Sri Lanka
Ceylon Electricity Board

Development Planning on Optimal Power Generation for Peak Demand in Sri Lanka

Final Report
Summary

February 2015

Japan International Cooperation Agency
Electric Power Development Co., Ltd.

IL
JR
15-022

TABLE OF CONTENTS

APPENDIX

LIST OF TABLES

LIST OF FIGURES

ABBREVIATION

Abbreviation	Formal Name
ADB	Asian Development Bank
ADCC	Auto Diesel Combined Cycle
ADGC	Auto Diesel Gas Turbine
AMI	Advanced Metering Infrastructure
BOD	Biochemical Oxygen Demand
BOI	Board of Investment
C/P	Counterpart
C_2F_6	Hexafluoroethane
CEA	Central Environment Authority
CEB	Ceylon Electricity Board
CF_4	Carbon Tetrafluoride
CFL	Compact Fluorescent Lamp
CFL	Compact Fluorescent Lamp
CH_4	Methane
CO	Carbon Monoxide
CO_2	Carbon Dioxide
COD	Chemical Oxygen Demand
CPC	Ceylon Petroleum Corporation
CR	Critically Endangered
CST	Coal Steam Thermal
DFR	Draft Final Report
DG	Director General
DGM	Deputy General Manager
DO	Dissolved Oxygen
DSM	Demand Side Management
EIA	Environmental Impact Assessment
ELT	Economic Life Time
EMP	Environmental Management Plan
EN	Endangered
ENEPEP	Energy and Power Evaluation Program
EPL	Environmental Protection License
EPZZ	Export Processing Zones
EW	Extinct in the Wild
EX	Extinct
F/S	Feasibility Study
FAC	Fuel Adjustment Charge
FAO	Food and Agricultural Organization
FIT	Feed-in Tariff
FOB	Free on Board
GBM	Geological Survey and Mines Bureau
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GMT	Greenwich Mean Time

Abbreviation	Formal Name
GN	Grama Niladari
GSHAP	Global Seismic Hazard Assessment Program
GTW	Gas Turbine World
HC	Highland Complex
IAEA	International Atomic Energy Agency
IAS	Invasive Alien Species
IBAs	Important Bird Areas
IEA	International Energy Agency
IEE	Initial Environmental Evaluation
IPP	Independent Power Producer
IUCN	International Union for Conservation of Nature
JETRO	Japan External Trade Organization
JICA	Japan International Cooperation Agency
KC	Kadugannawa Complex
LAA	Land Acquisition Act
LC	Least Concern
LCLTGEP	Least Cost Long Term Generation Expansion Plan
LECO	Lanka Electricity Company
LED	Light Emitting Diode
LKR	Lanka Rupee
LNG	Liquid Natural Gas
LNG IGCC	LNG Integrated Gas Combined Cycle PP
LOLP	Loss of Load Probability
LTGEP	Long Term Generation Expansion Plan
LTTDP	Long Term Transmission Development Plan
LTTE	Liberation Tigers of Tamil Eelam
MAB	Man and the Biosphere
MOPE	Ministry of Power and Energy
MOU	Memorandum of Understandings
MPN	Most Probable Number
N/A	not applicable
N_2O	Dinitrogen Monoxide
NBRO	National Building Research Organization
NCSDP	National Committee on Seismic Design Parameters
NEA	National Environmental Act
NGO	Non-governmental Organization
NIRP	National Involuntary Resettlement Policy
NO_2	Nitrogen Dioxide
NO3-N	Nitrate Nitrogen
NTFPs	Non-timber forest products
O&M	Operation and Maintenance
PAA	Project Approving Agency
PD	Project Director
PGCIL	Power Grid Corporation of India Limited

Abbreviation	Formal Name
PI	Preliminary Information
PM10	Particulate Matter 10
PM2.5	Particulate Matter 2.5
PO4-P	Phosphate Phosphorous
PP	Power Plant
PP	Project Proponent
PPA	Power Purchase Agreement
PS	Power Station
PSPP	Pumped Storage Power Plant
PUCSL	Public Utilities Commission of Sri Lanka
QC	Wanni Complex
Rs	Rupee
SEA	Strategic Environmental Assessment
SEA	Sustainable Energy Authority
SFC	Static Frequency Converter
SHM	Stakeholders Meeting
SLS	Sri Lanka Standard
SLSC	Standard Least-Squares Criterion
SO	Sulfur Dioxide
SPPA	Standard Power Purchase Agreement
SS	Sub-Station
SYSIM	System Simulation Package
T/L	Transmission Line
TEC	Technical Evaluation Committee
TOR	Terms of Reference
UNESCO	United Nations Educational, Scientific and Cultural Organization
USD	United States Dollar
VC	Vijayan Complex
VU	Vulnerable
WEPA	Water Environment Partnership in Asia
WHO	World Health Organization

Chapter 1 Introduction

1.1 Background of the Project

The change in the economic situation of Sri Lanka is shown in the Table 1.1-1. The Sri Lankan economy was under the influence of the worldwide financial crisis in 2008 originated from the Lehman Shock in the USA and its GDP was once reduced to growing rate of 3.5% by subsequent stagnation of the world economy, however, after the latter half of 2009, due to the restoration market after the end of the civil war, the mining and manufacturing businesses in Sri Lanka were rapidly booming and transportation and communication business became active, then in 2010 and 2011 the actual rate of growth of GDP achieved 8.0 % and 8.2 %, respectively. In 2012, though the economy came under the influence of the rolling blackouts due to abnormal drought happened in the latter half of the year and other adverse impact on the production activities in Sri Lanka, it showed firm growth and recorded a rate of growth of GDP of 6.3 % that is same level before the Lehman Shock, and it regain high level 7.3% in 2013.

Table 1.1-1 Annual Variation of Economic Indicator of Sri Lanka

	units	2007	2008	2009	2010	2011	2012	2013
Mid-Year Population	thousand	20,039	20,217	20,450	20,653	20,869	20,328	20,483
Growth of Population	%	1.2	1.1	1.1	1.0	1.0	0.9.	0.8
GDP at market price	billion Rs.	3,579	4,411	4,835	5,604	6,544	7,579	8,674
GDP per Capita	Rs.	178,845	218,167	236,445	271,346	313,576	372,814	423,467
Exchange Rate	Rs./USD	110.62	108.33	114.94	113.06	110.57	127.60	129.11
GDP per Capita	USD	1,617	2,014	2,057	2,400	2,836	2,922	3,280
GDP Real Growth	%	6.8	6.0	3.5	8.0	8.2	6.3	7.3

(Source: Annual Report 2012, Central Bank of Sri Lanka)

The trend of the situation in electric power supply and demand is shown in the Table 1.1-2.

Table 1.1-2 Annual Variation of Power Demand and Supply

Year	Generation (GWh)	Growth (%)	Demand (GWh)	Growth (%)	Peak Load (MW)	Growth (%)
2003	7,612	11.8	6,209	12.8	1,516	6.6
2004	8,043	5.7	6,781	9.2	1,563	3.1
2005	8,769	9.0	7,255	7.0	1,748	11.8
2006	9,389	7.1	7,832	8.0	1,893	8.3
2007	9,814	4.5	8,276	5.7	1,842	-2.7
2008	9,901	0.9	8,417	1.7	1,922	4.3
2009	9,882	-0.2	8,441	0.3	1,868	-2.8
2010	10,714	8.4	9,268	9.8	1,955	4.7
2011	11,528	7.6	10,023	8.1	2,163	10.6
2012	11,801	2.4	10,474	4.5	2,146	-0.8
2013	11,962	1.4	10,621	1.4	2,164	0.8
Ave.		4.6		5.5		3.6

(Source：LTGEP 2013-2032)

The average increasing rate of electric energy generated in last decade (2003 to 2013) is 4.6% and the same of energy demand is 5.5% under the steady economic circumstances. In regard to the annual maximum demand in Sri Lanka, the average increasing rate in last decade is 3.6%.

According to the Annual Report 2012 of Central Bank of Sri Lanka, it anticipates that the improvement activities of infrastructure and the growth of tourism will make the growth rate of GDP increase at around 8%. The electric power demand is substantially increasing, accordingly.

The peak power demand in Sri Lanka prevails in the evening time up to 22 o'clock mainly by power demand for lighting and is also driven up by the improvement of the electrification rate. Under such circumstances, in order to make up for the capacity degradation in power supply during dry season as evidenced in 2012 or to allow planned significant introduction of renewable energy by absorbing its power variation, CEB has planned the study of the development of pumped storage power plant for peak power demand, and requested technical assistance from Japanese Government.

To that end, JICA executed the Detailed Planning Survey. Consequently, the Study on pumped storage power plant was carried out after the selection of optimal power generation options available in Sri Lanka through the comparison study of options.

1.2 Purpose and Scope of Study

The Study aims at propounding optimal power generation for peak power demand in Sri Lanka that will contribute to development and improvement in Sri Lankan economy and living standard in a quick and efficient manner through stable supply of electricity and relief of peak power shortage and fluctuation in electric supply capacity according to season. In addition, through the joint study with Sri Lankan engineers, the Study will contribute to technology transfer and human resource development in the area of electric power development for peak power demand.

Specifically, the following items are main scope of the Study:

- to practice electric power demand projection for 15-20 years after the year 2013 and to confirm the necessity of power generation for peak power demand by comparison with existing power development plan,
- to propose optimal power generation for peak power demand (including combination of options) after comprehensive study on economic efficiency, technical, topographical and environmental restriction, and impact on power system in Sri Lanka of options for peak power demand, such as pumped storage, gas combined cycle, new hydropower for peak demand, expansion of existing hydropower, electricity interchange with Indian network and so on,
- to list up around 10 potential pumped storage sites including study sites of CEB after confirmation that Pumped Storage is the most suitable for Sri Lanka for peak power demand, to select three prevailing site in accordance with the evaluation criteria to be established, and to select conclusively the most promising candidate site in consideration of aspects in environmental and social considerations and topographical and geological investigations.

The detail procedures will be shown in the Chapter 1.3 “Study Plan”.

1.3 Study Plan

1.3.1 Study Procedure

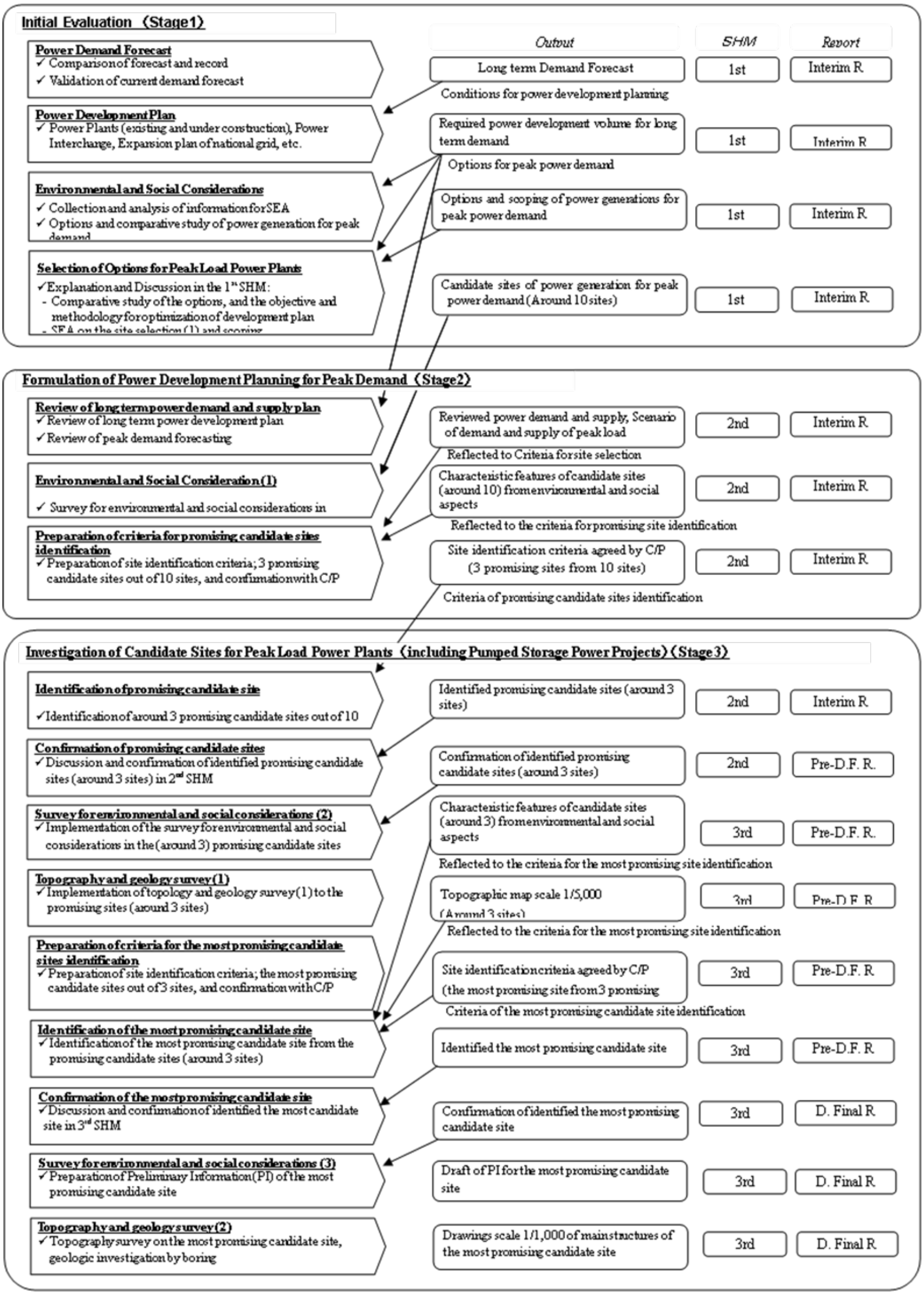


Figure 1.3.1-1 Work Contents and Output

1.3.2 Study Schedule and Study Items

Table 1.3.2-1 Study Schedule and Study Items

Study Items	FY 2012	FY 2013												FY 2014										
	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2
Preparation in Japan																								
(1) Data Collection & Preparation of Inception Report	□																							
First Study in Sri Lanka																								
(1) Discussion on Inception Report in JCC-1	▲▲																							
(2) Seminar	▲▲																							
(3) Data Collection & Analysis of Electric Power Sector	■	■																						
(4) Review of Power Demand Forecasting	■	■																						
(5) Confirmation of Existing Power Plants	■	■																						
(6) Review of Gen. & Grid Development Plan	■	■																						
(7) Data Collection of Env. & Social Considerations	■	■																						
(8) Comparative Study of Peak Generation Options	■	■																						
First Study in Japan																								
(1) Preparation of 1st SHM			□																					
(2) Preparation of Subcontract of Env. Survey			□																					
Second Study in Sri Lanka																								
(1) Confirmation of Options for Peak Demand in 1st SHM				▲▲																				
(2) Review of Long Term Generation Expansion Plan				■	■				□	□														
(3) Demand & Supply Scenario for Peak Demand				■	■																			
(4) Subcontract of Env. Survey-1					▨	▨	▨																	
Second Study in Japan																								
(1) Preparation of Criteria for Selection of Candidate Sites						□																		
(2) C/P Training in Japan						□																		
Third Study in Sri Lanka																								
(1) Consensus of Criteria for Site Selection in JCC-2							▲▲																	
(2) Supervision of Subcontract of Env. Survey-1							■																	
Third Study in Japan																								
(1) Identification of 3 Promising Sites								□																
(2) Preparation of Interim Report								□																
Fourth Study in Sri Lanka																								
(1) Evaluation of Candidate Sites									■	■														
(2) Explanation of Interim Report									▲▲															
(3) Confirmation of 3 Promising Sites in Second SHM										▲▲														
(4) Subcontract of Env. Survey-2											▨	▨	▨	▨	▨	▨	▨	▨						
(5) Subcontract of Topo & Geological Survey											▨	▨	▨	▨										
Fourth Study in Japan																								
(1) Prep. of Criteria for Selection of Most Promising Site											□													
(2) Evaluation of Topo & Geological Survey-1											□													
Fifth Study in Sri Lanka																								
(1) Consensus of Criteria for Most Promising Site in JCC-2													▲▲											
(2) Supervision of Env. Survey-2													■											
Fifth Study in Japan																								
(1) Identification of Most Promising Site														□										
(2) Preparation of Pre-draft Final Report														□										
Sixth Study in Sri Lanka																								
(1) Evaluation of Most Promising Site															■									
(2) Explanation of Pre-draft Final Report														▲▲										
(3) Consensus of Most Promising Site in Third SHM														▲▲										
(4) Analysis on Env. Survey-2															■									
(5) Preparation of PI for Most Promising Site															■									
(6) Execution of Topo & Geological Survey-2															▨	▨	▨	▨	▨	▨	▨			
Sixth Study in Japan																								
(1) Preparation of Draft Final Report																					□	□		
Seventh Study in Sri Lanka																								
(1) Explanation of Draft Final Report																							▲▲	
(2) Final Confirmation of Env., Topo & Geological Survey																							■	
第7次国内作業																								
(1) Preparation of Final Report																								□

Legend : ■ In Sri Lanka ▨ Subcontract □ In Japan ▲▲ Presentation

Chapter 2 Sri Lanka Power Sector Performance and Development Policy

2.1 Power Sector in Sri Lanka

2.1.1 Power Supply Performance

Sri Lankan economy has been growing steadily for the last two decades. The demand for electricity has also been constantly increasing, following economic growth. Characteristics of electricity demand and supply are explained hereunder;

- Power generation by private sector started in 1996 in the form of hired private power and self-generation. Purchase from private sector electricity was 307 GWh in 1996. Since then, the share of private sector generation has been increasing rapidly, and it was 48% (5,638 GWh) of total generation in 2012.

- The share of hydro power generation, excluding mini hydro, was 34.5% in three-year average from 2010 to 2012. It was more than 90% in early 1990's, but new additions of hydro power plants were limited only two, Kukule and Upper Kotmale, and large portion of increased power demand has been covered by CEB's thermals and IPP generation. The share of hydro power in 2012, excluding mini hydro was 23.5%, the lowest in history due to the extreme drought year. As more oil-based fuels (high cost generation) are used to meet the steady demand for electricity, the average cost of supply also pushed up accordingly.

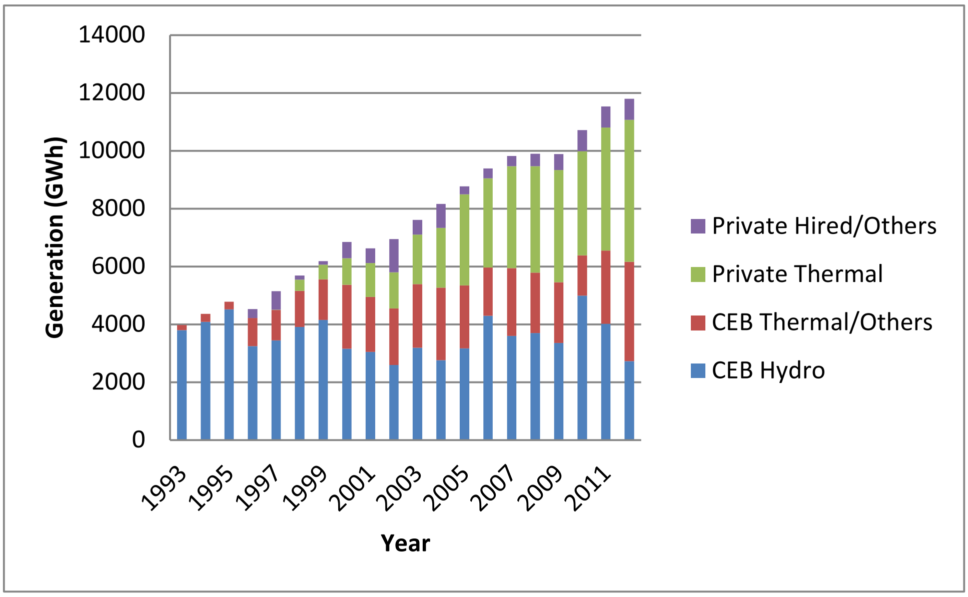


Figure 2.1.1-1 Sri Lanka: Share of Electricity Generation (1993-2012)

- In July 2011, the first coal power generation (300MW) commenced operations in Sri Lanka. Second and third same size coal power plants also started 2014. It is expected that adding coal power plants would bring unit generation cost to reasonably lower level.

- The household electrification rate was 67% inclusive of off-grid in 2003, and it increased to 94%

in 2012. This electrification level is higher when compared with neighboring countries.

- Shares of electricity consumption by customer categories have not been changing drastically for the last 10 years. Consumption by CEB customers in 2012 was 39.5% by domestic customers, 36.2% by industry, and 24.3% by general purpose and hotel. Domestic sector always occupies about 40% for the last 10 years, industry decreased by 5% in the same period, which were taken by general purpose and hotel.
- Figure 2.1.1-2 shows the load factor excluding non-conventional renewable energy. Though the load factor has been showing improving trend (becoming flat), the gap between peck demand and that of off-peak becomes larger. It means that the slight improvement of load factor has been off-set by increases of energy demand and peak power.

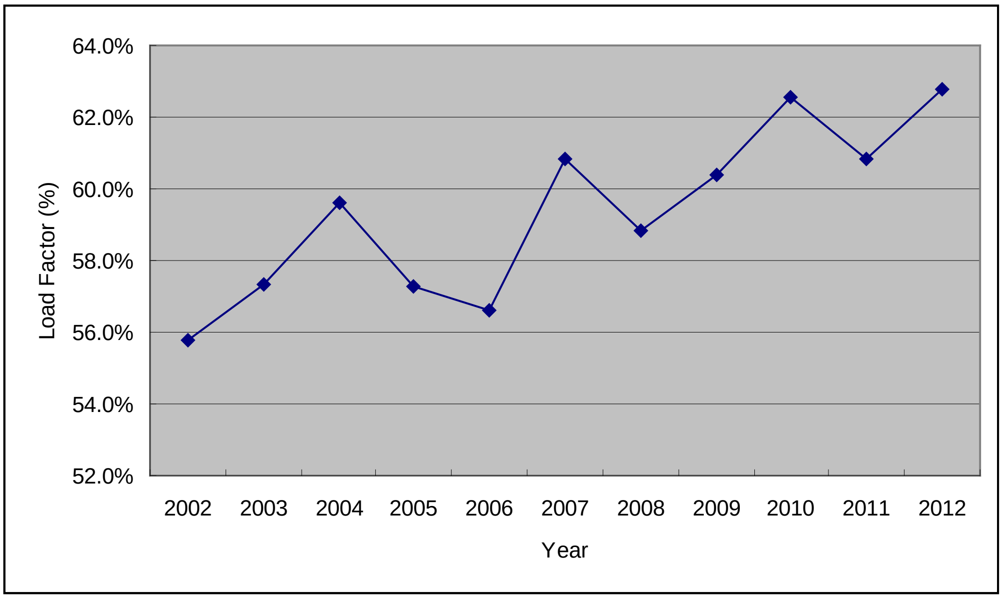


Figure 2.1.1-2 Sri Lanka: Load Factor (2002-2012)

2.1.2 Government Power Sector Policy

Serving electricity in Sri Lanka has been recognized as basic infrastructure service for peoples' quality life and economic development, and successive governments have placed electricity service as one of the priority sectors. Energy sector (including power sector) development policy papers were developed several time in the past, but most comprehensive and detail one was "National Energy Policy and Strategies of Sri Lanka" prepared by Ministry of Power and Energy, and approved by the Cabinet of Ministers in May 2006. The document spells out the implementing strategies, specific targets and milestones. Institutional responsibilities to implement each policy elements and associated strategies to reach the specified targets are also stated in the document. The document was also approved by the Parliament, which intended to ensure ownership by all political parties, and published in the Gazette in June 2008.

In order materialize the policy and strategies, the Government enacted the Sri Lanka Electricity Act No. 20 of 2009 which empowers the Public Utilities Commission of Sri Lanka (PUCSL) as the regulator of the electricity industry. Accordingly the PUCSL shall perform the roles of an economic, technical, and safety regulator for the electricity industry in Sri Lanka, ensuing transparency, fairness, and flexibility for the industry participants whilst safeguarding consumer rights to achieve policy objectives. Accordingly, PUCSL is to assure that a coordinated, efficient and economical system of electricity supply is provided for and maintained throughout Sri Lanka, at all times.

Under Section 5 of the Sri Lanka Electricity Act, the Minister of Power and Energy shall have the power to formulate “General Policy Guidelines on the Electricity Industry for the Public Utilities Commission of Sri Lanka” and these guidelines are to be forwarded to the Cabinet of Ministers for approval. The Guidelines must take into consideration, among other matters, the requirements for electricity to attain national targets including different geographical areas, and different socio-economic groups; fuel diversity; pricing policy; and the measures being taken the Government. The first Guidelines was issued by the Ministry in June 2009. PUCSL has to play its roles and functions, being consistent with the Guidelines.

While the Electricity Act does not require CEB for unbundling, the Government designed to make CEB be divided into functional business units (functional separation and financial segregation from each other business unit) to encourage CEB’s efficiency improvements by regulating each of its functional business units.

2.1.3 Organizations for Electricity Supply

The inter-organizational relations were drastically changed by enactment of Sri Lanka Electricity Act in 2009. The Ministry’s role is now restricted to formulate policy guidelines of electricity sector, and supervising CEB performance. The Public Utilities Commissions of Sri Lanka now plays roles as regulator, issuing licenses for generation, transmission and distribution, and approving and regulating tariffs and other charges.

The organizational relationships among stakeholders in electricity sector are shown in Figure 2.1.3-1.

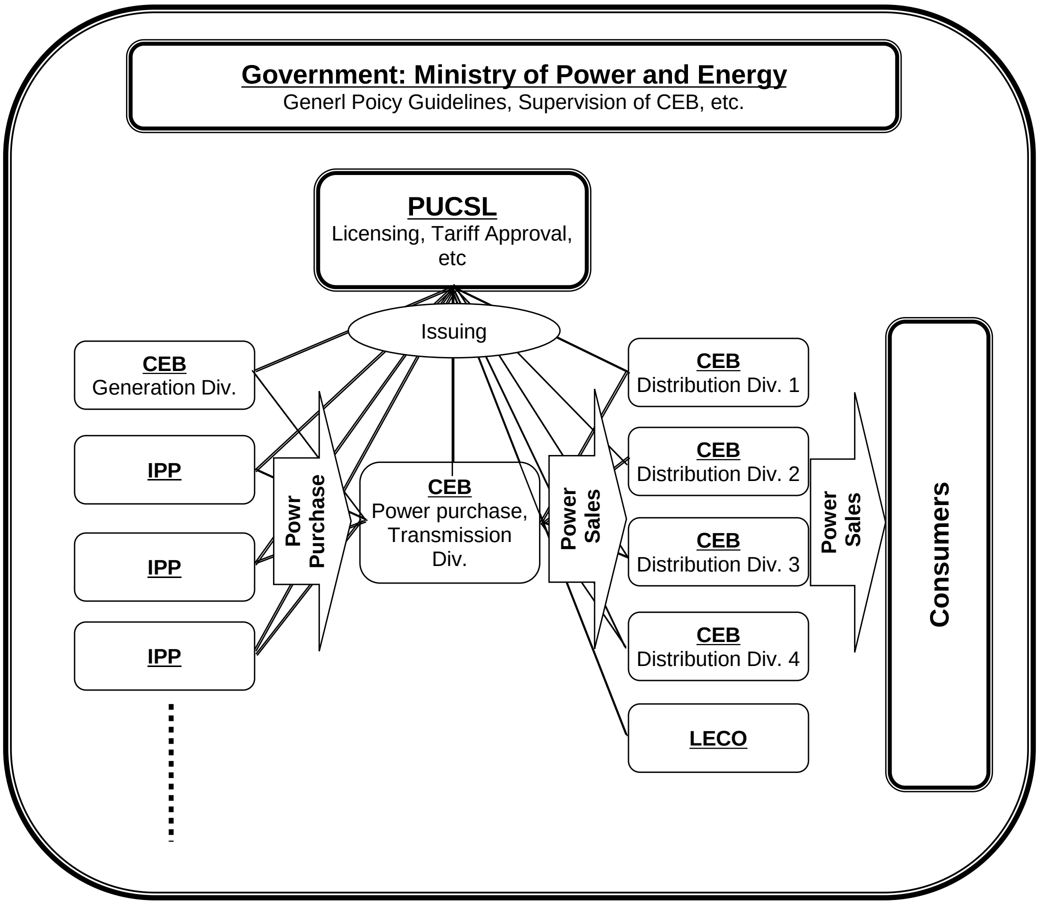


Figure 2.1.3-1 Institutional Framework of Electricity Industry in Sri Lanka

PUCSL has issues six licenses to CEB. Another distribution license to Lanka Electricity Company (LECO) and 11 generation licenses to IPPs. Small scale IPPs are also given generation licenses. In total, PUCSL has issued about 120 licenses to date.

2.1.4 Foreign Assistance to Power Sector

Most of development projects in generation, transmission and distribution have been implemented with foreign assistance in Sri Lanka. In electricity generation, recently completed notable projects are Norochcholai Coal Power Project financed by China (300MW × 3), and Upper Kotmale Hydro Power Project by JICA ODA Loan (150MW). Other bilateral export credit institutions have provided financing in power generation (Austria and France for Rehabilitation of Old Laxapana, and JBIC for Ukuwela Rehabilitation). Ongoing electricity generation projects are Broadlands Hydro 35MW by China, Uma Oya Hydro 120MW (with irrigation) by Iran, Moragolla Hydro 27MW by ADB, and National Thermal Power Corporation of India and CEB signed a joint venture agreement for a 500MW coal-fired power plant in Trincomalee. ADB and JICA have been continuously assisting in transmission and distribution expansion as the major development partners. China, Iran, Sweden and some other countries are assisting projects in rural electrification projects.

2.2 Electricity Tariffs and CEB's Financial Performance

Since electricity tariffs in Sri Lanka are to be determined by cost-reflective pricing including a reasonable return on equity[1], the licensees are not expected to face financial difficulties as far as they perform their business in efficient manner. There is, however, an extremely large financial loss in transmission licensee (it means CEB) because actual pricing has been always lower than actual costs. Revisions of tariff have been always facing with political and social difficulties. In 2011 and 2012 was an exceptionally difficult years for CEB, as were extreme draught conditions together with high oil price.

2.2.1 Electricity Tariffs

(1) Revisions in the past

Determining electricity tariffs are ruled by (i) Electricity Act Section 30 Tariffs, and (ii) General Policy Guidelines on the Electricity Industry issued by the Ministry of Power and Energy, (iii) Tariff Methodology, Dec. 2011, PUCSL. Principal rule to determining tariff is "supplying electricity to all categories of consumers at reasonable prices while ensuring financial viability of the sector. Average electricity price be gradually made cost reflective. Lifeline tariff to domestic consumers will be limited to Samurdi Beneficiaries. Licensees will be compensated adequately for all reasonable cost, if they are compelled to sell electricity to any category of consumers at subsidized prices, on directives by the GOSL."

Under the new electricity tariff setting system, the first 5-year electricity tariff for the period of 2011-2015 was prepared in 2010[2]. It plans gradually moving to cost reflective within 5 years with an expectation of lowering tariff by commissioning of Sri Lanka's first coal power plant.[3]

The first electricity tariff determined by PUCSL became effective on January 1st, 2011. Historical changes of electricity tariff in major consumer categories including pre-PUCSL period is summarized in Table 2.2.1-1.

[1] Sec. 3.5, National Energy Policy ad Strategies of Sri Lanka, 2008 GOSL Gazette Notification
[2] Consultation Paper on Setting Tariffs for the Period of 2011-2015, PUCSL, 2010
[3] At the end of this master plan study period, the Government announced reduction of domestic tariff by about 25% effective from September 2014, and other categories reduction by 15-25% effective from November 2014.

Table 2.2.1-1 Revisions of Electricity Tariffs 2008 - 2013

Effective from 2008/11/1		Effeftive fm 2011/1/1		Effective fm 2012/2/		Effective fm 2013/4/20	
Customer Catgry	Rs./kWh	Cus. Cat.	Rs./kWh	Cus. Cat.	Rs./kWh	Cus. Cat.	Rs./kWh
Domestic							
<=30	**3.00**	*<=30*	**3.00**	*<=30*	**3.75**	*<=30*	**3.75**
31 - 60	**4.70**	*31 - 60*	**4.70**	*31 - 60*	**6.35**	*31 - 60*	**6.35**
61 - 90	**7.50**	*61 - 90*	**7.50**	*61 - 90*	**10.50**	*61 - 90*	**13.20**
91 - 180	**20.80**	*91 - 120*	**21.00**	*91 - 120*	**29.40**	*91 - 120*	**37.10**
		121 -180	**24.00**	*121 -180*	**33.60**	*121 -180*	**42.70**
181 - 600	**32.50**	*181=<*	**36.00**	*181=<*	**50.40**	*181=<*	**58.80**
601=<	**39.00**						
General							
GP1	**19.50**	*GP1*	**19.50**	*GP1*	**24.38**	*GP-1 <211*	**24.38**
						GP-1 >210	**26.88**
GP2	**17.94**	*GP2*	**19.40**	*GP2*	**24.25**	*GP-2 peak*	**31.25**
						day	**25.63**
						off-p	**18.13**
GP3	**17.68**	*GP3*	**19.10**	*GP3*	**23.88**	*GP-3 peak*	**30.00**
						day	**24.38**
						off-p	**16.88**
Industrial							
I-1	**13.65**	*I-1*	**10.50**	*I-1*	**12.08**	*I-1*	**14.38**
I-2	**12.09**						
I-3	**11.83**						
I-2 (TD) peak	**31.98**						
off-p	**10.92**						
I-3 (TD) peak	**29.90**						
off-p	**10.40**						
I-2 (TD3) peak	**29.90**	*I-2 peak*	**13.60**	*I-2 peak*	**15.64**	*I-2 peak*	**24.15**
day	**9.49**	*day*	**10.45**	*day*	**12.02**	*day*	**13.00**
off-p	**6.89**	*off-p*	**7.35**	*off-p*	**8.45**	*off-p*	**8.05**
I-3 (TD3) peak	**27.90**	*I-3 peak*	**13.40**	*I-3 peak*	**15.41**	*I-3 peak*	**27.60**
day	**8.97**	*day*	**10.25**	*day*	**11.79**	*day*	**12.08**
off-p	**6.50**	*off-p*	**7.15**	*off-p*	**8.22**	*off-p*	**6.90**

Note: Above figures are uint charges (Rs./kWh) only. Fixed and demand charges not includ
Fuel adjustment charges are included in above figures.

(Source: CEB, PUCSL)

Table 2.2.1-2 Comparison of Category-wise Average Charge 2012/2013

Year	Category	Domstic	Religious	Industrial	Hotel	General Purpose	Govt+ Str light	LECO	Total
2012	Sales (GWh)	3,522	55	3,285	160	2,042	109	1,302	10,475
	Revenue (Rs. Mil)	42,887	377	46,079	2,676	52,309	0	18,628	162,956
	Revenue/unit (Rs./kWh	**12.2**	**6.9**	**14.0**	**16.7**	**25.6**		**14.3**	**15.6**
2013 (estimate)	Sales (GWh)	3,488	58	3,344	168	2,059	197	1,308	10,622
	Revenue (Rs. Mil)	52,373	405	53,529	3,297	56,783	1,724	22,376	190,487
	Revenue/unit (Rs./kWh	**15.0**	**7.0**	**16.0**	**19.6**	**27.6**	**8.8**	**17.1**	**17.9**
2013/12	Increase rate (%)	**23.3%**	**1.9%**	**14.1%**	**17.3%**	**7.7%**		**19.6%**	**15.3%**

Source: CEB Statistical Digest 2013

(2) Issues in Electricity Tariffs

- Tariff Approving Authority: PUCSL approved and announced new electricity tariffs in April 2013. That revision included about 25% increase of lifeline tariff, which caused a number of objections by socio-political groups. On May Day, the President indicated that no increase below 60kWh/month tariff, and moderate increase for 60-120kWh consumptions. Finally, PUCSL announced changes in the way the President indicated. The intervention hampered independence of PUCSL, and CEB's financial performance.
- Periodic Tariff Adjustment: Adjustment of tariff is supposed to be made every six months. It is, however, not practiced. Less frequent revisions of tariff tends to make changes relatively large, which may raise more oppositions. Periodic and automatic adjustment is preferable.
- Wider categories are now using mandatory application of time of use (TOU) tariff. It motivates consumers to shift from evening peak higher tariff to lower day and off-peak periods. Consumers, however, do not simply react to tariff changes. Therefore, it needs assessment of TOU effects. In parallel to introduction of TOU tariff, it is also important to create awareness and to provide technical support to consumers for their effective actions. Consumers response to TOU brings benefit to CEB, too.

