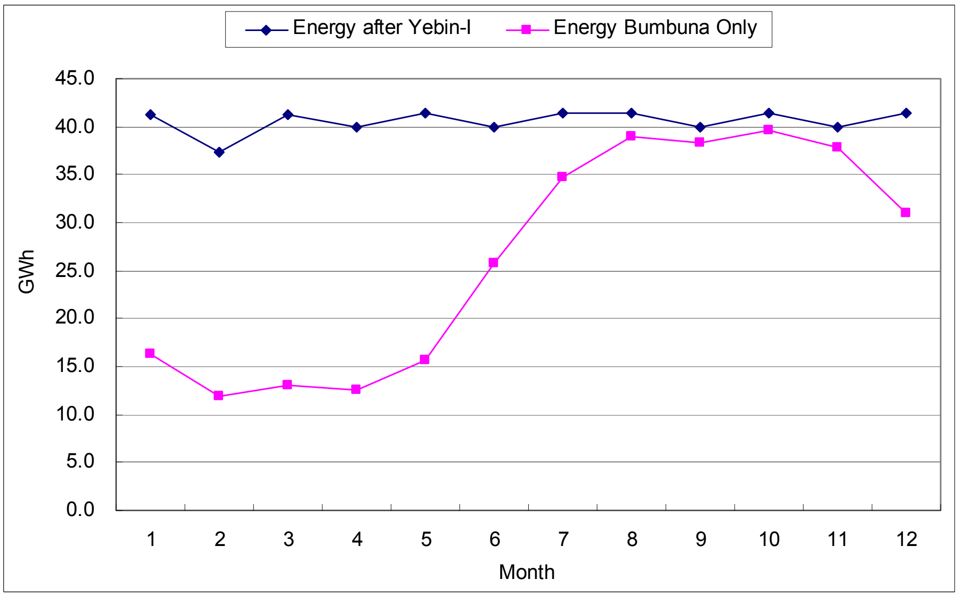
The advantage of constructing Yiben is not only the generating cost itself but also upstream regulation by Yiben dam enables Bumbuma to operate at its maximum capability. The output of Bumbuna fluctuates from 50MW (rated capacity, available in rainy season) to 17.5 MW (dry season) due to seasonal variation of water availability. Fig. 5.2-2 shows monthly output of Bumbuna hydro based on hydrological analysis.



Source: Studio Ing. G. Pietrangeli s. r. l. (July 2006) "Hydrological Studies Update"

Fig. 5.2-2 Monthly Output and Annual Generation of Bumbuna Hydro Power Plant

Fig. 5.2-3 shows the comparison of monthly generation profile of Bumbuna with and without Yiben regulation. If Yiben is constructed, Bumbuna can be operated at almost constant output throughout the year.



[Source] JICA Study Team

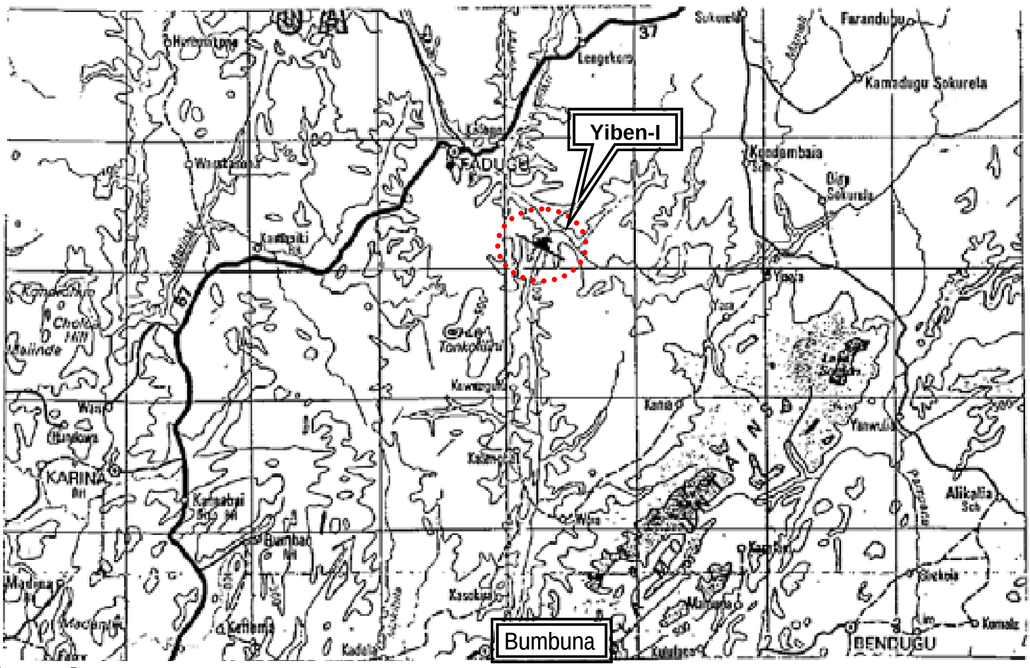
Fig. 5.2-3 Monthly Generation Profile of Bumbuna with and without Yiben Regulation

Furthermore, its proximity (approx. 30 km) to the existing Bumbuna-Freetown transmission line saves the cost to construct long lines going all the way to Freetown. These are the reasons why the Study Team includes Yiben (stage I and II) in both power development scenarios. Considering the following power demand and supply conditions, only Yiben-I and II should be included in candidate hydro sites to be developed until 2025; (1) peak demand in 2025 is forecast to be 136.3 MW, (2) the sum of rated generating capacity of Yiben-I (61.5 MW) and Yiben-II (62.1 MW) is 123.6 MW and (3) firm capacity of Bumbuna will be increased up to 50 MW after the construction of Yiben. Yiben-I should have higher priority than Yiben-II in terms of construction cost and generating cost.

The outline of Yiben-I and Yiben-II is as follows.

1) Yiben-I

Yiben-I is planned as rockfill-dam type hydroelectric power plan located at the Seli River, 26 km upstream of Bumbuna. The rated output is 61.5 MW consisting of three 20.5 MW Francis hydro turbines. Fig. 5.2-4 shows the location and Table 5.2-4 describes the outline of Yiben-I hydro.



［Source］ Lahmeyer International (1995.11), "Power Sector Master Plan, Sierra Leone"

Fig. 5.2-4 Location of Yiben-I Site

In the previous Master Plan Study (Lahmeyer International, 1996), ten years of flow records from 1970 to 1979 measured at Bumbuna stream gauge station in the Seli River were extended to the period from 1943 to 1992 by correlation with areal rainfall and project inflow at Yiben was derived from the extended data. In this Master Plan Study, the project inflow data, hydrological data and meteorological data are used to simulate reservoir operation and to calculate monthly available output (MW) and generation (GWh) of Yiben-I. The results are shown in Fig. 5.2-5.

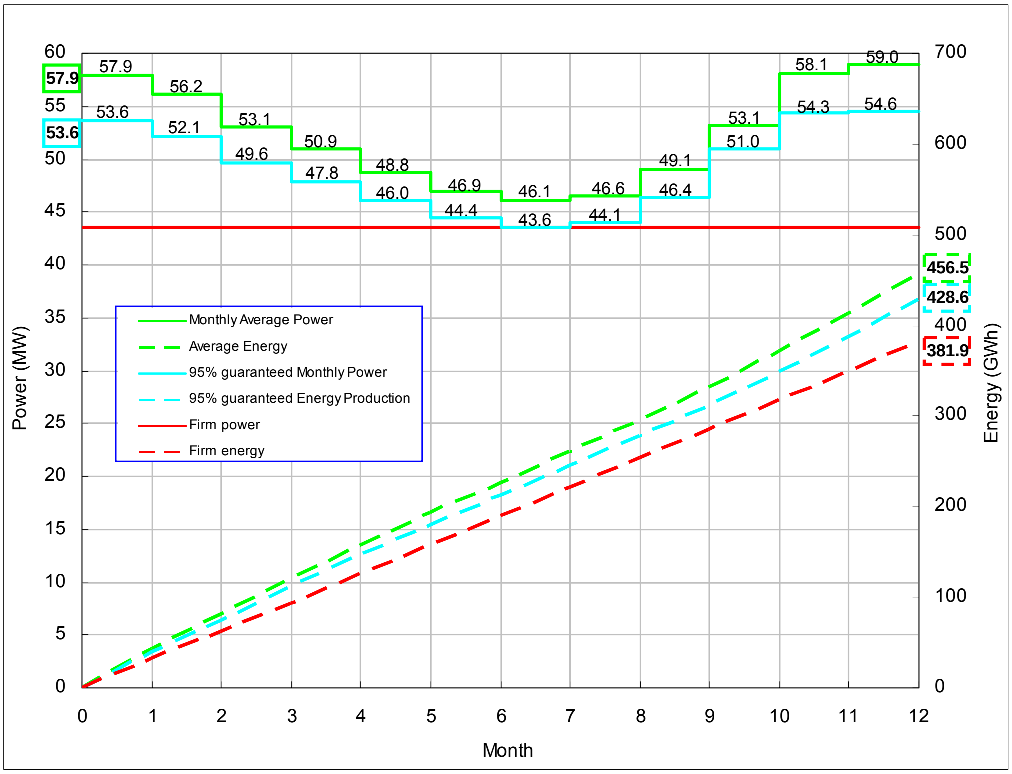
Table 5.2-4 Outline of Yiben-I Hydroelectric Power Plant

Province/District	North / Kondenbaia
Catchment	Seli River
Reservoir Surface Area	$126km^2$
Dam Type	Rockfill Dam
Rated Head	69.8m
Turbines, Rating at 50% Plant Factor	3 Francis 20.5MW
Plant capacity (ex-transformer)	61.5MW
Average/ Guaranteed Continuous Power	50.45/ 48.2MW
Average Annual Generation	442.9GWh
HV Feeder Line	161kV, 30km
Basic Project Cost*	172.3 million US$
Generation Cost (Weighted)*	5.33 USc/kWh

［Source］Lahmeyer International (1995.11), "Power Sector Master Plan, Sierra Leone"

［Remarks］* :

1. Construction cost and generating cost are adjusted to Y2009 prices by considering price escalation.
2. 1US$=97.28JPY

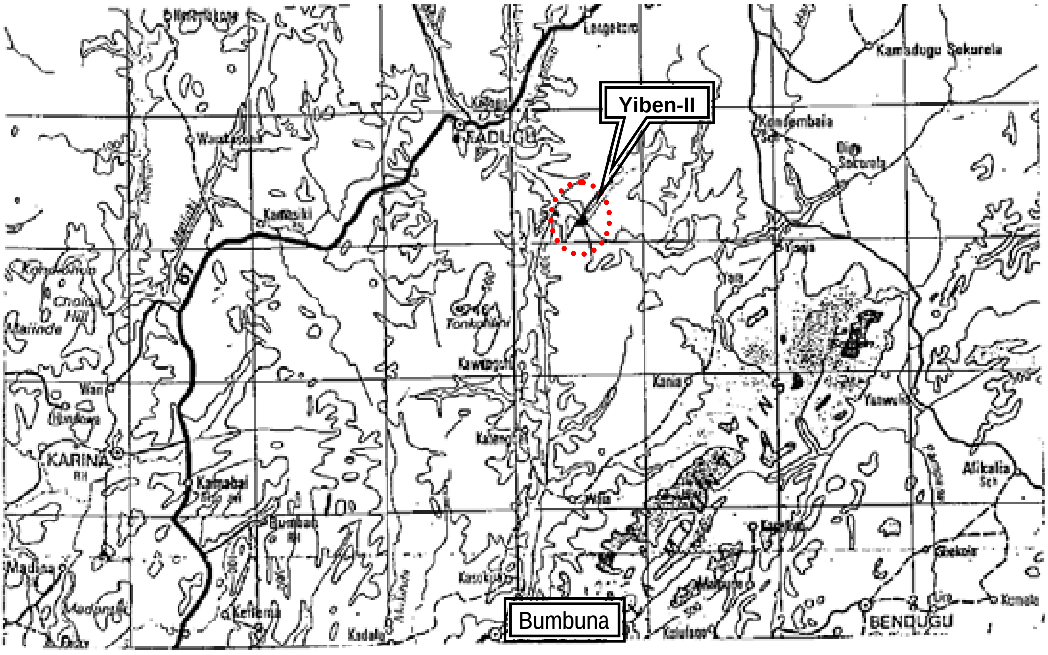


［Source］JICA Study Team

Fig. 5.2-5 Monthly available output (MW) and generation (GWh) of Yiben-I

2) Yiben-II

Yiben-II is planned as rockfill-dam type hydroelectric power plan located at the Seli River, 30 km upstream of Bumbuna. The rated output is 62.1 MW consisting of three 20.7 MW Francis hydro turbines. Fig. 5.2-6 shows the location and Table 5.2-5 describes the outline of Yiben-II hydro.