2.2.2 CEB's Financial Performance

CEB recorded largest loss in 2012. While sales of electricity Rs. 164.0 billion (up 24% from 2011), the cost of sales was Rs. 222.2 billion (up 46% from 2011). Loss before tax was Rs. 61.2 billion (up 212% from 2011). The size of CEB's loss is nearly 1% of Sri Lanka's GDP. This loss does not include subsidized portion of fuel from Ceylon Petroleum Corporation (CPC). Ministry of Finance and Planning, in its annual report, indicated that subsidies in fuel to CEB be estimated as Rs. 54.0 billion in 2012. The net loss to the economy caused by electricity sector becomes Rs. 115.2 billion, which accounts for 1.5% of Sri Lanka's GDP. Though this huge financial loss, the cash-flow of CEB has been maintained by short-term borrowing from government's commercial banks and moratorium of repayment to the government.

Major causes of increase of supply cost in 2012 were decrease of hydro generation and increase of fuel thermal generation, and high fuel oil price, and depreciation of SL rupees against US dollars. As a result, the balance sheet of CEB has deteriorated badly, accumulating borrowing (short and long terms) Rs. 325.6 billion (up 60% from 2011).

Table 2.2.2-1 CEB's Financial `Performance 2007 - 2013

		2007	2008	2009	2010	2011	2012	2013
Profit and Loss								
Sales of Electricity	Rs. Mln	87,575	111,287	110,518	121,226	132,460	163,513	194,147
Cost of Sales	Rs. Mln	-108,355	-145,713	-118,186	-116,168	-152,427	-222,419	-166,926
Gross Profit/(Loss)	**Rs. Mln**	**-20,780**	**-34,426**	**-7,668**	**5,058**	**-19,967**	**-58,906**	**27,221**
Admin. Expenses	Rs. Mln	-1,534	-1,487	-2,870	-1,851	-2,013	-2,997	-2,598
Operationg Profit/(Los	**Rs. Mln**	**-22,314**	**-35,913**	**-10,538**	**3,207**	**-21,980**	**-61,903**	**24,623**
Other Income	Rs. Mln	9,205	3,581	4,273	4,230	4,543	6,355	6,460
Finance Cost	Rs. Mln	-1,703	-1,537	-3,073	-2,605	-1,828	-5,898	-12,490
Profit/(Loss) Bef Tax	**Rs. Mln**	**-14,812**	**-33,869**	**-9,338**	**4,832**	**-19,265**	**-61,446**	**18,593**

Source: CEB Annual Report 2011, 2012, and CEB Financial Statements 2013 (unaudited)

For steady financial recovery, CEB needs to (i) increase and periodic revision of electricity tariff by cost-reflective principle, (ii) as-planned commencement of operations of Puttalam Coal Power Units 2 and 3, and continuous operations of all units. Others may be external factors, but (iii) average rain fall for hydro generations, (iv) low and stable fuel oil prices, and (v) stable exchange rate, etc.

Chapter 3 Electric Power Demand Forecast

3.1 Current Situation

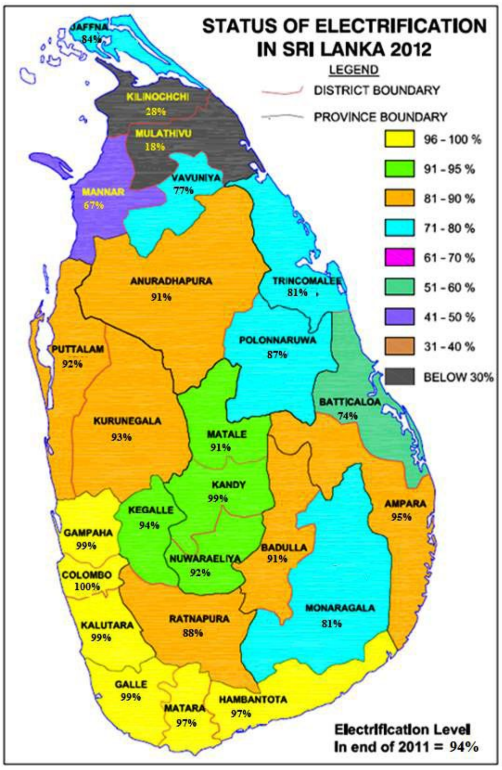
3.1.1 Actual Record of Electric Power Demand

According to the LTGEP of the CEB 2013-32, power generation of 2012 in Sri Lanka was 11,801 GWh (generating end, except private power generation), and electricity sales were 10,389 GWh. Average annual growth rate of power generation and electricity sales over the past 10 years are 4.6% and 5.5% respectively.

Though maximum power of the country remained lower than the previous year's level in 2009 and 2007, it grew solidly and reached 2,163 MW in 2011 and its annual growth rate was 3.6% on average over the past 10 years.

3.1.2 Electrification Rate

At the end of December 2012, household electrification of 93% had been achieved. Current status of the regional electrification rate of Sri Lanka is shown in Figure 3.1.2-1. Electrification rate has already reached more than 97% in the western and southern regions. On the other hand, electrification is delayed in the northern and eastern regions. Interconnection of the northern power system and Sri Lanka system is planned for 2012.

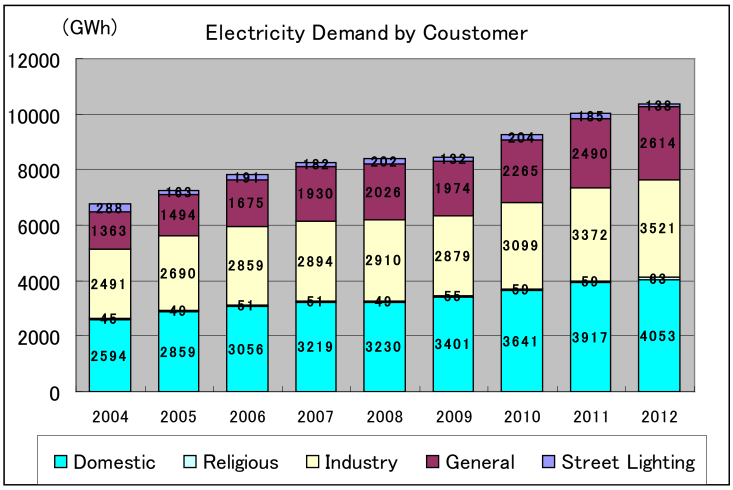


(Source: Long Term Generation Expansion Plan 2013-32,CEB)

Figure 3.1.2-1 Electrification in Sri Lanka 2012

3.1.3 Electricity Consumption by Customer

In 2012, electricity demand/consumption comprised 39% domestic, 34% industrial, 25% commercial (general), and 2% of religion/street lights. In 2004, it was 40% domestic, 37% industrial, 20% commercial, and 3% religion/street lights. Therefore, the share of commercial use has increased, while the amount of demand in the domestic sector, which is the primary sector, has grown.

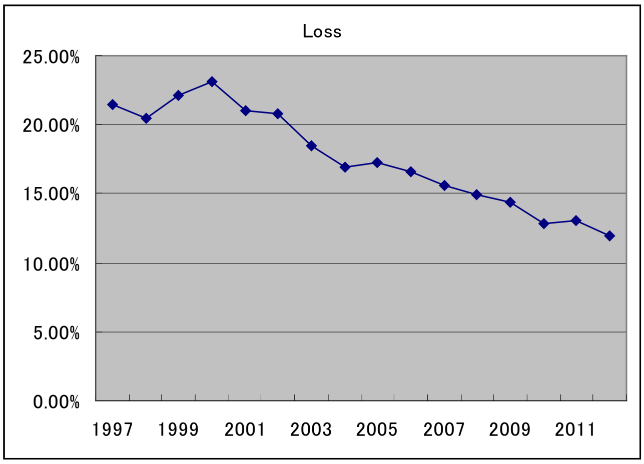


(Source: JICA Study Team based on CEB data)

Figure 3.1.3-1 Electricity Demand by Customer

3.1.4 Transmission and Distribution Loss

Transmission and distribution loss of the power system improved to 11% in the second half of 2012 after exceeding 20% in 1997. One of the reasons for the loss improvement seems to be the change of the electricity tariff system, which has introduced meter pricing instead of a flat-rate. Electric power meters were installed following the revision. Meanwhile, measures have been taken for reducing technical losses such as introducing a low-loss cable for some parts of the transmission line from the coal thermal power plant in Trincomalee that is under construction.



(Source: JICA Study Team based on CEB data)

Figure 3.1.4-1 Actual Record of Transmission/Distribution Loss

3.1.5 Load Factor of the Power System

Load factor increased to 57% in 2011 from 51.6% in 1996. In 2012, the load factor was 62.8% but this value does not reflect the actual situation since planned outages were carried out in this year.

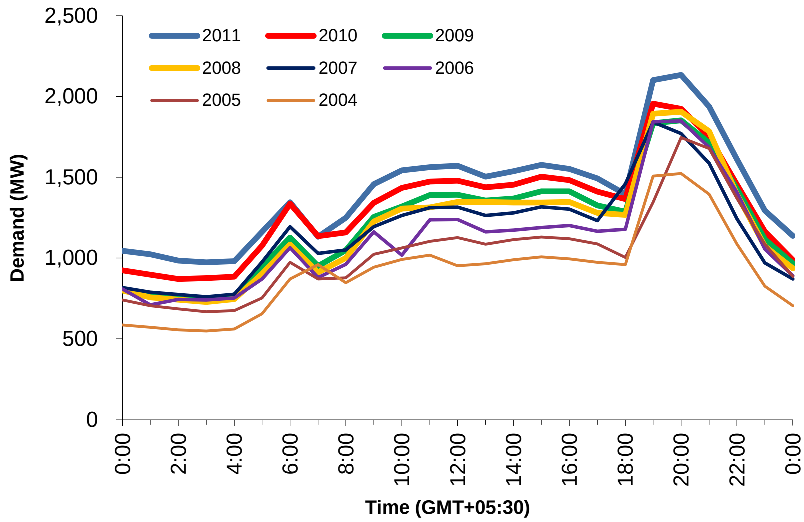
According to the analysis of the CEB, the increase in the load factor is considered to be the result of reducing peak demand by micro-hydropower. In addition, the policy of introducing fluorescent lights instead of filament bulb lights has been taken since peak demand appears at night.

As a peak cut measure by DSM, the introduction of time-of-day tariffs to increase the tariff rate in the peak time zone has been studied.

3.1.6 Daily Load Profile

(1) Load profile on the annual peak day

The shape of the daily load profile is not a big change over time, and peak demand is increasing year by year. Duration time of the evening peak is 3-4 hours. Demand scale, which appears as a peak, is about 600MW.



(Source: JICA Study Team based on CEB data)

Figure 3.1.6-1 Actual Record of Load Profile on the Annual Peak Day

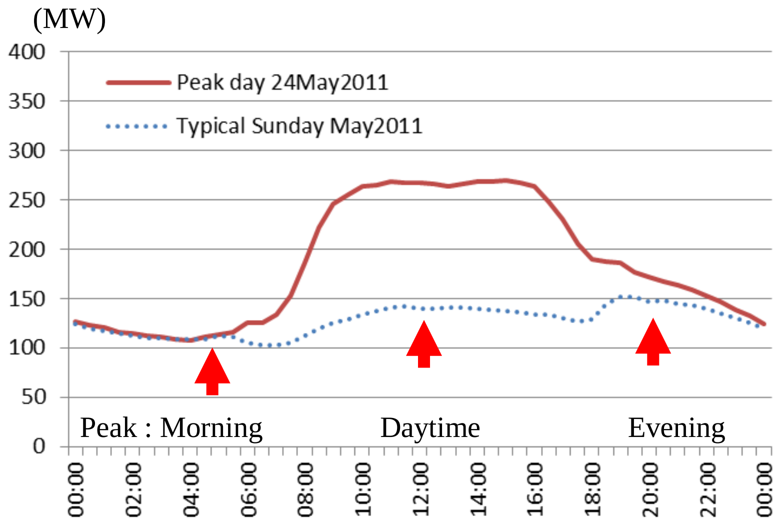
(2) Change of daily load profile

Since Sri Lanka aims at a tourism nation, it is expected that the day time demand stretches in the future when service sector is developed and becomes more active in addition to the industry development.

Daytime demand on weekdays in Colombo district has already increased and daily peak demand appears in daytime. Meanwhile on holidays, there are three peaks, i.e. the morning, daytime and evening peaks, on the daily load profile as same as that of whole country. (Refer to Figure 3.1.6-2). There is no difference of the demand in night time between weekdays and holidays, but day time demand on weekdays are higher than on holidays. Therefore, it is assumed that power demand in weekdays for industry and service sector have been increasing.

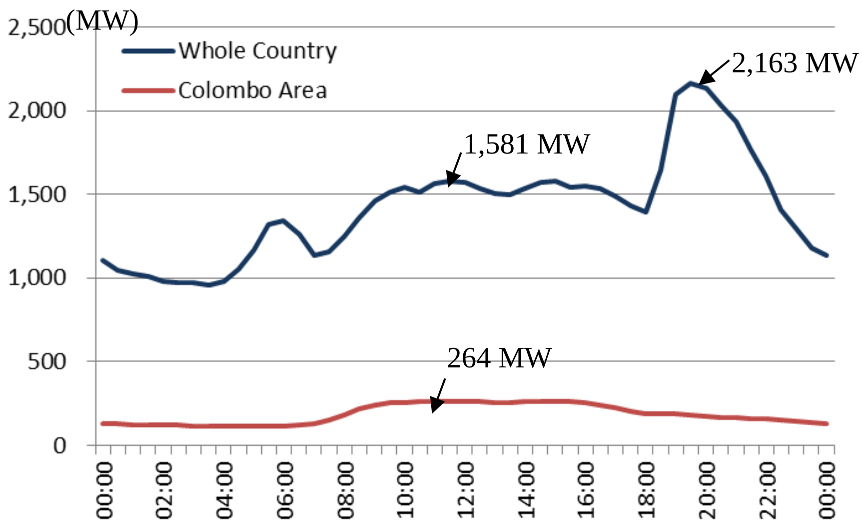
Change of load profile is important for the demand forecasting. However, in the current situation, daytime demand in the Colombo district is still small enough compared to that of the whole country (Figure 3.1.6-4), and it has not yet led to significant change in the daily load profile.

Therefore peak demand needs to forecast based on the trend of the evening peak. It is required to make a development plan for the peak supply to meet the increase of the peak demand forecasted, and also required to reliably develop.



(Source: JICA Study Team based on CEB data)

Figure 3.1.6-2 Daily Load Profile of Colombo District in 2011



(Source: JICA Study Team based on CEB data)

Figure 3.1.6-3 Daily Load Profile of the Whole Country and Colombo District (Annual Peak day in 2011)

3.2 Electric Power Demand and Economic Conditions

GDP share by each sector in 2012 is 23% trade, 17% industry, 14% transportation and communication, 11% agriculture/forestry/fisheries, 9% bank securities/real estate, 8% construction, 7% government -related, 3% mining, 3% services, 2% power/ gas/ water supply, and 3% others.

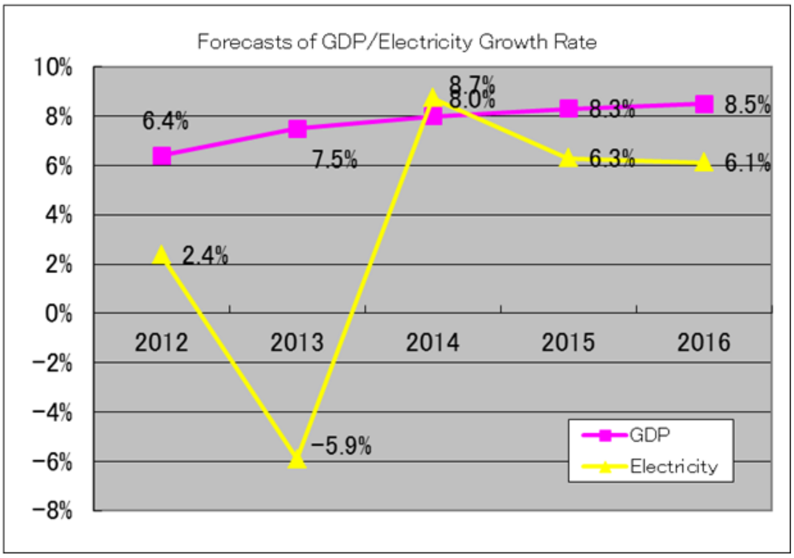
GDP share of the industry and mining sector, which has large electric power consumption, is 20% in total. Moreover electrification has not progressed in the transport sector. Therefore, a feature is that share of sectors which depend on electric power is low.

3.2.1 Relationship of GDP and Electricity Demand

The Central Bank of Sri Lanka has announced the GDP growth rate forecast for the four years in 2012 as shown in the following figure. Growth rate of electricity demand in this figure is the rate forecasted in LTGEP except the rate in 2012 and 2013 which are the actual records.

Actual records of the electricity growth rate are about 2%, which are lower than that of GDP. Forecasted growth rates for 2012 and 2013 are 6.3% and 7.3% respectively, which are almost the same rates of actual records. Therefore, the trend is the same in case of forecasted growth rate.

In 2014 growth rate of GDP and electricity demand is comparable, but growth rate of electricity demand is in the low status compared to the GDP growth rate.



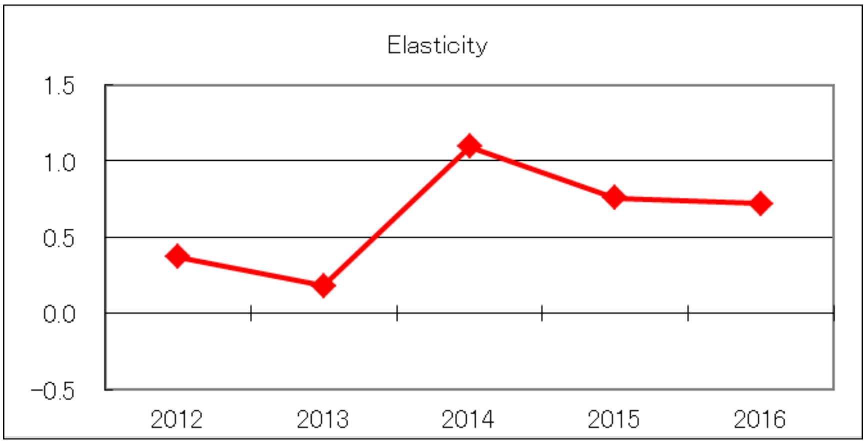
(Source: JICA Study Team based on CEB data)

Figure 3.2.1-1 Forecasted Growth of GDP and Electricity Demand

GDP elasticity, which is obtained by dividing the electricity demand growth rate by the GDP growth rate, is as shown in the following figure. GDP elasticity is less than 1 since electric power consumption of the sectors, which account for a large proportion of GDP, is not so large.

However, it is believed that GDP elasticity will increase to the range of 1-1.2 when GDP share of

Industry/Service sector is increased and/or electrification of transportation is progressed in the future.



(Source: JICA Study Team based on CEB data)

Figure 3.2.1-2 GDP Elasticity

3.3 Demand Forecast

3.3.1 Electric Power Demand Forecast

Since the economy, energy, and electric power policies of the Sri Lanka government have big influence on the future demand of electric power in Sri Lanka, it is valuable to confirm the forecasted demand of CEB and necessity of peaking supply, from the following viewpoints.

(i) Impact on electric power demand and load pattern changes by industrial structural change based on economic policy

(ii) Verification econometric model and variables of electric power demand forecast

(iii) Demand-Side Management (DSM) policy, energy conservation policy

The CEB Planning Department is in charge of power demand forecast in Sri Lanka. The demand forecast is revised once every several years. CEB makes up the power demand forecast along with the power facility development plan, and then the Public Utility Committee approves them.

Power demand in the future is forecasted utilizing econometric models. Based on this forecast, peak demand is forecasted considering effect of demand side management and improvement of the load factor based on policy, which is about 1.5% per year.

As stated in section 3.1.6, although peak demand appears in daytime in the capital area but peak demand of the whole country occurs in the evening. Daytime peak demand has remained at about 75% of the evening peak. Also, there is no significant difference in the annual growth rate for daytime/evening peak, and the load profile has not changed yet. Therefore it seems to be appropriate for demand forecasting based in the current load profile.

Econometric models that are currently used are a model the effect of past records and GDP is large.

However, it is considered appropriate as the assumed method of current situation since the contribution rate is high.

3.3.2 Power Demand Forecast Method

Electricity sales are forecasted using econometrical analysis. The model for the analysis is carefully composed based on the national policy of each category.

Power generation at sending end is projected based on the electricity sales forecast, considering the transmission/distribution losses, renewable energy forecasting, and the effect of energy conservation measures /DSM prediction.

Actual demand consists of four categories, which are Domestic, Industrial, Commercial and others including street lighting and religious use. And the power demand of each category is forecasted using multiple regression analysis.

Up to 2011, demand for industry and commercial category was forecasted together. But it has changed to independent forecasting taking into consideration the government's commercial promotion policy.

Power generation of renewable energy is assumed by Renewable Energy Authority, and CEB uses this for its forecast.

(1) Econometrical analysis for electricity sales forecast

Electricity sales are assumed by summation of the forecasted sales of categories which is performed by utilizing econometrical analysis. Variables used in the analysis modeling of multiple regression analysis are shown in the table below. Electricity sales of each category are forecasted using variables of previous demand, domestic consumer accounts and GDP.

As previously mentioned, growth rate of electricity sales is smaller than growth rate of GDP. Meanwhile correlation of them is strong. Therefore, it is believed that selecting these variables is reasonable.

Table 3.3.2-1 Variables used for Econometrical Modeling

Category	Variables
Domestic	Previous year Demand, GDP per Capita, Domestic Consumer Accounts
Industrial	Previous year Demand, GDP
Commersial	Previous year Demand, GDP
Others	Year

(Source: Long Term Generation Expansion Plan 2013-32,CEB)

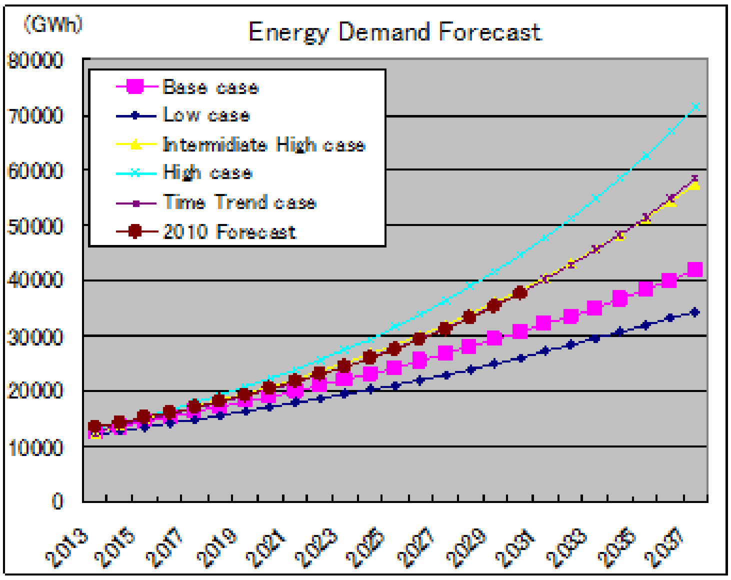
3.3.3 Electric Power Demand Forecast

(1) Power generation

CEB set the case based on the demand forecast using econometrical analysis mentioned in section 3.3.2 as the base case. In addition, sensitivity study was conducted, therefore, there are four other cases of forecast, which are;

- Low case: considering effects of the energy saving and the DSM, assumed by the Sustainable Energy Authority
- Middle-high case: considering population growth and GDP growth, assumed by the Central Bank of Sri Lanka
- High case: considering high population growth scenario and economic growth
- Time trend case: based on past trend of demand

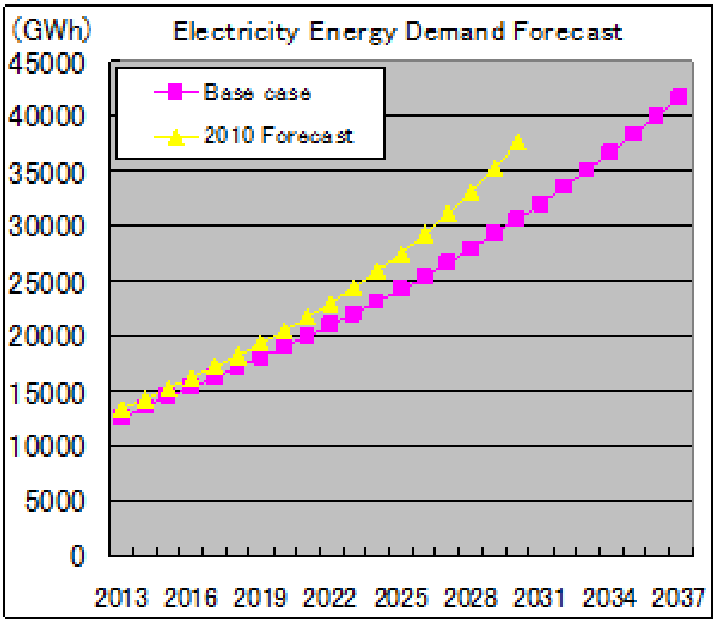
Comparing the projected values in these cases in 10 years' time, compared to the base case, the low case is delayed two years, the middle-high case is two years ahead, and the high cases is five years ahead.



(Source: JICA Study Team based on CEB data)

Figure 3.3.3-1 Electric Power Demand Forecast (GWh)

Power demand estimation of base case in Long Term Generation Expansion Plan 2013-32 is two years delay compared to the previous estimation of base case in 2010.



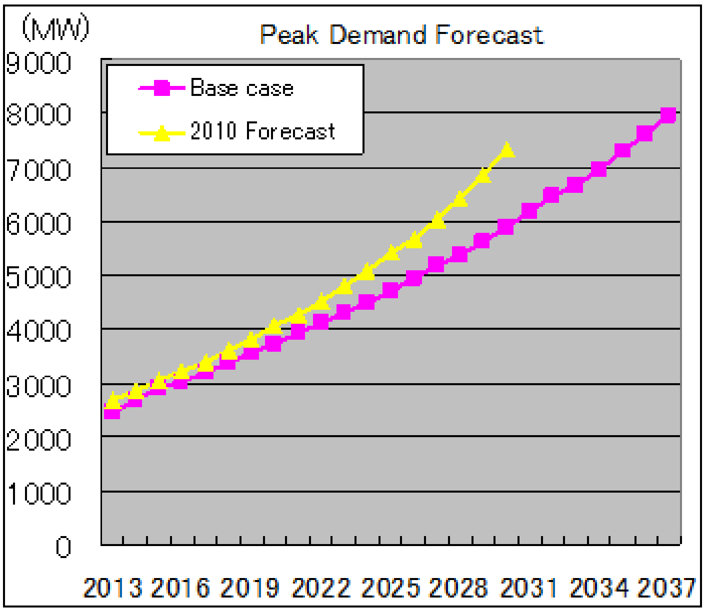
(Source: JICA Study Team based on CEB data)

Figure 3.3.3-2 Electric Power Demand Forecast in 2010 and 2013 (Base Case, GWh)

(2) Peak demand forecast

Peak demand is forecasted, considering estimated load factor and transmission/distribution losses, based on the assumed power generation. Load factor is assumed in the single regression analysis from past records. Load factor was 57% in 2011, and it is assumed to increase to 58-60%.

Forecasted peak demand is shown as follows.



(Source: JICA Study Team based on CEB data)

Figure 3.3.3-3 Peak Demand Forecast in 2010 and 2013

Chapter 4 Power Development Plan

4.1 Long Term Generation Expansion Plan of CEB

The Ceylon Electricity Board (CEB) is under a statutory duty to develop and maintain an efficient, coordinated and economical system of Electricity Supply for the whole of Sri Lanka. Therefore, CEB is required to generate or acquire sufficient amount of electricity to satisfy the demand. In order to fulfill the requirement, CEB annually plans its development activities in the document as Long Term Generation Expansion Plan covering the growing electric power demand.

In accordance with the power demand estimate mentioned in the Chapter 3, the LTGEP 2013 to 2032 was elaborated and approved in April 2014, and its revised base plan is shown in the Table 4.1-1.

Table 4.1-1 Generation Expansion Plan

YEAR	RENEWABLE ADDITIONS	THERMAL ADDITIONS	THERMAL RETIREMENTS	LOLP %
2013			4x5 MW ACE Power Matara 4x5 MW ACE Power Horana 4x5.63 MW Lakdanavi	1.821
2014		*4x5 MW Northern Power* *3x8 MW Chunnakum Extension* *1x300 MW Puttalam Coal (Stage II)*		1.357
2015		*1x300 MW Puttalam Coal (Stage II)* 3x75 MW Gas Turbine	6x16.6 MW Helandanavi Puttalam 14x7.11 MW ACE Power Embilipitiya 4x15 MW Colombo Power	1.228
2016	*35 MW Broadlands* *120 MW Uma Oya*			1.017
2017		1x105 MW Gas Turbine		1.483
2018	27 MW Moragolla	2x250 MW Trincomalee Coal	4x5 MW Northern Power 8x6.13 MW Asia Power	0.399
2019		2x300 MW Coal Plant	5x17 MW Kelanitissa Gas Turbines 4x18 MW Sapugaskanda Diesel	0.080
2020				0.247
2021		1x300 MW Coal Plant		0.162
2022	49 MW Gin Ganga	1x300 MW Coal Plant		0.085
2023		2x300 MW Coal Plant	163 MW AES Kelanitissa CCY 115 MW Gas Turbine 4x9 MW Sapugaskanda Diesel Ext.	0.045
2024				0.169
2025		1x300 MW Coal Plant	4x9 MW Sapugaskanda Diesel Ext.	0.162
2026				0.518
2027		1x300 MW Coal Plant		0.466
2028		1x300 MW Coal Plant		0.370
2029				1.078
2030		1x300 MW Coal Plant		1.094
2031		1x300 MW Coal Plant		1.140
2032		1x300 MW Coal Plant		1.233

Note: Committed plants are shown in *Italics*.
Source: LTGEP 2013-2032 Revised Base Case Plan

4.2 Necessity of Power Generation for Peak Power Demand

The composition of Power Generation in 2012 is shown in the Figure 4.2-1 according to the LTGEP 2013 to 2032.

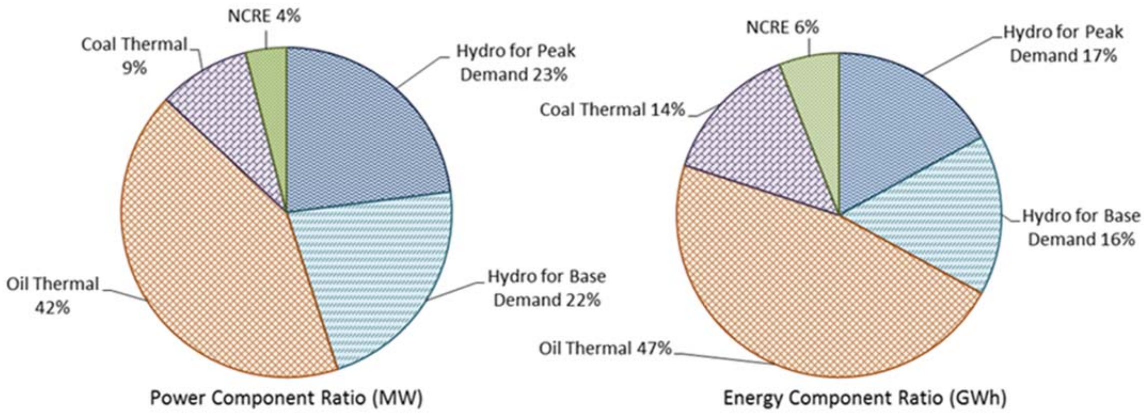


Figure 4.2-1 Composition of Power Generation in 2012

As mentioned in the Chapter 4.1 "Long Term Generation Expansion Plan of CEB", CEB has established generation expansion plan for the year 2013 to 2032 in LTGEP to supply adequately electricity for the growing power demand in future in accordance with the Sri Lankan economic growth. However, there are still following problems remaining:

a. There is no new construction of hydropower plant dedicated to supply for peak power demand after 2013.

b. It is not economical and difficult to construct new thermal power plant for peak power demand because of global inflationary prices of fossil fuel[1].

c. Thermal power plants taking on the supply for peak power demand is aging enough to retire.

For taking countermeasures in the generation expansion planning aspect, new construction of hydropower plant with large scale reservoir, shifting existing hydropower plant from middle or base road operation to peak load operation, and construction of pumped storage power plant can be considered as securement of power source for increment of peak power demand. These developments surely contribute to utilization of domestic renewable energy.

However, almost all potential hydropower in Sri Lanka has already developed or been under construction and promising hydropower site is quite limited, especially large scale hydropower site has already developed. In addition, for the existing hydropower expansion projects have real problems such as its economic efficiency and lowering of reservoir water level (means outage of existing power plant) during construction and so on.

The maximum-ever electric power demand was recorded at 19:30 on May 20, 2011. The daily load

1 e.g. according to U.S. Energy Information Administration Data, the spot price of U.S. Gulf Coast Ultra-Low Sulfur No.2 Diesel as of January 2014 is 204% compared with five years back price.

curve on the day is shown in Figure 4.2-2. The figure shows that the peak demand duration is 4 to 5 hours from 17:30 and the peak load is 735 MW. This peak load is supplied with CEB thermal power plant approximately 180 MW, IPP thermal power plant 130 MW[2] and CEB hydropower plant 425 MW[3].

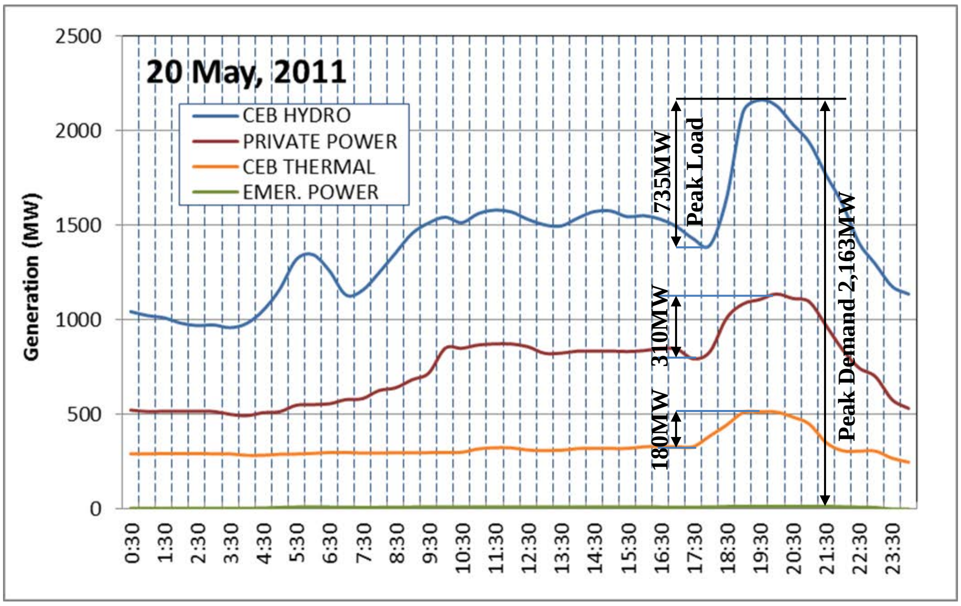


Figure 4.2-2 Generation Capacity and Peak Load

The daily load curve in Figure 4.2-2 is that of rather wet season. Figure 4.2-3 shows a daily load curve on November 16, 2011 as rather dry season for reference. There were no enough water for generation in the reservoir of hydropower plants in this day, and thermal power plants were almost in full operation even in off peak time, and the water of hydropower plants were backlogged for duration of peak power demand. As a result of this operation, the peak load of 514 MW was supplied with CEB hydropower plants 476 MW, CEB thermal power plants approximately 13 MW and IPP thermal plants 22 MW.

2 130MW=310MW-180MW
3 425MW=735MW-310MW

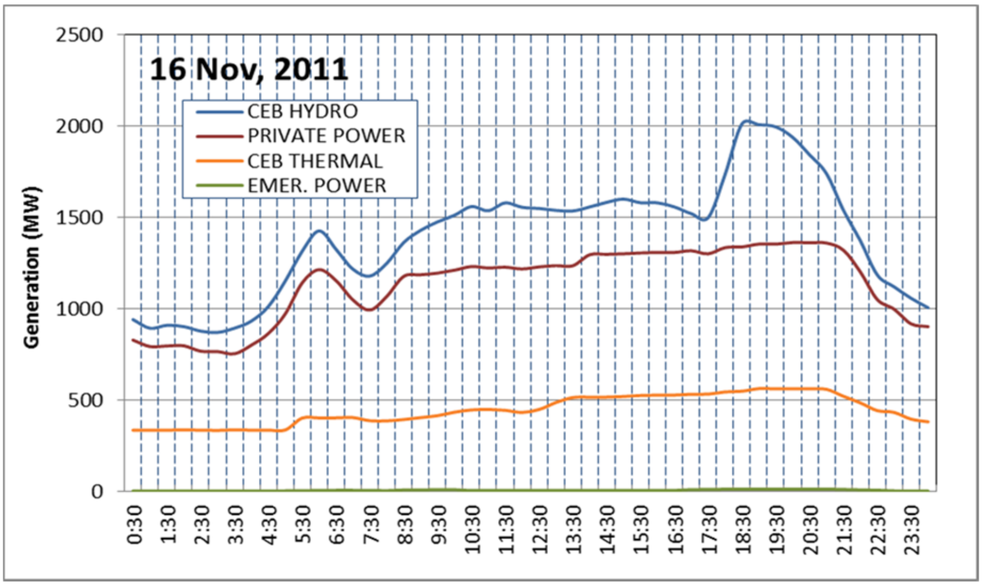


Figure 4.2-3 Generation Capacity and Peak Load

As mentioned above, CEB thermal power plants and IPP thermal power plants that have been used for peak power demand are now in retirement period. In addition, it is expected that the peak demand is increasing yearly. Therefore, measures of lining up of power source for peak demand are urgently needed n the future.

4.3 Constitution of Power Generation in 2025

The composition ratio in 2025 is shown in the Figure 4.3-1 according to the LTGEP 2013 to 2032.

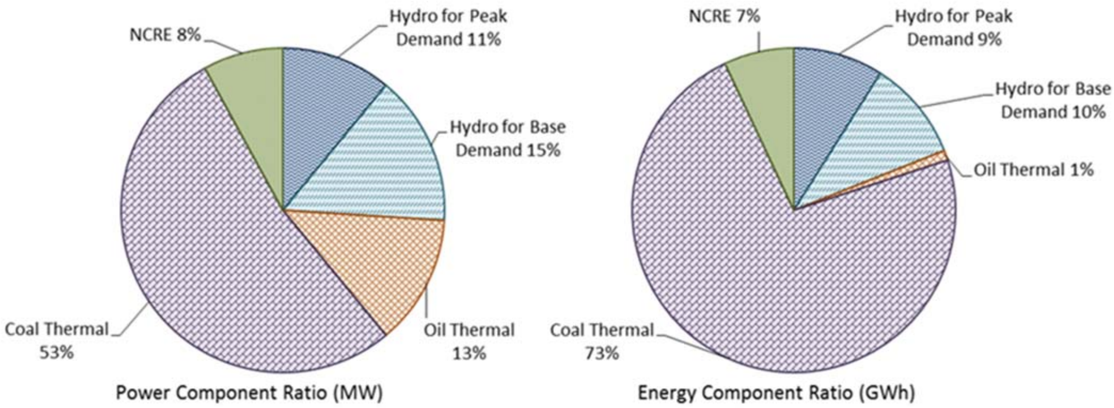


Figure 4.3-1 Composition of Power Generation in 2025

As shown in the figure, the energy constitution ratio of coal fired thermal power plants is around 73 % and large. This is because development of coal fired thermal plants has priority in order to reduce the electricity tariff in Sri Lanka. However, the constitution ratio of coal fired thermal plants is too high from a standpoint of best mix of power source. In this sense, substantial development of power generation for peak power demand is necessary for efficient operation of coal-fired thermal plant of low load following capability.

In 2025, the base load will be supplied by coal-fired thermal plant under currently developing. Their surplus capacity will be for the middle peak load or power source for pumping of pumped storage power plant that will be developed for peak power load or standby power source. Middle peak load will be supplied by existing CEB thermal, IPP thermal, a part of coal-fired thermal plants, and LNG combined cycle power plant though its development schedule is uncertain.

4.4 Necessary Development Scale of Power Source for Peak Power Demand

Table 4.4-1 shows generation records of power generation at just before off-peak time and peak time on maximum power demand day of each month in 2011. From this Table, the maximum peak load is 734 MW (34% of peak demand), the minimum peak demand is 514 MW (25% of the same) and average is 573 MW (28% of the same).

Table 4.4-1 Generation Record of Power Generation on Monthly Peak Demand Day in 2011

	Off-Peak Time (17:30) Load & Supply (A) MW					Peak Time (18:30-19:30) Load & Supply (B) MW					Balance (B-A) MW				
	Total	Hydro	CEB T.	IPP T.	Emer. P	Total	Hydro	CEB T.	IPP T.	Emer. P	Total	Hydro	CEB T.	IPP T.	Emer. P
Jan. 25	1,352.5	746.2	112.5	484.7	9.1	1,873.3	1,090.6	125.3	644.0	13.4	520.8	344.4	12.8	159.3	4.3
Feb. 23	1,358.1	639.3	337.0	371.1	10.7	1,961.1	907.7	391.7	646.9	14.8	603.0	268.4	54.7	275.8	4.1
Mar. 30	1,493.9	597.6	383.0	503.2	10.1	2,020.3	877.8	555.0	572.8	14.7	526.4	280.2	172.0	69.6	4.6
Apr. 05	1,465.4	737.2	284.5	433.6	10.1	1,994.3	1,157.2	385.8	438.2	13.1	528.9	420.0	101.3	4.6	3.0
May 20	1,428.6	634.2	320.5	463.9	10.0	2,163.1	1,055.0	499.5	594.0	14.6	734.5	420.8	179.0	130.1	4.6
Jun. 28	1,448.5	406.7	391.5	643.2	7.1	2,013.4	815.9	398.3	784.9	14.3	564.9	409.2	6.8	141.7	7.2
Jul. 21	1,388.5	264.0	469.0	648.6	6.9	1,985.5	619.8	566.5	785.4	13.8	597.0	355.8	97.5	136.8	6.9
Aug. 29	1,406.8	288.3	603.0	500.9	14.6	1,999.6	756.0	691.7	537.3	14.6	592.8	467.7	88.7	36.4	0.0
Sep. 28	1,446.8	257.0	350.0	828.4	11.4	2,033.4	783.1	397.5	838.0	14.8	586.6	526.1	47.5	9.6	3.4
Oct. 06	1,453.8	257.6	388.5	799.6	8.1	2,040.2	818.2	396.8	811.2	14.0	586.4	560.6	8.3	11.6	5.9
Nov. 16	1,500.3	197.9	522.0	768.2	12.2	2,013.8	673.8	535.2	789.9	14.9	513.5	475.9	13.2	21.7	2.7
Dec. 06	1,513.1	286.9	616.5	599.0	10.7	2,032.1	779.3	629.4	609.8	13.6	519.0	492.4	12.9	10.8	2.9
Minimum	1,352.5	197.9	112.5	371.1	6.9	1,873.3	619.8	125.3	438.2	13.1	513.5	268.4	6.8	4.6	0.0
Maxmum	1,513.1	746.2	616.5	828.4	14.6	2163.1	1157.2	691.7	838	14.9	734.5	560.6	179	275.8	7.2
Average	1,438.0	442.7	398.2	587.0	10.1	2,010.8	861.2	464.4	671.0	14.2	572.8	418.5	66.2	84.0	4.1

As target year 2025, the daily load curve is assumed under the following conditions:

- As record in 2011, peak load is 25 to 34 % of peak demand.
- From the LTGEP 2013 to 2032, the maximum electric energy and the maximum peak demand are 24,284 GWh and 4,717 MW, respectively.
- As mentioned in the Chapter 3.1.6 (2) power demand in daytime will increase with the development of industry and service sector, it will take time to mature these industries.
- Peak load is 1,320 MW as 28 % of peak power demand, assuming the daily load curve is keeping similar shape as 2011.
- Minimum power demand is 2,000 MW as 44 % of peak power demand.
- Middle peak load is 1,400 MW.

Assumed daily load curve model in 2025 is shown the Figure 4.4-1.

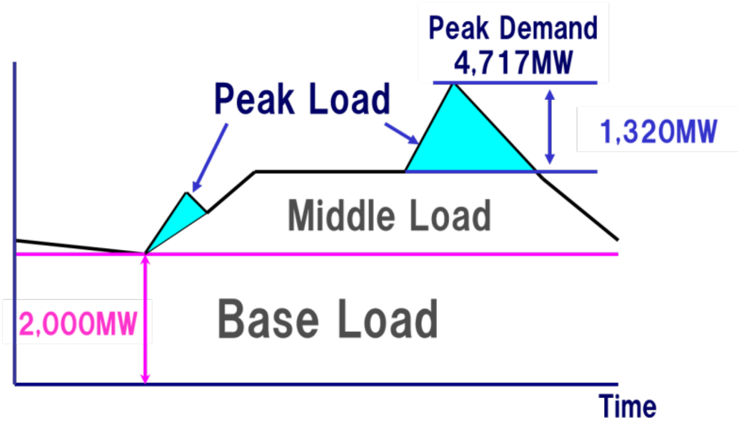


Figure 4.4-1 Daily Load Curve Model in 2025

Since there is no power plant for peak power demand in the LTGEP 2013 to 2032 as already mentioned, the necessary capacity for peak power demand to be developed in future is estimated as follows:

- Only hydropower will supply power for peak load in order to achieve high efficiency of thermal power plants
- Available capacity of hydropower plants for peak load in 2025 is 570 MW (420 MW + 150 MW: UKHP)
- Victoria Expansion (228 MW) will be commissioned before the year 2025.
- Necessary power sources to be newly developed by the year 2025 is about 520 MW (1,320 MW – 570 MW – 228 MW: Victoria Expansion)

It is assessed, from the above, that necessary capacity for peak power demand in 2025 to be developed is 750 MW and the capacity of new project other than Victoria Expansion is about 600 MW (> 520 MW) in consideration of future increment of power demand.

4.5 Commissioning Timing of Power Source for Peak Power Demand

At the present day, the peak load is managed by hydropower plants with reservoir solely used by power generation and petroleum thermal power plants. As shown in the Figure 4.2-1, available power output for peak load is around 65% (about 1,900MW) of total capacity in 2013. It will be reduced 24% (about 1,400MW) in 2025 as shown in the Figure 4.3-1. This phenomenon comes from that there is no development plan of large scale hydropower project with reservoir and retirements of petroleum thermal power plants are increasing. Consequently, the development of substantial amount of power generation for peak demand is required by the year 2025 when the retirement of thermal power plans reaches a peak.

Chapter 5 Long Term Transmission Development Plan and Power System Operation

5.1 Status of Power System Operation

5.1.1 Criteria of Power System Operation

Criteria of the power system presently adopted by CEB are as described in this chapter.

(1) Voltage Criteria

The criteria for voltage variation (%) for 220 kV system and 132 kV system are shown in Table 5.1.1-1.

Table 5.1.1-1 Voltage Criteria

Bus Bar Voltage	Allowable Voltage variation[%]	
	Normal Operation Condition	Single Contingency Condition
220kV	±10%	±10%
132kV	±10%	±10%

(Source: LTTDP 2013-2022)

(2) Thermal Criteria

The system should not exceed the capacity for transmission line and transformer of grid substations.

(3) Stability Criteria

The system stability shall be kept even if following accidents/disturbances occurs;

- Three-phase fault at any one overhead line terminal, cleared by the primary protection with successful and unsuccessful auto re-closing
- Loss of a generation unit
- Load rejection by loss of a transformer

(4) Short Circuit Criteria

The short circuit criteria limit the maximum three-phase fault currents at the bus-bars of any grid substations as shown in Table 5.1.1-2.

Table 5.1.1-2 Allowable Maximum 3 ϕ Short Circuit Levels

Bus-bar voltage	System	Maximum three-phase fault level (kA)
132kV and above	Over head	40.0
	Underground cable	40.0
33kV	Over head	13.1
	Underground cable	16.0
11kV	Underground cable	20.0

(Source: LTTDP 2013-2022)

(5) System Frequency Criteria

The system frequency shall be within 50Hz±1% under normal operations. If the system frequency drops due to faults, the load shedding shall be taken place to keep the system in stable until the system frequency can be recovered within 50Hz±1%. Load shedding scheme for frequency drops are shown in Table 5.1.1-3.

Table 5.1.1-3 Load Shedding Scheme for Frequency Drops

Stage	Target Frequency (Hz)	Break Time	Load Shedding
I	48.75Hz	100ms	5.00%
II	48.50Hz	500ms	5.00%
III	48.25Hz 49Hz AND df/dt<-0.85Hz/s	500ms 100ms	10.00% 3.00%
IV	48.00Hz 49Hz AND df/dt<-0.85Hz/s	500ms 100ms	10.00% 3.00%
V	47.50Hz 49Hz AND df/dt<-0.85Hz/s	instantaneous 100ms	10.00% 4.00%
VI	49Hz AND df/dt<-0.85Hz/s	100ms	10.00%

(Source: CEB System Control Center (As of June 2013))

(6) Spinning Reserve

Spinning Reserve for CEB should be kept more than 5%.

5.1.2 Status of Power System Operation

(1) Outline

Colombo City which is the largest city in Sri Lanka is the demand center of this country. Demand of Colombo metropolitan area occupied around a half; 1,009MW, of the total demand in Sri Lanka; 2,143MW in 2012.

The main power sources of this country are generally composed of thermal power plants located around Colombo metropolitan area (gas turbines, combined cycle and oil plants output around 1,300MW), hydro power plants in central high land area (output: 1,300MW), and thermal power plants North West area (coal, diesel, output: 400MW).

(2) Possible Concerns for Power System Operation

Possible concerns with power system operation are shown below. Countermeasures should be taken in the future.

- Voltage drops and over load of lines in and around Colombo metropolitan area under the normal state, especially in one line outage. Voltage drop is heavily dependent on the generation scenario.
- Voltage drops at New Anuradhapura GS 220kV bus-bars, Trincomalee GS and Valanchenai 132kV bus-bars in Eastern area under one line outage

- There may exist cases that Randeniga - Rantambe transmission line is overloaded under hydro maximum generating state in central highland area. Especially this occurs when the generation of Laxapana and Samanalawewa plants is low. Outage of that line would cause voltage collapse. As one of the countermeasures against such critical voltage drop, Hydro powers in Laxapana complex should be operated with their maximum generation level.

(3) System Frequency Operation

Presently, the system frequency is controlled automatically with free governor mode operations of units. However, the system frequency which is insufficient to control with free governor mode operations has to be controlled manually by one generator of hydro power plants, such as Victoria P/S, Kotmale P/S, Samanalawera P/S, and New Laxapana P/S following to orders from the system control center.

However, in case that several coal fired thermal plants are developed in the future as planed in LTGEP, the present facilities in the network will not be able to sustain frequency stability in years, and additional facilities to manage/absorb surplus energy in the off-peak will be required to be installed.

Adjustable speed pumped storage units can take the frequency control ability and the surplus power absorption ability in off-peak time, which is capable to control the network frequency in a pumping mode as well as in a generating mode and also has a wider adjustable range for generating output and pumping input than the conventional units.

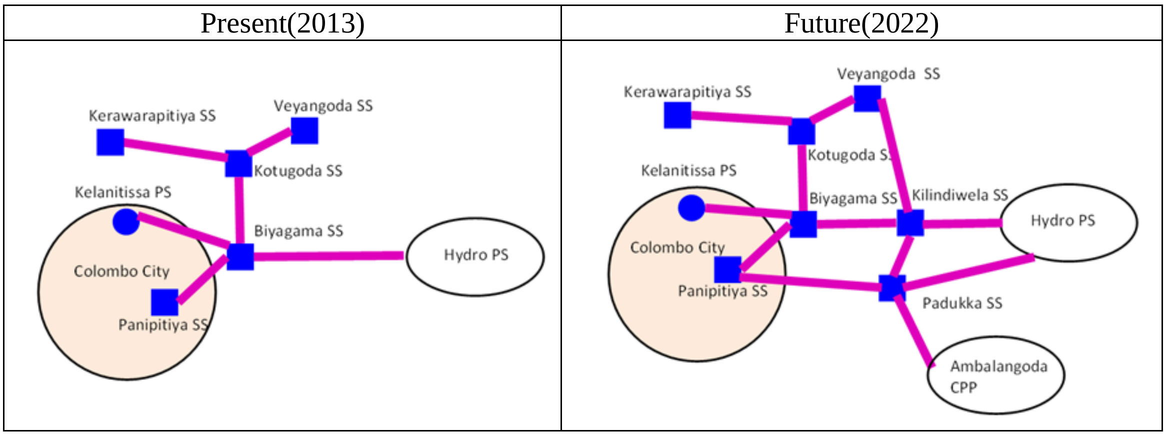
5.2 Status of Long Term Transmission Development Plan

5.2.1 Power Supply Measures for Metropolitan Area

Possible concerns are supposed as voltage drops and over load of transmission line in the metropolitan area. Also, Biyama GS is only 220kV substation which receives power to from main plants area. Then, power is distributed to the main grid substations in the metropolitan area. Under this situation, even if a fault occurs at Biyagama GS, such as a bus fault, power supply to the metropolitan area has to be limited significantly. In order to avoid such serious situation, expansion of transmission lines and substations as mentioned below are planned in LTTDP by 2022, which seems to be effective.

- Construction of 2nd rout from the metropolitan area to hydro power plants of the central highland
- Construction of 400 kV (Padukka) substation, 220kV (Kilindiwela) substations as trunk substations

The differences of the power system in the metropolitan area between 2013 and 2022 are shown in Figure 5.2.1-1.



(Source: LTTDP)

Figure 5.2.1-1 Power System for Metropolitan Area

5.2.2 Long Term Transmission Development Plan to LTGEP

According to Long Term Generation Expansion Plan (LTGEP 2013-2032), the main plants installed in the future are the coal fired power plants. New installation of 2,300MW is proposed up to 2022, which includes following 3 plants.

- Puttalam: 900MW (Installation of 600MW) North Western Area
- Sampoor: 800MW Eastern Area
- Ambalangoda: 900MW Southern Area

Power generated by above power plants will be supply to the metropolitan area. Therefore, the power system expansion should be planned considering the generation expansion plan.

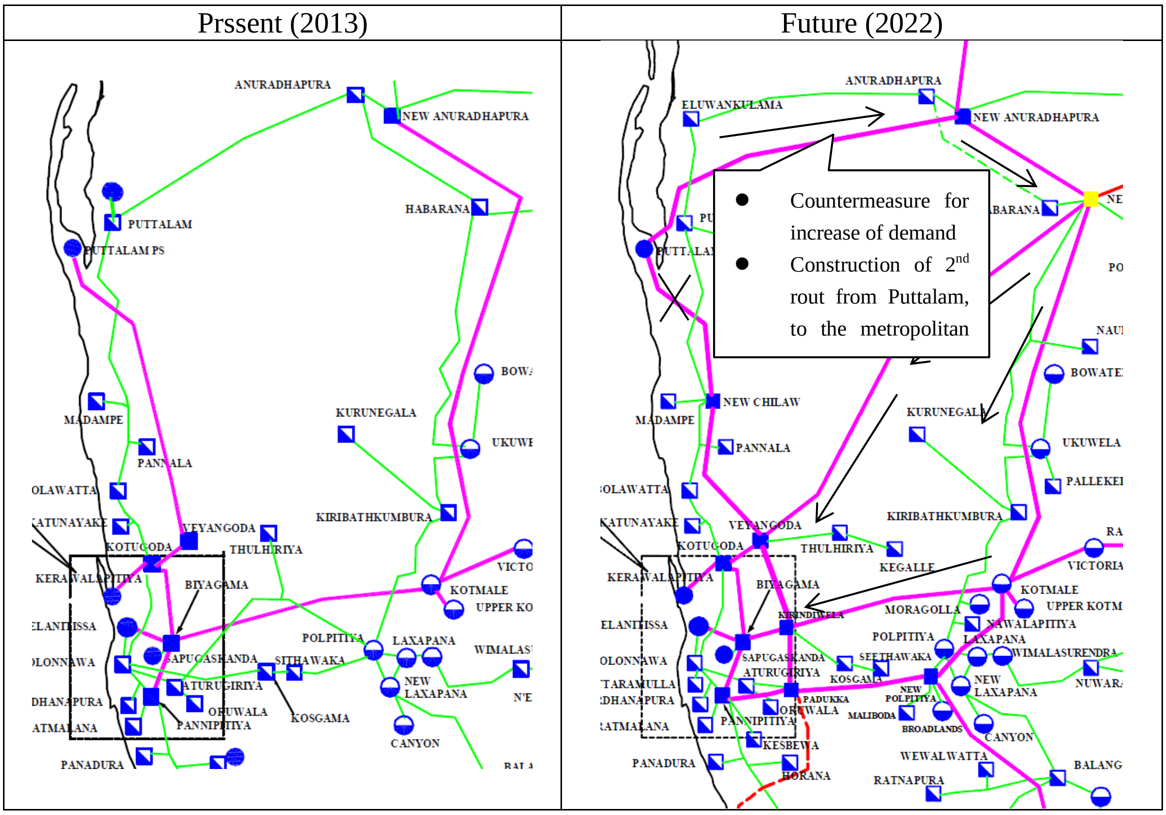
(1) Puttalam: 900MW North Western area

There is a route from Puttalam to the metropolitan area (Puttalam - Veyangoda 220kV transmission line) at present. However, according to Long Term Transmission Development Plan 2013-2022, the second route from Puttalam – New Anuradhapura will be constructed.

Even if one rout failure occurs, power can be supplied to the metropolitan area by remaining transmission line, and it is thought to be useful to avoid a supply failure.

Also, it can be useful for increased demand in Northern Area.

The difference of the power system in 2013 and in 2022 are shown Figure 5.2.2-1.



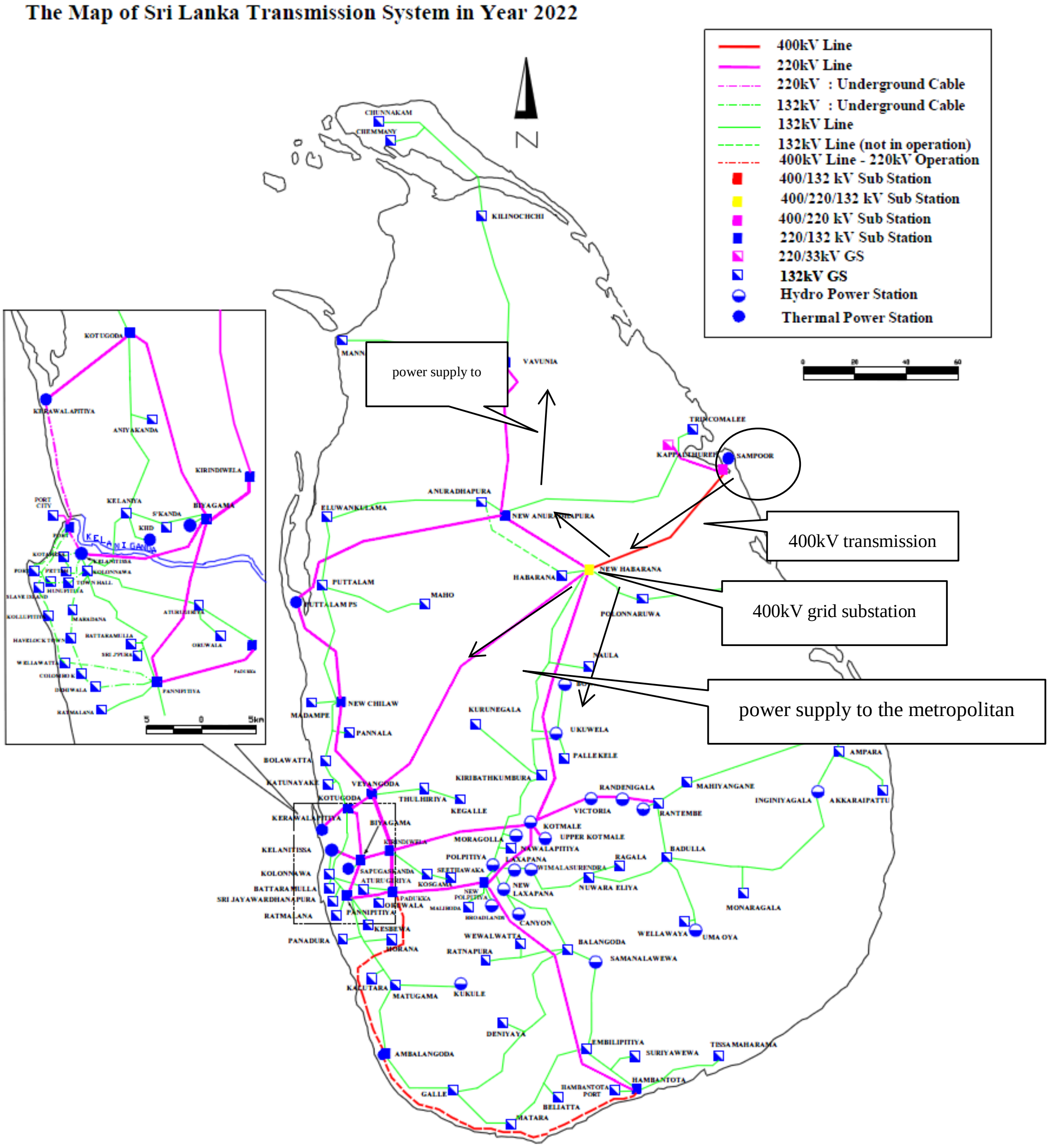
(Source: LTTDP)

Figure 5.2.2-1 Difference of Power System due to Installation of Puttalam between 2013 and 2022

(2) Sampoor: 800MW Eastern Area

Construction of Sampoor coal power plant (capacity: 800MW) is proposed in the eastern area at present up to 2022. Corresponding to this plan, construction of 400kV substation; New Habarana, and 400kV transmission line from Sampoor to Habarana are proposed. It is thought that 400kV transmission line from Sampoor to New Habarana is useful to avoid over load even under one line outage.

Electric power generated at Sampoor will mainly be supplied to the metropolitan area and the northern area via the said transmission line and substation.



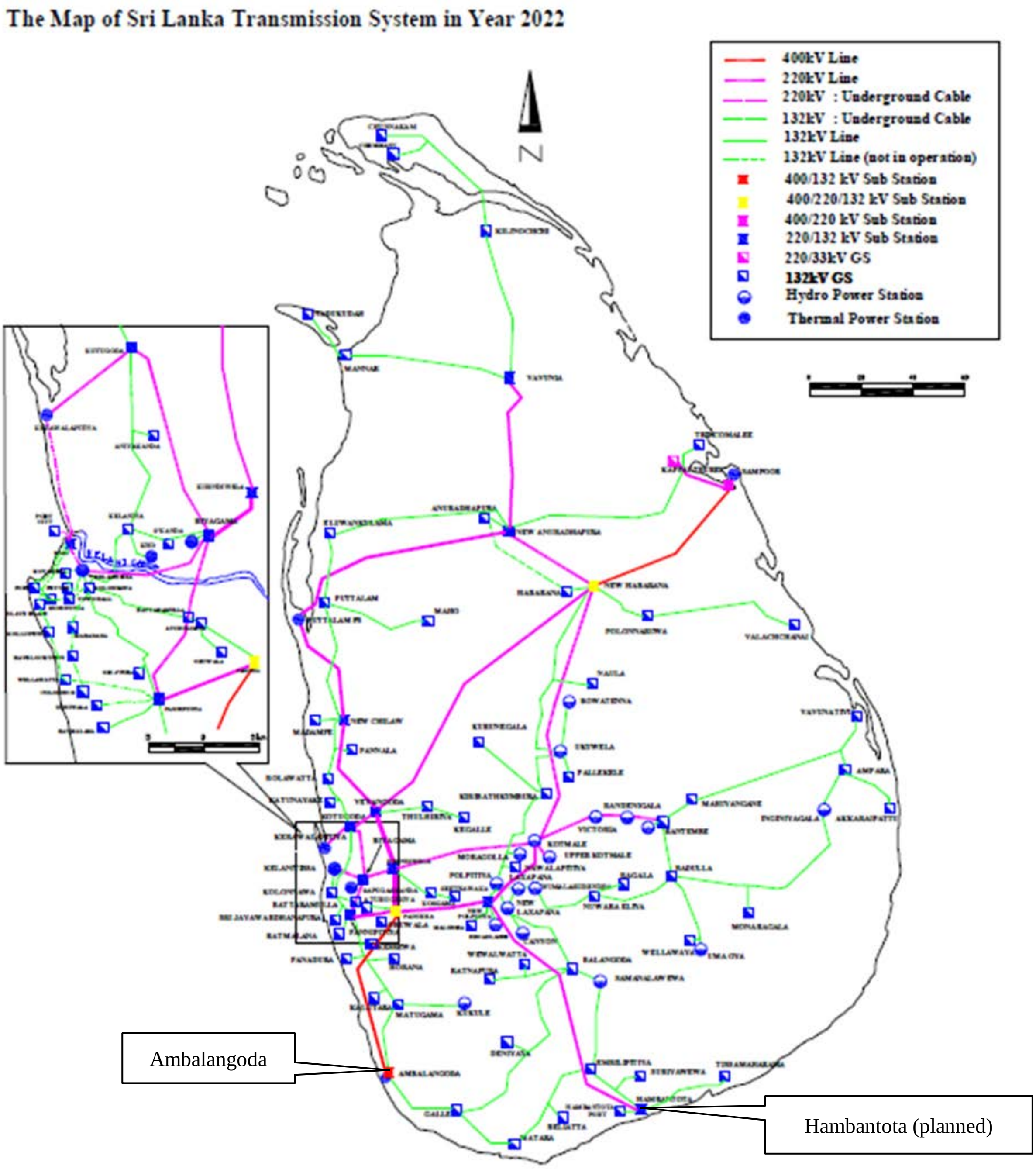
(Source: LTTDP)

Figure 5.2.2-2 Transmission and Substation Expansion due to Installation of Sampoor

(3) Ambalangoda: 900MW Southern Area

Construction of Ambalangoda coal power plant (capacity: 900MW) is proposed in the southern area at present up to 2022. Corresponding to this plan, construction of 400kV transmission line, from Ambalangoda to Padukka is proposed.

Also, according to LTGEP, in 2032, Hambantota coal power plant is planned to be constructed at approximately 150km east of Ambalangoda. Since the power flow at this line to the metropolitan area will be heavy, it is operated at 400kV.



(Source: LTTDP 2013-2022)

Figure 5.2.2-3 Transmission and Substation Expansion due to Installation of Ambalangoda

Chapter 6 Environmental and Social Considerations

6.1 General Information on Environmental and Social Conditions in Sri Lanka

6.1.1 Physical Features[1]

Sri Lanka is an island located at the south east of the Indian sub-continent, between 5° 54' and 9° 52' North and 79° 39' and 81° 53' East. Its land area is 65,610 km^2.

The island consists of a south central mountainous region with an elevation of 2,500 m above sea level, surrounded by broad lowland plains at an elevation of 0 - 75 m. From the mountainous region nine major rivers and 94 other rivers drain across the lowlands into the Indian Ocean.

Sri Lanka is in the equatorial and tropical zone, and it is influenced by the monsoons. North-east monsoon brings rain in the northern and eastern regions in December and January while the western, southern and central regions of the island get rain from May to July due to the south west monsoon.

6.1.2 Ecosystems in Sri Lanka

(1) General

The Ministry of Forestry and Environment[2] identifies, in Sri Lanka, four major groups of ecosystems, which are further divided into various ecosystems.

Forest and related ecosystems[3]: Among those ecosystems, wet zone rainforests (lowland, sub-montane and montane) are exceptionally rich in biodiversity.

Inland wetland ecosystems: Rivers and streams especially in and from the wet zone forests hold indigenous freshwater fish. Artificial reservoirs – tanks – in the lowland plains are home of fish species. Wet patanas in the montane area are unique in the wetland flora. The coastal wetlands are important especially for birds including migratory species.

Coastal and marine ecosystems: Among them, coral reefs are rich in biodiversity and provide key habitats for flora and fauna.

Agricultural lands: Agricultural lands such as rubber, tea plantations and paddy fields can be habitats for number of species. For example, tea plantations harbor a community of birds[4]. Sri Lanka also is known as holding high crop biodiversity.

---

[1] The information of this section are from Biodiversity Conservation in Sri Lanka – A Framework for Action (Ministry of Forestry and Environment, 1999), Climate Change Secretariat, Ministry of Environment, Sri Lanka web site: http://www.climatechange.lk/ccs_index.html, and Central Bank of Sri Lanka Annual Report 2013.

[2] Biodiversity Conservation in Sri Lanka – A Framework for Action (Ministry of Forestry and Environment,1999).

[3] Information on “Forest and related ecosystems”, “Inland wetland ecosystems” and “Coastal and marine ecosystems” and part of “Agricultural lands” are from Biodiversity Conservation in Sri Lanka – A Framework for Action (Ministry of Forestry and Environment,1999).

[4] Birds of Sri Lanka (Deepal Warakagoda, Carol Inskipp, Tim Inskipp and Richard Grimmett, 2012).

(2) Biodiversity Hotspot

Conservation International, international nature conservation NGO, identifies areas with high biodiversity and needs of urgent conservation actions as “Biodiversity Hot Spots”. Sri Lanka belongs to one of the Hot Spots, “Western Ghats & Sri Lanka”.

(3) Important Bird Areas[5]

BirdLife International, international bird conservation NGO, has identified “Important Bird Areas (IBAs)” in the world (including Sri Lanka) since the areas usually have one (or more) of the following features:

- Significant numbers of one or more globally threatened species;
- One of a set of sites that together hold a suite of restricted-range species or biome-restricted species ; and,
- Exceptionally large numbers of migratory or congregating species.

IBAs are considered to be key sites for conservation – small enough to be conserved in their entirety and often already part of a protected area network in the concerned country.

6.1.3 Current Status of Species

(1) Endangered species

Sri Lanka is part of one of the Biodiversity Hotspots as described in the previous lines. Its high biodiversity can be derived from a wide variety of climatic, topographic and soil conditions that has resulted in a diverse array of aquatic and terrestrial habitats and also from its zoogeographic features – history of the continental drift and the eventual separation from the Indian continent[6].

Many of its fauna and flora are now facing risk of extinction because of increase of human population, and decrease and fragmentation of its forests. In 2007, the International Union for Conservation of Nature (IUCN) with the Government of Sri Lanka published “The 2007 Red List of Threatened Fauna and Flora of Sri Lanka”. In 2012, the Ministry of Environment updated the data and revised it as “The National Red List 2012 of Sri Lanka – Conservation Status of the Fauna and Flora”.

Table 6.1.3-1, and Table 6.1.3-2 summarize the contents of the Red List 2012.

[5] BirdLife International web site. http://www.birdlife.org/action/science/sites/

[6] The National Red List 2012 of Sri Lanka - Conservation Status of the Fauna and Flora (Ministry of Environment, Sri Lanka, 2012).

Table 6.1.3-1 Red List of Faunal Species of Sri Lanka

Taxonomic group	Critically Endangered	Critically Endangered possibly extinct	Endangered	Vulnerable	Total number of threatened species	Total number of species
Spiders	41 (14)	-	21 (10)	-	62 (24)	501 (257)
Freshwater crabs	34 (34)	-	12 (11)	-	46 (45)	51 (50)
Dragonflies	26 (22)	-	18 (14)	17 (4)	61 (40)	118 (47)
Ants	25 (5)	-	18 (3)	16	59 (8)	194 (33)
Bees	48	-	38	20	106	130
Butterflies	21 (5)	-	38 (10)	40 (7)	99 (22)	245 (26)
Land snails (excluding 21 not evaluated)	80 (70)	-	76 (72)	23 (20)	179 (162)	253 (205)
Freshwater fish	19 (16)	2 (2)	19 (17)	5 (4)	45 (39)	91 (50)
Amphibians	34 (34)	1 (1)	28 (27)	10 (9)	73 (71)	111 (95)
Reptiles (including marine species)	38 (36)	1 (1)	50 (39)	18 (11)	107 (87)	211 (124)
Birds	18	-	18 (7)	31 (11)	67 (18)	240 (27)
Terrestrial mammals	13 (6)	-	25 (8)	15 (4)	53 (18)	95 (21)

Numbers with brackets indicate endemic species.