［Source］ Lahmeyer International (1995.11), "Power Sector Master Plan, Sierra Leone"

Fig. 5.2-6 Location of Yiben-I Site

Table 5.2-5 Outline of Yiben-II Hydroelectric Power Plant

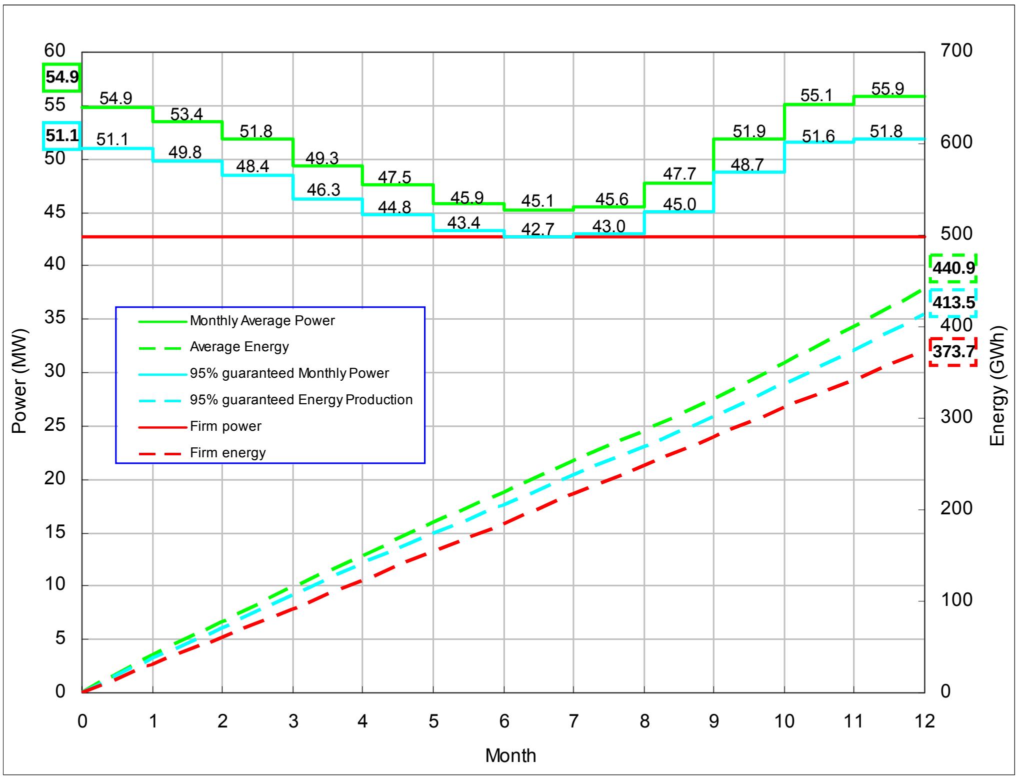
Province/District	North / Kondenbaia
Catchment	Seli River
Reservoir Surface Area	93.2km^2
Dam Type	Rockfill Dam
Rated Head	78.4m
Turbines, Rating at 50% Plant Factor	3 Francis 20.7MW
Plant capacity (ex-transformer)	62.1MW
Average/ Guaranteed Continuous Power	49.1/ 47.4MW
Average Annual Generation	430.2GWh
HV Feeder Line	161kV, 35km
Basic Project Cost*	223.5 million US$
Generation Cost (Weighted)*	7.00 USc/kWh

[Source] Lahmeyer International (1995.11), "Power Sector Master Plan, Sierra Leone"

[Remarks]*:

1. Construction cost and generating cost are adjusted to Y2009 price by considering price escalation
2. 1US$=97.28JPY

In the previous Master Plan Study (Lahmeyer International, 1996), ten years of flow records from 1970 to 1979 measured at Bumbuna stream gauge station in the Seli River were extended to the period from 1943 to 1992 by correlation with areal rainfall and project inflow at Yiben was derived from the extended data. In this Master Plan Study, the project inflow data, hydrological data and meteorological data are used to simulate reservoir operation and to calculate monthly available output (MW) and generation (GWh) of Yiben-II. The results are shown in Fig. 5.2-7.



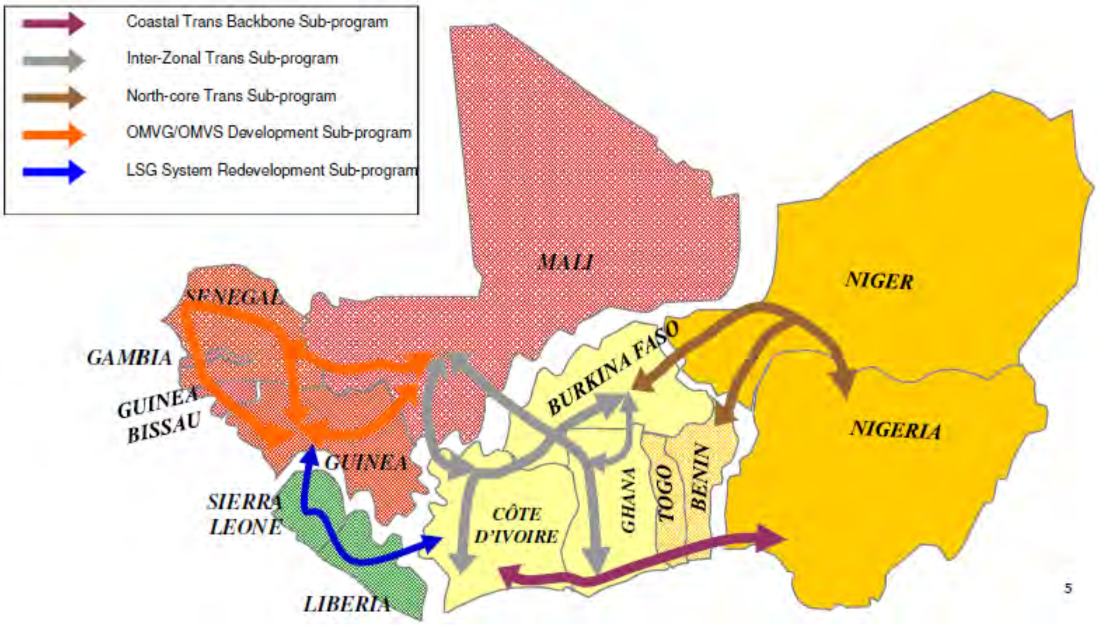
［Source］ JICA Study Team

Fig. 5.2-7 Monthly available output (MW) and generation (GWh) of Yiben-II

(3) West African Power Pool

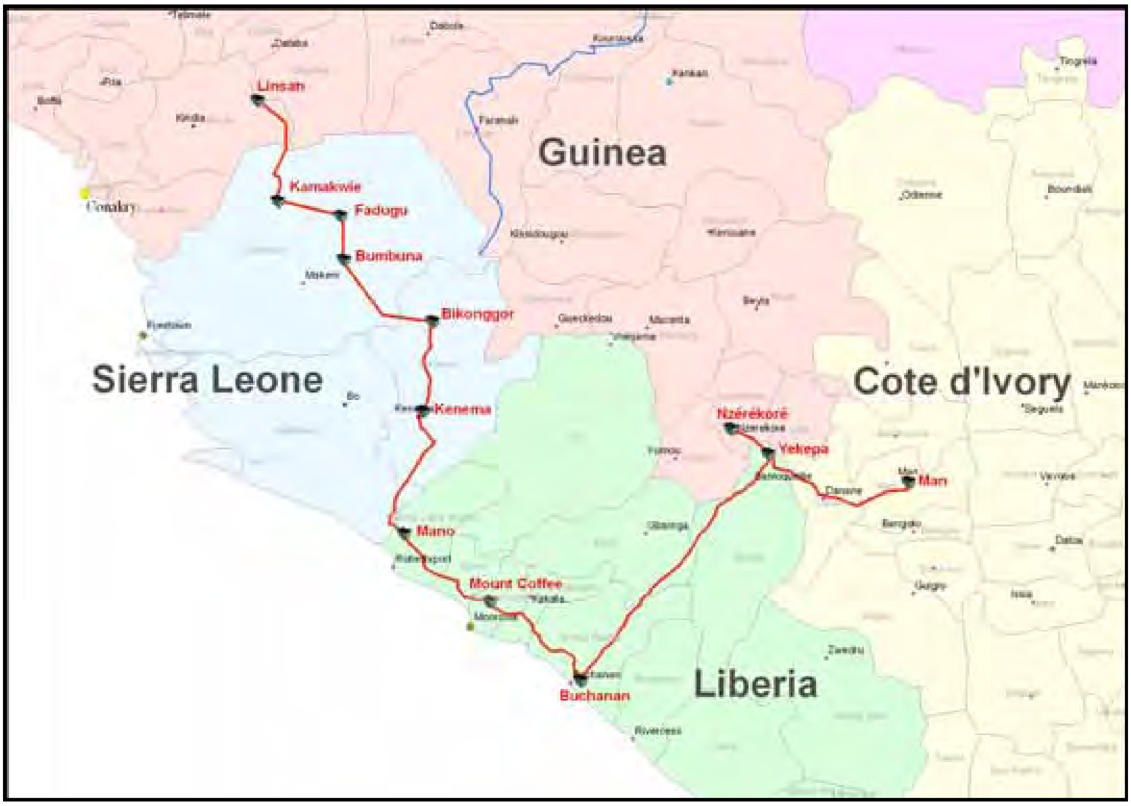
West African Power Pool (WAPP) was created by Decision (A/DEC.5/12/99) during the 22nd Summit of the Authority of ECOWAS Heads of State and Government in order to address the issue of power supply deficiency within West Africa. The vision of WAPP is to integrate the national power system operations into a unified regional electricity market – with the expectation that such mechanism would, over the medium to long term, assure the citizens of ECOWAS Member States a stable and reliable electricity supply at affordable costs. Outline of cross border transmission rinks in the WAPP is shown in Table 5.2-8. WAPP projects consist of not only cross border transmission lines but also development of hydro and thermal power plants.

Fig. 5.2-9 shows cross border transmission routes that connect Sierra Leone and neighboring countries as indicated by a blue line named LSG System Redevelopment Sub-program in Fig. 5.2-8. A 225kV transmission line that will connect Linsan in Guinea and Man in Cote d' Ivory for 1,100km will be constructed. Site reconnaissance and environmental impact assessment for the line has been conducted by the Korean Electric Power Corporation (KEPCO). The interconnection line is expected to be completed in 2014. However, financial resources for the construction work have not been committed yet and at the moment it is unclear whether the project will be realized or not. In addition, current power supply capacity in West African countries is not sufficient as a whole and it is difficult to export or import power even though the interconnection lines are completed without constructing new power plants. Based on above situation, the Study Team refrains from taking power import from the WAPP as a power supply source in power development planning.