Critically Endangered possibly extinct is defined as "species with no distribution records in last 60 years". Total number of threatened species means the total number of Critically Endangered, Endangered and Vulnerable species.

(Source: The National Red List 2012 of Sri Lanka - Conservation Status of the Fauna and Flora (Ministry of Environment, Sri Lanka, 2012))

Table 6.1.3-2 Red List of Floral Species of Sri Lanka

Taxonomic group	Critically Endangered	Critically Endangered possibly extinct	Endangered	Vulnerable	Total number of threatened species	Total number of species
Pteridophytes	42 (10)	21 (5)	88 (11)	70 (12)	200 (33)	336 (49)
Angiosperms	218 (1029	177 (72)	552 (272)	615 (220)	1,385 (594)	3,154 (894)
Gymnosperms	1	-	-	1	2	-

Numbers with brackets indicate endemic species.

Critically Endangered possibly extinct is defined as "species with no distribution records in last 60 years". Total number of threatened species means the total number of Critically Endangered, Endangered and Vulnerable species.

(Source: The National Red List 2012 of Sri Lanka - Conservation Status of the Fauna and Flora (Ministry of Environment, Sri Lanka, 2012))

(2) Globally threatened species

IUCN prepares "The IUCN Red List of Threatened Species" as "the most comprehensive, objective global approach for evaluating the conservation status of plant and animal species[7]". Regarding Sri Lanka, IUCN recognized the status of threatened species as in Table 6.1.3-3.

[7] http://www.iucnredlist.org/about/red-list-overview#introduction

Table 6.1.3-3 Numbers of Globally Threatened Species in Sri Lanka

Taxsonomic group	Mammals	Birds	Reptiles	Amphibians	Fishes	Molluscs	Other invertebrates	Plants	Total
Number	30	15	11	56	43	0	130	286	571

(Source: Threatened species in each country (totals by taxonomic group) in IUCN Red List version 2013.1.)

6.1.4 Conservation Status of Biodiversity in Sri Lanka

(1) Protected Areas and conservation of forests

Department of Wildlife Conservation, Sri Lanka, manages the total area of 938,771.91 ha as protected areas such as national parks[8], and Forest Department manages the total area of 1,180,227ha such as National Heritage and Wilderness Area[9] to conserve important ecosystems

Regarding the conservation of the remaining forests, logging ban in natural forests was imposed in 1990, and a change to this policy is not to be anticipated in the near future[10].

(2) Environmental Protection Areas[11]

Central Environment Authority (CEA) has declared areas with unique environmental features as Environmental Protection Areas under the provisions in the National Environmental Act. CEA is responsible for physical planning and development within an Environmental Protection Areas.

The following nine (9) areas declared up to date:

- Muthurajawela buffer zone
- Bolgoda Lake
- Maragala Kanda, Moneragala
- Wathurana Swamp Forest
- Bulathsinhala
- Hanthana
- Knuckles
- Thalangama Tank
- Lake Gregory, Nuwara Eliya

The following four (4) areas to be declared as EPAs:

- Benthara Ganga
- Dedigamuwa Kanda
- Koggala Lagoon
- Gin Oya

8 Information from Mr. Channa Suraweera, Assistant Director - Natural Resource management, Department of Wildlife Conservation received on 15July 2013.
9 Progress Report 2011 and Action Plan 2012 (Ministry of Environment).
10 Sri Lanka Forestry Outlook Study (FAO, 2009).
11 PROGRESS REPORT 2011 and ACTION PLAN 2012 Ministry of Environment

(3) Ramsar Wetlands[12]

The Convention on Wetlands of International Importance especially as Waterfowl Habitat (Ramsar Convention, 1971) states that “Each Contracting Party shall designate suitable wetlands within its territory for inclusion in a List of Wetlands of International Importance”, and the listed wetlands are recognized as being of significant value not only for the country, or the countries, in which they are located, but for humanity as a whole.

There are 5 (five) Ramsar Wetlands in Sri Lanka.

(4) World Natural Heritages[13]

The Government of Sri Lanka is a member of “Convention Concerning the Protection of the World Cultural and Natural Heritage (World Heritage Convention)”, and has registered two (2) natural heritages - Sinharaja Forest Reserve and Central Highlands.

(5) Biosphere Reserves[14]

United Nations Educational, Scientific and Cultural Organization (UNESCO) and Sri Lankan Government establish Biosphere Reserves under UNESCO's Man and the Biosphere (MAB) Programme to promote sustainable development based on local community efforts and sound science. There are four (4) biosphere reserves in Sri Lanka.

(6) Species protection

Species in Sri Lanka are protected under Fauna and Flora Protection Ordinance. The Fauna and Flora Protection (amendment) Act, 2009, specifies these protected species and not protected ones under the following schedules. These provisions mainly prohibit collection such as hunting and other activities on individual of each species.

Schedule I:	List of Mammals and Reptiles that are not protected;
Schedule II:	Mammals and Reptiles that are strictly protected;
Schedule III:	List of Birds that are not protected;
Schedule IV:	Birds that are strictly protected;
Schedule V:	List of Amphibians that are not protected;
Schedule VI:	List of Fish that are protected;
Schedule VII:	List of Invertebrates that are protected; and,
Schedule VIII:	List of Plants that are protected.

(7) Threats to the biodiversity

The government of Sri Lanka has identified following factors as the threats to its biodiversity[15]:

[12] From the website of Ramsar Convention (http://www.ramsar.org/cda/en/ramsar-documents-list/main/ramsar/1-31-218_4000_0__)
[13] From the website of UNESCO World Heritage Centre (http://whc.unesco.org/en/list/#note28)
[14] From the website of UNESCO Biosphere Reserves (http://www.unesco.org/new/en/natural-sciences/environment/ecological-sciences/biosphere-reserves/)

- Habitat loss and fragmentation;
- Habitat degradation;
- Overexploitation of biological resources;
- Loss of traditional crop and livestock varieties and breeds;
- Pollution;
- Human – wildlife conflicts;
- Spread of invasive alien species; and,
- Increasing human population density

6.1.5 Social Environment

(1) Population

According to the Census of Population and Housing 2011: Preliminary Report-1 published by the Department of Census and Statistics, the national population stands at approximately 20 million as of 2011, an increase of 1.4 million or 7.9% compared to 2001.The rate of annual population growth reached a peak of 2.8% in 1953 and then dropped to 1.2% in 2001 and 0.7% in 2011.

(2) Ethnic Groups and Religions

According to 2012 data published by the Department of Census and Statistics, the principal ethnic groups in Sri Lanka are Sinhalese (74.9%), Sri Lankan Tamils (11.1%), Indian Tamils (4.1%) and Sri Lankan Moors (9.3%). Other minority groups include Burghers and Malays with a few percent each. The identity of many of these ethnic groups is based on religion and language.

Distribution of Population by Religion, Buddhists account for 70.1%, Muslims for 9.7%, Hindus for 12.6%, Catholics for 6.2% and other Christians for 1.4%

(3) Politics and Administration

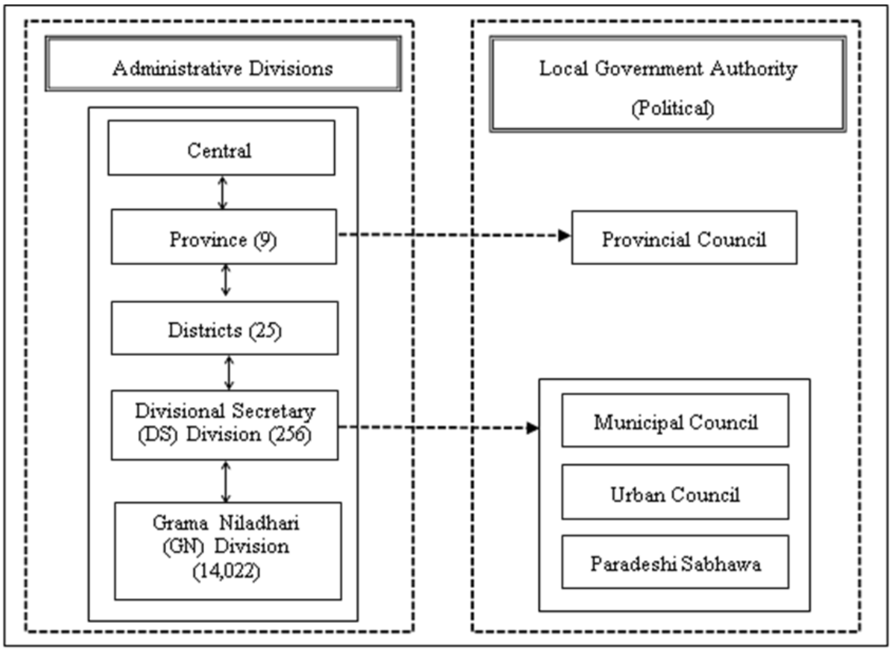
Sri Lanka is a republic which combines a presidential system and parliamentary cabinet system. The legislative branch consists of a unicameral parliament with 225 seats. Members service six year terms of office. 196 out of 225 are elected with a system of proportional representation in respect of 22 electoral districts, while 29 out of 225 to be declared elected on the basis of the total number of votes polled by the respective political parties or independent groups at the national level. Therefore the parliament has a proportional system at the district level and a proportional system at the national level based on the same poll[16].

Local administration is handled by administrative divisions and local authorities headed by elected governors, etc. as shown in Figure 6.1.5-1. According to the Department of Census and Statistics, there are 9 provinces, 25 districts, 256 divisional secretariats and 14,022 GN divisions.

[15] Fourth Country Report from Sri Lanka to the United Nations Convention on Biological Diversity (2009)
[16] From the website of Parliament of Sri Lanka:
http://www.parliament.lk/en/members-of-parliament/the-system-of-elections-in-sri-lanka/the-electoral-system

The head of each administrative unit is appointed by the central government.

Over a long period of time, local authorities have been differentiated to form the present structure consisting of provincial councils, municipal councils, urban councils and Pradeshiya Sabha to be responsible for local administration in their own areas.



(Source: made by the JICA Study Team)

Figure 6.1.5-1 Administrative Services and Local Authorities

(4) Outline of Industries

The Sri Lanka economy has traditionally relied on agriculture centering on the production of rice and three major plantation crops (tea, rubber and coconuts). The economic growth of the country has expanded the shares of the manufacturing sector and wholesale and retailing sector. Garments have been the largest export item in recent years.

In 2010, the real GDP growth rate was as high as 8%, recording the highest figure in 30 years. The service sector in particular made an impressive contribution as the revitalized domestic demand and increased number of foreign visitors due to the improved security situation since the end of the civil war pushed up the turnover of hotels and restaurants. There has been a growing demand for construction materials for the reconstruction and development of infrastructure in the Northern and Eastern Provinces[17].

(5) Work Force

The census report 2011 mentioned earlier lists the population of 10 years old or older at 17.9 million (males: 8.4 million; females: 9.4 million), of which some 8.5 million are classified as

[17] The website of Ministry of Foreign Affairs of Japan, the situation of Sri Lanka

working age population. As the actual number of employed people stands at 8.19 million, the unemployment rate is approximately 4.2%, indicating an almost halving of the unemployed in the last 10 years.

In the period from 1993 to 2011, the employed population by sector has shown a gradual increase in the manufacturing and service sectors. In contrast, the agricultural population has been gradually declining since 1997.

The minimum wage for workers by sector was 1,176.5 Rp per month in 2001 and 3,427.2 Rp in 2011 for agricultural workers. In the manufacturing sector, the minimum monthly wage was 919.6 Rp in 2001 and 2,402.1 Rp in 2011. In the service sector, the corresponding figure was 657.6 Rp in 2001 and 1,851.8 Rp in 2011. In each sector, the minimum monthly wage more than doubled in 10 years.

(6) Education

The literacy rate in Sri Lanka is 92.5%[18]. Sri Lanka's education system consists of five years of primary education, six years of secondary education, two years of collegiate education and tertiary education. Only person who pass a uniform examination can enroll collegiate education. The primary school enrolment rate is 99%, secondary education is 70%, and college is 2.5%[19].

(7) Poverty

According to the latest survey (HIES) conducted in FY 2009/10, the national poverty rate of Sri Lanka is 8.9%. By sector, urban areas have the lowest poverty rate of 5.3%, followed by rural areas with 9.4% and estates with 11.4%.

By province, Eastern Province has the highest poverty rate of 20.3%, followed by Uva province (13.7%) and Northern Province (12.8%).

By district, Batticaloa in the Eastern Province has a high poverty rate of 20.3%, while Jaffina in the Northern Province and Moneragala in Uva Province have a poverty rate of 20.3% and 14.5% respectively.

Among the 10 candidate sites which are located in Kandy, Nuwara-eliya, Badulla, Ratnapura and Kegalle Districts for pumped storage hydroelectric power generation, the Badulla District has a relatively high poverty rate of 13.3%.

(8) Indigenous People

According to the 2011 update report of International Group for Indigenous Affairs (IWGIA)[20],

[18] United Nations Educational, Scientific and Cultural Organization (UNESCO) as of 2010
[19] The website of Ministry of Education in Sri Lanka
[20] http://www.iwgia.org/iwgia/who-we-are-/organisational-structure

Vedda (huntsmen) are historically recognized as indigenous people who served a defined role, recognised by royal decree, and who owed allegiance to the King with European colonisation. They used to live in south-eastern and eastern coastal belt, the northern tracts and the central part of the island. Vedda people as a distinct ethnic group and gave population figures of between 1,229 and 4.510 people during British colonial record, but census surveys of the last three decades have not distinguished them as a separate ethnic group. A systematic census to estimate the population of Vedda has yet to be conducted. Integration with neighbouring forest-dependent communities, the population census counts the Vedda people are incorporated in the major ethnic group of Sinhalese, Muslims and Tamil people. There is no national legislation that would recognize the status and protect the right of the Vedda.

(9) World Cultural Heritages[21]

The Government of Sri Lanka is a member of "Convention Concerning the Protection of the World Cultural and Natural Heritage (World Heritage Convention)", and has registered six (6) cultural heritages as follows.

- Sacred City of Anuradhapura
- Ancient City of Polonnaruwa
- Ancient City of Sigiriya
- Sacred City of Kandy
- Old Town of Galle and its Fortifications
- Golden Temple of Dambulla

6.2 Profile of Environmental and Social Consideration in Sri Lanka

6.2.1 Legal System Relating to Environmental and Social Consideration

(1) Environmental Policies

The basic document stipulating the environmental policies in Sri Lanka is the National Environmental Action Plan 1992 - 1996 formulated by the Ministry of Environment and Parliamentary Affairs. The contents of this strategy were a) general statement on the Sri Lankan environment, b) management of the ecosystem for sustainable development, c) human activities, including those related to the environment, d) constraints for environmental protection and sustainable development, e) strategy and f) implementation of the strategy.

Below are summaries of the parts dealing with land, water resources and energy in the current Action Plan as these matters are specially connected to hydroelectric power generation.

1) Land

The Action Plan examines and presents improvement methods for such environmental issues as a) reduce land degradation in agricultural areas, b) rehabilitate deteriorated lands, c) develop and

[21] The website of UNESCO World Heritage Centre, http://whc.unesco.org/en/statesparties/LK/

implement programmes for the use of non-cultivated agricultural lands, d) optimize soil conservation through mandatory & other measures, (e) promote precision farming, traditional verities of crops and crops to fit agro-ecological condition, f) conserve, restoring and improve important representative landscapes, g) carry out assessment on forest cover of Sri Lanka, including different categories of forests h) promote the integrated management of upper watersheds, i) mitigate and adaptation to drought

2) Water Resources

The Action Plan examines a) establish a systematic water allocation system and improve efficiency and equity in water distribution for various purposes, b) organize a rehabilitation scheme for small tanks and revitalize the tank cascade system developed, c) transform the irrigation system to meet new challenges, d) keep drinking water sources free from contamination through proper zoning and control measures, e) Strengthen implementation of integrated water resource management systems, f) reduce fertilizer leaching and eutrophication

3) Energy[22]

The Action Plan to deal with the growing power demand in the coming years calls for (a) diversification of the sources of electric energy, (b) reduction of oil-fired thermal power plants, (c) promotion of coal-fired thermal power plants and wide use of renewable energies and (d) promoting energy efficiency and conservation.

(2) Poverty reduction policy[23]

The Government of Sri Lanka made the Millennium Development Goals by 2015 in 2000, and the Poverty reduction strategy Paper in 2002. Based on these documents, poverty reduction policy was stated in Mahinda Chintana as follows.

- Eradication of hunger and hard-core poverty
- Universalization of secondary education for all
- Reducing malnutrition rate of children from a third to 12-15 percent
- Increasing life expectancy from 76 to 80 years.
- Increasing access to clean water in urban areas from 65 to 90 percent

(3) Empower agriculture and rural development

80% of the people live in rural areas and 70 percent of the people work in agriculture. Accounting for 11% of GDP and one third of export revenues, a vibrant agriculture sector can be a driving force for economic growth over the coming decade. The followings are the strategies in this sector.

- Intensifying agricultural production to increase output by 6% per annum
- Diversifying agricultural production to raise livelihood activities

[22] National Energy Policy & Strategies of Sri Lanka 2008

[23] Extract from the Development Policy Framework (Mahinda Chintana) which targets from 2006 until 2016. It was revised in 2010.

- Creating opportunities for off-farm employment
- Rural infrastructure expansions

(4) Laws Relating to Environmental and Social Considerations

The Constitution of Sri Lanka of 1978 stipulates that “It is the duty of every person in Sri Lanka to protect nature and conserve its riches” (Article 28 (d) and (f)), and “The State shall protect, preserve and improvement the environment for the benefit of the community (Article 27-(14)). Based on this Constitution, the National Environmental Act No. 47 of 1980 (NEA) was enacted in 1980 to stipulate the basic framework for environmental protection and management in Sri Lanka. In 1981, the Central Environmental Authority (CEA) was established as the implementing agency for official environmental protection and management measures. This National Environmental Act was subsequently revised in 1998 and 2000.

(5) Permits and licenses for hydropower development in Sri Lanka

It is necessary to obtain the following permits and licenses for hydropower development in Sri Lanka. Table 6.2.1-1 is the list of permits and licenses.

Table 6.2.1-1 Necessary Permits and Licenses for Hydropower Development

No.	Name of government agency	Requirement
1	Divisional Secretariat	Approval of social acceptability
2	Local government authorities’ (Urban council, Municipal Council, and Pradeshiya Sabhas) approval for construction	Approval for construction activities (ex. Transport, unloading, excavation, building, dumping and so on.)
3	Mahaweli Authority	In case of a project location is along Mahaweli River and its reservation.
4	Road Development Authority	In case of existing roads are to be affected by a proposed project, and/or new road is necessary for a project
5	Department of Archaeology	To study on archaeological artifacts and structures of historical interest whether lying or hidden beneath the surface of the ground or in any water/lake
6	Geological Survey and Mines Bureau	Quarry permit, quarry extraction, transport and unloading
7	Department of Agriculture	Soil erosion, and soil conservation plan In case of a proposed project site is within a radius of 1 km from the boundary of botanic gardens
8	National Water Supply & Drainage Board, Department of Irrigation, Mahaweli Authority, and the concerned government agencies	There is no written rule for water right in Sri Lanka. But if a proposed project will affect water distribution for water supply for drinking, irrigation and so on, the concerned agencies have to be consulted.
9	Project Approving Agency appointed by CEA	EIA/IEE
10	Land and Land Development Authority	Resettlement Action Plan Land acquisition

(Source: made by JICA study team after hearing with CEB, and CEA)

(6) Strategic Environmental Assessment[24] (SEA)

In Sri Lanka, strategic environmental assessment (SEA) is currently being introduced. SEA is a system of incorporating environmental considerations into policies, plans, programmes and strategies before or simultaneously with the formulation of them. In May 2006, the Government of Sri Lanka endorsed that all policies and plans, programmes should be subjected to SEA in future. To promote the introduction of SEA, CEA formulated ‘A Simple Guide to Strategic Environmental Assessment (SEA)’ in 2009 to help all administrative entities understand the contents and implementation method. Under the SEA, all such environmentally sensitive areas as forests, wildlife areas, elephant corridors and other unique ecosystems have been identified for conservation purposes.

(7) Environmental Impact Assessment[25] (EIA)

1) EIA in the National Environment Act

The National Environmental (Amendment) Act (NEA) No. 56 of 1988 introduced EIA, as a part of the strategy to achieve sustainable development for the entire country and the Central Environmental Authority was assigned regulatory functions.

Part IV C of the amendment act mandated that all “prescribed” development projects are required to be subjected to Environmental Impact Assessment. (Gazette No. 772/22 of 24 June 1993, 859/14 of 23 February 1995, 1104/22 of 5 November 1999 and 1106/1 of 29 November 1999.)

Concerning the power generation and transmission, above mentioned gazette stipulates at Part I as below (Table 6.2.1-2).

Table 6.2.1-2 Power Generation and Transmission Projects

1	Construction of hydroelectric power stations exceeding 50 MW
2	Construction of thermal power plants having generation capacity exceeding 25 MW at a single location or capacity addition exceeding 25 MW to existing plants
3	Construction of nuclear power plants
4	All renewable energy based electricity generating stations exceeding 50 MW
5	Installation of overhead transmission lines of length exceeding 10 km and voltage above 50 kv
6	Involuntary resettlement exceeding 100 families other than resettlement effected under emergency situations

(Source：Guidance for implementing the environmental impact assessment process No.1 (CEA))

Only large scale development projects that are likely to have significant impacts on environment are listed as prescribed projects.

[24] A simple guide to strategic environmental assessment, Central Environmental Authority
[25] Guidance for implementing the environmental impact assessment process No.1 and No.2, CEA

2) Project Approving Agency (PAA)

The NEA stipulates that approval for all prescribed projects must be granted by a Project Approving Agency (PAA). At present, 23 Government Agencies have been designated as PAAs. A single Project Approving Agency is established as responsible for administrating the EIA process for a project. When there is more than once PAA is involved the appropriate PAA is decided by the CEA.

3) Steps in EIA Process

The National Environmental Act has identified two levels in the EIA process. If the environmental impacts of the project are not very significant then the project proponent may be asked to do an Initial Environmental Examination (IEE), which is a relatively short and simple study. However, if the potential impacts appear to be more significant, the project proponent may be asked to do an EIA which is a more detail and comprehensive study of environmental impacts.

a) Preliminary Information

A project proponent is required to provide the CEA with preliminary information on the proposed project, in order for the EIA process to be initiated.

The best time for a project proponent to submit the preliminary information on the proposed project is as soon as the project concept is finalized and the location of the project is decided. The Basic Information Questionnaire form prepared

b) Environmental Scoping[26]

When a prescribed project is referred to CEA, the CEA will decide a suitable Project Approving Agency (PAA). The PAA will organize a scoping meeting that a project proponent will present the project outline. Then the scoping meeting members visit the project site, and carry out scoping and Terms of Reference (ToR) for the EIA/IEE will be issued to the project proponent..

c) EIA/IEE Report Preparation

It is the responsibility of the project proponent to prepare the EIA/IEE report and to submit it to the PAA for evaluation. Preparation of EIA reports may require the services of a team of consultants as many specialized areas have to be covered. A list of consulting firms who prepare EIA reports is available at the CEA.

[26] Based on the EIA guideline in Sri Lanka, official and unofficial stake holder meetings are held though; direct affected individuals or groups are not always included during scoping. Only up to Divisional Secretariat level attend scoping meeting. Thus there is a gap on scoping between the EIA guideline by CEA and the JICA guideline on Environmental and Social Consideration

d) Public Participation and Evaluation of the Report

On receipt of an EIA report, it will be subjected to an adequacy check in order to ensure that the TOR issued by the PAA has been met. It will then be open for public inspection / comments for a period of 30 working days

If there are any public comments on the IEA report, they will be sent to the project proponent for response.

Subsequent to the public commenting period the PAA will appoint a Technical Evaluation Committee (TEC) to evaluate the EIA report and make its recommendations.

IEE reports are not required to be opened for public comments and are thus subjected to technical evaluation only.

e) Decision Making

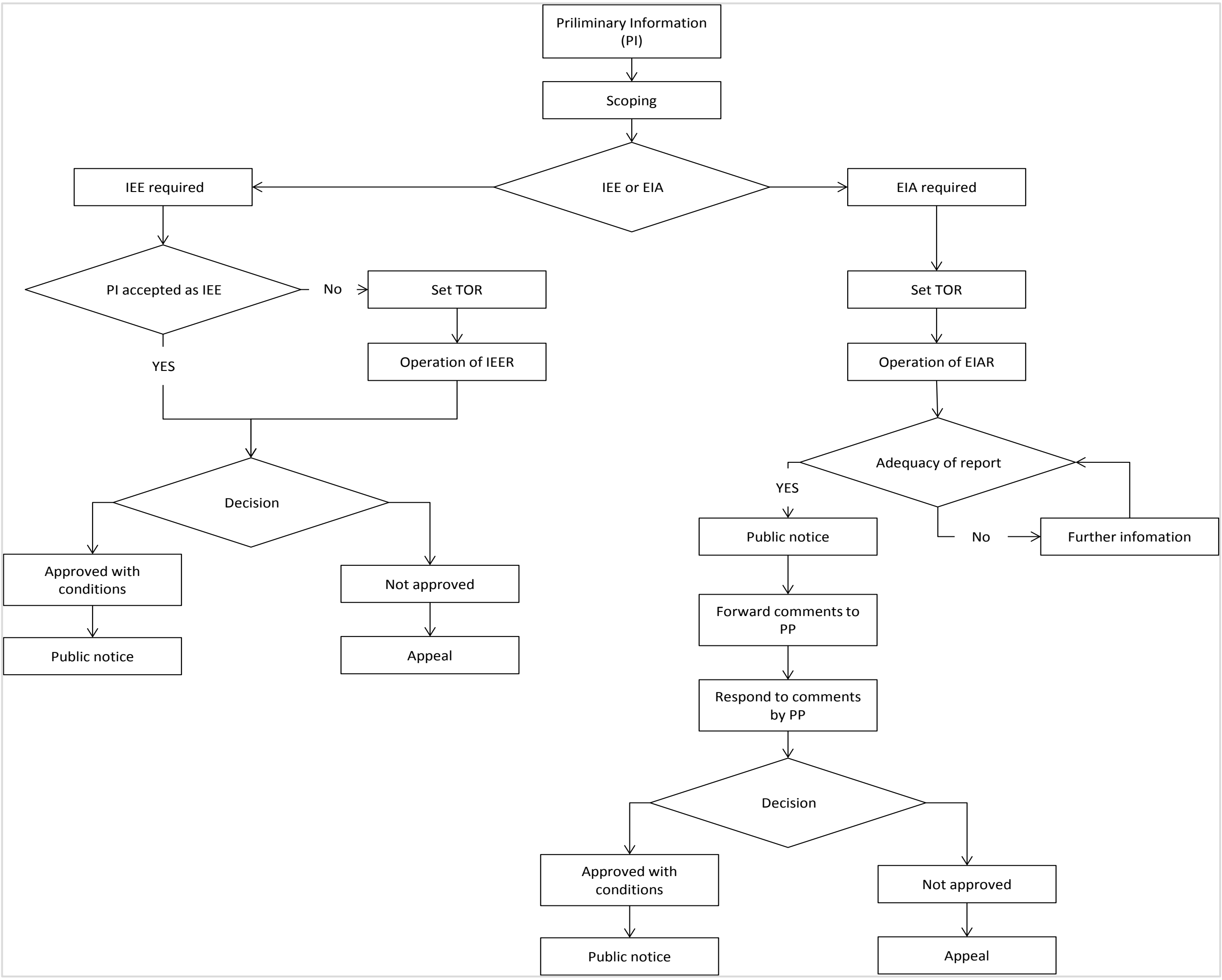
Based on the recommendation of the TEC, the PAA makes its decision on whether to grant approval for a project. If the PAA is not the CEA, it should obtain the concurrence of the CEA prior to granting approval.

If the project proponent does not agree with the decision he has a right to appeal to the Secretary to the Ministry of Environment. The decision of the Secretary to the Ministry of Environment is final

f) Compliance Monitoring

EIA/IEE approval is generally given with conditions which the project proponent is expected to meet. The CEA or the PAA will monitor the implementation of conditions / mitigation measures. If the project proponent violates the conditions, the approval may be revoked.

Figure 6.2.1-1 shows the flow of EIA/IEE.



(Source: Guidance for Implementing the Environmental Impact Assessment Process No.1)

Figure 6.2.1-1 Flow of EIA (on the Right Flow) and IEE

(8) Land acquisition and involuntary resettlement

1) Land acquisition and involuntary resettlement

The Government of Sri Lanka has adopted the National Involuntary Resettlement Policy in 2001, and issued the guide[27] for public officials on good practice in 2013. The policy is designed to ensure that i) project affected persons are adequately compensated, relocated and rehabilitated, ii) delays in project implementation and cost overruns are reduced, and iii) better community relations are restored.

In case where a land is required for a public purpose of any Ministry, Department, Corporation, Statutory Board, Provincial Council or a Local Government Institution, the Head of the particular Department forwards an acquisition proposal to the Secretary, Ministry of Land and Land Development through the Secretary to the Ministry of which the particular institution fallen

[27] Land Acquisition and Implementation of the National Involuntary Resettlement Policy

under the purview. Process for land acquisition and resettlement, which is based on the Land Acquisition Act, No. 9 of 1950 (LAA) was built upon the Land Acquisition Ordinance of 1876. After confirming accuracy of the proposal, the acquisition procedure is commenced on the approval of the Minister of Land and Land Development. The lands are acquired under the provisions of the Land Acquisition Act and regulations imposed thereto and compensation and interests are paid to the land owners in respect of the lands acquired[28].

2) Types of resettlement plans

The National Involuntary Resettlement Policy (NIRP) of 2001 requires that a Resettlement Action Plans (RAP) is prepared for the projects where 20 or more families are affected regardless of the source of funding of the project.

Formulation of an RP and its implementation is the responsibility of the project executing agency and project management unit (PMU) of a development project.

3) Grievance redress

The Land Acquisition Act (LAA) provides a limited grievance redress mechanism whereby certain grievances of the affected persons relating to compensation can be referred to the Board of review established under the LAA. This is a limited redress mechanism that only addresses issues pertaining to compensation.

(9) Environmental Standards[29]

The central Environment Authority (CEA) would be established by the National Environmental Act enacted in 1980, the comprehensive regulation in connection with ambient air, water pollution, waste, soil pollution, noise, and a bad smell will be defined in the Act revision in 1988.

6.2.2 Differences between the JICA Guidelines and the Sri Lankan legislations

Regarding an EIA process and involuntary resettlement issues in the Social and Environmental Considerations, there are some differences between the JICA Guidelines (2010) and the Sri Lankan legislation. Table 6.2.2-1 and Table 6.2.2-2 summarize the differences.

[28] The website of Ministry of Land & Land Development
[29] Source: Environmental Norms 2011, Board of Investment of Sri Lanka

Table 6.2.2-1 Differences regarding an EIA process in the JICA Guidelines and the Sri Lankan legislation

Item	JICA Guidelines	Sri Lankan legislation
Public consultation in an EIA process	SEA stage: The project proponent is obliged to collect comments and/or concerns from the stakeholders in the affected areas and to reflect the comments and concerns to the plan.	SEA stage: No specific opportunities for general stakeholders are provided.
	EIA stage: At the stages of Scoping (draft) and EIA Report (draft), the project proponent is obliged to hold stakeholders meetings (especially for affected people) in the affected area to explain the contents of the scoping (draft) and EIA report (draft). Appropriate comments and concerns should be reflected in the plan.	EIA stage: Stakeholders are provided an opportunity to comment on the plan at its scoping stage. In this case, the stakeholders are usually related governmental organizations (not local/general stakeholders). The stakeholders can submit queries and comments on the EIA report.
Environmental checklist	Environmental checklist is provided by the guidelines for each sector. An EIA report should contain the items in the checklist.	No specific checklist is provided. The PAA shall prepare terms of reference for an EIA (or IEE) study.

(Source: JICA Study Team)

Table 6.2.2-2 Differences regarding involuntary resettlement issues in the JICA Guidelines and the Sri Lankan legislation

Item	JICA Guidelines	Sri Lankan legislation
Resettlement Action Plan (RAP)	The project proponent is obliged to prepare a RAP. If number of resettled household is small (e.g. one household), the RAP can be simplified one. The RAP is prepared as part of the EIA Report.	In case that the number of resettled households is 20 or more, the NIRP requires a RAP.
Compensation for land resettlement	Full replacement cost must be applied as much as possible.	The LAA provides for the payment of compensation on the basis of "market value" which is defined as the "amount which the land might be expected to have realized if sold by a willing seller in the open market as a separate entity". The Land Acquisition regulations of 2008 redefines the valuation approach to determine "market value" stating that "in case of land where part of land is acquired and when its value as a separate entity deems to realize a value proportionately lower than the market value of the main land the compensation should be proportionate to the value of the main land". The NIRP recommends that compensation for loss of land, structures, other assets and income should be based on full replacement cost and should be paid promptly together with transaction costs.
Compensation for non-registered residents	All residents before the cut-off-date are eligible.	The LAA does not have any provisions on this issue. The NIRP recommends that affected persons who do not have documented title to land should receive fair and just treatment.
Grievance redress mechanism	The project proponent is obliged to have a grievance redness mechanism.	The LAA provides a limited grievance redress mechanism whereby certain grievances of the affected persons relating to compensation can be referred to the Board of Review established under the LAA. The NIRP recommends the establishment of an internal monitoring system by project executing agencies to monitor the implementation of RAPs and handling of grievances. Grievances redress mechanism formally instituted by the project authorities with the support of the Divisional Secretaries of the project area.

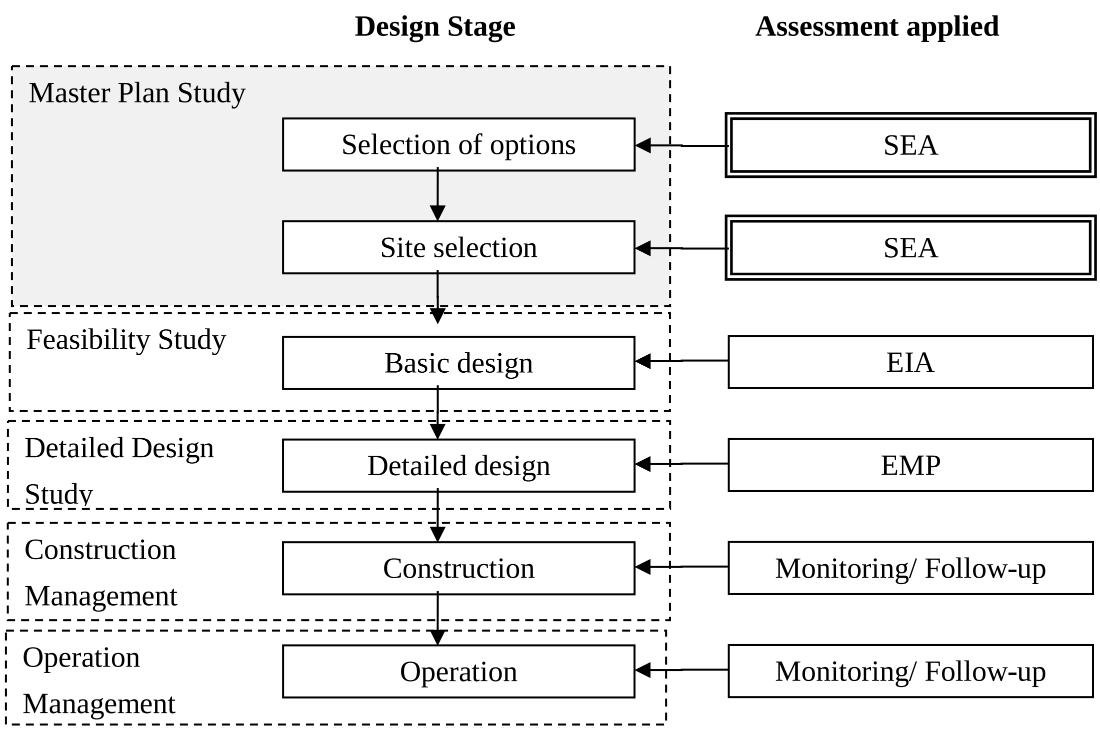
(Source: JICA Study Team)

6.3 Strategic Environmental Assessment

6.3.1 Strategic Environmental Assessment and the Study

In the Study, Strategic Environmental Assessment (SEA) is conducted. Figure 6.3.1-1 shows a flow of the environmental assessments in a development study. The Study is "Master Plan Study" in the figure, and SEA is one of the most suitable environmental assessments at a master plan study. This is because a) project details are not decided; and, b) alternative options can be discussed with wider stakeholders.