［Source］Babatunde Adeyemo (2007), "Overview of WAPP generation and cross border transmission projects", West African Power Industry Convention 2007

Fig. 5.2-8　Outline of Cross Border Transmission Lines in WAPP

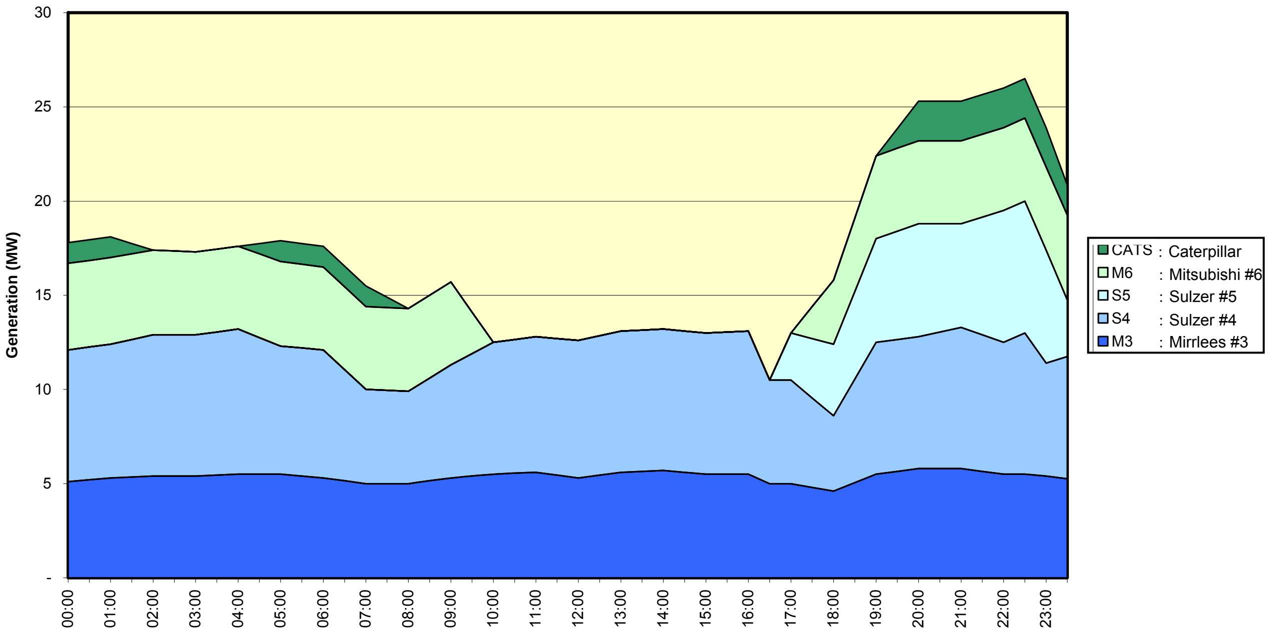


［Source］Korean Electric Power Corporation (2009.1), "CÔTE D'IVOIRE – LIBERIA – SIERRA LEONE – GUINEA INTERCONNECTION PROJECT, Line Route, Environmental and Social Impact Assessment Study, Inception Report"

Fig. 5.2-9　Cross Border Transmission Line Routes in Sierra Leone and Neighboring Countries

5.2.4 Load Duration Curve

The highest peak demand in Western Area that was recorded on December 5, 2002 reached 26.5 MW. The following Fig. 5.2-10 shows the daily load curve on that day.

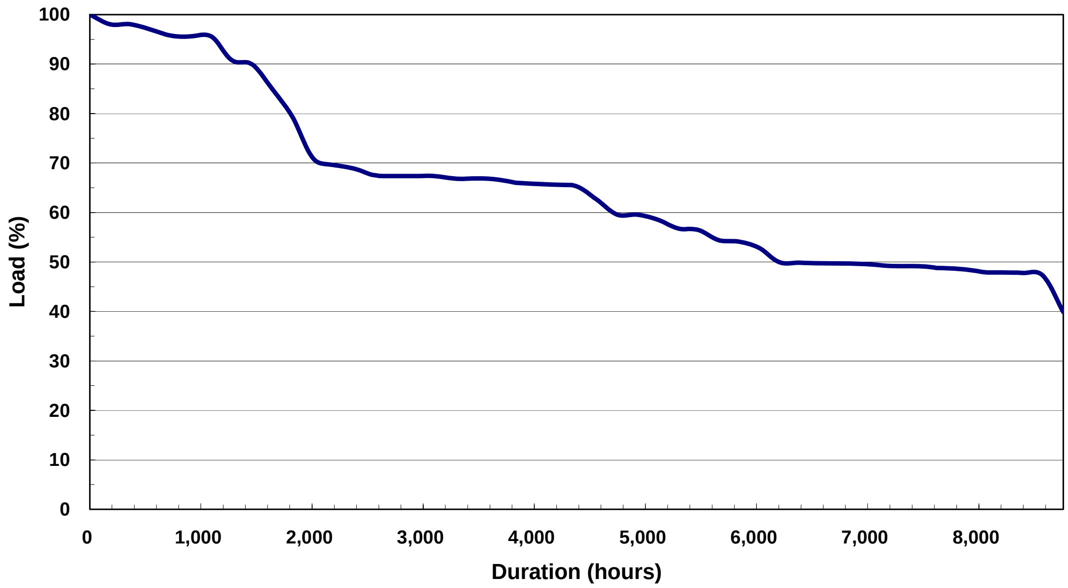


［Source］ Power Planning Associates (2004), "Rehabilitation and Reinforcement of the Western Area Sub-transmission and Distribution, FINAL REPORT"

Fig. 5.2-10 Daily Load Curve on December 5, 2002

The highest daily peak was observed at 22:30, later than ordinary system peak. It also seems strange that daytime demand (10:00am-17:00) is much lower than the demand in midnight and very early morning (23:00-5:00am). According to these features, it is assumed that daily load curve in Western Area represents household electricity demand rather than industrial demand.

Since load shedding is a kind of daily activity in the Western Area power system recently, measured load curve may not represent the actual load pattern. Therefore, it is inevitable that a typical load duration curve is prepared utilizing a load pattern in the past when power supply capacity was sufficient enough to meet power demand. Within the above limitation, daily load curve shown in Fig. 5.2-10 that satisfies the conditions of no-load shedding and availability of hourly load data is utilized to formulate a typical load duration curve as is shown below. In power development planning of this Master Plan Study, generating mode (base, middle and peak) and required capacity of each generating mode is examined based on the load duration curve shown below.



［Source］NPA and JICA Study Team

Fig. 5.2-11 Load Duration Curve in Western Area Power System

5.2.5 Reserve Margin

In this power development planning, LOLP (Loss Of Load Probability) is applied as an indicator that represents power supply reliability and a power development plan with necessary reserve margin that is enough to achieve the target LOLP is to be formulated. LOLP is widely used as the indicator of power supply reliability, for example, in the United States (NERC: North American Electric Reliability Corporation) target LOLP is set as 1day/10years, in Indonesia (PLN) target LOLP is 1day/1year and in Sri Lanka (CEB：Ceylon Electricity Board) target LOLP is 3days/1year. In Sierra Leone, it is very difficult to define current power supply reliability because power demand is always suppressed by load shedding. On the other hand, electricity consumers will require higher quality of electricity along with the economic development of the country. Considering reliability standards of other developing countries and future development of Sierra Leone, target LOLP in the Western Area Power System is set as 7days/1year (1.918%/year) in this study.

In addition, the largest single unit capacity of a diesel generator should be secured as maintenance reserve. Power development plan should satisfy both LOLP and such maintenance reserve.

Theory of Loss of Load Probability (LOLP)

LOLP (Loss of Load Probability) that represents the degree of power supply reliability is defined as time when power supply capacity falls short of power demand. The reasons of supply capacity decrease are seasonal fluctuation of hydro output, forced outage of thermal plants, etc. Probability of forced outage is defined as FOR (Forced Outage Rate).

Suppose the following power supply system as a model to calculate LOLP.

- Power Supply Capacity：30 MW (10 MW×3 units)
- Peak Demand：18 MW
- Forced Outage Rate：10%

The Capacity Outage Probability Table shown below expresses the operation and outage status of generating units as well as the probability of each occasion in this power supply system. Forced outage rate of 10% means that the unit will be operable with the probability of 0.9 (90%) and outage with the probability of 0.1 (10%). The operation/outage status of multi-units can be expressed by multiplying the probability of individual unit. The probability that all three units are operational is calculated as follows; 0.9×0.9×0.9＝0.729.

Table 5.2-6 Capacity Outage Probability Table

Capcacity Outage Cases	Operating Status			Probability of Operating Status					Outage Capacity (MW)
	Unit #1	Unit #2	Unit #3	Unit #1	Unit #2	Unit #3	Total		
All units up	○	○	○	0.9	0.9	0.9	0.729		0
2units up, 1unit down	×	○	○	0.1	0.9	0.9	0.081	0.243	10
	○	×	○	0.9	0.1	0.9	0.081		
	○	○	×	0.9	0.9	0.1	0.081		
1unit up, 2units down	×	×	○	0.1	0.1	0.9	0.009	0.027	20
	×	○	×	0.1	0.9	0.1	0.009		
	○	×	×	0.9	0.1	0.1	0.009		
All units down	×	×	×	0.1	0.1	0.1	0.001		30

[Remarks] ○:Operational, ×:Outage Sum= 1.000

[Source] JICA Study Team

For example, there are three occasions where two units are operable and one unit is out and the sum of the probability is calculated as 0.243(= 0.081 + 0.081 + 0.081). In this case, supply capacity does not fall short because available capacity is 20 MW and larger than the peak demand (18 MW).

There are also three occasions where one unit is operable and two units are out and combined probability of the case is 0.027(= 0.009 + 0.009 + 0.009). In this case available capacity drops up to 10 MW by the capacity outage of 20 MW and falls short of peak demand (18 MW). According to the load duration curve of the system expressed in Fig. 5.2-10, supply shortage continues for 292 days.

There is one occasion where all three units are out and the probability is 0.001(= 0.1×0.1×0.1). In this case, supply shortage continues for 365 days.

where, O, P and t are defined as follows;

O_i : Capacity outage amount that causes supply shortage

P_i : Probability that capacity outage of O_i happens

t_i : Time when capacity outage O_i continues

Hence,

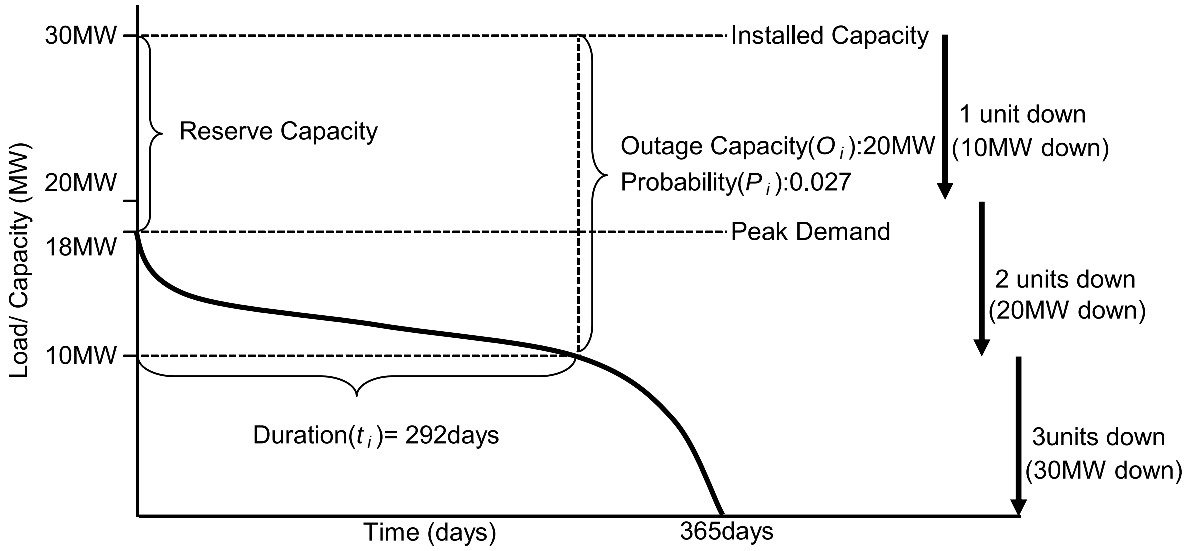
$$\text{LOLP} = \Sigma P_i \cdot t_i$$

LOLP of the model case is calculated as follows based on the conditions of Table 5.2-6 and load duration curve in Fig. 5.2-12.

LOLP ＝ 0.027×292days + 0.001×365days＝8.249 days/year

LOLP can be expressed in percent by dividing the LOLP (days/year) by 365days.

LOLP(%) ＝ 8.249 days/year÷365days ＝ 2.26% /year



［Source］ JICA Study Team

Fig. 5.2-12 Load Duration Curve

5.2.6 Fuel Procurement

In Sierra Leone, parastatal NPC (National Petroleum Company Limited) is the single importer and distributer of heavy fuel oil (HFO) that is the major fuel of diesel engine generators. NPC owns heavy oil storage tanks with the total capacity of 60,000 tons (12,000 tons×5) and stores heavy oil imported from Swiss-based Addax Petroleum. Addax owns heavy oil storage facilities in Senegal, Cote d’Ivoire, Benin and Nigeria and transports heavy oil to Sierra Leone by its tankers. The NPA used to be the biggest consumer of heavy oil receiving 3,000～5,000 tons/month, but currently Sierra Rutile takes first place. NPC expressed an intention to expand its storage facility and handling capability if many HFO-fired diesel generators are introduced in the future.

A 5MW class, HFO-fired diesel generator consumes approximately 720 tons of HFO if it is continuously operated at the rated output for a month. This means that NPA’s past HFO consumption (3,000～5,000 tons/month) is equal to the amount that diesel generators with the capacity of 20～35MW are operated for a month at the rated output. In this study, peak demand in 2025 is forecast to be 136.3 MW. Suppose that 100 MW out of 136.3 MW is supplied by HFO-fired diesel generators and the plants are operated at the utilization factor of 70%, the monthly consumption of HFO will be 10,100 tons. This amount accounts for only 17% of NPC’s HFO storage capacity and fuel supply capability will not be a problem.

While Sierra Leone has rich resources of mining such as iron ore, bauxite, gold, rutile, etc., no coal and gas reserves have been observed. Recently, potential oil reserves were observed offshore of the country. However, it is not clear when and how much oil will be produced. Therefore, for the time being Sierra Leone has no choice other than to import fossil fuel for use in thermal generation.

5.2.7 Earliest Completion Year of Candidate Plants

The possible earliest completion years of the candidate plants such as diesel generating plants and hydroelectric power plants (Yiben-I and II) are estimated as follows taking necessary steps such as fund procurement, details design, bidding, environmental impact assessment, construction, etc. into consideration.

(1) Thermal Power Plant

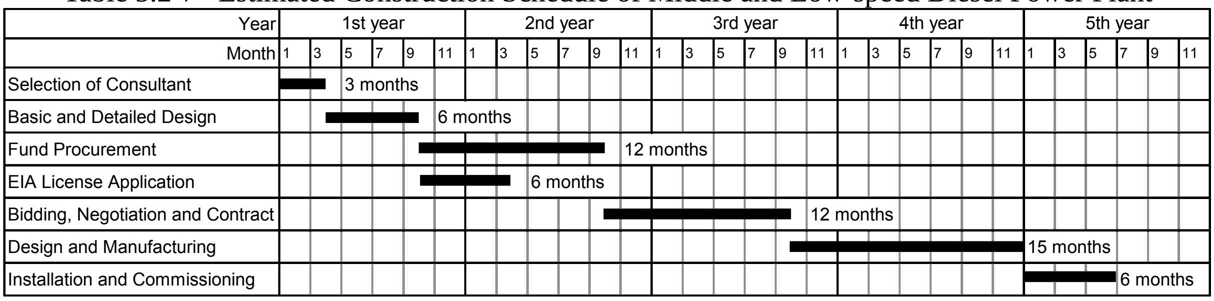
1) High-speed diesel

The earliest completion year of high-speed diesel is set as 2010 because package-type high-speed diesel can be delivered within one year from an order.

2) Mid-speed and low-speed diesel

Since the construction period of mid-speed and low-speed diesel power plant is estimated to be 4.5 years as is shown in Table 5.2-7, the earliest completion year of both types of plants is set as 2014. The third unit, an additional generator to the Blackhall Road Power Station can be completed by the end of 2011 because the request for additional funding has already been applied to BADEA and it seems highly possible that BADEA's board will approve the application. In such case, the third unit will be added as an amendment to the signed contract and the period of fund procurement, bidding, etc. in Table 5.2-7 can be skipped. The third unit of Blackhall Road was deleted from the scope of the project through bidding process due to the limitation of the budget.

Table 5.2-7 Estimated Construction Schedule of Middle and Low-speed Diesel Power Plant

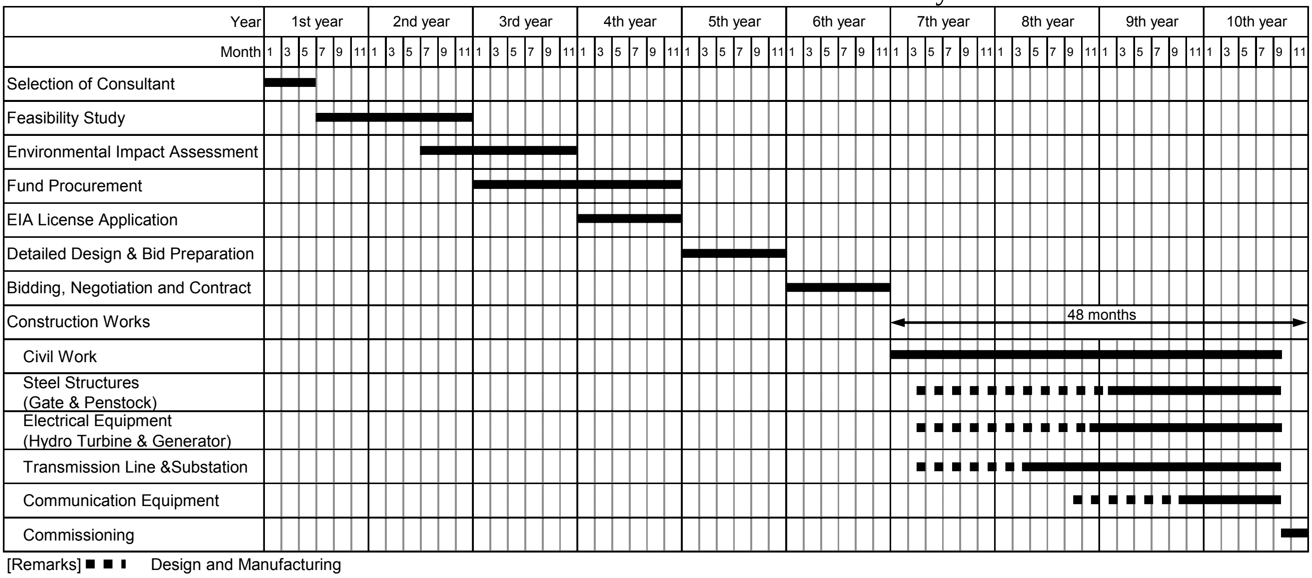


［Source］JICA Study Team

(2) Hydroelectric Power Plant

Since the construction period of Yiben-I and Yiben-II is estimated to be 10 years, as is shown in Table 5.2-8, the earliest completion year of Yiben-I and Yiben-II is set as 2019.

Table 5.2-8 Estimated Construction Schedule of Yiben-I and Yiben-II Hydroelectric Power Plant



［Source］ JICA Study Team

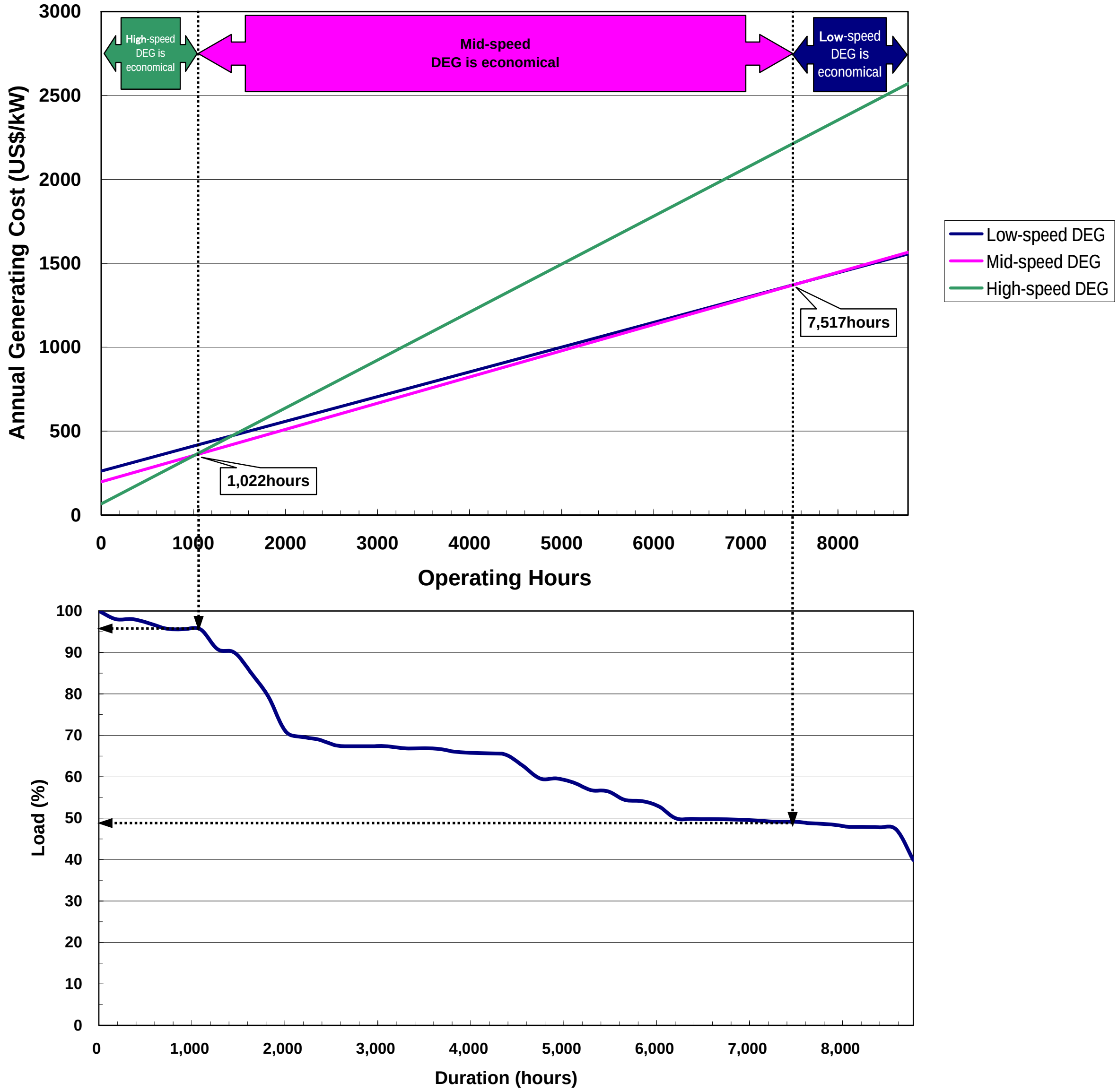
5.3 Examination of Optimal Power Development Plan

5.3.1 Preliminary Examination by Screening Analysis

As a preliminary examination to the least cost power development planning, screening analysis is conducted to seek the most economic operation hours by type of diesel engine generator. Investment cost is converted to annual fixed cost by capital recovery factor and variable cost such as fuel cost and maintenance cost are calculated based on annual operation hours. The sum of fixed cost and variable cost is divided by the capacity (kW) and thus annual generating cost per kW is calculated.