In the Study, SEA is conducted in the following two stages - the stage of selecting a power generation option for peak demand, and the site selection stage - to set up a logical framework of appropriateness of power generation development scenario and site selection.



(EIA: Environmental Impact Assessment, EMP: Environmental Management Plan)

Figure 6.3.1-1 Design Stages and Assessment applied

Power generation options and candidate sites are examined in technical, economic and environmental & social aspects at each stage. Information on the SEA is disclosed, and stakeholders meetings are held to discuss the main contents of the SEA throughout the SEA process in the Study.

The JICA Study Team follows the guidelines provided by CEA, Sri Lanka, and experiences from other master plan studies carried out by JICA in other countries.

6.3.2 SEA at Selecting Power Generation Options

At the selection of power generation options for peak demand, two screenings are conducted. At the 1st screening step, all alternative power generation options are examined by critical conditions for the power generation for peak demand in Sri Lanka. At the 2nd step, the remaining alternatives are compared by technical, economic and environmental & social criteria.

6.3.3 SEA at Selecting Candidate Sites

At the stage of selecting a suitable site for pumped storage power plant development, two screenings are conducted.

At the 1st screening step, 11 candidate sites are examined at technical, economic and environmental & social criteria, and three (3) promising sites are selected. It is therefore an Environmental Study (the 1st Environmental Study) is conducted to collect information on natural and social environments of the sites.

At the 2nd step, the three (3) selected sites are examined in more details at technical, economic and environmental & social criteria. The 2nd Environmental Study is conducted to collect more detailed information on natural and social environments of the three sites to compare them at environmental and social criteria.

6.3.4 Stakeholders Meetings

One of the most important steps of SEA is information discloser and reflecting comments from stakeholders into a plan as much as possible.

In the Study, three (3) Stakeholders Meetings (SHMs) are held

At each SHM, questions from the participants are answered by CEB and the JICA Study Team. Comments from the participants are collected, and they are reflected into the plan as much as possible.

The details of each SHM are described in Chapter 7.

Chapter 7 Stakeholders Meetings

7.1 1st Stakeholders Meeting

7.1.1 Objectives and Stakeholders

(1) Objectives

There are two main objectives of the 1st SHM as follows:

- To discuss power generation options for peak demand in Sri Lanka, and to agree on validity of pumped storage power plant (PSPP) development based on the above discussion; and,
- To explain and discuss SEA on selecting suitable sites from candidate sites of PSPP.

(2) Stakeholders

In case of the 1st SHM, the first half of the meeting is allocated to discuss power generation options in Sri Lanka, and all citizens in the country are theoretically considered as the stakeholders. However, since it is not realistic to invite them to the meeting, experts and social Non-governmental Organizations (NGOs) are invited to the meeting. These experts and social NGOs are expected to express their questions and comments on behalf of the citizens.

Regarding natural environmental aspects of the plan, experts and NGOs on natural environment are invited to the SHM.

Table 7.1.1-1 Invited Experts and NGO

Social environment	Natural environment
- Centre for Environmental Justice（Friends of the Earth Sri Lanka）	- IUCN
	- Dr. Sarah W. Kotagama
- Green Movement of Sri Lanka	- Field Ornithology Group of Sri Lanka (FOGSL)
- Consortium of Humanitarian Agencies	- Environmental Foundation Limited
- International Centre for Ethnic Studies	- EMACE Foundation
- Lanka Mahila Samiti	- National Solid Waste Management Support Centre
- Sarvodaya	- Sri Lanka Environmental Journalists Forum
- Sewalanka Foundation	- Sri Lanka Wildlife Conservation Society
	- Wildlife & Nature Protection Society

The following relevant governmental organizations are invited to the meeting.

Table 7.1.1-2 Invited Governmental Organizations

Government Agency
- Ministry of Power and Energy
- Central Environmental Authority
- Department of External Affairs (Ministry of Finance and Planning)
- Department of Irrigation
- Mahaweli Authority (Ministry of Irrigation and Water Resources Management)
- Department of Wildlife
- Department of Forest
- Sustainable Energy Authority

7.1.2 Reconnaissance Site Visits

The latter half of the meeting is allocated to discuss on the selection of suitable sites from candidate sites of PSPP, so that CEB and the JICA Study Team conducted reconnaissance site visits and interviews with the Divisional Secretaries.

Based on the reconnaissance site visits, a scoping table (draft: Table 7.1.2-1) was prepared and presented at the 1st SHM.

Table 7.1.2-1 Scoping (draft) for 11 Candidate Sites

Natural environment	Impacts on fauna and flora	Inundated forest area
		Impacts on protected areas
		Impacts on endangered species (especially fish and other aquatic species)
Social environment	Impacts on local communities	Number of those who to be resettled
		Area of land to be acquired
		Impacts on water utilization (e.g. drinking water, irrigation)
		Impacts on utilization of forest and grassland
		Impacts on public facilities (e.g. school)
	Impacts on industries	Agriculture
		Forestry
		Tourism
	Impacts on cultural heritages	Religious, cultural and/or archeological facilities
		Impacts on landscape

7.1.3 Contents of the 1st SHM

The 1st SHM was held on 27 June 2013 at Hilton Hotel in Colombo, and the contents of the meeting are summarized in Table 7.1.3-1. The total number of participants was 66 excluding JICA Study Team members (8 National Government agencies, and 4 NGOs). Regarding the selection of power generation options for peak demand, the participants had no objections for the process of selecting power generation option, and the evaluation methodology, and they agreed that the best option for peak demand was PSPP. The methodology for optimization process of planning of PSPP, and the draft scoping for the environmental assessment for 10 candidate sites of PSPP were accepted by the participants. The Department of Forest and IUCN had comments for the survey as in Table 7.2.3-2, and the Study Team agreed to reflect their advices to the next survey plan.

Table 7.1.3-1 Summary of the 1st SHM

Date	27 June 2013 (Thursday)
Time	09:00 – 13:00
Venue	Moonstone & Amethyst Room, Hilton Hotel, Colombo
Participants	77 persons including 11 persons from the JICA Study team 12 persons from 8 concerned government agencies except CEB 5 persons from 4 NGOs (13 NGOs are invited)
Main points of the meeting	1. Power generation for peak power demand ・ To explain the current status of electricity demand and supply in Sri Lanka; ・ To list up the possible power generation options for dealing peak power demand ・ To compare the options from technical, economic and environmental aspects; and, ・ To confirm pumped storage power plant development as one of the most feasible and necessary option for the Study. 2. Optimization process of planning of pumped storage power plant ・ To explain the study process and 10 candidate sites for planning of pumped storage power plant. 3. Scoping of strategic environmental assessment (SEA) for development of pumped storage power plant ・ To explain the process of the SEA for the selection of candidate sites; and, ・ To explain the scoping (draft: Table 7.2.2-3); and, ・ To invite comments / suggestions from the stakeholders. 4. Questions and answers

7.2 2nd Stakeholders Meeting

7.2.1 Objectives and Stakeholders

(1) Objectives

There are two main objectives of the 2nd SHM as follows:

- To explain and discuss the primary screening results (from 11 candidate sites to 3 promising sites) under the SEA by the JICA Study Team; and,
- To explain and discuss the methodology of the secondary screening exercise (from 3 promising sites to the most promising site).

(2) Stakeholders

The stakeholders of the 2nd SHM are basically the same as the 1st SHM. The related Tea Estate, World Vision (NGO), Divisional Secretariat Offices and Public Utility Commission of Sri Lanka are additionally invited to the 2nd SHM.

Table 7.2.1-1 Invited Experts and NGO

Social environment	Natural environment
- Centre for Environmental Justice (Friends of the Earth Sri Lanka) - Green Movement of Sri Lanka - Consortium of Humanitarian Agencies - International Centre for Ethnic Studies - Lanka Mahila Samiti - Sarvodaya - Sewalanka Foundation - Maturata Plantations - World Vision Lanka	- IUCN - Dr. Sarah W. Kotagama - Field Ornithology Group of Sri Lanka (FOGSL) - Environmental Foundation Limited - EMACE Foundation - National Solid Waste Management Support Centre - Sri Lanka Environmental Journalists Forum - Sri Lanka Wildlife Conservation Society - Wildlife & Nature Protection Society

Table 7.2.1-2 Invited Governmental Organizations

Government Agency
- Ministry of Power and Energy - Department of Irrigation - Ministry of Irrigation and Water Resources Management - Mahaweli Authority (Ministry of Irrigation and Water Resources Management) - Department of Wildlife - Department of Forest - Sustainable Energy Authority - Public Utility Commission of Sri Lanka - Divisional Secretariats (Aranayake, and Walapane)

7.2.2 Reconnaissance Site Visits

CEB and the JICA Study Team conducted reconnaissance site visits and interviews with the Divisional Secretaries before the 2nd SHM.

Based on the reconnaissance site visits, a scoping table (draft: Table 7.2.2-1) was prepared and presented at the 2nd SHM.

Table 7.2.2-1 Scoping (draft) for 3 Promising Sites

Natural environment	Impacts on fauna and flora	Inundated forest area (including natural, secondary, plantation forests, and home garden)
		Impacts on faunal endangered species (including aquatic species)
		Impacts on floral endangered species (including aquatic species)
		Impacts on ecosystems
Social environment	Impacts on local communities	Number of those who to be resettled
		Area of land to be acquired
		Number of those who to be affected by losing livelihood
		Impacts on public facilities (e.g. school, road)
		Impacts on the poor people and minority
		Impacts on water utilization (e.g. drinking water, bathing, washing, irrigation, mini-hydropower plant) of rivers and wells
	Impacts on industries	Agriculture (including tree & rubber plantation)
		Tourism (e.g. water fall)
	Impacts on culture and landscape	Religious, and/or cultural facilities, burial ground
		Impacts on landscape

7.2.3 Contents of the 2nd SHM

The 2nd SHM was held on 21 November 2013 at Galadari Hotel in Colombo, and the contents of the meeting are summarized in Table 7.2.3-1.

The total number of participants was 66 excluding JICA Study Team members (9 National Government Agencies including 2 Local Government Administrations, 4 NGOs, and 1 Tea Estate.) The participants agreed the primary screening results from 11 candidate sites to 3 promising sites for the PSPP development after the confirmation of the opinions by the Department of Forest, NGO (social environment) and IUCN. There was no participant against the process of the selection and evaluation.

Table 7.2.3-1 Summary of the 2nd SHM

Date	21st November 2013 (Thursday)
Time	09:00 – 13:00
Venue	Meeting Room-Bougainvillea, Galadari Hotel, Colombo
Participants	77 persons including 11 persons from the JICA Study team 13 persons from 9 concerned government agencies except CEB 4 persons from 4 NGOs (13 NGOs are invited) 1 person from 1 tea estate (2 tea estates are invited)
Main points of the meeting	1. Introduction ・ Briefing of the Project ・ Present progress of the Project ・ Points of the 2nd Stakeholders Meeting 2. Primary screening results from 11 candidate sites to 3 promising sites ・ First screening ・ Evaluation from the geological aspects ・ Evaluation from the ease of construction works ・ Manufacturing limitation of pump turbine ・ Construction cost ・ Evaluation from the natural and social environmental aspects ・ Ranking of the candidate sites by even evaluation ・ Ranking of candidates sites by environment weighted evaluation ・ Selection of the 3 promising sites ・ Briefing of the 3 sites 3. Methodology of the secondary screening from 3 promising sites to the most promising site ・ Technical and economic aspects ・ Environmental aspects from the results of detailed sites survey ・ Assessment from economic aspects ・ Overall discussion and conclusion

7.3 3rd Stakeholders Meeting

7.3.1 Objectives and Stakeholders

(1) Objectives

There are two main objective of the 3rd SHM as follows:

- To explain and discuss the process of the selection of the most promising candidate site from 3 promising sites; and,
- To explain the outlines of the most promising site and to confirm the site among the stakeholders.

(2) Stakeholders

The stakeholders of the 3rd SHM are basically the same as the 1st and the 2nd SHM. National Water Supply & Drainage Board (Head and Regional offices), chairmans of related Pradeeshiya Sabha, and mini hydropower developers are additionally invited to the 3rd SHM.

7.3.2 Contents of the 3rd SHM

The 3rd SHM was held on 27 May 2014 at Galadari Hotel in Colombo, and the contents of the meeting are summarized in Table 7.3.2-1. The total number of participants was 77 excluding the JICA Study Team members (10 National Government Agencies including 2 Local Governments Administrations, 1 Local Government Authority, 7 NGOs, 1 Tea Estate, and 1 hydropower company). There was no objection to the methodology and the process of evaluation to select the most promising site from the 3 candidates' sites. Comments from the participants were on the features of each site, and the JICA Study Team explained the conditions of each site in details. The participants agreed that the Maha 3 site was the most promising site for the PSPP development.

Table 7.3.2-1 Summary of the 3rd SHM

Date	27st May 2014 (Tuesday)
Time	09:30 – 13:00
Venue	Meeting Room-Grand Ballroom C, Galadari Hotel, Colombo
Participants	86 persons including 9 persons from the JICA Study Team 10 persons from 7 concerned government agencies except CEB 7 persons from 7 NGOs (13 NGOs were invited) 1 person from a tea estate (2 tea estates were invited) 1 person from 1 Pradeeshiya Sabha (2 Pradeeshiya Sabhas were invited) 1 person from 1 mini hydropower developer (2 developers were invited)
Main points of the meeting	Session I : Briefing of the Study Session II: Evaluation of the promising sites II-1 Technical/Economic evaluation of options II-2 Environmental evaluation of options Session III: Overall rating and ranking for the most promising site Session IV: Overall discussion and conclusion

Chapter 8 Selection of Power Generation Options for Peak Power Demand

8.1 Introduction

Objectivity and reliability are emphasized in process of the selection of power generation options for peak power demand. For this reason, power generation options described in the LTGEP 2013-2032 are adopted as potential options for development, and their aptitude for the peak power demand is examined as the first screening in this chapter. Then, the second screening is carried out from viewpoints of power generation characteristics, environmental and social consideration, and economic effectiveness. In addition, the necessity of combination development of power generation options with further efficient measures to peak power demand is reviewed.

8.2 Selection of Options (First Screening)

8.2.1 Power Generation Options

(1) Hydropower Plant (New Construction)

The following projects are under construction or study according to the LTGEP 2013-2032.

Table 8.2.1-1 Options of Hydropower (New)

	Output	Remarks
Broadlands	35 MW	Committed, Run-of-River Type
Uma Oya	120 MW	Committed, Multipurpose
Moragolla	27 MW	Run-of-River Type
Gin Ganga	49 MW	Run-of-River Type
Total	231 MW	

In case of Run-of-River type hydropower, it cannot be used for power generation for peak power demand because its reservoir capacity is too small. In case of hydropower attached to multipurpose dam project, the priority of usage of stored water in the reservoir for power station is lower than that for irrigation project, and its contribution to peak power demand cannot always be expected.

The new hydropower plants cannot be expected as supply for future peak power demand, because they are run-of river type or attached to multipurpose dam project.

(2) Hydropower Plant (Capacity Extension, Upgrading)

According to the LTGEP 2013-2032, the following projects are reviewed. They can be categorized into three, that is, capacity expansion project that aim at peaking duty by new installation of power generation unit, upgrading projects by refresh works of generation equipment and enhancement projects in kWh by increasing utilizable water for power generation.

Table 8.2.1-2 Options of Hydropower (Extension)

	Output	Remarks
Samanalawewa	120 MW	for peaking duty, economically unfeasible
Wimalasurendra	-	upgrading
New Laxapana	-	upgrading
Old Laxapana	-	upgrading
Victoria	228 MW	for peaking duty, waiting for determination of irrigation intake location
Kotmale	-	30m dam raising, approx. 20% energy to be increased
Upper Kotmale	-	Additional diversion scheme, approx. 30% energy to be increased
Total	348 MW	

Among them, only Samanalawewa and Victoria capacity extension projects can be options for peak power demand. However, the status of the study on Samanalawewa capacity extension project is too primitive without feasibility study and environmental impact assessment to develop shortly, even though the facilities such as a bifurcation and a space for additional units have been provided during construction stage of existing power station. In addition, the existing power station is in trouble with the leakage of the storage water in the reservoir through the dam abutment.

On the contrary, feasibility and environmental impact assessment have already provided for Victoria capacity extension project by JICA and the project is ready to move on to the next step. As a sticking point, as an intake location of the irrigation project for the northern part of Sri Lanka has not determined yet whether downstream of the Victoria reservoir or upstream, the expected value of the extension project has not been fixed and the procedure for the development has been suspended. Once the location of the intake determined in a short time, the Victoria capacity extension project is expected for the peak power demand in 2020. However, since the increasing capacity by the extension project is 228 MW and rather small compared with the expected peak power demand in 2025 (1,000-1,600 MW), combination development with further option for peak power demand is necessary.

In addition, such capacity extension project is not listed in the Revised Base Case Scenario of the LTGEP 2013-2032.

(3) Pumped Storage Power Plant (PSPP)

During the off-peak time, electric energy generated mainly by base load and middle peak power plants is stored in Upper Pond of pumped storage power plant as Potential Energy. During the peak time, power is generated using stored potential energy in Upper Pond for peak power demand. Characteristics of PSPP for peak power demand are; Power control range 25 to 100%, Power variation 50%/min, Start-up time 1 to 2 min. The PSPP technology is a well-established technology with 86 GW of installed capacity in the world. Since stored water can be utilized repeatedly for pumping and generation, operation of pumped storage power plant can be operated without any restriction by river floe due to even heavy drought. It has side benefits as follows as well:

- Contribution to improvement in efficiency of base load or middle peak load power plants
- Contribution to maintenance of stability by absorbing grid turbulence during generation mode
- Contribution to the same stability during pumping mode by adoption of variable speed PSPP

(4) Coal Fired Thermal Plant

According to the LTGEP 2013-2032, the following coal fired thermal power plants are planned to develop before 2025 in order to achieve the policy element "provision of electricity at the lowest possible cost" in the "National Energy Policy & Strategies of Sri Lanka" published by MOPE in 2008.

Table 8.2.1-3 Options of Coal Thermal Power

	Output	Remarks
Puttalam	300MW × 3units	2nd and 3rd units are under construction
Trincomalee	250MW × 2units	Not committed, expected to be completed in 2018 & 2019
New Site	300MW × 6units	Expected to be completed up to 2025
Total	3,200 MW	

Coal fired thermal plant has the advantage of being low cost of power generation compared with other fossil fired thermal plant because its fuel cost is cheaper than that of other fossil fuel. On the contrary, coal fired thermal plant has low load following capability because coal is a solid fuel and is disqualified as power generation for peak power demand.

(5) LNG Combined Cycle Power Plant

LNG combined cycle power plant is studied in the LTGEP 2013-2032 as case study with condition that certain restriction would be put on the development of coal fired thermal plant in future and is not planed in the base case of the generation expansion plan.

LNG combined cycle power plant has high load following capability (Power control range 20 to 100%, Power variation 10%/min, Start-up time around 1 hour) compared with other fossil thermal power plant and is used for power generation for peak power demand in countries and areas where are not blessed with hydro resources. However, the operation specialized for peak power demand results in high generation cost because the load factor of the LNG combined cycle power plant is held down by such operation. In this sense, for the country like Sri Lanka with abundant hydro potential, LNG combine cycle power plant should be an option for middle or base load demand and it should contribute as an option for peak demand only in a dry spell in term of economic efficiency.

(6) Gas Turbine Power Plant

Existing gas turbine power plant of CEB is only Kelanitissa 215 MW (old: 20 MW × 5 units, new: 115 MW × 1 unit). New projects in the expansion plan in the LTGEP 2013-2032 are 225 MW (75 MW x 3 units) in 2015, 105 MW (1 unit) in 2017.

The characteristics of gas turbine power plant are short start-up time and good load following capability (Power control range 20 to 100%, Power variation 10%/min, Start-up time around 10 to 20 minutes) during operation and short construction period. On the other hand, it has demerits such as low heat rate and short life period. In addition, its fuel cost is comparatively high as same as other petroleum fuel thermal power plants. Therefore, gas turbine power plant is used for peak power demand and standby generator if an emergency arises.

(7) Diesel Power Plant

Existing diesel power plants of CEB are Sapugaskande 160 MW (A: 20 MW × 4 units, B: 10 MW x 8 units) at outskirts of Colombo and Chunnakam 8 MW (1 unit) at northern island. No new diesel power plant other than remote power sources in northern island since 1999.

Since diesel power plant is small scale and its fuel cost is comparatively high in general, it is not taken up as an option for the LTGEP 2013-2032 and only planned as power source for restoration of northern district. Start-up time of Diesel for peak power demand is within several minutes and load following characteristics is good.

(8) Power Plant using Renewable Energy

The development of renewable energy (mini hydro, wind, solar and biomass) belongs to Sustainable Energy Authority (SEA, Ministry of Environment). The National Energy Policy and Strategies of Sri Lanka states that Sri Lanka will endeavor to reach a target of at least 10% by 2015 and "Mahinda Chinthana" future vision states the target of 20% by 2020 from the total energy supplied to the grid from non-conventional renewable resources by a process of facilitation including access to green funding such as CDM.

- Mini Hydro: Hydropower less than 10MW in output is categorized as mini hydro and shall be developed by private company. The generated electricity shall be sold to CEB under Feed-in-Tariffs (FIT) system. Total 217MW mini hydro has been developed up to 2012 and Standard Power Purchase Agreement (SPPA) has been signed among developers and CEB for 153 MW.
- Wind Power: Mannar Island located north-west of Sri Lanka has 400 to 500 MW potential of wind power and 100 MW among them is under study as a wind farm in the said study. As of 2012, 74 MW wind power has been developed and SPPA has been signed for 31MW.
- Solar Power: Solar power is regarded as power option for remote area. As of 2012, 1.4 MW solar powers have been developed.

- Biomass Power: Biomass power generation using particular plant as fuel has been planned and 0.5 MW power generation is undergoing and 62 MW SPPA has been signed as of 2012. Co-generation using industrial and agricultural waste as fuel has been also developed and 11 MW power generations are undergoing and 4MW SPPA has been signed.

However, as renewable power options generally respond to natural phenomena and its output has large fluctuation, it possesses low reliability, and, therefore, are not suitable for power generation for peak power demand.

8.2.2 Other Options other than Power Generation

(1) IPP

IPP thermal power was introduced in Sri Lanka where the power supply capacity has been in severe shortage of electricity in past years. Nine sites of IPP thermal power are now under operation and their total capacity is 804.5 MW and account for about 49 % of total thermal power plants' output. These IPP thermal power plants undertake an important role at the moment as base load, middle load and peak load power generation under constant shortage of supply capability of CEB.

On the contrary, the heat rate of small scale IPP thermal power plants is low and the procurement cost of petroleum fuel is unstable, and they weigh on the financial standings of CEB. The unit costs of IPP thermal, CEB thermal and hydropower plant are shown in the Table 8.2.2-1.

Table 8.2.2-1 Generation Cost (2012)

	Annual Generation (GWh)	Total Cost to CEB (M.LKR)	Average Unit Cost (LKR/kWh)
All Hydro	2,466	10,269	4.16
All CEB Thermal	3,442	57,464	16.69
All IPP Thermal	4,906	110,609	22.55
All Plants	11,543	188,174	16.30

Consequently, CEB is carrying out its vision of fuel diversification from oil to coal and LNG and development of high efficiency large scale thermal power plant and turning up of CEB financial standings. Concurrently, CEB is going to phase out the procurement of electricity from IPP.

As mentioned above, IPP thermal power plant cannot be considered as power source for peak power demand in future but only for a limited time by the introduction of new peak power generation.

(2) Demand Side Management (DSM)

DSM is not a power generation, but allows for reduction of peak power demand and shifting of its timing and is regarded as measures for peak power demand. Specifically, reduction of electric power consumption by introduction of energy-saving products and peak time shift by introducing hourly tariff of electricity by linking with smart grid technology are effective.

- Introduction of Energy-saving Products: Night time peak demand of electricity is caused by mainly domestic lighting demand. As for lighting, CFL has been already in widespread use even in rural area, the effect on peak power cut in the replacement of CFL with LED is limited.
- Hourly Electricity Tariff: Hourly electricity tariff system in Sri Lanka is applied for general and industrial consumers but not for domestic consumers. If it is applied for domestic consumers, peak shift or peak cut can be expected. However, the introduction of hourly tariff causes degradation of convenience and strong objection from citizen. In addition, its effect is small and the feasibility of hourly electricity tariff for domestic consumers is quite low.

(3) Interconnection with Indian Grid

Power Grid Corporation of India Limited (PGCIL) carried out preliminary study of the linkage between Indian grid and Sri Lankan grid in 2006. In 2010, MOU for study was concluded between Sri Lanka and India and now feasibility study is undergoing base on the MOU, However, the development schedule is uncertain.

When the power interchange realizes after completion of the interconnecting transmission line, it will definitely contribute to the stability of Sri Lankan grid and expected to receive electricity for peak power demand from India. However, even optimistic case that Sri Lanka can purchase electricity for peak demand duration, its tariff might be quite high. Therefore, the linkage with Indian grid cannot contribute to peak power demand in Sri Lanka.

8.2.3 Result of First Screening

Capability and suitability of 11 power generation options for peak power demand are mentioned in the Chapter 8.2.1 and 8.2.2. As a result of the first screening, the following options are selected for the reason mentioned in the chapters.

- Hydropower Plant (Capacity Extension)
- Pumped Storage Power Plant
- LNG Combined Cycle Power Plant
- Gas Turbine Power Plant

8.3 Optimal Options (Second Screening)

The suitable and feasible power generation options, viz. Hydropower Plant (Capacity Expansion), Pumped Storage Power Plant, LNG Combined Cycle Power Plant, and Gas Turbine Power Plant, for peak power demand selected in the Chapter 8.2.3 are compared each other from the aspects of load following capability and generating characteristics. In this chapter, the most suitable option for peak power demand after 2025 is selected by conducting comparison studies on load following capability and generation, environmental and social considerations, and economic efficiency.

8.3.1 Load Following Capability and Generation Characteristics

The expected daily load curve in 2025 is shown in the Figure 4.3-1. Power demand starts increasing rapidly at around 4:00 AM. After 6:00 AM with the coming of dawn, the power demand for lighting goes down once. And then, the power demand starts increasing again and keeps in a certain level up to the evening due to industrial activities. In addition, the lighting demand after 18:00 rapidly makes it markedly high level up to 21:00. It is necessary to divide power supply capability into three; peak, middle and base, and to develop power plants suitable for each in order to supply electricity in an economic and stable manner.

The Comparison table is shown in the Table 8.3.1-1. In this table, the following rating is applied for four options; 3 = very good, 2 = good and 1 = fair. This table also includes the evaluation of potential capacity, easiness of procurement of fuel during operation stage. The option having high total score has high suitability and feasibility as power generation for peak power demand.

Table 8.3.1-1 Comparison of Generation Characteristics

	Hydropower (Extension)	PSPP	LNG CC	Gas Turbine
Power Control Range	3	3	2	2
Start-up Time	3	3	1	2
Load Following Capability	3	3	2	2
Potential Capacity	1	3	3	3
Procurement of Fuel	3	2	1	2
Total Score	13	14	9	11
Total Ranking	2	1	4	3

8.3.2 Environmental and Social Considerations

The power generation options after the 1st screening are compared in the following 10 environmental and social aspects: air pollution; water pollution; greenhouse gas emissions; impacts on ecosystems; impacts caused by resettlement; impacts on water right / water resources; impacts on agriculture; impacts on fishery; impacts on tourism; and impacts on human health.

Rating is conducted by the JICA Study Team in four (4) ranks: 4 = no negative impacts; 3 = small negative impacts; 2 = medium negative impacts; and 1 = large negative impacts are expected..

1) Air pollution

Pumped storage PP uses electricity for pumping from other energy sources (i.e. coal fired thermal PP in Sri Lanka), of which pollutants needs to be counted.

Regarding LNG Combined Cycle PP (LNG CC), the impacts from air pollution are estimated based on the life cycle assessment of IEA as New hydro PP.

Gas turbine thermal PP produces more air pollutants than LNG CC PP, however the Gas turbine thermal PP is not considered to give “large negative impacts” like a coal fired PP.

The results are shown in Table 8.3.2-1.

Table 8.3.2-1 Air Pollution by Each Power Generation Option

Power Generation Option	SO_2 (t SO_2/TWh)	NOx (t NOx/TWh)	Particulate Matter (t/TWh)	Rating
New hydro PP* *(A baseline scenario)*	5 to 60	3 to 42	5	3
Hydro capacity extension	Less than New hydro PP	Less than New hydro PP	Less than New hydro PP	3
Pumped storage PP	More than New hydro PP	More than New hydro PP	More than New hydro PP	2
LNG Combined Cycle PP (LNG CC) PP*	4 to 15,000+	13+ to 1,500	1 to 10+	2
Gas turbine thermal PP*	N/A	N/A	N/A	2

*: Hydropower and the Environment: Present Context and Guidelines for Future Action. Vol. II: Main Report (International Energy Agency, 2000)

2) Water pollution

The impacts are considered to be in the areas which may directly be affected.

The results are shown in Table 8.3.2-2.

Table 8.3.2-2 Water Pollution by Each Power Generation Option

Power Generation Option	Impacts	Probability of occurrence	Severity of impacts with mitigation	Rating
Hydro capacity extension	• Alternation of the water temperature • Prolongation of turbid water discharging	Low	Low	3
Pumped storage PP	• Alternation of the water temperature • Prolongation of turbid water discharging	Low	Low	3
LNG CC PP*	• Change of the water temperature due to heated effluent • Boiler blowdown • Boiler cleaning wastes	Low	Low	3
Gas turbine thermal PP	• Change of the water temperature due to heated effluent • Boiler blowdown • Boiler cleaning wastes	Low	Low	3

All data are prepared by the JICA Study Team, and the rating is conducted by the JICA Study Team.

3) Greenhouse gas emissions

Since Pumped storage PP uses electricity for pumping from other energy sources (i.e. coal fired thermal PP in Sri Lanka), of which GHGs need to be counted.

The data shows in the Table 8.3.2-3 are the emissions of CO_2 equivalent of these gases.

Table 8.3.2-3 Greenhouse Gas Emissions of Power Generation Option

Power Generation Option	Greenhouse Gas Emissions (kt eq. CO_2/TWh)	Rating
New hydro PP* *(A baseline scenario)*	2 to 48	3
Hydro capacity extension	Less than New hydro PP	3
Pumped storage PP	Depending on GHG emission of Pumping Power*[1]	1
LNG CC PP*[2]	389 to 511	2
Gas turbine thermal PP*	Similar to LNG CC PP.	2

*[1]: Trial assessment because there is no common perspective in GHG emission of PSPP (Refer to Appendix)

*[2]: Hydropower and the Environment: Present Context and Guidelines for Future Action. Vol. II: Main Report (International Energy Agency, 2000)

4) Impacts on ecosystems

Its impacts on the ecosystem are evaluated by types of impacts, impacts on local and regional ecosystems, impacts on biomass, and impacts on genetic diversity at the world level. This is based on the assessment by IEA (2000).

The results are shown in Table 8.3.2-4.

Table 8.3.2-4 Impacts on Ecosystems by Each Power Generation Option

Power Generation Option	Impacts	Local and regional ecosystems	Biomass	Genetic diversity at the world level	Rating
New hydro PP* *(A baseline scenario)*	• Barriers to migratory fish • Loss of terrestrial habitats • Change in water quality • Modification of water flow	x x x x			1
Hydro capacity extension	Nil	Nil	Nil	Nil	4
Pumped storage PP	• Barriers to migratory fish • Loss of terrestrial habitats • Change in water quality • Modification of water flow • Climate change • Acid precipitation	x x x x x x	x	x	2
LNG CC PP	• Climate change • Acid precipitation • Loss of coastal habitats • Change of the water temperature due to heated effluent	x x x x	x	x	1
Gas turbine thermal PP	• Climate change • Acid precipitation • Loss of coastal habitats • Change of the water temperature due to heated effluent	x x x x	x	x	1

*: Hydropower and the Environment: Present Context and Guidelines for Future Action. Vol. II: Main Report (International Energy Agency, 2000)

5) Impacts caused by resettlement

Impacts caused by resettlement are evaluated by land requirements and severity of impacts with mitigation measures.

The results are shown in Table 8.3.2-5.

Table 8.3.2-5 Impacts Caused by Resettlement by Each Power Generation Option

Power Generation Option	Land Requirements (km^2/TWh/y)	Severity of impacts with mitigation	Rating
New hydro PP* *(A baseline scenario)*	2 to 152*	High to Medium	1
Hydro capacity extension	Nil	Nil	4
Pumped storage PP	Less than New hydro PP	High to Low	2
LNG CC PP	Small	Medium to Low	2
Gas turbine thermal PP	Small	Medium to Low	2

*: Hydropower and the Environment: Present Context and Guidelines for Future Action. Vol. II: Main Report (International Energy Agency, 2000)

6) Impacts on water right / water resources

Impacts on water right / water resources are evaluated by types of impacts, probability of occurrence, and severity of impacts with mitigation measures.

Thermal PPs (LNG CC and Gas turbine) discharge heated effluent and may affect water utilization pattern around the plants.

The results are shown in Table 8.3.2-6.

Table 8.3.2-6 Impacts on Water Right /Water Resources by Each Power Generation Option

Power Generation Option	Impacts	Probability of occurrence	Severity of impacts with mitigation	Rating
Hydro capacity extension	Nil	Nil	Nil	4
Pumped storage PP	• Change in the flow pattern	Low	Low	3
LNG CC PP	• Change of the water temperature due to heated effluent	Low	Low	3
Gas turbine thermal PP	• Change of the water temperature due to heated effluent	Low	Low	3

7) Impacts on agriculture

Impacts on agriculture are evaluated by types of impacts, the types of impacts, probability of occurrence, and severity of impacts with mitigation measures.

The results are shown in Table 8.3.2-7.

Table 8.3.2-7 Impacts on Agriculture by Each Power Generation Option

Power Generation Option	Impacts	Probability of occurrence	Severity of impacts with mitigation	Rating
Hydro capacity extension	Nil	Nil	Nil	4
Pumped storage PP	• Loss of land • Degradation of water quality • Change in the flow pattern	Low	Low	3
LNG CC PP	• Loss of land • Degradation of air quality	Low	Low	3
Gas turbine thermal PP	• Loss of land • Degradation of air quality	Low	Low	3

8) Impacts on fishery

Impacts on fishery are evaluated by types of impacts, probability of occurrence, and severity of impacts with mitigation measures.

The results are shown in Table 8.3.2-8.

Table 8.3.2-8 Impacts on Fishery by Each Power Generation Option

Power Generation Option	Impacts	Probability of occurrence	Severity of impacts with mitigation	Rating
Hydro capacity extension	Nil	Nil	Nil	4
Pumped storage PP	• Change in the flow pattern	Low	Low	3
LNG CC PP	• Change in water quality • Loss of coastal habitats • Change of the water temperature due to heated effluent • Degradation on substrate	Medium	Low	2
Gas turbine thermal PP	• Change in water quality • Loss of coastal habitats • Change of the water temperature due to heated effluent • Degradation on substrate	Medium	Low	2

9) Impacts on tourism

Impacts on tourism are evaluated by types of impacts, probability of occurrence, and severity of impacts with mitigation measures.

The results are shown in Table 8.3.2-9.