Fig. 5.3-1 shows the screening curves of low, middle and high-speed diesel generators. If the operation hours of a unit are less than 1,022hours/year, high-speed diesel is the most economical, middle speed engine is the most preferable with the operation hours of 1,022～7,517, and low-speed engine is suitable for the operating hours of more than 7,517. This time range can be converted to preferable load range so that each type of generator is operated by combining screening curve and load duration curve (see the following Fig. 5.3-1). As is shown in the figure, load range less than 48% of peak load should be borne by low-speed diesel, 48～95% of peak load should be covered by middle-speed diesel, and higher than 95% of peak should be supplied by high-speed diesel in order to achieve the least cost generation in terms of investment, operation and maintenance.

In this study, least cost analysis of power development plan is conducted by utilizing power development planning software “WASP” (Wien Automatic System Planning Package) developed by IAEA. However, screening analysis is usually applied to formulate a power development plan that mainly consists of thermal power plants by a simple method.



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

Fig. 5.3-1 Screening Curves and Load Duration Curve

CRF (Capital Recovery Factor) that converts investment cost into equalized annual fixed cost is calculated as follows;

$$CRF = \frac{r(1+r)^n}{(1+r)^n - 1}$$

where,

r : Discount Rate

n : Plant Life

In the calculation above, discount rate of 10% /year is applied. Annual generation cost is calculated by the following equation.

Annual generation cost ＝ Investment Cost × CRF ＋ Fuel Cost ＋ O&M Cost

5.3.2 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.

5.3.3 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) Pre-conditions to WASP Analysis

1) Specifications of Candidate Plants

Specifications of the candidate plants are set as is shown in Table 5.3-1. The construction cost of diesel generators is estimated based on the latest market price and the construction cost of Yiben-I and Yiben-II is estimated by adjusting the price of previous Master Plan Study (Lahmeyer International, 1996) to date.

Table 5.3-1 Specifications of Candidate Plants

Items	Thermal Power Plants			Hydro Power Plants	
Plant Type/Name	High-speed diesel	Mid-speed diesel	Low-speed diesel	Yiben-I	Yiben-II
Capacity (MW)	1.8	8.0	15.0	61.5 (20.5x3)	62.1 (20.7x3)
Construction Cost (US$/kW)	400	1,500	2,200	2,802	3,599
Plant life (years)	10	20	30	50	50
Construction period (years)	1	2	2	4	4
Expected earliest completion	2010	2014	2014	2019	2019
Fuel type	Diesel	Heavy Fuel	Heavy Fuel	-	-
Fixed O&M cost (US$/kW-month)	-	-	-	1.2	1.2
Variable O&M cost (US$/MWh)	20	20	20	-	-

[Source] JICA Study Team

Detailed specifications of diesel generators shown in Table 5.3-2 are input to WASP.

Table 5.3-2 WASP Input Data for Diesel Generators

Input items	High-speed Diesel	Mid-speed Diesel	Low-speed Diesel
Rated capacity at generator end (MW)	1.8	8.0	15.0
Minimum operating level* (MW)	0.45	1.9	3.56
Maximum operating capacity* (MW)	1.8	7.6	14.25
Heat rate at minimum operating level (kcal/kWh)	2,600	2,400	2,250
Average incremental heat rate (kcal/kWh)	2,400	2,200	2,060
Spinning reserve as % of unit capacity	0	10	10
Forced outage rate (%)	10	10	10
Scheduled maintenance days per year	10	40	40
Fuel cost (cents/million kcal)	11,284.3	5,050.5	5,050.5
Variable operation and maintenance cost ($/MWh)	20	20	20
Heat value of the fuel used (kcal/kg)	10,032	9,769	9,769

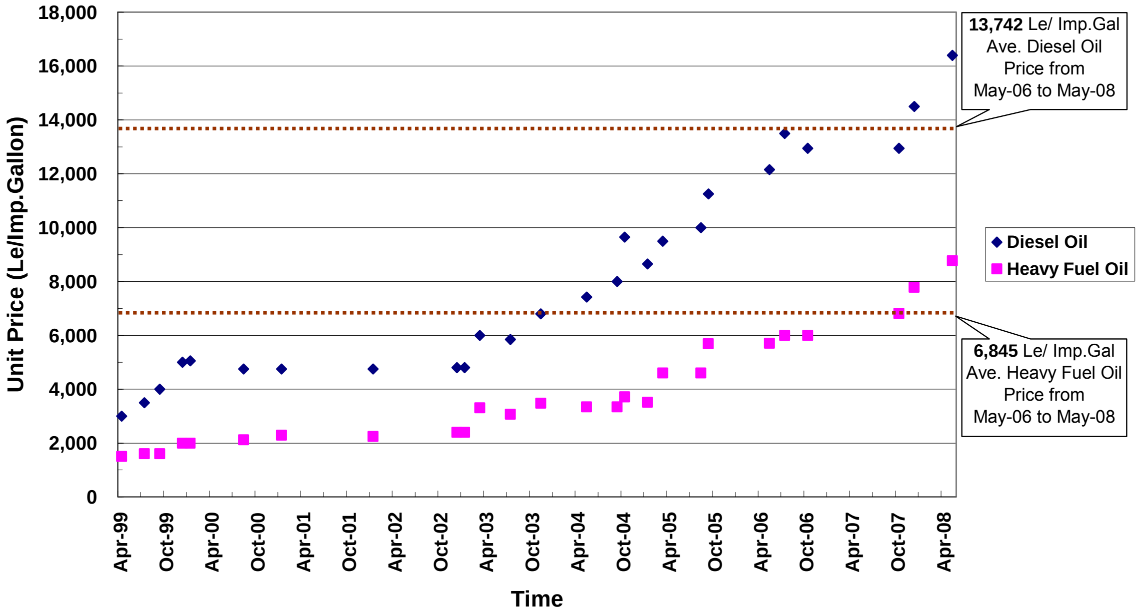
[Remarks] *: capacity at ex-transformer

[Source] JICA Study Team

2) Fuel Price

Due to the price hike in the world oil market, the price of fuel such as HFO and diesel oil that the NPA procures has sharply increased. Fig. 5.3-2 shows the trend of fuel prices since April 1999. The price gradually increased from 2003 and steep hike has been observed since 2007. Since these fuel price trends seem set to continue for the time being, fuel price to be used for power development economics is calculated by averaging the price between May 2006 and May 2008 and the numbers are as follows.

HFO : 6,845 Le/Imp. gallon Diesel Oil : 13,742 Le/Imp. gallon



[Source] NPA

Fig. 5.3-2 Trend of HFO and Diesel Oil Price

3) Discount Rate

The latest interest rate of short term treasury bonds (three months) disclosed by the Bank of Sierra Leone in June 2009 was 9.83 %. Thus, discount rate of 10% is applied to this study for converting future price to present value.

4) Calculation Period

Due to the theory of WASP's economic calculation, a power plant that has huge investment cost and low operating cost like hydro might have larger objective function i.e. might be evaluated as more expensive plant than a plant that has less investment cost and higher operation cost like diesel generators around the end of calculation period. This is because WASP calculates overall generating cost by integrating investment cost and O&M (operation and maintenance) cost during planning period but does not calculate average generating cost for economic plant life. Considering this characteristic of WASP, the calculation period to seek the least cost development plan is extended until 2030 even though the study period is for fifteen years until 2025.

5) Forced Outage Rate (FOR)

10%/year is applied for WASP calculation as the forced outage rate of diesel generators. NERC (North American Electric Reliability Corporation) discloses the reliability statistics of various types and capacity of generating plants in the United States and the EFORd (Equivalent Forced Outage Rate demand) of diesel generators from 2003 to 2007 was 8.41%.

Forced outage of hydro plants is not considered in WASP because hydro plants are highly reliable. Therefore, only the FOR of thermal plants is set in this study.

(2) 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 5.3-3. 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 5.3-3 Least Cost Power Development Plan (Thermal Scenario)

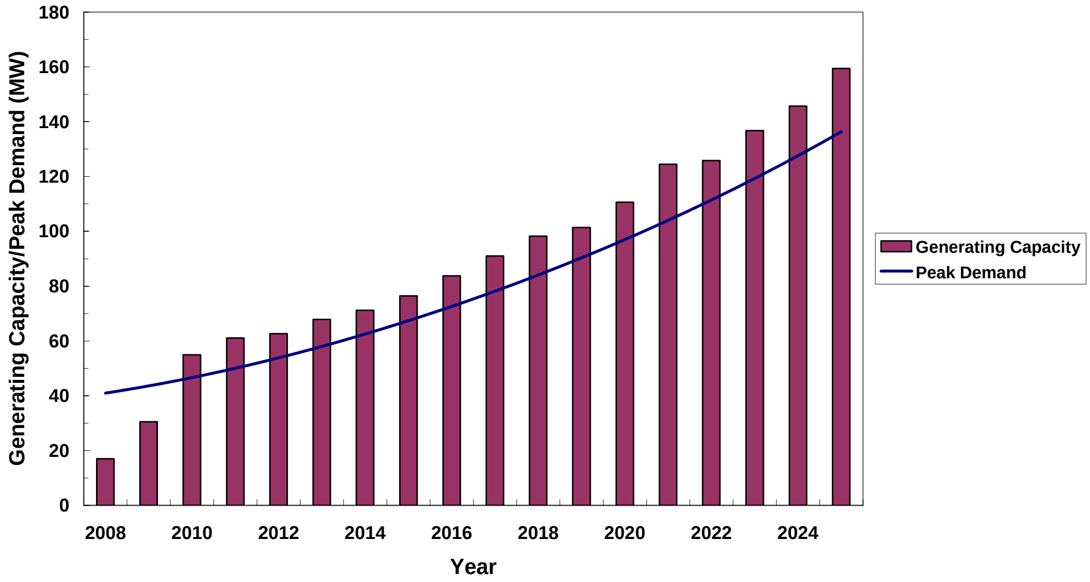
Year	High-speed Diesel (MW) (1.8MW/unit)	Mid-speed Diesel (MW) (8.0MW/unit)	Low-speed Diesel (MW) (15MW/unit)	Annual Total (MW)	LOLP* (%)
2010	5.4			5.4	1.584
2011		8.28		8.3	0.674
2012	1.8			1.8	1.670
2013	5.4			5.4	1.668
2014	3.6			3.6	1.788
2015	1.8	8.0		9.8	1.902
2016		8.0		8.0	1.438
2017		8.0		8.0	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

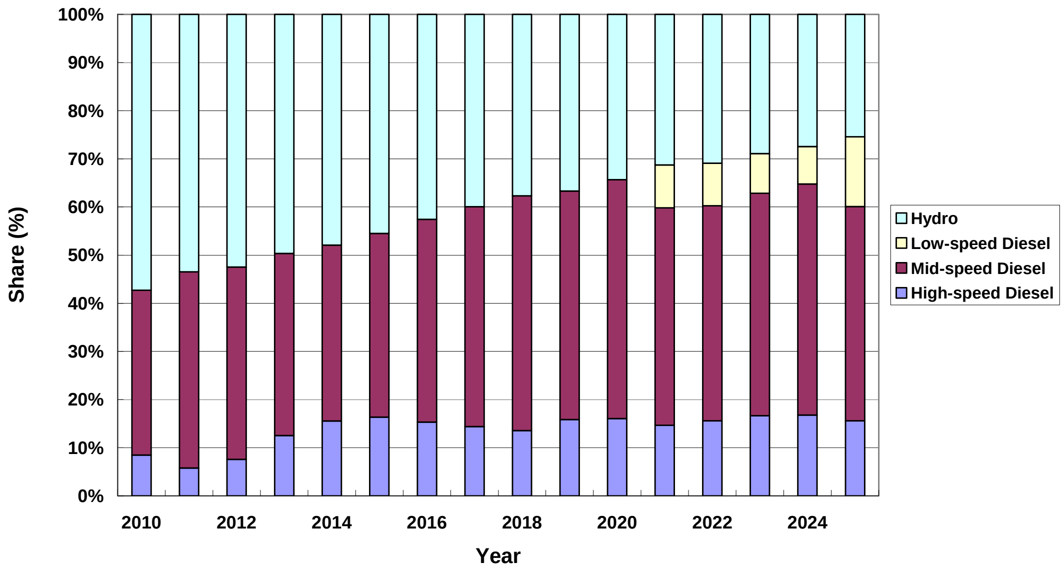
Power demand and supply balance in the development plan above are shown in Fig. 5.3-3 and Table 5.3-5. In terms of the share of generating capacity by the type of generation, hydro accounts for 57% of capacity in 2010, however, the share of diesel gradually increases and it reaches 75% in 2025. Fig.

5.3-4 shows the share of generating capacity by the type of generation.



[Source] JICA Study Team

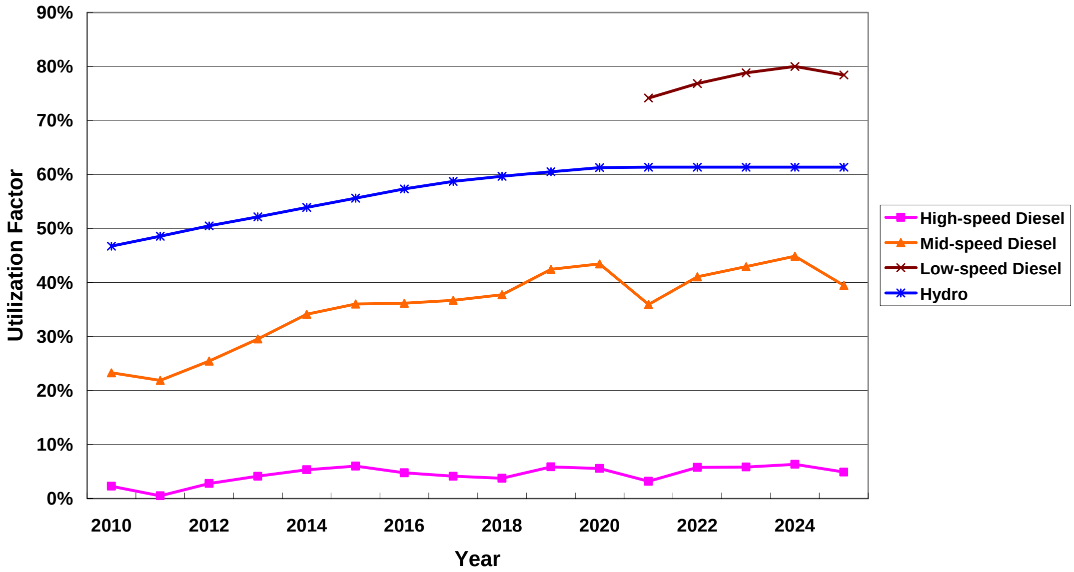
Fig. 5.3-3 Power Demand and Supply Balance (Thermal Dominant Scenario)



[Source] JICA Study Team

Fig. 5.3-4 Share of Generating Capacity by Type of Generation

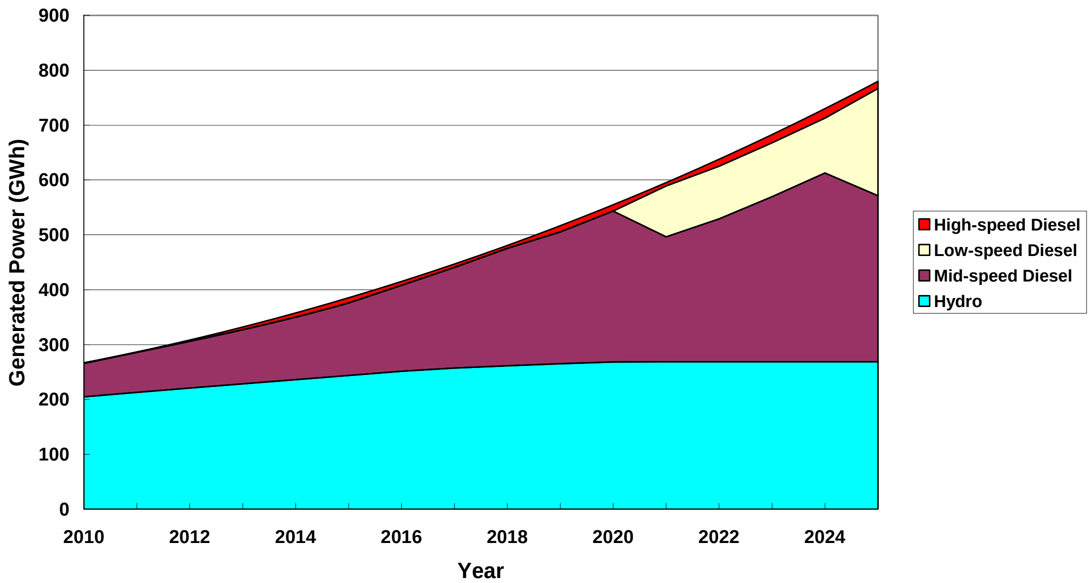
Fig. 5.3-5 shows the utilization factor by the type of generation and plant. The utilization factor of hydro no longer increases after 2020 and Bumbuna seems to reach the limit of its annual generation at the moment. Thus, low-speed diesel generators are added as new base load plants after 2021.



[Source] JICA Study Team

Fig. 5.3-5 Utilization Factor by Type of Generation and Plants

Fig. 5.3-6 shows the composition of generated power by the type of generation and plants. Hydro accounts for 77% of generation in 2010, however, the share gradually decreases and it reaches below 50% in 2020. On the other hand, the share of diesel steadily increases until it reaches 66% in 2025. The share of high-speed diesel is only 1～2% because it is mainly used for peak cut purposes.



[Source] JICA Study Team

Fig. 5.3-6 Composition of Generated Power by Type of Generation and Plant

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 5.3-4. 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 5.3-4 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 5.3-5 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).

(3) 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 5.3-6. Until 2025, 18 MW of high-speed diesel, 40.3 MW of middle-speed diesel and Yiben-I hydro are to be developed.

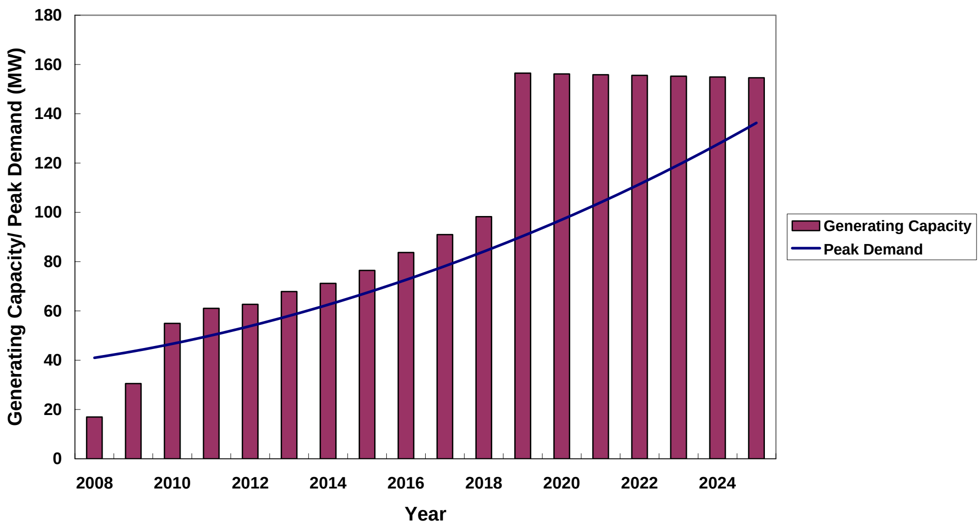
After the completion of Yiben-I in 2019, the system will have plenty of reserve capacity for the time being and this situation allows high-speed diesels used for peaking capacity to be relocated to non-electrified rural areas.

Table 5.3-6 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**	

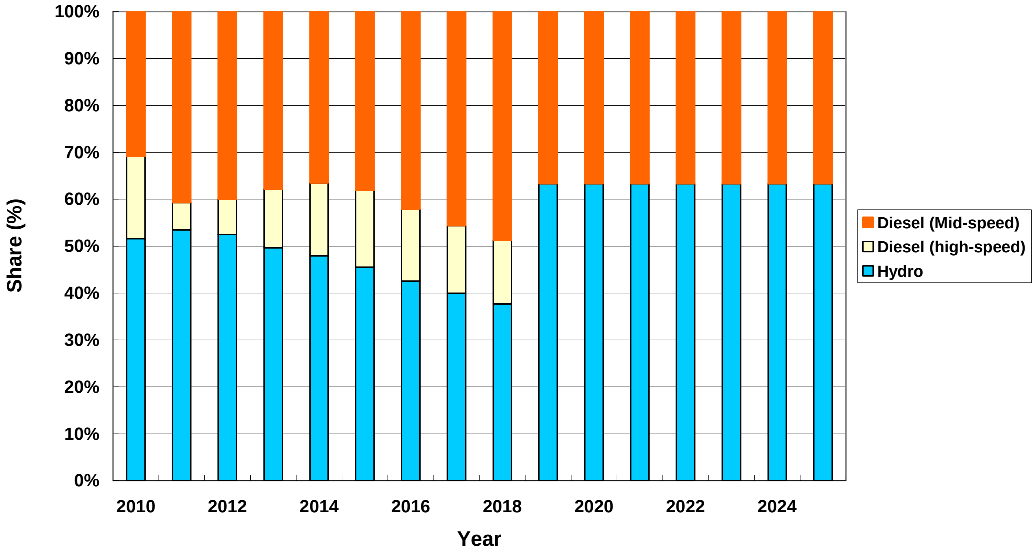
[Remarks]
*: LOLP= Loss of Load Probability
Target LOLP<1.918% (7days/year)
[Source] JICA Study Team

Power demand and supply balance in the case of power development above is shown in Fig. 5.3-7 and Table 5.3-8. The share of generating capacity by the type of generation and plants until 2018 is similar to the Thermal Dominant Scenario. After the completion of Yiben-I in 2019, hydro accounts for 63% of generating capacity. Fig. 5.3-8 shows the share of generating capacity by the type of generation and plants.