Table 8.3.2-9 Impacts on Tourism by Each Power Generation Option

Power Generation Option	Impacts	Probability of occurrence	Severity of impacts with mitigation	Rating
Hydro capacity extension	Nil	Nil	Nil	4
Pumped storage PP	• Impacts on sport / leisure • Impacts on landscape	Low	Low	3
LNG CC PP	• Impacts on sport / leisure • Impacts on landscape	Low	Low	3
Gas turbine thermal PP	• Impacts on sport / leisure • Impacts on landscape	Low	Low	3

10) Impacts on human health

Impacts on human health are evaluated by types of impacts, probability of occurrence, and severity of impacts with mitigation measures.

The results are shown in Table 8.3.2-10.

Table 8.3.2-10 Impacts on Human Health by Each Power Generation Option

Power Generation Option	Impacts	Probability of occurrence	Severity of impacts with mitigation	Rating
Hydro capacity extension	• Risks from water-borne diseases, particularly when there is irrigation (local and/or regional)	Low	Low	3
Pumped storage PP	• Acid precipitation by power supply sources (local) • Climate change by power supply sources (global)	High to Low	Low	2
LNG CC PP	• Fire (local) • Explosion (local) • Acid precipitation (local) • Photochemical smog (local) • Climate change (global)	High to Low	Medium	2
Gas turbine thermal PP	• Fire (local) • Explosion (local) • Acid precipitation (local) • Photochemical smog (local) • Climate change (global)	High to Low	Medium	2

11) Result

The result of the assessment is summarized in Table 8.3.2-11.

Hydro capacity extension has the smallest negative impacts, and has the lowest score. The rest of the options are not very different in the aspects of environmental and social considerations.

Table 8.3.2-11 Environmental and Social Considerations on Power Generation Options

POWER GENERATION OPTION	Air pollution	Water pollution	Greenhouse gas emissions	Impacts on ecosystems	Impacts caused by resettlement	Impacts on water right/ water resources	Impacts on agriculture	Impacts on fishery	Impacts on tourism	Impacts on human health	TOTAL
Hydro capacity extension	3	3	3	4	4	4	4	4	4	3	36
Pumped storage PP	2	3	1	2	2	3	3	3	3	2	24
LNG CC PP	2	3	2	1	2	3	3	2	3	2	23
Gas turbine thermal PP	2	3	2	1	2	3	3	2	3	2	23

8.3.3 Economic Aspect of Options

The most suitable peak power generation in term of economic efficiency is selected in this chapter by comparison study among power generation options to be developed and connected to Sri Lankan electric power system in future after calculation of their annual cost related to construction unit cost and fuel cost, and generation cost. Using this method, which power generation option has an economic aptitude for peak power generation (plant factor less than 30%), middle one (the same 30%

to 59%) and base one (60% and above) can be figured out.

The generation unit cost ($/kWh) is roughly expressed as sum of unit capital cost mainly consists of interest and depreciation of project construction cost, and unit energy cost mainly consists of fuel cost.

Where: $\textit{Capital Cost}\ (\$/\text{kWh}) = \dfrac{\textit{Construction Unit Cost}\ (\$/kW)\times \textit{CapitalRecovery Factor}}{\textit{Plant Factor}\times 8{,}760\ (hr)}$

$\textit{Energy Cost}\ (\$/\text{kWh}) = \dfrac{\textit{Fuel Unit Cost}\ (\$/kcal)\times 860\ (kWh/kcal)}{\textit{Thermal Efficiency}}$

The power generation options are categorized into three, namely:

- Low capital cost but high energy cost like gas turbine and pumped storage power plant
- Middle range option like LNG combined cycle
- High capital cost but low energy cost like coal thermal plant and run-of river hydropower plant

The Figure 8.3.3-1 shows basic concept of annual generation cost in relation to the variation of plant factor. For the power generation option for the peak power demand of which plant factor must be low less than 30%, a low capital cost option should be selected. In this sense, gas turbine and pumped storage power plants are suitable for power generation for peak power demand provided that their unit construction unit cost is low. In case pumped storage power plant, its output scale can be made larger considering the development scale and the construction unit cost can be lower, accordingly. Regarding hydropower expansion option, it is also suitable for power generation for peak power demand because its construction unit cost is lower compared with the same scale new hydropower plant.

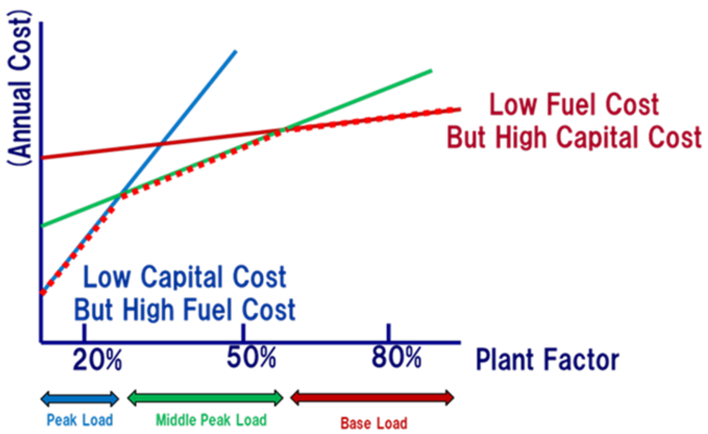


Figure 8.3.3-1 Annual Cost of Generation

The Table 8.3.3-1 shows capital cost, economic life time and so on of each power generation option that is planned to develop in future in the LTGEP 2013-2032. In the table, the capital cost of pumped storage power plant is 1,200 USD/kW that is from estimated construction cost in this JICA study, and indices of hydropower expansion come from JICA study “Feasibility Study for Expansion of Victoria Hydropower Station (May, 2009)”. Other indices come from LTGEP 2013-2032. Indices of combined cycle power plant using auto diesel and coal thermal power plant are also indicated for reference.

Table 8.3.3-1 Indices of Generation Options

	PSPP (PSPP)	Gas Turbine (ADGT)	Combined Cycle (ADCC)	LNG CC (LNGCC)	Coal Steam (CST)	Hydro Ex. (HPPEx)
Unit Capacity (MW)	600	105	300	250	300	228
Minimum Capacity (%)	N.A.	30	33	33	75	N.A.
Fuel	El. from CST	Auto Diesel	Auto Diesel	LNG	Coal	N.A.
Capital Cost ($/kW)	1,200	515	935	1,300	1,964	1,022
ELT (years)	50	20	30	30	30	50

(Source: as mentioned above)

Annual cost and specific cost is calculated using indices of each option in the Table 8.3.3-1. The calculation results are shown in the Figure 8.3.3-2.

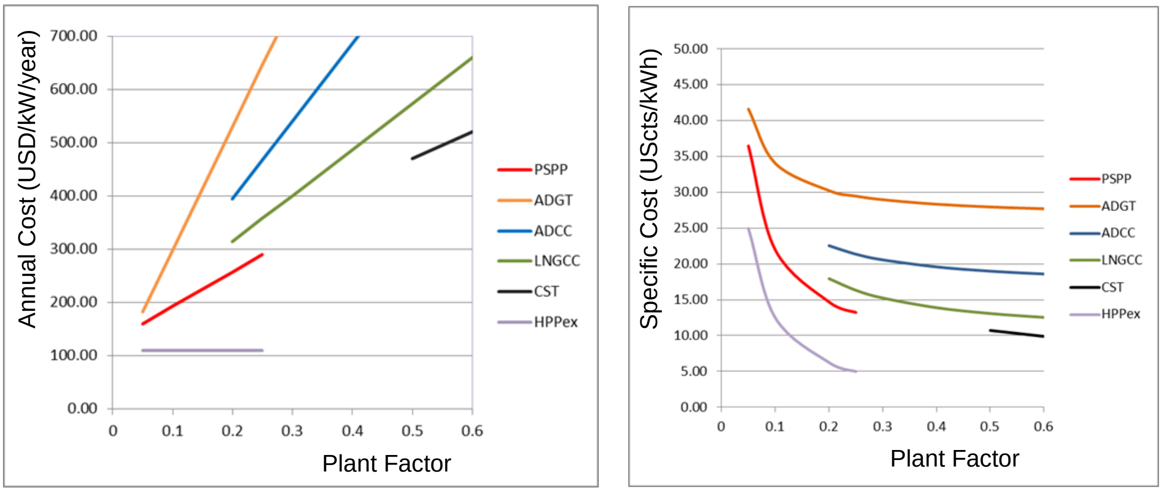


Figure 8.3.3-2 Annual Cost & Specific Cost of Generation of Options

As is clear from the Figure 8.3.3-2 the ranking of four peak power options from economic aspects is shown in the Table 8.3.3-2.

Table 8.3.3-2 Ranking of Options from Economic Aspect

	Hydropower (Extension)	PSPP	LNG CC	Gas Turbine
Ranking from Economic Aspect	1	2	3	4

8.3.4 Selection of Optimal Option for Peak Power Demand

The evaluation and ranking from load following capability and generation characteristics, environmental and social considerations, and economic aspects are mentioned in the Chapters 8.3.1, 8.3.2 and 8.3.3. The Table 8.3.4-1 shows concise summary of the ranking.

Table 8.3.4-1 Ranking Summary of Options

	Hydropower (Extension)	PSPP	LNG CC	Gas Turbine
Generation Characteristics	2	1	4	3
Environment & Social Considerations	1	2	3	3
Economic Aspect	1	2	3	4

It is very obvious from the Table 8.3.4-1 that hydropower capacity extension and pumped storage power plant should be selected as optimal power options from technical, environmental and economi aspects.

Regarding the hydropower extention, however, the Victoria Expansion is only a potential project in future. This JICA study aims at master plan of power generation for peak power demand after the year 2025, however, the capacity of the Victoria Expansion Project by itself is not enough for the peak demand in 2025.

On the other hand, pumped storage power plant has high development potential in Sri Lanka, but no systematical study in detail has been carried out. In addition, since the pumped storage power plant is suitable for increasing peak power demand after the year 2025, the Stage 2 and Stage 3 of this study highlights solely pumped storage power plant and its optimization study (master plan study) is carried out.

8.4 Proportion of Pumped Storage Power Plant

As mentioned in the Chapter 4.3, necessary capacity for peak power demand in 2025 to be developed is 750 MW and the capacity of new project is about 600 MW in consideration of future increment of power demand.

8.5 Combination Development

8.5.1 Pumped Storage Power Plant and Renewable Energy Power Plant

As mentioned in the Chapter 8.2.1 (3), pumped storage power plant has side benefits that it can absorb fluctuation of frequency and contributes to the stability of the grid. If the variable speed PSPP is applied, same stability can be attained during pumping mode.

According to National Energy Policy and Mahinda Chinthana 10 Years Development Framework, it is the target that 10 % of total power generation in Sri Lanka will be supplied by the renewable energy power plant in 2015. In addition the Sri Lankan Government established Sustainable Energy Authority (SEA) in October 2007, and expects stable and reliable electric power supply with low electricity tariff through renewable energy. For approaching steadily toward the target, the construction of the pumped storage power plant is requisite.

8.5.2 Pumped Storage Power Plant and LNG Combined Cycle Power Plant

Though the timing of introduction of LNG combined cycle power plant is unknown, the combination development of pumped storage and LNG combined cycle power plant is expected for future power generation for peak power load and middle load in Sri Lanka.

Consequently, for the future best mix of power source in Sri Lanka, demarcation of power source is necessary, namely pumped storage power plan is for peak power load and LNG combined cycle is for mainly middle power load sometimes peak power load and base load as a complementary supply to deficit, if any.

8.5.3 Pumped Storage Power Plant and LNG Gas Turbine

This is just a case study of peak power generation after the point that the LNG supply system and LNG combined cycle would be available in Sri Lanka. Though LNG combined cycle power plant is not for peak power demand, but LNG gas turbine power plant can be an option for peak power demand after LNG supply system would be available. In this chapter, comparison study between pumped storage power plant and LNG gas turbine solely for the peak power demand is executed.

Pumped storage power plant comes under influence of fuel cost of pumping-up source generation. Study cases are selected from the coal limited cases in the scenarios of LTGEP 2013-2032 and shown in the Table 8.5.3-1, because only coal limited cases contain LNG combine cycle power plants, and LNG gas turbine power plants can be available.

Table 8.5.3-1 Study Cases

	Case-1	Case-2
Limitation of Coal Thermal	60％ from total generation	No coal plants permitted after Trincomalee
Time point of 2025		
Total Capacity of Coal Plants	2,600 MW	2,000 MW
Total Capacity of LNGCC	750 MW	1,250 MW
Pump-up Source for PSPP	Mix of coal plants 600 MW and LNG CC 750 MW	LNG CC 1,250 MW

The annual cost and specific cost of the Case-1 are shown in the Figure 8.5.3-1. The same data of gas turbine using auto diesel also indicated in the figure for reference.

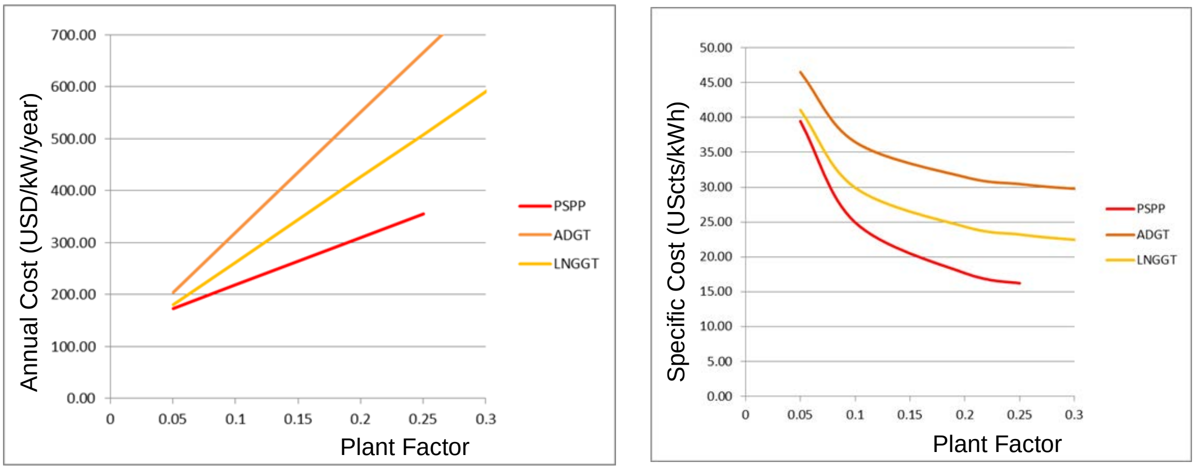


Figure 8.5.3-1 Annual Cost & Specific Cost of Generation of Options (Case-1)

These figures show that LNG gas turbine is economically better than auto diesel gas turbine but has no advantage over pumped storage power plant.

The same comparison is made for the Case-2 and the results are shown in the Figure 8.5.3-2. The difference in the figures between the Case-1 and Case-2 is only the data of pumped storage power plant that depends entirely on pumping-up power source due to the development scenario of coal thermal and LNG CC. In other word, the pumping-up power source is only from high price LNG combined cycle in the Case-2.

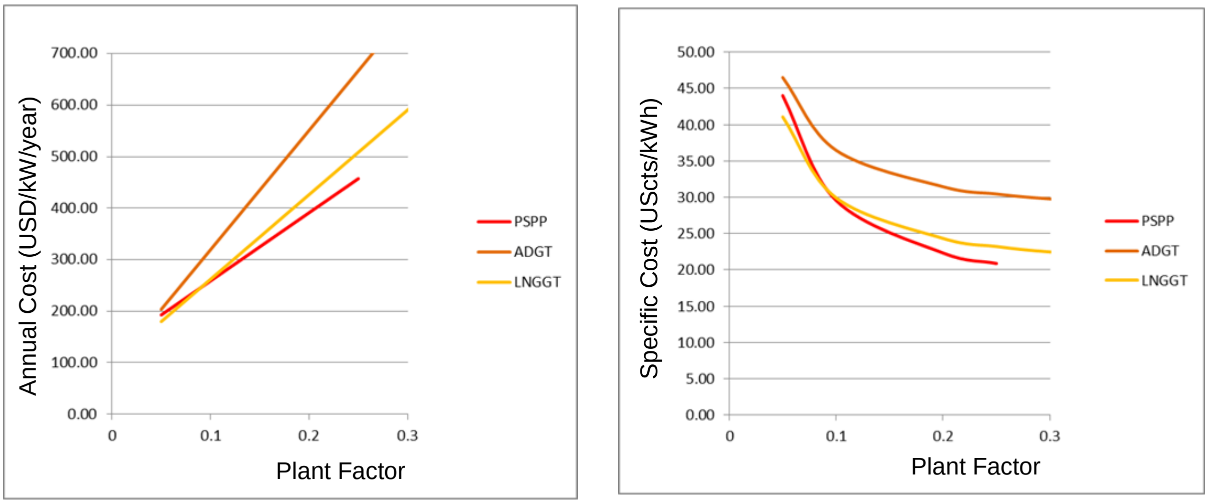


Figure 8.5.3-2 Annual Cost & Specific Cost of Generation of Options (Case-2)

From the Figure 8.5.3-2, pumped storage power plant has better economic efficiency than LNG gas turbine above the boundary plant factor 0.09, and not economical below it, but no remarkable difference. Consequently, the annual cost can be calculated in the case of standard operation hours per annum at 1,000 hours (plant factor: 11.4%) as the Table 8.5.3-2.

Table 8.5.3-2 Case Study of Annual Cost along with Pumping Source

		Revised Base Case	Case-1	Case-2
Pumping Power Source	Coal Thermal	100%	62%	0%
	LNG CC	0%	38%	100%
Annual Operation Time (hour)		1,000		
Plant Factor		11.4% (1,000 hours operation per year)		
Annual Cost (USD/kW/year)	PSPP (A)	201.40	231.21	277.37
	LNG GT (B)	285.04		
	(B) – (A)	83.64	53.83	7.67

As aforesaid, the development of the LNG combined cycle power plant leads annual cost rise of the total power development cost in future and electricity tariff rise, though it has significant outcome in security of stable supply of energy and global environmental issue. However, the more development of LNG combined cycle power plant, the lesser economic efficiency of pumped storage. In this sense, the development of LNG combined cycle should be subjected to the policy decision of the government. Even in the extreme case LNG combined cycle power plant supply pumping power 100%, it is demonstrated that the pumped storage power plant has an economical advantage over LNG gas turbine in case it operates during its standard operation hours.

Chapter 9 Selection of Promising Candidate Sites

9.1 General Features of Candidate Sites

Table 9.1-1 shows the general features of 11 candidate sites. 10 pumped storage power projects were planned in the project formation study by JICA carried out in 2012 (hereafter the initial JICA study). In this study, those 10 projects are reviewed more definitely, and one possible site is added newly.

Table 9.1-1 General Features of 11 Candidate Sites (200MW * 3 units)

Candidate Site		unit	Kiriketi I	Kiriketi II	Maussa-kelle A	Maussa-kelle B	Halgran 1	Halgran 2	Halgran 3	Halgran 4	Maha 1	Maha 2	Logal
Installed Capacity		MW	600	600	600	600	600	600	600	600	600	600	600
Unit Capacity		MW	200	200	200	200	200	200	200	200	200	200	200
Number of Units		unit	3	3	3	3	3	3	3	3	3	3	3
Peak Generating Time		hours	3.8	2.52	6.42	6.28	6.19	6.11	6.05	6.1	6.03	6.09	6.16
Rated Head		m	664.67	731.81	450.30	463.60	576.01	679.25	657.08	465.18	464.23	434.78	561.76
Rated Discharge		m^3	108.37	98.43	159.96	155.37	125.05	106.04	109.62	154.84	155.16	165.67	128.22
Upper Pond	Latitude		6°46'00"	6°45'13"	6°46'49"	6°46'49"	7°01'30"	7°02'30"	7°02'14"	7°04'14"	7°06'01"	7°07'20"	7°06'20"
	Longitude		80°46'15"	80°46'34"	80°33'42"	80°33'42"	80°53'06"	80°52'35"	80°52'31"	80°52'24"	80°28'35"	80°27'26"	81°07'46"
	Catchment Area	km^2	1	1	2	2	32	20	2	2	10	5	5
	Reservoir Area	km^2	0.14	0.04	0.37	0.37	0.17	0.12	0.16	0.15	0.39	0.15	0.43
	Crest Elevation	E.L.-m	1960	1731	1829	1829	1270	1381	1412	1224	792	769	1002
	High Water Level	E.L.-m	1,954	1,725	1,823	1,823	1,264	1,375	1,406	1,218	786	763	996
	Low Water Level	E.L.-m	1,934	1,687	1,813	1,813	1,243	1,343	1,384	1,166	774	729	985
	Drawdown	m	20	38	10	10	21	32	22	52	12	34	11
	Sediment Level	E.L.-m	1,921	1,673	1,800	1,799	1,230	1,330	1,371	1,153	760	715	369
	Gross Capacity	MCM	1.96	1.12	3.82	3.82	4.80	3.48	3.21	3.68	6.08	4.35	4.59
	Available Capacity	MCM	1.62	0.99	3.69	3.69	2.79	2.33	2.39	3.42	3.71	3.67	3.16
	Dam Height	m	35	81	39	39	80	116	57	89	52	79	42
	Crest Length	m	1280	300	1200	1200	250	500	200	550	210	310	220
Lower Pond	Latitude		6°45'58"	6°44'44"	6°47'42"	6°47'48"	7°02'34"	7°02'34"	7°03'57"	7°03'57"	7°07'50"	7°07'50"	7°7'23"
	Longitude		80°47'43"	80°47'03"	80°32'21"	80°32'50"	80°54'53"	80°54'53"	80°54'11"	80°54'11"	80°28'27"	80°28'27"	81°05'46'
	Catchment Area	km^2	5	14	20	10	70	70	16	16	35	35	5
	Reservoir Area	km^2	0.08	0.09	0.34	0.25	0.30	0.28	0.15	0.18	0.24	0.24	0.15
	Crest Elevation	E.L.-m	1263	952	1355	1342	661	659	720	726	305	306	416
	High Water Level	E.L.-m	1,257	946	1,349	1,336	655	653	714	720	299	300	410
	Low Water Level	E.L.-m	1,229	934	1,339	1,323	642	642	693	693	282	282	383
	Drawdown	m	28	12	10	13	13	11	21	27	17	18	27
	Sediment Level	E.L.-m	1,216	920	1,326	1,309	628	628	680	680	269	269	369
	Gross Capacity	MCM	1.91	2.04	5.31	4.25	7.82	7.22	3.95	4.83	6.13	6.40	3.66
	Available Capacity	MCM	1.48	0.89	3.71	3.51	2.94	2.33	2.52	3.40	3.37	3.63	2.84
	Dam Height	m	93	72	55	52	81	79	65	71	75	76	76
	Crest Length	m	250	240	170	1070	420	430	220	290	360	360	540
Headrace Tunnel													
	Inner Diameter	m	4.8	4.6	5.9	5.8	5.2	4.8	4.9	5.8	5.8	6.0	5.3
	Length	m	1,070	100	300	300	950	960	1,350	1,000	2,030	510	1,750
	Nos. of lines	-line	1	1	1	1	1	1	1	1	1	1	1
Penstock Tunnel													
	Inner Diameter	m	3.8	3.6	4.6	4.5	4.0	3.7	3.8	4.5	4.5	4.6	4.1
	Length	m	1,260	1,349	939	961	1,116	1,256	1,236	927	940	898	1,106
	Nos. of lines	-line	1	1	1	1	1	1	1	1	1	1	1
Tailrace Tunnel													
	Inner Diameter	m	5.3	5.1	6.4	6.3	5.7	5.2	5.3	6.3	6.3	6.5	5.8
	Length	m	500	180	2,050	1,280	2,300	2,240	2,200	1,430	390	1,000	1,230
	Nos. of lines	-line	1	1	1	1	1	1	1	1	1	1	1
Access Tunnel to PH													
	Length	m	350	550	1,300	1,050	1,650	1,850	1,500	1,850	850	1,000	1,600

(Source: Study Team)

9.2 First Screening

Some candidate sites have difficulties for their developments. Because in those sites, the upper and/or the lower reservoirs are located within the sanctuaries, in which any actions for developments are prohibited by the concerned laws. In other sites, the manufacturing limitation of the pump-turbines, which is derived from limitation of applicable unit capacity for ensuring stability of the national grid, cannot be cleared. Therefore, candidates site falling into such those two issues are eliminated from the candidate sites list for promising candidate sites selection conducted in the later.

Table 9.2-1 shows the result of the first screening. Rating “C” for “Impacts on Fauna and Flora” means that those of Upper reservoir and/or Lower reservoir are located in the environmental protected areas (sanctuaries) and that for “Manufacturing Limitation” is given if 200 MW/unit cannot be applicable. In this regard, if the 200 MW/unit is applicable, those sites can be developed at least by 200 MW/unit basis. (If 150 MW/unit is applicable, it is judged that 200 MW/unit is also applicable automatically because the manufacturing limitation becomes more severe when it goes smaller unit capacity.) This is the reason why evaluation of 200 MW/unit is employed for the first screening.

As a result, 6 candidate sites out of 11 candidate sites remains in the list for later promising sites selection; Halgran 1, Halgran 3, Halgran 4, Maha 1, Maha 2, and Loggal.

Table 9.2-1 Result of First Screening

	Kiriketi 1	Kiriketi 2	Maussa-kelle A	Maussa-kelle B	Halgran 1	Halgran 2	Halgran 3	Halgran 4	Maha 1	Maha 2	Loggal
Impacts on Fauna and Flora (Sanctuary)	C	C	C	C							
Manufacturing Limitation		C				C					
1st screening	NG	NG	NG	NG		NG					

(Source: Study Team)

9.3 Evaluation from Natural and Social Environmental Aspects

The environmental survey for natural environmental aspects, as well as from social environmental aspects, is conducted for every candidate site as described in the sub-chapter 9.5. Results of the survey and the evaluation are as summarized in Table 9.3-1.

Table 9.3-1 Summary of the Natural and Social Environments of the Six Candidate Sites

Evaluation points/Name of site	Halgran 1	Halgran 3	Halgran 4	Maha 1	Maha 2	Loggal
1. Impacts on fauna and flora	[Upper dam/reservoir]: B · Biodiversity and species richness = low (farmland mainly tea plantation; already altered by human activities) · National endangered species: Fauna: CR - 1, EN- 3 [Lower dam/reservoir]: B · Biodiversity and species richness = low (farmland - terraced rice fields and others; already altered by human activities) · Fauna: CR - 1, Flora: CR - 1	[Upper dam/reservoir]: B · Biodiversity and species richness = high (farmland mainly tea plantation; already altered by human activities; good riverine vegetation) · Fauna: EN - 5 · Flora: EN-2 [Lower dam/reservoir]: B · Biodiversity and species richness = low (farmland; already altered by human activities) · Fauna: CR - 1, Flora: EN - 1	[Upper dam/reservoir]: A · Biodiversity and species richness = low (tea plantation, crop fields and eucalyptus plantation) · Fauna: EN - 2 [Lower dam/reservoir]: B The same as the lower dam/reservoir of the Halgran 3.	[Upper dam/reservoir]: A · Biodiversity and species richness = low (farmland mainly tea plantation) [Lower dam/reservoir]: B · Biodiversity and species richness = medium · Fauna: CR - 3, EN - 5, Flora: CR – 1, EN - 1	[Upper dam/reservoir]: B · Biodiversity and species richness = low (farmland mainly tea plantation) · Fauna: EN - 1 [Lower dam/reservoir]: B The same as the lower dam/reservoir of the Maha 1 .	[Upper dam/reservoir]: B · Biodiversity and species richness = high · Fauna: CR - 1, EN - 2, Flora: EN - 1 [Lower dam/reservoir]: B · Biodiversity and species richness = medium · Fauna: EN - 2
	Rating: B	Rating: B	Rating: B	Rating: B	Rating: B	Rating: B
2. Impacts on local communities	[Upper dam/reservoir]: B · Inundated No. of houses: 15 · No use of river water by local community · No fishery [Lower dam/reservoir]: A · Inundated No. of houses: 9 · Local people use river water for bathing · 1 existing irrigation canal on the right bank · No fishery	[Upper dam/reservoir]: A · No resettlement · No use of river water by local community · No fishery [Lower dam/reservoir]: B · Inundated No. of houses: 3 · Local people use river water for bathing · 2 existing irrigation canals (One of the canals will be inundated). · No fishery	[Upper dam/reservoir]: B · Inundated No. of houses: 11 · A pre-school, tank of drinking water, 0.25 km of B413 inundated · No use of river water by local community · No fishery [Lower dam/reservoir]: B The same conditions as the lower dam/reservoir of Halgran 3	[Upper dam/reservoir]: C · Inundated No. of houses: 76 · 2km of estate road and some wells inundated · No fishery [Lower dam/reservoir]: B · Inundated No. of houses: 8 · 2 existing mini-hydro will be inundated · 4 water pipes for drinking inundated · No fishery	[Upper dam/reservoir]: B · Inundated No. of houses: 8 · 1 km of estate road inundated · No fishery [Lower dam/reservoir]: B The same conditions as the lower dam/reservoir of Maha 1	[Upper dam/reservoir]: B · Inundated No. of houses: 18 · Local people use river water for washing and bathing · 1 existing mini-hydro will be affected during construction. · No fishery [Lower dam/reservoir]: B · Inundated No. of houses: 14 · A primary school, a post office, and 1 km of village road inundated · No fishery
	Rating: B	Rating : B	Rating : B	Rating : C	Rating : B	Rating : B
3. Impacts on industries	[Upper dam/reservoir]: B · Extent in ha within the inundation area+ 50 m buffer zone Home garden:2.3ha Tea plantation: 7.8ha Other cultivation: 16.3ha Total: 26.4ha [Lower dam/reservoir]: B · Extent in ha within the inundation area+50 m buffer zone Paddy: 12.5ha Home garden: 7.6ha Other cultivation: 5.9ha Total: 26.0ha	[Upper dam/reservoir]: B · Extent in ha within the inundation area+ 50 m buffer zone Tea plantation: 14.3ha Forest: 13.2ha Total: 27.5ha [Lower dam/reservoir]: B · Extent in ha within the inundation area+ 50m buffer zone Paddy: 21.8ha Home garden: 6.9ha Tea plantation: 0.18ha Other cultivation: 0.6ha Total: 29.5ha	[Upper dam/reservoir]: B · Extent in ha within the inundation area+ 50 m buffer zone Tea plantation: 15.8ha Other cultivation: 7.4ha Forest: 0.2ha Total: 23.4ha [Lower dam/reservoir]: B The same condition as the lower dam/reservoir of Halgran 3	[Upper dam/reservoir]: B · Extent in ha within the inundation area+ 50m buffer zone Tea plantation : 50ha Other cultivation: 5.3ha Paddy: 2.6ha Home garden: 1.1ha Total: 59.0ha [Lower dam/reservoir]: B · Extent in ha within the inundation area+ 50 m buffer zone Rubber plantation: 20.7ha Home garden: 6.4ha Total: 27.1ha	[Upper dam/reservoir]: B · Extent in ha within the inundation area+ 50m buffer zone Tea plantation: 21.8ha Home garden: 1.8ha Total: 23.6ha [Lower dam/reservoir]: B The same condition as the lower dam/reservoir of Maha 1	[Upper dam/reservoir]: B · Extent in ha within the inundation area+ 50m buffer zone Paddy: 13.7ha Home garden: 19.3ha Forest: 3.4ha Total: 36.4ha [Lower dam/reservoir]: B · Extent in ha within the inundation area+ 50m buffer zone Paddy: 9.4ha Home garden: 8.3ha Total: 17.7ha
	Rating : B	Rating : B	Rating : B	Rating : B	Rating : B	Rating : B

Evaluation points/Name of site	Halgran 1	Halgran 3	Halgran 4	Maha 1	Maha 2	Loggal
4. Impacts on culture and landscape	[Upper dam/reservoir]: A ・No cultural heritage ・No impact on landscape [Lower dam/reservoir]: A ・No cultural heritage ・No impact on landscape ・There is a small burial ground.	[Upper dam/reservoir]: A ・No cultural heritage ・No impact on landscape [Lower dam/reservoir]: A ・No cultural heritage ・No impact on landscape ・There is a small burial ground.	[Upper dam/reservoir]: A ・No cultural heritage ・No impact on landscape [Lower dam/reservoir]: A The same condition as the lower dam/reservoir of Halgran 3	[Upper dam/reservoir]: A ・No cultural heritage ・No impact on landscape [Lower dam/reservoir]: A ・Nationally famous water fall can be seen from the site (2 km straight line distance from the dam axis). ・No cultural heritage ・No impact on landscape	[Upper dam/reservoir]: A ・No cultural heritage ・No impact on landscape [Lower dam/reservoir]: A The same condition as the lower dam/reservoir of Maha 1	[Upper dam/reservoir]: B ・A Buddhist temple which has a long history of over a century and it is the only temple in the vicinity of the area. But it is not designated as cultural heritage ・No impact on landscape [Lower dam/reservoir]: B A Buddhist temple with historic and cultural value is located on the right bank will be inundated.
	Rating：A	Rating：A	Rating：A	Rating：A	Rating：A	Rating：B

A：Project is not likely to have significant adverse impacts on natural environment and society and/or limited to a small scale,
B：Project is likely to have negative impact on natural environment and society, but less adverse than C ,
C：Project is likely to have significant adverse impacts on natural environment and society

9.4 Evaluation from Geological Aspects

Geologic features at every site investigated by site reconnaissance, accordingly, the result is summarized in Table 9.4-2.