[Source] JICA Study Team

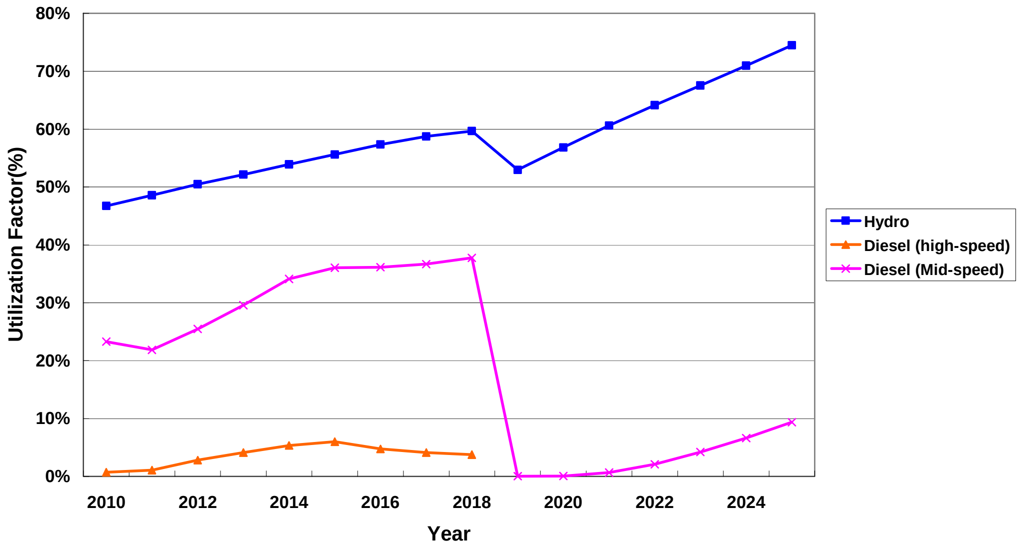
Fig. 5.3-7 Power Demand and Supply Balance (Hydro Dominant Scenario)



[Source] JICA Study Team

Fig. 5.3-8 Share of Generating Capacity by Type of Generation and Plants

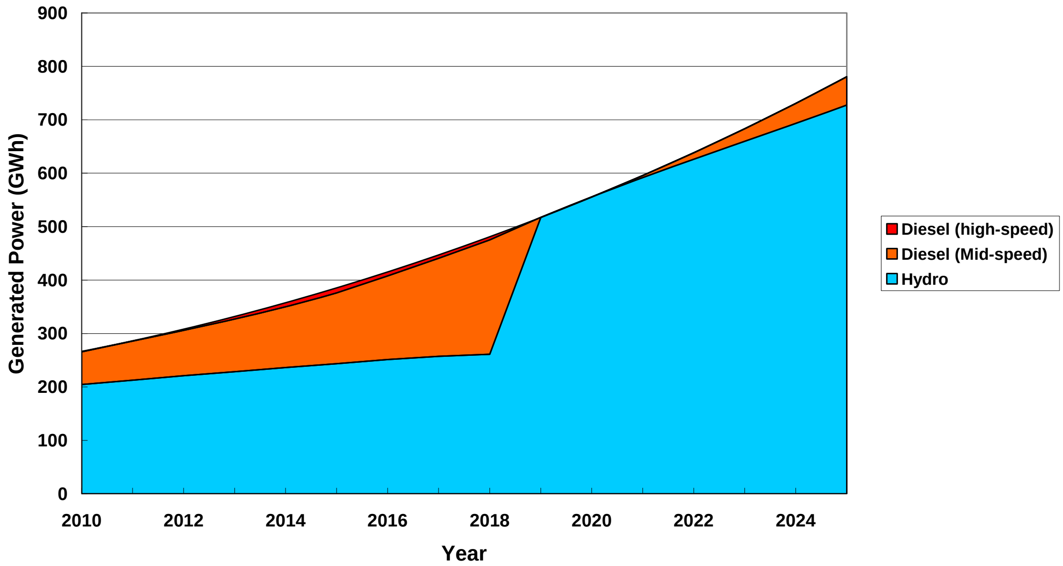
Fig. 5.3-9 shows the utilization factor by the type of generation and plants. After the completion of Yiben-I, the utilization factor of diesel generators sharply drops to lower than 10%.



[Source] JICA Study Team

Fig. 5.3-9 Utilization Factor by Type of Generation and Plants

Fig. 5.3-10 shows the composition of generated power by the type of generation and plants. After 2019, more than 90% of generation will be borne by hydro power.



[Source] JICA Study Team

Fig. 5.3-10 Composition of Generated Power by Type of Generation and Plant

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 5.3-7.

Table 5.3-7 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 5.3-8 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).

Outline of WASP (Wien Automatic System Planning Package)

The WASP-IV code permits finding the optimal expansion plan for a power generating system over a period of up to 30 years, within constraints given by the planner such as reliability criteria (LOLP), reserve margin, fuel availability, environmental emission, etc. The optimum is evaluated in terms of minimum discounted total costs. A simplified description of the model follows.

Each possible sequence of power units added to the system (expansion plan or expansion policy) meeting the constraints is evaluated by means of a cost function (the objective function), which is composed of:

- Depreciable capital investment costs: equipment, site installation costs (I);
- Salvage value of investment costs (S);
- Non-depreciable capital investment costs: fuel inventory, initial stock of spare parts etc. (L);
- Fuel costs (F);
- Non-fuel operation and maintenance costs (M);
- Cost of the energy-not-served (O).

The cost function to be evaluated by WASP can be represented by the following expression:

$$B_j = \sum_{t=1}^{T} [\, \overline{I}_{j,t} - \overline{S}_{j,t} + \overline{L}_{j,t} + \overline{F}_{j,t} + \overline{M}_{j,t} + \overline{O}_{j,t} \,]$$

where:

B_j is the **objective function** attached to the expansion plan j,

t is the time in years (1, 2, ... , T),

T is the length of the study period (total number of years), and

The bar over the symbols has the meaning of discounted values to a reference date at a given discount rate i.

The optimal expansion plan is defined by: Minimum B_j among all j

Fig. 5.3-11 shows a simplified flow chart of WASP-IV illustrating the flow of information from the various WASP modules and associated data files. Descriptions of WASP modules are as follows.

Module 1, LOADSY (**Load Sy**stem Description), processes information describing period peak loads and load duration curves for the power system over the study period.

Module 2, FIXSYS (**Fix**ed **Sys**tem Description), processes information describing the existing generation system and any predetermined additions or retirements, as well as information on any constraints imposed by the user on environmental emissions, fuel availability or electricity generation by some plants.

Module 3, VARSYS (**Var**iable **Sys**tem Description), processes information describing the various generating plants which are to be considered as candidates for expanding the generation system.

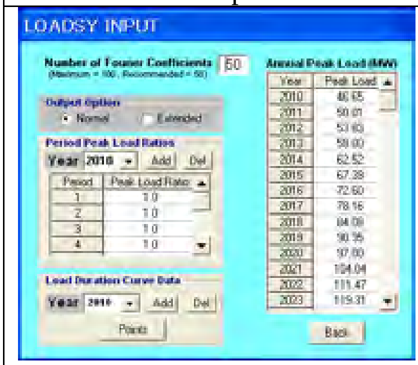
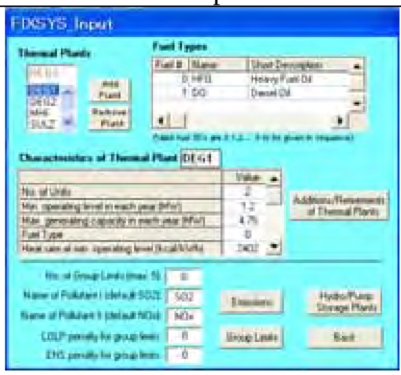
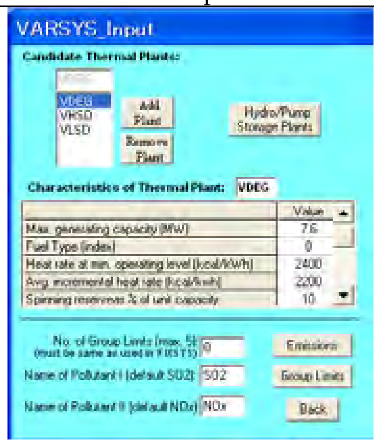
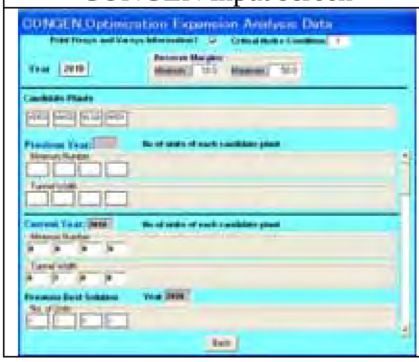
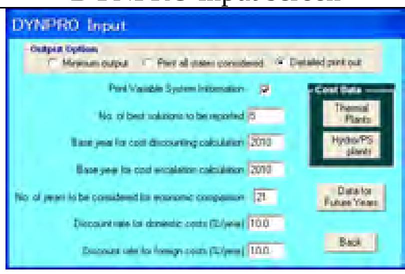
Module 4, CONGEN (**Con**figuration **Gen**erator), calculates all possible year-to-year combinations of expansion candidate additions which satisfy certain input constraints and which in combination with the fixed system can satisfy the loads. CONGEN also calculates the basic economic loading order of the combined list of FIXSYS and VARSYS plants.

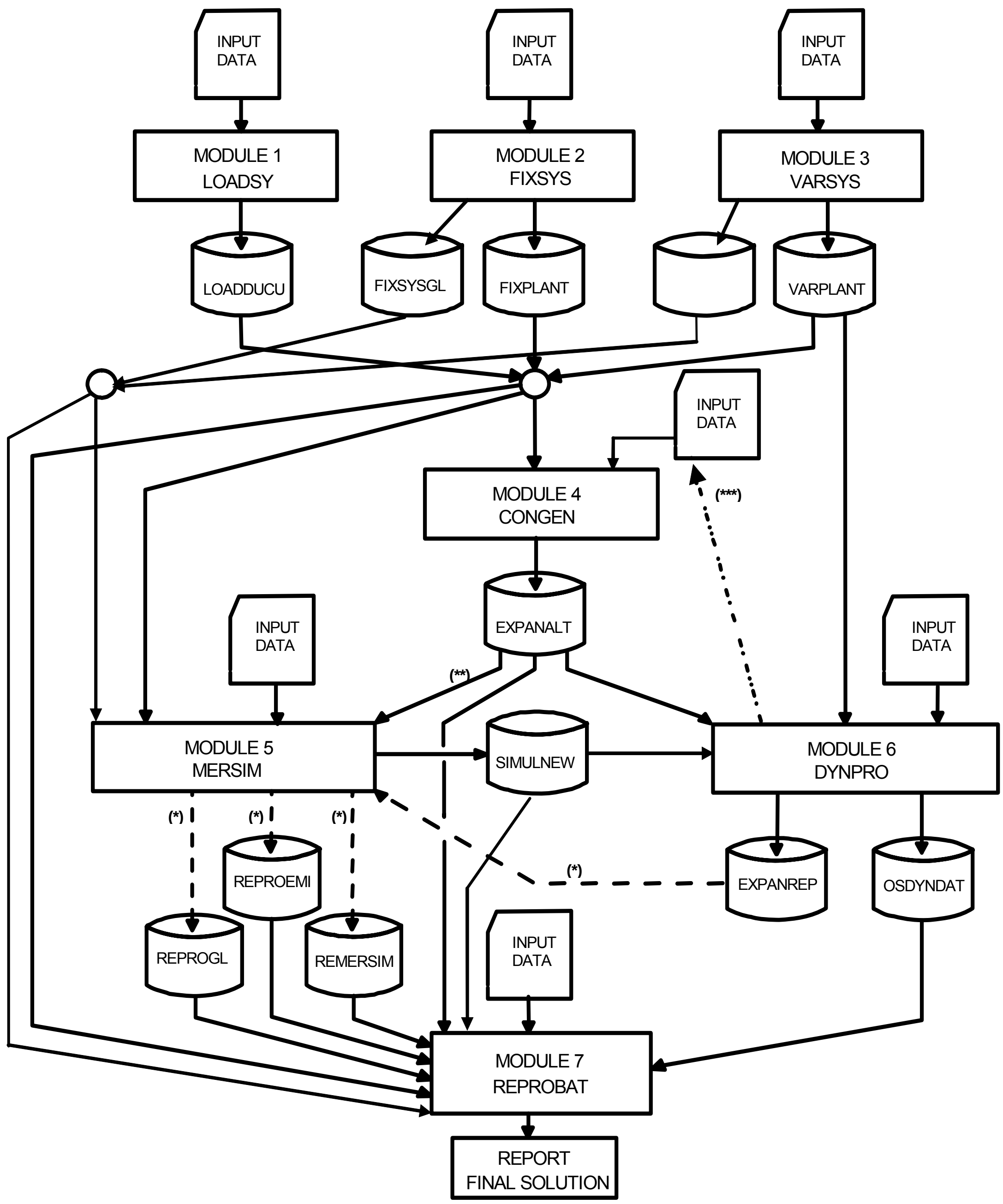
Module 5, MERSIM (**Mer**ge and **Sim**ulate), considers all configurations put forward by CONGEN and uses probabilistic simulation of system operation to calculate the associated production costs, energy-not-served and system reliability for each configuration. In the process, any limitations imposed on some groups of plants for their environmental emissions, fuel availability or electricity generation are also taken into account. The dispatching of plants is determined in such a way that plant availability, maintenance requirement, spinning reserve requirements and all the group-limitations are satisfied with minimum cost. MERSIM can also be used to simulate the system operation for the best solution provided by the current DYNPRO run and in this mode of operation is called REMERSIM.

Module 6, DYNPRO (**Dyn**amic **Pr**ogramming **O**ptimization), determines the optimum expansion plan based on previously derived operating costs along with input information on capital costs, energy-not-served cost and economic parameters and reliability criteria.

Module 7, REPROBAT (**Rep**ort W**r**iter **o**f WASP in a **Bat**ched Environment), writes a report summarizing the total or partial results for the optimum or near optimum power system expansion plan and for fixed expansion schedules.

[Examples of WASP input screens]

LOADSY input screen	FIXSYS input screen	VARSYS input screen
		
CONGEN input screen	MERSIM input screen	DYNPRO input screen
		



(*) *FOR RESIMULATION OF BEST SOLUTION ONLY*

(**) *OMMIT FOR RESIMULATION OF BEST SOLUTION*

(***) *ITERATION PATTERN IF BEST SOLUTION STILL CONSTRAINED*

[Source] WASP-IV User's Manual

Fig. 5.3-11 Simplified flow chart of the WASP-IV computer code

5.4 Evaluation of Power Development Plans

5.4.1 Evaluation of Power Development Scenarios

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 5.4-1. 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 5.4-1 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

5.4.2 Sensitivity Analysis

Sensitivity analyses in which Hydro Dominant Scenario is situated as the Base Case of power development are conducted with the variation of fuel price, forced outage rate and discount rates.

(1) Worse Forced Outage Rate (FOR=20%)

In the base case analysis, forced outage rate of 10% is applied. In this case, forced outage rate of 20% is applied and the least cost power development plan that meets the target reliability standard (LOLP ＜7days/year or 1.918) is calculated (Table 5.4-2). In this case, 9 MW (5 units) more high-speed diesel generators are required and it necessitates additional US$7.5 million investment compared to the base case.

Table 5.4-2　Sensitivity Analysis on Power Development Plan（FOR=20%/year）

Year	Base Case (FOR=10%)					Forced Outage Rate = 20%				
	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* (%)	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	10.8			10.8	1.820
2011		8.28		8.28	0.674		8.28		8.3	1.098
2012	1.8			1.8	1.670	3.6			3.6	1.665
2013	5.4			5.4	1.668	5.4			5.4	1.758
2014	3.6			3.6	1.788	5.4			5.4	1.607
2015	1.8	8		9.8	1.902	1.8	8.0		9.8	1.911
2016		8		8	1.438		8.0		8.0	1.735
2017		8		8	1.240		8.0		8.0	1.738
2018		8		8	1.159		8.0		8.0	1.827
2019	(-18.0)		61.5	61.5	<0.0005	(-27.0)		61.5	61.5	<0.0005
2020				0	<0.0005				0.0	<0.0005
2021				0	<0.0005				0.0	<0.0005
2022				0	<0.0005				0.0	0.004
2023				0	0.003				0.0	0.050
2024				0	0.049				0.0	0.383
2025				0	0.475				0.0	1.830
Total	**18.0**	**40.3**	**61.5**	**119.8**		**27.0**	**40.3**	**61.5**	**128.8**	

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

[Source] JICA Study Team

(2) Higher Fuel Price

In this case, the highest fuel price so far recorded in May 2008 is applied to calculate the least cost power development plan. The results are shown in Table5.4-3. HFO price of Le 8,768/ Imp.gallon (28% higher) and diesel oil price of Le 16,400/ Imp.gallon (19% higher) are used. Even though the fuel price increases up to the level in May 2008, least cost power development pattern will be the same as the base case.

Table 5.4-3　Sensitivity Analysis on Power Development Plan (Higher Fuel Price)

Year	Base Case					Fuel Price Inflated				
	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* (%)	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	5.4			5.4	1.584
2011		8.28		8.28	0.674		8.28		8.3	0.674
2012	1.8			1.8	1.670	1.8			1.8	1.670
2013	5.4			5.4	1.668	5.4			5.4	1.668
2014	3.6			3.6	1.788	3.6			3.6	1.788
2015	1.8	8		9.8	1.902	1.8	8.0		9.8	1.902
2016		8		8	1.438		8.0		8.0	1.438
2017		8		8	1.240		8.0		8.0	1.240
2018		8		8	1.159		8.0		8.0	1.159
2019	(-18.0)		61.5	61.5	<0.0005	(-18.0)		61.5	61.5	<0.0005
2020				0	<0.0005				0.0	<0.0005
2021				0	<0.0005				0.0	<0.0005
2022				0	<0.0005				0.0	<0.0005
2023				0	0.003				0.0	0.003
2024				0	0.049				0.0	0.049
2025				0	0.475				0.0	0.475
Total	**18.0**	**40.3**	**61.5**	**119.8**		**18.0**	**40.3**	**61.5**	**119.8**	

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

[Source] JICA Study Team

(3) Lower Fuel Price

In this case, fuel price is reduced by 25% from the base case price. High-speed diesel becomes more economical compared to mid-speed with the situation of lower fuel price and 5.4 MW (3 units) more high-speed diesel generators and 8 MW (1unit) less mid-speed diesel generator are selected in the least cost development pattern. Still, the desirable completion year of Yiben-I is 2019.

Table 5.4-4 Sensitivity Analysis on Power Development Plan (Lower Fuel Price)

Year	Base Case					Fuel Price Deflated (-25%)				
	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* (%)	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	5.4			5.4	1.584
2011		8.28		8.28	0.674		8.28		8.3	0.674
2012	1.8			1.8	1.670	1.8			1.8	1.670
2013	5.4			5.4	1.668	5.4			5.4	1.668
2014	3.6			3.6	1.788	3.6			3.6	1.788
2015	1.8	8		9.8	1.902	1.8	8.0		9.8	1.902
2016		8		8	1.438	5.4			5.4	1.881
2017		8		8	1.240		8.0		8.0	1.606
2018		8		8	1.159		8.0		8.0	1.478
2019	(-18.0)		61.5	61.5	<0.0005	(-23.4)		61.5	61.5	<0.0005
2020				0	<0.0005				0.0	<0.0005
2021				0	<0.0005				0.0	<0.0005
2022				0	<0.0005				0.0	0.001
2023				0	0.003				0.0	0.014
2024				0	0.049				0.0	0.187
2025				0	0.475				0.0	1.361
Total	**18.0**	**40.3**	**61.5**	**119.8**		**23.4**	**32.3**	**61.5**	**117.2**	

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

[Source] JICA Study Team

(4) Higher Discount Rate

Discount rate of 10%/year is applied to the base case analysis while discount rate of 12% is applied in this sensitivity analysis. As is shown in Table 5.4-5, the least cost development pattern of this case (discount rate = 12%/year) is the same as the case of lower fuel price (25% lower).

Table 5.4-5 Sensitivity Analysis on Power Development Plan (Discount Rate=12%)

Year	Base Case					Discount Rate Increased (12%/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* (%)	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	5.4			5.4	1.584
2011		8.28		8.28	0.674		8.28		8.3	0.674
2012	1.8			1.8	1.670	1.8			1.8	1.670
2013	5.4			5.4	1.668	5.4			5.4	1.668
2014	3.6			3.6	1.788	3.6			3.6	1.788
2015	1.8	8		9.8	1.902	1.8	8.0		9.8	1.902
2016		8		8	1.438	5.4			5.4	1.881
2017		8		8	1.240		8.0		8.0	1.606
2018		8		8	1.159		8.0		8.0	1.478
2019	(-18.0)		61.5	61.5	<0.0005	(-23.4)		61.5	61.5	<0.0005
2020				0	<0.0005				0.0	<0.0005
2021				0	<0.0005				0.0	<0.0005
2022				0	<0.0005				0.0	0.001
2023				0	0.003				0.0	0.014
2024				0	0.049				0.0	0.187
2025				0	0.475				0.0	1.361
Total	**18.0**	**40.3**	**61.5**	**119.8**		**23.4**	**32.3**	**61.5**	**117.2**	

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

[Source] JICA Study Team

(5) Lower Discount Rate

Discount rate of 10%/year is applied to the base case analysis while discount rate of 8% is applied in this sensitivity analysis. As is shown in Table 5.4-6, the least cost development pattern of this case (discount rate = 8%/year) is the same as the base case.

Table 5.4-6 Sensitivity Analysis on Power Development Plan (Discount Rate = 8%)

Year	Base Case					Discount Rate Decreased (8%/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* (%)	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	5.4			5.4	1.584
2011		8.28		8.28	0.674		8.28		8.3	0.674
2012	1.8			1.8	1.670	1.8			1.8	1.670
2013	5.4			5.4	1.668	5.4			5.4	1.668
2014	3.6			3.6	1.788	3.6			3.6	1.788
2015	1.8	8		9.8	1.902	1.8	8.0		9.8	1.902
2016		8		8	1.438		8.0		8.0	1.438
2017		8		8	1.240		8.0		8.0	1.240
2018		8		8	1.159		8.0		8.0	1.159
2019	(-18.0)		61.5	61.5	<0.0005	(-18.0)		61.5	61.5	<0.0005
2020				0	<0.0005				0.0	<0.0005
2021				0	<0.0005				0.0	<0.0005
2022				0	<0.0005				0.0	<0.0005
2023				0	0.003				0.0	0.003
2024				0	0.049				0.0	0.049
2025				0	0.475				0.0	0.475
Total	**18.0**	**40.3**	**61.5**	**119.8**		**18.0**	**40.3**	**61.5**	**119.8**	

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

[Source] JICA Study Team

(6) Summery of the Result of Sensitivity Analysis

Even if the fuel price and discount rate is changed, power development pattern will not largely differ from the base case scenario and the economic benefit of completing Yiben-I in 2019 is robust. However, additional reserve capacity will be required and financial burden of NPA will be increased if forced outage rate is worsened.

5.5 Recommendations to Realize the Proposed Power Development Plan

In order to realize the proposed power development plan, the government of Sierra Leone, the Ministry of Energy and Water Resources and the NPA are strongly recommended to deal with the following issues as soon as possible.

5.5.1 Revision of Feasibility Study on Yiben

A feasibility study on Bumbuna and Yiben was conducted in the past, however, the study was completed in 1980. Since then, almost 30 yeas have passed and the contents of the feasibility study should be revised in order to conform to the changes of social, natural and economic environment.

5.5.2 Fund Procurement

No financial resources have been committed to the proposed power development project so far. Fund procurement, including the examination of financial scheme, is extremely important to realize the power development projects because the construction of Yiben-I requires the huge investment of approximately US$190 million.