Based on the above results, geological conditions of every candidate site is evaluated in terms of the strength of foundation rocks, the impermeability, the faults, the river bed deposits thickness, and the stability around the reservoirs. The result of evaluation is as shown in Table 9.4-1. Meanings of rating A, B, and C are respectively as follows;

A: likely to be no serious problems, or very limited to, if any,

B: likely to have some problems but not serious

C: obviously serious problems exist, or serious problems with high possibility

Table 9.4-1 Evaluation from Geological Aspects

	Halgran 1	Halgran 3	Halgran 4	Maha 1	Maha 2	Logal
Strength	B	B	A	B	B	A
Impermiability	A	B	B	B	B	A
Faults	B	B	B	B	B	A
Riverbed Deposite	A	A	A	A	A	B
Slope	B	A	B	B	B	A
Overall Evaluation	B	B	B	B	B	B

Notes; the ratings are given based on the study by site reconnaissance, evaluation from existing relevant materials, etc. (not by any geological investigations)

(Source: Study Team)

Table 9.4-2 Outline of Geological Features of 11 Candidate Sites (4-1)

No	Site	1;100,000 Gelogical map	Strucutre	Landslide Hazard Map (1:50,000 or 1:10,000)	Aerophotographs	Mines permits
1	Kiriketti 1	North wing of syncline axis thus NW dipping (dipping upstream). NE-SW faults developped area. Upper reservoir: Hard Charnokite with no faults. Lower reservoir: Charnokite with partial quartzite on right. NE-SW fractured fault along Kiriketti river crossing dam axis. Water route passes 2 NNE-SSW faults.	many faults, crosssing dam axis	1:50,000 hazard map : Upper damsite 2, upper reservoir 2, Lower damsite 1, lower reservoir 3	Upper reservoir: Impossible to use photo (covererd by clouds), Lower reservoir: Possible colluvium deposit on left rim from scarp cliff. No landslide or talus on right steep rim. River flow anticipated to be formed by fault erosion	none
2	Kiriketti 2	North wing of syncline thus NW dipping (dipping upstream). NE-SW faults developped area. Upper reservoir: Hard Charnokite with no faults. NE-SW trending fault right NE of the ridge (water leakage). Lower reservoir: Charnokite with gneiss on left. NE-SW fractured fault along Kiriketti river crossing dam axis. Water route passes NNE-SSW 1 fault.	many faults, crosssing dam axis	1:50,000 hazard map : Upper damsite 3, upper reservoir 3, Lower damsite 3, lower reservoir 3	Upper reservoir: Very steep mountain ridge valley with fault eroding on the ridge. Thin weathering but water sealing problem esp. for right abutment. Lower reservoir: Steep slope on right but without landslides. Many colluviums on left bank .Clear NE-SW fault scarp cliff on the left rim with many colluviums on the bottom. NE-SW fault along river flow with lateral displacement and river flow anticipated to be formed by fault erosion.	one Exploration License is close
3	Maussakelle 1	Upper reservoir: North wing of syncline thus SW dipping (dipping downstream). Placed on the summit- ridge of Charnokite mountain and hard. Partially granitic but anticipated minor issue. No faults. Lower reservoir: North wing of synbcline thus SW dipping. comprises Biotite gneiss. EW fault is right downstream of the dam axis with a waterfall. Water route passes in gneiss without fault.	fault crossing reservoir	1:50,000 hazard map : Upper damsite 1, upper reservoir 1, Lower damsite 2, lower reservoir 2	Upper reservoir: Flat plateou on the mountain that is hard and weatherering anticipated shallow from its shape. The mountain is a residual hill of Charnokite. Lower reservoir: No landslide on both banks (right bank with slow slope but none, left bank with small possible collapses. a collapse in the upper end of the reservoir on left but higher than HWL. EW fault passes around this steep slope on the left bank but no unstable features on the left bank other than this place)	none
4	Maussakelle 2	Upper reservoir: same as above. Lower reservoir: North wing of syncline thus S dipping (dipping upstream). biotite gneiss. EW fault right downstream of the dam axis with a waterfall. Water route passes no fault in gneiss.	fault crossing reservoir	1:50,000 hazard map : Upper damsite 1, upper reservoir 1, Lower damsite 2, lower reservoir 2	Upper reservoir: same as above. Lower reservoir: Slow slope without minor undulation. No landslides in the reservoir (not clear due to the clouds). EW fault crosses the right abutment ridge. The upstream of the reservoir on the right has a landslide colluvium.	none

Table 9.4-2 Outline of Geological Features of 11 Candidate Sites (4-2)

	Site	1;100,000 Gelogical map	Strucutre	Landslide Hazard Map (1:50,000 or 1:10,000)	Aerophotographs	Mines permits
5	Halgran 1	Upper reservoir: North wing of syncline thus SW dipping (dipping upstream). quartzite on the right, Charnokite on the left. Rocks are fine. Shape indicates the right quartzite harder as it suffers no erosion remaining itself as residual hill. the left bank is low in elevation with many tea plants. Potentially thick in weathering. NE-SW fault near by the left of the reservoir does not touch the HWL line. Lower reservoir: South wing of syncline axis thus NE dipping (dipping upstream), Charnokite but limestone possiblly extends to right dam abutment. the reservoir is supported by Charnokite beneath limestone. No faults. Water route passes close to NE-SW fault. It also passes NW-SE fractured fault that may be made by the anticlinal folding between 2 synclines. It has certain displacement. The water route may encounter inferior limestone as the Charnokite embeds limestone near the fault. (this limestone may be encountered in any of Halgran 1-4 water routes)	fault crossing reservoir	1:100,000 hazard map : Upper damsite 3, upper reservoir 3 (right2 left3), Lower damsite 4, lower reservoir 4 (right3 left4) as a whole no good	Upper reservoir: No landslides around dam and reservoir. The right rim middle slope and left rim slow slope. NE-SW fault (on the geology map) is not clearly visible. Lower reservoir: Left rim-left abutment steep in slope with possible landslides. 300m wide landslide on right rim but higher than HWL thus little affects. The possibility of landslide occurence on the left rim may be not so high as the shape of the mountain is firm and little weathered.	none
6	Halgran 2	Upper reservoir: North wing of syncline thus SW dipping (dipping upstream). Charnokite -quartzite, quartzite schist. a fault apart but pararell to river on the left rim. (limestone appears but apart from reservoir). Lower reservoir : same as above. The water route passes NW-SE fractured fault that may be made by the anticlinal folding between 2 synclines. It has certain displacement. The water route may encounter inferior limestone as the Charnokite embeds limestone near the fault. (this limestone may be encountered in any of Halgran 1-4 water routes)	fault 2	1:100,000 hazard map : Upper damsite 3, upper reservoir 3 (right3 left2), Lower damsite 4, lower reservoir 4 (right3 left4) as a whole no good	Upper reservoir: Slow slope in right rim but no landslides around reservor. Quartzite is hard residual hill and has no unstable slopes. Charnokite on right rim may possibly has a deep weathering. NE-SW fault is not clearly visible. Lower reservoir : same as above.	none
7	Halgran 3	Upper reservoir: North wing of syncline thus SW dipping (dipping upstream). quartzite - quartzite schist. (limestone appears but apart from reservoir on the left). Lower reservoir : South wing of syncline thus NE dipping (dipping downstream). Limestone covers reservoir thorough left bank of dam to downstream. (limestone overlain by Charnokite thus no waterleakage in reservoir likely. but the rock extends through downstream of the damsite). NE-SW fault in reservoir. Water route passes NW-SE fractured fault that may be made by the anticlinal folding between 2 synclines. It has certain displacement. The water route may encounter inferior limestone as the Charnokite embeds limestone near the fault. (this limestone may be encountered in any of Halgran 1-4 water routes)	fault 2	1:100,000 hazard map : Upper damsite 2, upper reservoir 2 , Lower damsite 2, lower reservoir 2	Upper reservoir: No landslides around dam and reservoir. Lower reservoir: No landslides on dam and reservoir. But Dam left abutment is thin (200m aprat from dam abutment is Limestone. the rock forms sunk basin shape thus indicating lower water level). May need to extend water sealing treatment towards left upheight. few issues on right abutment as it is gneiss.	none

Table 9.4-2 Outline of Geological Features of 11 Candidate Sites (4-3)

cc	Site	1;100,000 Gelogical map	Strucutre	Landslide Hazard Map (1:50,000 or 1:10,000)	Aerophotographs	Mines permits
8	Halgran 4	Upper reservoir: South wing of anticline axis thus dipping SW (dipping towards left bank). Charnokite and partially on higher place on right bank is quartzite. NW-SE fractured fault on right bank 200m apart from reservoir but firm residual hill of quartzite lies inbetween reservoir and fault. a NE-SW fault crosses reservoir. the upper reservoir is close to ancline thus potentially easier to develop fractures. Lower reservoir; same as above. Water route paase NW-SE fractured fault that may be made by the anticlinal folding between 2 synclines. It has certain displacement. The water route may encounter inferior limestone as the Charnokite embeds limestone near the fault. (this limestone may be encountered in any of Halgran 1-4 water routes)	fault 2	1:100,000 hazard map : Upper damsite 3, upper reservoir 2 , Lower damsite 2, lower reservoir 2	Upper reservoir; No landslides on right banks of dam and reservoir. A clear landslide on the upper end of the reservoir on the left on higher elevation. Another potential landslide on near HWL.(needs to be verified). Both NE-SW fault and NW-SE fault are not clearly visible.	none
9	Maha 1	Upper reservoir: South wing of syncline axis thus dipping NE. Gneisses. NE-SW fault along river on left bank. Rock layer dipping downstream. Lower reservoir: Gneiss (gneiss on right, Charnokite on left), and a limestone band lies along riverbed with certain thickness embedded by gneisses. NW-SE fractured fault erodes the river in the same direction. the fault displacement is not clear on the map. Water route passes 1 NW-SE fractured fault and 1 fault. the limestone band may have suffered successive erosion caused by the fractured fault and river flow.	fault crossing dam axis in Lower reservoir	1:50,000 hazard map : Upper damsite 4, upper reservoir 3 , Lower damsite 4 (right 4 left 3), lower reservoir 4	Upper reservoir: Some minor scale collapses on the right bank. None on the left. Lower reservoir: Thin ridge on the right bank, possibly landslide form (needs to be verified). A clear landslide is shown on the left bank. Lineament along the river flow is anticipated as a lateral fault with surrounding ridge shapes. Fracture scale unknown. Small scale if consolidated but possibly differentially eroded)	none
10	Maha 2	Upper reservoir: South wing of anticline axis thus dipping NE. Gneisses without fault. A NS fractured fault on upstream ot resservoir but above HWL. rock layer dipping downstream. Water route paases 1 NW-SE fractured fault. The limestone band may have suffered successive erosion caused by the fractured fault and river flow. Lower reservoir: same as above.	fault crossing dam axis in Lower reservoir	1:50,000 hazard map : Upper damsite 3, upper reservoir 3 , Lower damsite 4 (right 4 left 3), lower reservoir 4	Upper reservoir: some ridge on right is partially thin. steep valley beneath dam axis. No landslides or collapses near damsite but 1km upstream of the reservoir on left bank is the landslide trace on the right bank (it may be issue when HWL can possibly raises). There are none landslides on Landslide Hazard Map thus the trace can be just deep weathered slow slope.	none

Table 9.4-2 Outline of Geological Features of 11 Candidate Sites (4-4)

	Site	1;100,000 Gelogical map	Strucutre	Landslide Hazard Map (1:50,000 or 1:10,000)	Aerophotographs	Mines permits
11	Loggar	Upper reservoir: A long anticline axis thus dipping NW. Charnokite. No faults. Lower reservoir: North wing of suncline axis to anticline axis thus dipping NW (nearly flat but dipping towards left bank). Quartzite and Charnokite, no limestone. No faults. Water route paases in gneisses, with partially limestone but without faults. Limestone may have been fractured but has 2-300m in thickness from the map.	fault crossing dam axis in Lower reservoir	1:50,000 hazard map : Upper damsite 2, upper reservoir 2, Lower damsite 3, lower reservoir 3	Upper reservoir: Slow in slope, no landslides. Lower reservoir: A Steep cliff on left bank but no landslide traces. Right bank medium-slow slope. Riverbed is a broad alluvium deposit.	none

(Landslide map 凡例)
1: landslides not likely 2: landslides modest level
3: landslides expected 4: landslides most likely
5. subsidence & rockfall 6: landslides occurred in the past

9.5 Evaluation from Easy of Construction Works

The easy of construction works of every candidate sites is evaluated in terms of the access to Upper reservoirs and Lower reservoirs, reclamation of temporary yards for construction works including new access road constructions, and others. The result of evaluation is as shown in Table 9.5-1. Meanings of rating A, B, and C are respectively as follows;

A: likely to be no serious problems, or very limited to, if any,

B: likely to have some problems but not serious, and

C: obviously serious problems exist, or serious problems with high possibility.

Table 9.5-1 Evaluation from Easy of Construction Works

	Halgran 1	Halgran 3	Halgran 4	Maha 1	Maha 2	Logal
Access to Upper Dam	C	B	C	A	A	A
Access to Lower Dam	B	B	B	A	A	B
Temporary Yards	C	A	C	A	A	A
Others			C	A		
Overall Evaluation	C	B	C	A	A	B

(Source: Study Team)

The rating C is given to Halgran 4 as well as the rating A is given to Maha 1 in “Others” row in Table 9.6.4-1 from following reasons;

In Halgran 4, the drawdown depth of Upper reservoir exceed to 50 m, which may cause the instability of surrounding slope of the reservoir because the large extent in height on the slope is to be exposed wet and dry conditions repeated by daily pumping and generating operation. Consequently, a large scale of countermeasures would be required to ensure the slope stability.

In Maha 1, the length of the access tunnel to the powerhouse is less than 1,000 m, which is advantageous points to shorten the whole of the construction period because all of construction activities in the powerhouse cannot be started until the access tunnel from the outside is completed in case of underground type.

9.6 Manufacturing Limitation of Pump-turbine

The candidate sites by the initial JICA Study included those of which the gross head exceed 700 m on the basis of 250 MW/unit. In this study, unit capacity is limited to less than 200 MW/unit from the stability of the national power system; consequently, the manufacturing limitation of pump-turbines is examined in every site, because a smaller unit capacity with a high head has generally more severe manufacturing limitation. Therefore, the candidate sites concerned about the manufacturing limitation are reviewed in order to make those appropriate for 200 MW/unit basis at least. However, in several candidate sites, the issue of the manufacturing limitation remains still due to topographical conditions. Evaluation from the manufacturing limitation is definitely described in the sub-chapter 9.5. Table

9.6-1 shows result of the evaluation from manufacturing limitation aspects. Meanings of rating A, B, and C are respectively as follows;

A: both 200 MW/unit and 150MW/unit are applicable

B: 200MW/unit is applicable; however, 150MW/unit is not applicable

C 200MW/unit is not applicable (already eliminated in the first screening)

Table 9.6-1 Result of Evaluation from Manufacturing Limitation Aspects

	Halgran 1	Halgran 3	Halgran 4	Maha 1	Maha 2	Logal
Evaluation	B	B	A	A	A	A

(Source: Study Team)

9.7 Construction Cost

The construction cost of every site is estimated. Table 9.7-1 shows unit price per kW and its evaluation. Meanings of the rating A, B, and C for the evaluation are as follows;

A: less than 1,200 USD/kW

B: from 1,200 to 1,400 USD/kW

C: more than 1,400USD/kW

Table 9.7-1 Unit Price of Construction Cost

	unit	Halgran 1	Halgran 3	Halgran 4	Maha 1	Maha 2	Loggal
Construction Cost	USD/kW	1,335	1,042	1,414	1,094	1,216	1,280
Evaluation		B	A	C	A	B	B

(Source: Study Team)

9.8 Selection of Promising Sites

The ranking study on 6 candidate sites is conducted with the evaluation results as the above mentioned, and three of the promising site are selected in this sub-chapter. The method of the sites ranking is as described below;

1) 1. Score is allocated to every large criterion for the evaluation; such as “1. Technical Evaluation”, “2. Economical Evaluation”, “3. Environmental Evaluation”. In the Even Case, 50 points are given to “1. Technical Evaluation, 2. Economical Evaluation”, and the other 50 points are given to “3. Environmental Evaluation”. In the environment weighed case, 30 points are given to “1. Technical Evaluation, 2. Economical Evaluation” and 70 points are given to “3. Environmental Evaluation”.

2) “1. Technical Evaluation” is divided into three of small criteria; therefore, the score is

allocated to every small criterion so that the total score of the three can be equal to allocated score to "1. Technical Evaluation" as a large criterion. As for the manufacturing limitation, two rating remain still in six candidate sites after the first screening; one is applicable for both 150 MW/unit and 200 MW/unit as rated A, and the other is applicable for 200 MW/unit only as rated in B. There are not significant differences in unit price of the construction cost between the scheme by three sets of 200 MW/unit and by four sets of 150 MW/unit; therefore, a scheme by 150 MW/unit has a potential for the project forming in the later stages. The criteria of "the manufacturing limitation" is weighed in "1. Technical Evaluation" considered following two aspects; a) a plant having four sets of 150 MW/unit would be more convenient in its operation than a plant having three sets of 200 MW/unit and b) 150 MW/unit has less impact on the power system than 200 MW/unit.

3) "3. Environmental Evaluation is divided into four of small criteria; the score is allocated to every small criterion so that the total score of the four can be equal to allocated score to "3. Environment Evaluation". As for the small criteria of "Impact on local communities", it is weighed considered that it includes the evaluation of the number of possible resettlements.
4) Rating A, B, and C, are given 1.0, 0.6, and 0.3 respectively.
5) Each candidate site is ranked by the sum of small criterion's score. The score of each criterion is calculated with multiplying the points and the rating A, B, and C.

In addition, as another consideration for three promising candidate sites selection, one project is selected from same region. This is taken in order to avoid concentrating plural promising sites in one region. Furthermore, a common reservoir in plural candidate sites is also considered. That is to say, if one project has been developed, others could not be developed anymore, because a common reservoir is already utilized by the developed project in advance. For example, Halgran 3 has a common lower reservoir with Halgran 4, as well as Maha 1 has a common lower reservoir with Maha 2.

As a result, in Halgran region, Halgran 3 is the highest in both cases; the even case and the environment weighed case.

In Maha region, ranking of Maha 1 is higher than that of Maha 2 in the even case; however, Maha 2 predominates in the environment weighed case. This is due to Maha 1's evaluation by "Impact on social environmental", which has low rating because of the number of possible inundated houses; total 76, in Upper reservoir. On the other hand, Maha 2's ranking is ranked 3 to Maha 1's ranking 1, and it does not have such serious environmental problems; therefore, Maha 2 is selected from Maha region.

Loggal is a sole candidate site in Loggal region; however, it is not automatically selected but following considerations are taken into. Loggal has higher ranking than Halgran 1's one in the even case; however, it is reversed in the environment weighed case. (Halgran 4 cannot be developed if Halgran 3 is selected because its Lower dam is a common reservoir with Halgran 3, so that Halgran 4 is automatically dropped off when Halgran 3 is selected.) Halgran 1's Upper reservoir is located near Halgran 3's one, environmental impact on the region would be rather significant. The score difference between Halgran 1 and Loggal is so limited even in the environmental weighed case. Therefore, it is better to follow the consideration as the above-mentioned; to avoid more than two projects are selected from the same region.

As a result, Halgran 3, Maha 2, and Loggal are selected as three of the promising site.

Table 9.8-1 Result of Ranking Study on Candidate Sites (Even Case)

Criteria		Score allocation	Halgran 1			Halgran 3			Halgran 4			Maha 1			Maha 2			Loggal		
			Eva	Rate	Score	Eva	Rate	Score	Eva	Rate	Score	Eva	Rate	Score	Eva	Rate	Score	Eva	Rate	Score
1. Technical Evaluation		25			12.75			15.00			16.75			22.00			22.00			19.00
1.1	Geological aspects	7.5	B	0.60	4.50	B	0.60	4.50	B	0.60	4.50	B	0.60	4.50	B	0.60	4.50	B	0.60	4.50
1.2	Ease of construction works	7.5	C	0.30	2.25	B	0.60	4.50	C	0.30	2.25	A	1.00	7.50	A	1.00	7.50	B	0.60	4.50
1.3	Manufacturing Limitation	10	B	0.60	6.00	B	0.60	6.00	A	1.00	10.00	A	1.00	10.00	A	1.00	10.00	A	1.00	10.00
2. Economical Ealuation		25	B	0.60	15.00	A	1.00	25.00	C	0.30	7.50	A	1.00	25.00	B	0.60	15.00	B	0.60	15.00
3. Environmental Evaluation		50			33.60			33.60			33.60			27.60			33.60			30.00
3.1	Impact on Fauna and Flora	12	B	0.60	7.20	B	0.60	7.20	B	0.60	7.20	B	0.60	7.20	B	0.60	7.20	B	0.60	7.20
3.2	Impact on local communities	20	B	0.60	12.00	B	0.60	12.00	B	0.60	12.00	C	0.30	6.00	B	0.60	12.00	B	0.60	12.00
3.3	Impact on industries	9	B	0.60	5.40	B	0.60	5.40	B	0.60	5.40	B	0.60	5.40	B	0.60	5.40	B	0.60	5.40
3.4	impact on culture and landscape	9	A	1.00	9.00	A	1.00	9.00	A	1.00	9.00	A	1.00	9.00	A	1.00	9.00	B	0.60	5.40
	Total	100			61.35			73.60			57.85			74.60			70.60			64.00
	Rank				5			2			6			1			3			4

Table 9.8-2 Result of Ranking Study on Candidate Sites (Environment Weighed Case)

Criteria	Score allocation	Halgran 1			Halgran 3			Halgran 4			Maha 1			Maha 2			Loggal		
		Eva	Rate	Score	Eva	Rate	Score	Eva	Rate	Score	Eva	Rate	Score	Eva	Rate	Score	Eva	Rate	Score
1. Technical Evaluation	15			7.65			9.00			10.05			13.20			13.20			11.40
1.1 Geological aspects	4.5	B	0.60	2.70	B	0.60	2.70	B	0.60	2.70	B	0.60	2.70	B	0.60	2.70	B	0.60	2.70
1.2 Ease of construction works	4.5	C	0.30	1.35	B	0.60	2.70	C	0.30	1.35	A	1.00	4.50	A	1.00	4.50	B	0.60	2.70
1.3 Manufacturing Limitation	6	B	0.60	3.60	B	0.60	3.60	A	1.00	6.00	A	1.00	6.00	A	1.00	6.00	A	1.00	6.00
2. Economical Ealuation	15	B	0.60	9.00	A	1.00	15.00	C	0.30	4.50	A	1.00	15.00	B	0.60	9.00	B	0.60	9.00
3. Environmental Evaluation	70			46.80			46.80			46.80			37.80			46.80			42.00
3.1 Impact on Fauna and Flora	16	B	0.60	9.60	B	0.60	9.60	B	0.60	9.60	B	0.60	9.60	B	0.60	9.60	B	0.60	9.60
3.2 Impact on local communities	30	B	0.60	18.00	B	0.60	18.00	B	0.60	18.00	C	0.30	9.00	B	0.60	18.00	B	0.60	18.00
3.3 Impact on industries	12	B	0.60	7.20	B	0.60	7.20	B	0.60	7.20	B	0.60	7.20	B	0.60	7.20	B	0.60	7.20
3.4 impact on culture and landscape	12	A	1.00	12.00	A	1.00	12.00	A	1.00	12.00	A	1.00	12.00	A	1.00	12.00	B	0.60	7.20
Total	100			63.45			70.80			61.35			66.00			69.00			62.40
Rank				4			1			6			3			2			5

Chapter 10 Selection of the Most Promising Site

10.1 Outline

In this chapter, the most promising site is selected from the promising candidate sites selected in the Chapter 9. As shown in the sub-chapter 9.8, Halgran 3, Maha 2, and Loggal are selected as the promising candidate sites from 11 candidate sites as a result of the ranking study.

At Maha 2 site, alternative candidate site for the upper reservoir has been found in the vicinity of the original Upper reservoir site. Accordingly, new pumped storage power plant using the alternative upper reservoir has been planned by 1/10,000 topological map as same way to the previous stage. As a result, it is identified that the pumped storage scheme by the alternative upper reservoir has a potential to be on the similar level with the original Maha 2 from technical point of view as well as from the economic point of view. Also, serious problems have not been detected from the primary survey of natural/social environmental aspect as well as from that of geological aspect. Therefore, study for selection of the promising site is carried out including the alternative upper reservoir candidate site found in the vicinity of the original Maha 2. Although, the lower reservoir of the alternative Maha 2 is common with the original Maha 2, the pumped storage scheme using the alternative upper reservoir is called as Maha 3 afterward.

In the promising candidate 3 sites, (4 schemes: Halgran 3, Maha 2, Maha 3, and Loggal), 1/5,000 topographic surveys were planned to be conducted by the local consultant. In the primary site selection as mentioned in the chapter 9 (the selection of the promising candidate sites), 1/10,000 topographic maps (published by Survey Department of Sri Lanka) was utilized for pumped storage planning. Therefore, the topographical survey as the above-mentioned was planned to improve precision of the pumped storage planning for the most promising site selection. In Loggal, however, due to strong opposition for the environmental survey, which was also planned to be conducted in every promising site, the planned topographic survey was canceled by consultation with CEB. Accordingly, review of the pumped storage planning by 1/5,000 topographic map has been carried out in following 3 sites; Halgran 3, Maha 2, and Maha 3.

Table 10.1-1 shows reviewed general features of the promising candidate sites.

Every 4 reviewed pumped storage scheme is evaluated from geological condition, easy of construction works, transmission line, impact on the power system, construction cost, and natural/social environmental impacts. In this sub-chapter, ranking study is conducted based on results of evaluation from various aspects as the above-mentioned in order to select the most promising site in 4 promising sites. Evaluation results from every aspect, which are utilized for the ranking study, are summarized in the following sub-chapters.

Table 10.1-1 General Features of Promising Sites

Candidate Site		unit	Halgran 3	Maha 2		Maha 3		Logal	
				case1	case2	case1	case2	case1	case2
Installed Capacity		MW	600	600	600	600	600	600	600
Unit Capacity		MW	200	200	150	200	150	200	150
Number of Units		unit	3	3	4	3	4	3	4
Peak Generating Time		hours	6.03	6.00	6.00	6.09	6.03	6.16	6.16
Gross Head		m	677.34	448.93	450.40	512.00	513.06	591.33	591.33
Rated Head		m	643.47	426.48	427.88	486.40	487.40	561.76	561.76
Rated Discharge		m^3	111.94	168.89	168.34	148.09	147.78	128.22	128.22
Upper Pond	Latitude		7°02'14"	7°07'20"	7°07'20"	7°06'23"	7°06'23"	7°06'20"	7°06'20"
	Longitude		80°52'31"	80°27'26"	80°27'26"	80°28'49"	80°28'49"	81°07'46"	81°07'46"
	Catchment Area	km^2	2	5	5	1	1	5	5
	Reservoir Area	km^2	0.16	0.15	0.15	0.23	0.23	0.43	0.43
	Crest Elevation	E.L.-m	1400.0	765.0	764.0	821.0	819.5	1002.0	1002.0
	High Water Level	E.L.-m	1,394.0	759.0	758.0	815.0	813.5	996.0	996.0
	Low Water Level	E.L.-m	1,366.0	724.0	720.6	795.4	792.0	985.0	985.0
	Drawdown	m	28.0	35.0	37.4	19.6	21.5	11.0	11.0
	Sediment Level	E.L.-m	1,354.6	710.5	710.5	782.1	782.1	369.3	369.3
	Gross Capacity	MCM	2.77	4.35	4.21	3.94	3.58	4.59	5
	Available Capacity	MCM	2.45	3.65	3.69	3.25	3.29	3.16	3
	Dam Height	m	70	80	79	61	60	42	42
	Crest Length	m	210	250	250	275	275	220	220
Lower Pond	Latitude		7°03'57"	7°07'50"	7°07'50"	7°07'50"	7°07'50"	7°7'23"	7°7'23"
	Longitude		80°54'11"	80°28'27"	80°28'27"	80°28'27"	80°28'27"	81°05'46'	81°05'46'
	Catchment Area	km^2	16	35	35	35	35	5	5
	Reservoir Area	km^2	0.17	0.15	0.15	0.23	0.23	0.15	0.15
	Crest Elevation	E.L.-m	720.0	310.5	307.5	308.0	305.0	416.0	416.0
	High Water Level	E.L.-m	714.0	304.5	301.5	302.0	299.0	410.0	410.0
	Low Water Level	E.L.-m	694.0	286.2	282.4	285.4	281.8	383.0	383.0
	Drawdown	m	20.0	18.3	19.1	16.6	17.2	27.0	27.0
	Sediment Level	E.L.-m	681.6	271.8	271.8	271.8	271.8	369.3	369.3
	Gross Capacity	MCM	3.79	6.92	6.21	6.33	5.65	3.66	4
	Available Capacity	MCM	2.43	3.73	3.67	3.28	3.21	2.84	3
	Dam Height	m	75	71	68	68	65	76	76
	Crest Length	m	280	350	350	350	350	540	540
Headrace Tunnel									
	Inner Diameter	m	4.90	6.00	4.30	5.70	4.00	5.30	3.70
	Length	m	1,350	510	510	1,100	1,100	1,750	1,750
	Nos. of lines	-line	1	1	2	1	2	1	2
Penstock Tunnel									
	Inner Diameter	m	3.80	4.70	3.30	4.40	3.10	4.10	2.90
	Length	m	1,212	885	889	979	983	1,106	1,106
	Nos. of lines	-line	1	1	2	1	2	1	2
Tailrace Tunnel									
	Inner Diameter	m	5.40	6.60	4.70	6.20	4.40	5.80	4.10
	Length	m	2,200	1,000	1,000	500	500	1,230	1,230
	Nos. of lines	-line	1	1	2	1	2	1	2
Access Tunnel to PH									
	Length	m	1,500	1,000	1,000	900	900	1,600	1,600

(Source: JICA Study Team)

10.2 Geological Evaluation

As mentioned in every previous sub-chapter, any serious geological problems are not found in every promising site. Results of geological evaluation for every promising site are shown in Table 10.2-1. Evaluation on upper dams and lower dams is made from following aspects; rock quality, permeability, existence of faults, volume of river bed deposition, and slope stability of reservoir rim, as well as evaluation on waterway is from following aspects; rock quality, existence of faults, relation of direction of tunnel axis and dominant joints. Evaluation results are expressed by four-grade rate; A, B, C, and D. Meaning of every rate is “from Excellent to Poor; A>B>C>D”.

In addition, evaluation results in Loggal is made based on those in Chapter 9, because the geological survey by the local consultant was not able to be carried out in Loggal; therefore, Overall evaluation of Loggal is discounted due to its rather inferior accuracy of the evaluation compared to those in other promising sites.

Table 10.2-1 Evaluation on Site Geology

Items	Halgran 3			Maha 2			Maha 3			Loggal		
	UD	LD	Route	UD	LD	Route	UD	LD	Route	UD	LD	Route
Rock Quality	B	C	B	A	B	B	B	B	B	A	B	B
Permiability	C	C		B	B		B	B		B	B	
Faults	B	B	C	A	C	B	A	C	A	A	A	B
River bed	A	B		A	A		A	A		A	C	
Slope	A	C		A	C		B	C		A	B	
Direction			C			A			C			A
Overall Evaluation		C			A			B			C	

(Source: JICA Study Team)

10.3 Evaluation from Construction Works

As for evaluation from easy of construction works, it is made from following aspects; access to upper reservoirs and lower reservoirs, easiness of land reclamation for temporary yards, length of access tunnel to powerhouse caverns, and drawdown depth based on topographic conditions in and around every site. In a pumped storage scheme, a deeper drawdown depth is one of unfavorable conditions due to influence on the slope stability of reservoir rim considering repeated saturation and drain condition caused by daily operation. It is obvious that deeper drawdown depth cause larger influence on the slope stability; consequently, it causes difficulties of construction works. In this regards, 30m is upper limitation for the drawdown depth of upper reservoirs and lower reservoirs of pumped storage schemes in general, which is operated on the daily basis. The evaluation results are expressed by four-grade rate; A, B, C, and D. Meaning of every rate is “from Excellent to Poor; A>B>C>D”.

Table 10.3-1 Evaluation from Construction Works

Items	Halgran 3	Maha 2	Maha 3	Loggal
Access to Upper Dam	C	B	A	C
Access to Lower Dam	B	B	B	B
Temporary Yards	B	B	B	B
Length of Access to PH	C	B	A	C
Drawdown depth	B	C	B	B
Overall Evaluation	C	B	A	C

(Source: JICA Study Team)

10.4 Transmission Connection and Power system Stability

The candidate routes of connecting transmission lines are envisaged considering to the existing transmission lines passing and existing sub-stations around the sites, environmental protected area and urban areas on the routes. Furthermore, the power system analysis is carried out for every determined transmission line routes in order to confirm impact on the existing power system. As a result, the most preferable transmission line routes are selected from technical and economic aspect and environmental consideration aspect.

For Halgran 3 and Loggal, the route to Kotmale P/S is selected, distance and numbers of conductor of which are 45km × 1 cct for Halgran 3 and 65km × 1cct for Loggal. On the other hand, the route with PI connecting to the existing transmission line between Kotmale P/S and Kirindiwela S/S, distance and numbers of conductor of which is 3.8km × 2cct. In this regard, the distance and numbers of conductor of the connecting transmission line are excluded from evaluation criteria because those are finally reflected to the construction cost.

Table 10.4-1 shows evaluation results by rates for impact on the existing power system which was derived from the power system analysis. As the serious impact, the step-out is simulated in case of 3-phase fault in Loggal. Other than that, any serious impacts are not detected by the analysis. The evaluation results are expressed by four-grade rate; A, B, C, and D. Meaning of every rate is "room from the criteria; A>B>C and D means out of the criteria"

Table 10.4-1 Evaluation for System Analysis Results

Items	Halgran 3	Maha 2	Maha 3	Loggal
Power Fault Analysis	A	B	B	A
Short Circuit Currents Analysis	A	A	A	A
Stability to 3-phase line fault	A	A	A	D
200 MW unit Trip	B	B	B	B
Overall Evaluation	A	B	B	D

(Source: JICA Study Team)

10.5 Manufacturing Limitation of Pump-turbine

Applicability of the unit capacity 200MW is examined based on the revised pumped storage scheme as well as that of the unit capacity 150MW for every promising site. Table 10.5-1 shows results of the examination. It is revealed that for Halgran 3, applicability of unit capacity 200 MW is plotted near the boundary between applicable extent and inapplicable extent as well as unit capacity 150MW is plotted on near the boundary for Loggal.

The evaluation results are expressed by four-grade rate; A, B, C, and D. Meaning of every rate is as follows; "room from the criteria; A>B>C and D means out of the criteria" and in Overall evaluation, A; both 200MW and 150MWare applicable, C; only 200MW is applicable, D; both 200MW and 150MW are inapplicable.

Table 10.5-1 Evaluation for Manufacturing Limitation of Pump-turbine

	Halgran 3	Maha 2	Maha 3	Loggal
200 MW	B	A	A	A
150 MW	D	A	A	B
Overall Evaluation	C	A	A	B

(Source: JICA Study Team)

10.6 Construction Cost

Based on the revised pumped storage scheme, the construction cost is reviewed for every promising site. Reviewed construction cost of every promising site is shown in Table 10.6-1, which includes the construction cost of connecting transmission line. Shown construction cost for Loggal is same one with calculated in the Chapter 9; however, construction cost for the connecting transmission line is newly added to that. The evaluation results are expressed by four-grade rate; A, B, C, and D. Meaning of every rate is as follows; A: less than 1,200USD/kW, B; from 1,200kW to 1,300USD/kW, C; from 1,300USD/kW to 1,400USD/kW, D; more than 1,400USD/kW.

Table 10.6-1 Evaluation on Construction Cost

Unit Capacity	Item	Halgran 3	Maha 2	Maha 3	Loggal
200 MW	Construction Cost	724,521,769	751,103,052	672,351,670	870,120,301
	per kW	1,208	1,252	1,121	1,450
150 MW	Construction Cost		759,946,784	680,846,576	890,862,448
	per kW		1,267	1,135	1,485
Evaluation		B	B	A	D

(Source: JICA Study Team)

10.7 Evaluation from the Environmental Considerations

(1) Evaluation Criteria

At the first site screening stage (refer to Chapter 9), A to C is allocated to each site and cluster according to its impacts to the environments. At the second site screening stage, A to D is allocated to each site and cluster according to its impacts but their magnitudes are given as A＜B＜C＜D. A criterion is given to each score.

The reasons why four scores are given are (1) it can more appropriately reflect the results of the detailed study; and (2) it can give clear differences among three candidate sites and clusters.

Table 10.7-1 shows the evaluation criteria.

Table 10.7-1 Selection Criteria from the Environmental Considerations

<table>
<tr><th></th><th></th><th>item</th><th>Evaluation criterion</th><th>Notes</th></tr>
<tr><td rowspan="4">Impacts on fauna and flora</td><td>1</td><td>Inundated forest area (including natural, secondary forest, and home garden)</td><td>Criterion: ratio of the area of forests to the reservoir area.
A: 0-24%
B: 25-49%
C: 50-74%
D: 75-100%</td><td>Areas of the upper reservoirs are 0.15-0.43 km^2, and ones of the lower reservoirs are 0.15-0.24 km^2, which are far smaller than the large hydropower reservoirs in Sri Lanka. For example, the area of the Victoria reservoir is 22.7km^2.
Impact is thought to be limited in the case of this Project. When this item is weighed, it is therefore not to give big weight to this item.</td></tr>
<tr><td>2</td><td>Impacts on faunal endangered species (including aquatic species)</td><td rowspan="2">All observed species shall be classified into the Global and Sri Lankan endangered categories, and the categories are used as the criterion.
If there are two or three categories in a site, the category which is bigger is selected as the category of the site because of the precautionary approach.</td><td rowspan="2">The table below shall separately be formulated for both fauna and flora endangered species of site.
<table><tr><th>Global / Sri Lankan</th><th>CR</th><th>EN</th><th>VU</th><th>Others</th></tr><tr><td>CR</td><td>D</td><td>D</td><td>D</td><td>D</td></tr><tr><td>EN</td><td>D</td><td>D</td><td>D</td><td>D</td></tr><tr><td>VU</td><td>C</td><td>C</td><td>B</td><td>B</td></tr><tr><td>Others</td><td>B</td><td>B</td><td>A</td><td>A</td></tr></table>CR: Critically Endangered, EN: Endangered, VU: Vulnerable
Global category by IUCN, Sri Lankan category: Government of Sri Lanka (2012)
Others: NT (Near Threatened), LC (Least Concern) and non-classified

The Sri Lankan categories are considered to be more important than the Global ones. This is because a species which is rare in Sri Lanka will be more sensitive and receive bigger impact.</td></tr>
<tr><td>3</td><td>Impacts on floral endangered species (including aquatic species)</td></tr>
<tr><td>4</td><td>Impacts on ecosystem</td><td>Ecosystems of a site are classified into the following four categories.

A: Monoculture area
B: Secondary ecosystem (single stratum)
C: Secondary ecosystem (multiple strata)
D: Natural habitat

Regarding the “Secondary ecosystem (multiple strata)” and “Natural habitat”, their areas are also considered when category is finally given.</td><td>Monoculture area: One species is uniformly grown and managed such as tea plantation, rice field and Eucalyptus plantation.
Secondary ecosystem (single stratum): Several cash crops and native species are grown and managed but its structure is simple such early stage of home garden.
Secondary ecosystem (multiple strata): Several cash crops and native species are grown and managed for long time to form good ecosystems with multiple strata such as mature home garden.
Natural habitat: 1. (a) Natural habitats are land and water areas where (i) the ecosystems' biological communities are formed largely by native plant and animal species, and (ii) human activity has not essentially modified the area's primary ecological functions.”(World Bank OP4.04 Annex A). An example is a riverine forest.

Regarding the secondary ecosystem (multiple strata), if the affected area is small (i.e. less than 1/3</td></tr>
</table>

				of reservoir area), it may be classified as category "B". Regarding the natural habitat, if it exists in a site, category "D" is given no matter how small it is from the point of precautionary approach.

Social		**item**	**Evaluation criterion**	**Notes**
Impacts on local communities	1	Number of those who to be resettled	Number of affected households A: 0 B: 1-14 C: 15-29 D: more than 30	The numbers of affected households (hhs) in other hydropower development projects are shown as a reference. Upper Kotmale hydropower development project: 497 hhs Moragola hydropower development project: 26 hhs Victoria expansion project: 57 hhs
	2	Area of land to be acquired	Affected land area A: less than 15ha B: 15-19ha C: 20-24ha D: more than 25ha	
	3	Number of those who to be affected by losing livelihood	Number of affected households A: 0 B: less than 15 C: 15-29 D: More than 30	
	4	Impacts on public facilities (e.g. school, road)	Number of public facilities (school, road and hospital) to be inundated A: 0 B: Of those facilities, one of them is inundated. C: Of those facilities, two of them are inundated, or two of the same facility are inundated. D: Of those facilities, three of them are inundated, or three of the same facility are inundated.	
	5	Impacts on the poor people and minorities	Number of affected households of the poor people and minorities A: 0 B: Less than 10 C: 11-19 D: More than 20	No minority lives or works in the selected sites. The upcounry Tamils are considered to be "poor people". Vedda, indigenous and minority in Sri Lanka, do not live nor work in the selected sites.
	6	Impacts on water utilization (e.x. drinking water, bathing, washing, irrigation,	Number of drinking water facility, irrigation facility and mini-hydropower plant A: 0 B: Of those facilities, one of them is found.	Three major water utilizations such are considered in this assessment exercise. There is no fishery at each site, and fishery is not considered. Although washing and bathing are practiced at the sites, they are excluded since they receive relatively small impacts in this project.

		mini-hydropower plant) of rivers and wells	C: Of those facilities, two of them are found. D: More than 3 of those facilities are found.	
Impacts on industries	7	Agriculture (including tea & rubber plantation)	Area of affected tea plantation, home garden, rice field, and other plantations A: Less than 15ha B: 15-19ha C: 20-24ha D: More than 25ha	
	8	Tourism (e.g. water fall)	Existence of tourism projects, and impacts on tourism resources A. No tourism resources B. There are tourism resources but direct or indirect impacts can be avoided. C. There are tourism resources and they receive direct and/or indirect impacts. But the impacts can be reduced. D. No mitigation measures are taken for tourism resources.	
Impacts on culture and landscape	9	Religious, and/or cultural facilities, burial ground	A. No locally important religious and/or cultural facilities B. There are locally important religious and/or cultural facilities but direct or indirect impacts can be avoided. C. There are locally important religious and/or cultural facilities and they receive direct and/or indirect impacts. But the impacts can be reduced. D. No mitigation measures are taken for locally important religious and/or cultural facilities.	
	10	Impacts on landscape	A. There are no landscapes which are appreciated by the local people in their daily lives. B. Impacts on major landscapes in the area are avoidable. C. Impacts on major landscapes can be reduced with appropriate measures. D. No mitigation measures are taken for major landscapes.	

(Source: JICA Study Team)

(2) Evaluation results and the outlines of the environments of each site

Table 10.7-2 shows the evaluation results and the outlines of environments of each site. The evaluation is conducted based on Table 10.7-1.

Table 10.7-2 Outlines and Results of Evaluation of Each Site

<table>
<tr><th colspan="2" rowspan="2">Evaluation items</th><th colspan="2">Halgran</th><th rowspan="2">Evaluation</th><th colspan="2">Loggal</th><th rowspan="2">Evaluation</th></tr>
<tr><th>Upper</th><th>Lower</th><th>Upper</th><th>Lower</th></tr>
<tr><td rowspan="4">Impacts on fauna and flora</td><td>Inundated forest area (including natural, secondary forest, and home garden)</td>
<td>【Explanation】
The total area of the reservoir is 15.6 ha. There are Eucalyptus plantation (4.3 ha), and riverine forest (5.6 ha). The total area of the forests is 9.9 ha, and the ratio of the forests to the reservoir is 63.5%.
【Evaluation】C</td>
<td>【Explanation】
The total area of the reservoir is 14.6 ha. There are secondary forest (1.1 ha) and home gardens (0.3 ha). The total area of the forests is 1.4 ha, and the ratio of the forests to the reservoir is 9.6%.
【Evaluation】A</td>
<td>C</td>
<td>【Explanation】
The total area of the reservoir is 35.4 ha. There are home gardens (total 16.2 ha: the area of home garden with tea plantation is 7.4 ha), and pine and acacia plantations (0.6 ha), and riverine forests (0.8 ha). The total area of the forests is 17.6 ha and the ratio of the forests to the reservoir is 49.7%.
【Evaluation】B</td>
<td>【Explanation】
The total area of the reservoir is 17.6 ha. There are home gardens (5.0 ha), secondary forests (5.0 ha) and riverine forests (0.03 ha). The total area of the forests is 10.0 ha, and the ratio of the forests to the reservoir is 56.8%.
【Evaluation】C</td>
<td>C</td></tr>
<tr><td>Impacts on faunal endangered species (including aquatic species)</td>
<td>【Explanation】
The figure of each cell is number of species.
<table>
<tr><th>Global / Sri Lankan</th><th>CR</th><th>EN</th><th>VU</th><th>Others</th></tr>
<tr><td>CR</td><td>0</td><td>0</td><td>0</td><td>1</td></tr>
<tr><td>EN</td><td>0</td><td>2</td><td>0</td><td>8</td></tr>
<tr><td>VU</td><td>0</td><td>1</td><td>0</td><td>8</td></tr>
<tr><td>Others</td><td>0</td><td>1</td><td>0</td><td>16</td></tr>
</table>
【Evaluation】D</td>
<td>【Explanation】
The figure of each cell is number of species.
<table>
<tr><th>Global / Sri Lankan</th><th>CR</th><th>EN</th><th>VU</th><th>Others</th></tr>
<tr><td>CR</td><td>0</td><td>0</td><td>0</td><td>1</td></tr>
<tr><td>EN</td><td>0</td><td>1</td><td>0</td><td>5</td></tr>
<tr><td>VU</td><td>0</td><td>1</td><td>1</td><td>6</td></tr>
<tr><td>Others</td><td>0</td><td>1</td><td>0</td><td>21</td></tr>
</table>
【Evaluation】D</td>
<td>D</td>
<td>【Explanation】
The figure of each cell is number of species.
<table>
<tr><th>Global / Sri Lankan</th><th>CR</th><th>EN</th><th>VU</th><th>Others</th></tr>
<tr><td>CR</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>EN</td><td>0</td><td>2</td><td>0</td><td>2</td></tr>
<tr><td>VU</td><td>0</td><td>1</td><td>0</td><td>4</td></tr>
<tr><td>Others</td><td>0</td><td>1</td><td>0</td><td>13</td></tr>
</table>
【Evaluation】D</td>
<td>【Explanation】
The figure of each cell is number of species.
<table>
<tr><th>Global / Sri Lankan</th><th>CR</th><th>EN</th><th>VU</th><th>Others</th></tr>
<tr><td>CR</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>EN</td><td>0</td><td>2</td><td>1</td><td>4</td></tr>
<tr><td>VU</td><td>0</td><td>1</td><td>0</td><td>6</td></tr>
<tr><td>Others</td><td>0</td><td>1</td><td>0</td><td>24</td></tr>
</table>
【Evaluation】D</td>
<td>D</td></tr>
<tr><td>Impacts on floral endangered species (including aquatic species)</td>
<td>【Explanation】
The figure of each cell is number of species.
<table>
<tr><th>Global / Sri Lankan</th><th>CR</th><th>EN</th><th>VU</th><th>Others</th></tr>
<tr><td>CR</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>EN</td><td>0</td><td>0</td><td>0</td><td>9</td></tr>
<tr><td>VU</td><td>0</td><td>1</td><td>2</td><td>13</td></tr>
<tr><td>Others</td><td>1</td><td>3</td><td>4</td><td>3</td></tr>
</table>
【Evaluation】D</td>
<td>【Explanation】
The figure of each cell is number of species.
<table>
<tr><th>Global / Sri Lankan</th><th>CR</th><th>EN</th><th>VU</th><th>Others</th></tr>
<tr><td>CR</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>EN</td><td>0</td><td>0</td><td>0</td><td>1</td></tr>
<tr><td>VU</td><td>0</td><td>0</td><td>1</td><td>13</td></tr>
<tr><td>Others</td><td>0</td><td>0</td><td>1</td><td>1</td></tr>
</table>
【Evaluation】D</td>
<td>D</td>
<td>【Explanation】
The figure of each cell is number of species.
<table>
<tr><th>Global / Sri Lankan</th><th>CR</th><th>EN</th><th>VU</th><th>Others</th></tr>
<tr><td>CR</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>EN</td><td>0</td><td>0</td><td>0</td><td>1</td></tr>
<tr><td>VU</td><td>0</td><td>0</td><td>1</td><td>4</td></tr>
<tr><td>Others</td><td>0</td><td>1</td><td>3</td><td>0</td></tr>
</table>
【Evaluation】D</td>
<td>【Explanation】
The figure of each cell is number of species.
<table>
<tr><th>Global / Sri Lankan</th><th>CR</th><th>EN</th><th>VU</th><th>Others</th></tr>
<tr><td>CR</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>EN</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>VU</td><td>0</td><td>0</td><td>1</td><td>1</td></tr>
<tr><td>Others</td><td>0</td><td>0</td><td>2</td><td>0</td></tr>
</table>
【Evaluation】B</td>
<td>D</td></tr>
<tr><td>Impacts on ecosystem</td>
<td>【Explanation】
Monoculture area: tea plantation and Eucalyptus plantation.
Secondary ecosystem (single stratum): non.
Secondary ecosystem (multiple strata): non
Natural habitat: riverine forests with the area of 5.6 ha, and the ratio of them to the reservoir is 35.9%. The forests are with multiple strata and with high biodiversity.
【Evaluation】D</td>
<td>【Explanation】
Monoculture area: rice fields (including abandoned ones) and agricultural lands
Secondary ecosystem (single stratum): non
Secondary ecosystem (multiple strata): secondary forests and home gardens. Their total area is 1.4 ha, and the ratio of them to the reservoir is 9.6%. There are also poor secondary riverine forests (very small area).
Natural habitat: non
【Evaluation】B</td>
<td>D</td>
<td>【Explanation】
Monoculture area: rice field, pine plantation and acacia plantation
Secondary ecosystem (single stratum): home garden with tea plantation
Secondary ecosystem (multiple strata): mature home gardens with the area of 8.8 ha, and the ratio of them to the reservoir is 24.8%. Riverine forests with the area of 0.8 ha and the ratio of them is 2.2%.
Natural habitat: non
【Evaluation】B</td>
<td>【Explanation】
Monoculture area: rice fields
Secondary ecosystem (single stratum): non
Secondary ecosystem (multiple strata): secondary forests and home gardens with the area of 10.0 ha, and the ratio of them to the reservoir is 56.8%. There are also poor secondary riverine forests (very small area).
Natural habitat: non
【Evaluation】C</td>
<td>C</td></tr>
<tr><td rowspan="2">Impacts on local communities</td><td>Number of those who to be resettled</td>
<td>【Explanation】
There is no family to be resettled by the project. Two small structures are located just below the dam axis, and 5 families live within the buffer zone.
【Evaluation】A</td>
<td>【Explanation】
There are 4 families to be resettled by the project.
There are 163 families to be indirectly affected by the project in the buffer zone.
【Evaluation】B</td>
<td>B</td>
<td>【Explanation】
There are 21 families to be resettled by the project.
There are 99 families to be indirectly affected by the project in the buffer zone.
【Evaluation】C</td>
<td>【Explanation】
There are 4 families to be resettled by the project.
There are 24 families to be indirectly affected by the project in the buffer zone.
【Evaluation】B</td>
<td>C</td></tr>
<tr><td>Area of land to be acquired</td>
<td>【Explanation】
Eucalyptus plantation : 4.33ha
Riverine forests :5.65ha
Tea plantation : 5.62ha
Total : 15.60ha
【Evaluation】B</td>
<td>【Explanation】
Mixed perennial crops : 2.5ha
Paddy : 5.1ha
Abandoned paddy : 4.0ha
Secondary forest : 1.1ha
Home garden : 0.3ha
Water body） : 1.6ha
Total : 14.6ha
【Evaluation】A</td>
<td>B</td>
<td>【Explanation】
Home garden : 8.76ha
Home garden with tea : 7.43ha
Paddy : 14.6ha
Planted forest : 0.6ha
Riverine forest : 0.88ha
Scrub : 0.4ha
Temple : 0.42ha
Total : 35.4ha
【Evaluation】D</td>
<td>【Explanation】
Home garden : 4.98ha
Paddy : 7.02ha
Riverine : 0.03ha
Secondary forest : 4.96ha
Stream : 0.60ha
Total : 17.59ha
【Evaluation】B</td>
<td>D</td></tr>
</table>

Evaluation items		Halgran Upper	Halgran Lower	Evaluation	Loggal Upper	Loggal Lower	Evaluation
	Number of those who to be affected by losing livelihood	【Explanation】 There is no family to be affected by losing livelihood within the directly affected area. (There is no data for those losing livelihood within indirectly affected area of buffer zone. 【Evaluation】A	【Explanation】 4 families who live in the directly affected area, and 78 families who live in the indirectly affected area (buffer zone) will lose livelihood 【Evaluation】D	D	【Explanation】 21 families who live in the directly affected area will lose livelihood. 【Evaluation】C	【Explanation】 4 families who live in the directly affected area will lose livelihood. 【Evaluation】B	C
	Impacts on public facilities (e.g. school, road)	【Explanation】 There are no public facilities that will be affected by the project. 【Evaluation】A	【Explanation】 There are no public facilities that will be affected by the project. 【Evaluation】A	A	【Explanation】 A school and existing road will be inundated by the project. 【Evaluation】C	【Explanation】 A school will be inundated by the project. 【Evaluation】B	C
	Impacts on the poor people and minorities	【Explanation】 There are no minority people and family who receive the government aid of Samurdhi in both directly affected area by the project and buffer zone. 【Evaluation】A	【Explanation】 There are no minority people in the area. There is one family who receive the government aid of Samurdhi in the directly affected area, and 26 families receive it in the indirectly affected area of bugger zone. 【Evaluation】B	B	【Explanation】 Since it was not possible to conduct the social survey, no data is collected. 【Evaluation】No evaluation	【Explanation】 Since it was not possible to conduct the social survey, no data is collected. 【Evaluation】No evaluation	No evaluation
	Impacts on water utilization	【Explanation】 There is no family to use river water for drinking, irrigation purpose in the directly affected area by the project. There is 4 families in the buffer zone which use river water for drinking 1 km away from their home. 【Evaluation】A	【Explanation】 Some families use river water for drinking and irrigation purposes in the directly affected area by the project. 【Evaluation】C	C	【Explanation】 33 ha of paddy get water from small irrigation where is outside of the project area. Since no social survey in the area, there is no detail data, but local people of the directly affected area and the buffer zone use river water for bathing and for vegetable fields, but not for drinking. There is a mini-hydropower plant downstream of river where is outside of the buffer zone will be indirectly affected during construction. 【Evaluation】B	【Explanation】 65 ha of paddy during Maha, and 21 ha of paddy during Yala get water from irrigation where is located outside of the project area. Since no social survey in the area, there is no detail data, but local people of the directly affected area and the buffer zone do not use river water for drinking. 【Evaluation】A	B
Impacts on industries	Agriculture (including tree & rubber plantation)	【Explanation】 Eucalyptus plantation (4.33 ha), and tea plantation (5.62 ha) Total: 9.95 ha 【Evaluation】A	【Explanation】 Mixed perennial crops (2.52 ha), paddy (5.14 ha), secondary forest (1.08 ha), and home garden (0.32 ha) Total: 9.06 ha 【Evaluation】A	A	【Explanation】 Home garden (8.76 ha), home garden with tea (7.43ha), paddy (14.60 ha), secondary forest (0.60 ha) Total: 31.39 ha 【Evaluation】D	【Explanation】 Home garden (4.98 ha), paddy (7.02 ha), secondary forest (4.96 ha) Total: 16.96 ha 【Evaluation】B	D
	Tourism (e.g. water fall)	【Explanation】 There are no tourism spot or tourism resources in the directly affected area. 【Evaluation】A	【Explanation】 There are no tourism spot or tourism resources in the directly affected area. 【Evaluation】A	A	【Explanation】 There are no tourism spot or tourism resources in the directly affected area. 【Evaluation】A	【Explanation】 There are no tourism spot or tourism resources in the directly affected area. 【Evaluation】A	A
Impacts on culture and landscape	Religious, and/or cultural facilities, burial ground	【Explanation】 There are two Hindu temples which will be inundated by the project. 【Evaluation】C	【Explanation】 There are no religious and cultural facilities in the directly affected area by the project. There are 7 Buddhist temples which are not protected by the state, but important for local people in the buffer zone. 【Evaluation】A	C	【Explanation】 One Buddhist temple which is only one in the area will be inundated by the project. 【Evaluation】C	【Explanation】 One Buddhist temple which is only one in the area will be inundated by the project. 【Evaluation】C	C
	Impacts on landscape	【Explanation】 There is no house in the directly affected area and a few houses in the buffer zone. Tea plantation on the left side bank and Eucalyptus plantation are spread in the right side bank. There is no landscape resource which has to be protected. 【Evaluation】A	【Explanation】 The view of rural landscapes of paddy, home garden and vegetable fields are spread in the area. There is no landscape resource which has to be protected. 【Evaluation】A	A	【Explanation】 The proposed project site is located in mountainous area and there are isolated villages where most of local people are engaged in farming of paddy, home garden and forest plantation. Except that scenery, there is no landscape resource which has to be protected. 【Evaluation】A	【Explanation】 The proposed project site is located in mountainous area and there are isolated villages where most of local people are engaged in farming of paddy, home garden and forest plantation. Except that scenery, there is no landscape resource which has to be protected. 【Evaluation】A	A

(Source: JICA Study Team)

<table>
<tr><th rowspan="2" colspan="2">Evaluation items</th><th>Maha 2</th><th>Maha 3</th><th>Maha Lower</th><th>Maha 2 & Lower</th><th>Maha 3 & Lower</th></tr>
<tr><th>Upper</th><th>Upper</th><th>Lower</th><th>Evaluation</th><th>Evaluation</th></tr>
<tr><td rowspan="4">Impacts on fauna and flora</td><td>Inundated forest area (including natural, secondary forest, and home garden)</td><td>【Explanation】
The total area of the reservoir is 15.2 ha. There is no forest.
【Evaluation】A</td><td>【Explanation】
The total area of the reservoir is 23.2 ha. There are riverine forest (0.06 ha), home garden with tea plantation (6.1 ha). The total area of the forests is 6.2 ha, and the ratio of the forests to the reservoir is 26.7%.
【Evaluation】A</td><td>【Explanation】
The total area of the reservoir is 23.7 ha. There are secondary forest (3.1 ha), home gardens with rubber (16.3 ha), and rubber plantation (0.9 ha). The total area of the forests is 20.3 ha, and the ratio of the forests to the reservoir is 85.7%.
【Evaluation】D</td><td>D</td><td>D</td></tr>
<tr><td>Impacts on faunal endangered species (including aquatic species)</td><td>【Explanation】
The figure of each cell is number of species.<table><tr><th>Global / Sri Lankan</th><th>CR</th><th>EN</th><th>VU</th><th>Others</th></tr><tr><td>CR</td><td>0</td><td>0</td><td>0</td><td>0</td></tr><tr><td>EN</td><td>0</td><td>0</td><td>0</td><td>1</td></tr><tr><td>VU</td><td>0</td><td>0</td><td>0</td><td>2</td></tr><tr><td>Others</td><td>0</td><td>0</td><td>0</td><td>9</td></tr></table>【Evaluation】D</td><td>【Explanation】
The figure of each cell is number of species.<table><tr><th>Global / Sri Lankan</th><th>CR</th><th>EN</th><th>VU</th><th>Others</th></tr><tr><td>CR</td><td>0</td><td>0</td><td>0</td><td>0</td></tr><tr><td>EN</td><td>0</td><td>0</td><td>0</td><td>1</td></tr><tr><td>VU</td><td>0</td><td>1</td><td>0</td><td>2</td></tr><tr><td>Others</td><td>0</td><td>1</td><td>0</td><td>8</td></tr></table>【Evaluation】D</td><td>【Explanation】
The figure of each cell is number of species.<table><tr><th>Global / Sri Lankan</th><th>CR</th><th>EN</th><th>VU</th><th>Others</th></tr><tr><td>CR</td><td>0</td><td>0</td><td>0</td><td>0</td></tr><tr><td>EN</td><td>0</td><td>1</td><td>0</td><td>4</td></tr><tr><td>VU</td><td>0</td><td>2</td><td>0</td><td>10</td></tr><tr><td>Others</td><td>0</td><td>1</td><td>0</td><td>17</td></tr></table>【Evaluation】D</td><td>D</td><td>D</td></tr>
<tr><td>Impacts on floral endangered species (including aquatic species)</td><td>【Explanation】
The figure of each cell is number of species.<table><tr><th>Global / Sri Lankan</th><th>CR</th><th>EN</th><th>VU</th><th>Others</th></tr><tr><td>CR</td><td>0</td><td>0</td><td>0</td><td>0</td></tr><tr><td>EN</td><td>0</td><td>0</td><td>0</td><td>0</td></tr><tr><td>VU</td><td>0</td><td>0</td><td>0</td><td>0</td></tr><tr><td>Others</td><td>0</td><td>0</td><td>0</td><td>1</td></tr></table>【Evaluation】A</td><td>【Explanation】
The figure of each cell is number of species.<table><tr><th>Global / Sri Lankan</th><th>CR</th><th>EN</th><th>VU</th><th>Others</th></tr><tr><td>CR</td><td>0</td><td>0</td><td>0</td><td>0</td></tr><tr><td>EN</td><td>0</td><td>0</td><td>0</td><td>0</td></tr><tr><td>VU</td><td>0</td><td>0</td><td>0</td><td>2</td></tr><tr><td>Others</td><td>0</td><td>0</td><td>0</td><td>0</td></tr></table>【Evaluation】B</td><td>【Explanation】
The figure of each cell is number of species.<table><tr><th>Global / Sri Lankan</th><th>CR</th><th>EN</th><th>VU</th><th>Others</th></tr><tr><td>CR</td><td>0</td><td>0</td><td>0</td><td>0</td></tr><tr><td>EN</td><td>0</td><td>0</td><td>0</td><td>0</td></tr><tr><td>VU</td><td>0</td><td>2</td><td>0</td><td>10</td></tr><tr><td>Others</td><td>0</td><td>0</td><td>0</td><td>4</td></tr></table>【Evaluation】C</td><td>C</td><td>C</td></tr>
<tr><td>Impacts on ecosystem</td><td>【Explanation】
Monoculture area: tea plantations which occupy 81.6% of the reservoir area.
Secondary ecosystem (single stratum): degraded and scrublands which occupy 4.6% of the reservoir area.
Secondary ecosystem (multiple strata): non
Natural habitat: non

Estate settlement occupies 13.8% of the reservoir area.
【Evaluation】A</td><td>【Explanation】
Monoculture area: abandoned rice fields, abandoned tea plantation and tea plantation
Secondary ecosystem (single stratum): home garden with tea plantation, shrubs
Secondary ecosystem (multiple strata): secondary and poor riverine forest (0.06 ha)
Natural habitat: non
【Evaluation】B</td><td>【Explanation】
Monoculture area: rice fields (with very small area) and rubber planation
Secondary ecosystem (single stratum): non
Secondary ecosystem (multiple strata): secondary forests and home gardens with rubber. Their total area is 19.4 ha, and the ratio of them to the reservoir is 81.9%.
Natural habitat: non
【Evaluation】C</td><td>C</td><td>C</td></tr>
<tr><td rowspan="2">Impacts on local communities</td><td>Number of those who to be resettled</td><td>【Explanation】
There are 3 estate line rooms where an estimated 34 families (84 people) who to be resettled.
There are 14 families who will be indirectly affected by the project in the buffer zone.
【Evaluation】D</td><td>【Explanation】
There are 28 families who to be resettled.
There are 27 families who will be indirectly affected by the project in the buffer zone.
【Evaluation】C</td><td>【Explanation】
There are 11 families who to be resettled.
There are 88 families who will be indirectly affected by the project in the buffer zone.
【Evaluation】B</td><td>D</td><td>C</td></tr>
<tr><td>Area of land to be acquired</td><td>【Explanation】
Estate settlement : 2.12ha
Scrub & Degraded land : 0.73ha
Tea plantation : 12.39ha
Total : 15.24ha
【Evaluation】B</td><td>【Explanation】
Abandoned paddy : 3.05ha
Abandoned tea plantation : 0.52ha
Home garden with tea : 6.12ha
Tea plantation : 13.22ha
Riverine forest : 0.06ha
Scrub : 0.25ha
Total : 23.22ha
【Evaluation】C</td><td>【Explanation】
Forest : 3.13ha
Paddy : 0.05ha
Land of hydropower plant : 0.15ha
Rubber plantation : 0.87ha
Rubber with Home garden : 16.25ha
Total : 23.52ha
【Evaluation】C</td><td>C</td><td>C</td></tr>
</table>

Evaluation items		Maha 2	Maha 3	Maha Lower	Maha 2 & Lower	Maha 3 & Lower
		Upper	Upper	Lower	Evaluation	Evaluation
	Number of those who to be affected by losing livelihood	【Explanation】 34 families (3 line houses, 84 people) who live in the directly affected area will lose livelihood. 【Evaluation】D	【Explanation】 28 families who live in the directly affected area will lose livelihood. 【Evaluation】C	【Explanation】 11 families who live in the directly affected area will lose livelihood. 【Evaluation】B	D	C
	Impacts on public facilities (e.g. school, road)	【Explanation】 There are no public facilities in the directly affected area. 【Evaluation】A	【Explanation】 There are no public facilities in the directly affected area. 【Evaluation】A	【Explanation】 There are no public facilities in the directly affected area. 【Evaluation】A	A	A
	Impacts on the poor people and minorities	【Explanation】 Since it was not possible to conduct the social survey, no data collect. 【Evaluation】No evaluation	【Explanation】 7 out of 28 families who will be affected by the project receive the government aid of Samurudhi can be considered as poor people. 【Evaluation】B	【Explanation】 3 out of 11 families who will be affected by the project receive the government aid of Samurudhi can be considered as poor people. 【Evaluation】B	No evaluation	B
	Impacts on water utilization	【Explanation】 Nobody uses river water for any purpose in the directly affected area. 【Evaluation】A	【Explanation】 Some families use river water for drinking and for agriculture purpose in the directly affected area. 【Evaluation】C	【Explanation】 Some families use river water for drinking and irrigation purpose in the directly affected area, and 2 small scale hydropower plants also use river water in the directly affected area. 【Evaluation】D	D	D
Impacts on industries	Agriculture (including tree & rubber plantation)	【Explanation】 Tea plantation (12.39 ha) Total: 12.39 ha 【Evaluation】A	【Explanation】 Home garden (6.12 ha), and tea plantation (13.22 ha) Total: 19.34 ha 【Evaluation】B	【Explanation】 Forest (3.13 ha), paddy (0.05ha), rubber plantation (0.87 ha), home garden with rubber (16.25 ha) Total: 20.30 ha 【Evaluation】C	C	C
	Tourism (e.g. water fall)	【Explanation】 There are no tourism spot or tourism resources in the directly affected area. 【Evaluation】A	【Explanation】 There are no tourism spot or tourism resources in the directly affected area. 【Evaluation】A	【Explanation】 There are no tourism spot or tourism resources in the directly affected area. There is one water fall which is seen from the proposed lower reservoir, the direct distance from the site is around 2 km. It is located outside of the buffer zone. The local authority has a tourism development plan by utilizing the water fall. The related infrastructure development of surrounding area will be possible through a joint development scheme with the PSPP project in future. This kind of joint venture may give positive impacts on the area. 【Evaluation】A	A	A
Impacts on culture and landscape	Religious, and/or cultural facilities, burial ground	【Explanation】 There is a Hindu Temple in the directly affected area. 【Evaluation】C	【Explanation】 There are some burial grounds in the directly affected area by the project. 【Evaluation】C	【Explanation】 There are no religious and cultural facilities in the directly affected area by the project. 【Evaluation】A	C	C
	Impacts on landscape	【Explanation】 Tea plantation covers the proposed reservoir. Except that scenery of tea plantation, there is no landscape resource which has to be protected. 【Evaluation】A	【Explanation】 Mixed scenery of well-maintained tea plantation and abandoned tea plantation covers both directly and indirectly affected areas. Except that scenery, there is no landscape resource which has to be protected. 【Evaluation】A	【Explanation】 A water fall is seen from the proposed reservoir site which 2 km is away, and the proposed project can mitigate the impact on the viewpoint and landscape resource. 【Evaluation】B	B	B

(Source: JICA Study Team)

(3) Evaluations on the proposed routes of the transmission lines

The evaluation results of the routes from Halgran, Maha and Loggal to each connecting point are shown in Table 10.7-3.

Table 10.7-3 Environmental and Social Assessment on the proposed transmission lines' routes

Assessment aspect	Halgran – Kotmale PS	Maha				Loggal – Kotmale PS
		Kirindiwela SS	Polpitiya SS	Kotmale PS -Kirindiwela SS T/L	Kotmale PS	
Population Density and its growth	A	A	A	A	A	A
Social Environment (barriers)	A	A	A	A	A	A
Overall Evaluation (Social Environment)	**A**	**A**	**A**	**A**	**A**	**A**
Natural Environment (barriers)	A	A	B	A	A	A
Overall Evaluation	**A**	**A**	**B**	**A**	**A**	**A**

(**Source: JICA Study Team**)

A: Project is not likely to have significant negative impacts on natural environment and society and/or limited to a small scale.

B: Project is likely to have negative impacts on natural environment and society.

C: Project is likely to have significant negative impacts on natural environment and society.

D: Project clearly gives significant negative impacts on natural environment and society.

10.8 Selection of the Most Promising Site

Based on geological evaluation, ease of the construction works, the power system analysis, the manufacturing limitation, the construction cost, and the natural/social environmental evaluation as described in the sub-chapter 10.2 ~ 10.7, the score of each promising site is calculated, and then the rank of each promising site is determined. Calculation of the score and determination of rank are done according to the following procedures;

- 1.0, 0.75, 0.50 and 0.25 are given to rating A, B, C, D, respectively.
- Evaluation criteria are divided into following four large categories and 25 points are given to each large category; 1. The technical evaluation (Geology, Construction works, Power system stability, Manufacturing limitation), 2. Construction cost, 3. Natural environmental impact and 4. Social environmental impact.
- Large categories are composed of small categories and given 25 points to a large category are

allocated to its small categories considering those importance within their large category.

- Score of each small category is calculated multiplying ranting and allocated point and total score is calculated for each large category.
- Considering the environmental survey (2) was not able to be conducted fully in the upper reservoir area of Maha 2 as well as in the upper and the lower reservoir of Loggal, “3 .Natural environmental impact” and “4. Social environmental impact” of those two projects are corrected; accordingly, a point of large category 3 and that of 4 are discounted by multiplying 0.9 in Maha 2 as well as by multiplying 0.8 in Loggal.
- Total score of each promising site is calculated to summing up score of four large categories.
- The rank of each promising site is determined by its calculated point. Such ranking study is carried out in the following two cases;

1) Even case	1. (Technical evaluation + 2. Construction Cost) : (3. Natural environment + 4. Social environment) = 50 : 50 (Calculated points of 4 large categories are summed up as those are.)
2) Environmental weighed case	(1. Technical evaluation + 2. Construction Cost) : (3. Natural environment + 4. Social environment) = 30 : 70 (Calculated points of 1. Technical evaluation and 2. Construction cost are multiplied by 15/25 as well as those of 3. Natural environment and Social environment are multiplied by 35/25)

Table 10.8-1 shows the score calculation of each promising site.

Table 10.8-1 Score Calculation of Each Promising Site

Criteria		Score allocation	Halgran 3			Maha 2			Maha 3			Loggal		
			Eva	(rate)	Score	Eva	(rate)	Score	Eva	(rate)	Score	Eva	(rate)	Score
1. Technical Evaluation		25			15.50			22.00			21.75			12.50
1.1	Geological aspects	7	C	0.50	3.50	A	1.00	7.00	B	0.75	5.25	C	0.50	3.50
1.2	Ease of construction works	6	C	0.50	3.00	B	0.75	4.50	A	1.00	6.00	C	0.50	3.00
1.3	Manufacturing Limitation	6	C	0.50	3.00	A	1.00	6.00	A	1.00	6.00	B	0.75	4.50
1.4	System Stability	6	A	1.00	6.00	B	0.75	4.50	B	0.75	4.50	D	0.25	1.50
2. Economical Evaluation		25	B	0.75	18.75	B	0.75	18.75	A	1.00	25.00	D	0.25	6.25
3. Natural Environmental Evaluation		25			7.25			10.75			10.75			9.00
	Correction			*1.0	7.25		*0.9	9.68		*1.0	10.75		*0.8	7.20
3.1	Inundated forest area	1	C	0.50	0.50	D	0.25	0.25	D	0.25	0.25	C	0.50	0.50
3.2	Impacts on faunal endangered species	8	D	0.25	2.00	D	0.25	2.00	D	0.25	2.00	D	0.25	2.00
3.3	Impacts on floral endangered species	8	D	0.25	2.00	C	0.50	4.00	C	0.50	4.00	D	0.25	2.00
3.4	Impacts on ecosystem	7	D	0.25	1.75	C	0.50	3.50	C	0.50	3.50	C	0.50	3.50
3.5	Transmission line-Natural environment	1	A	1.00	1.00	A	1.00	1.00	A	1.00	1.00	A	1.00	1.00
4. Social Environmental Evaluation		25			17.50			11.50			13.75			11.75
	correction			*1.0	17.50		*0.9	10.35		*1.0	13.75		*0.8	9.40
3.6	Number of those who to be resettled	6	B	0.75	4.50	D	0.25	1.50	C	0.50	3.00	C	0.50	3.00
3.7	Area of land to be acquired	5	B	0.75	3.75	C	0.50	2.50	C	0.50	2.50	D	0.25	1.25
3.8	Number of those who to be affected by losing livelihood	3	D	0.25	0.75	D	0.25	0.75	C	0.50	1.50	C	0.50	1.50
3.9	Impacts on public facilities	1	A	1.00	1.00	A	1.00	1.00	A	1.00	1.00	C	0.50	0.50
3.1	Impacts on water utilization	2	C	0.50	1.00	D	0.25	0.50	D	0.25	0.50	D	0.25	0.50
3.11	Agriculture	2	A	1.00	2.00	C	0.50	1.00	C	0.50	1.00	D	0.25	0.50
3.12	Tourism	1	A	1.00	1.00	A	1.00	1.00	A	1.00	1.00	A	1.00	1.00
3.13	Religious, and/or cultural facilities, burial ground	3	C	0.50	1.50	C	0.50	1.50	C	0.50	1.50	C	0.50	1.50
3.14	Impacts on landscape	1	A	1.00	1.00	B	0.75	0.75	B	0.75	0.75	A	1.00	1.00
3.15	Transmission line-Social environment	1	A	1.00	1.00	A	1.00	1.00	A	1.00	1.00	A	1.00	1.00

(Source :JICA Study Team 出典)

In addition, Table 10.8-2 shows the rank of each promising site in the even case as well as Table 10.8-3 shows that in the environmental weighed case.

Table 10.8-2 Rank of Promising Site in Even Case

	Score Allocation	Halgran 3	Maha 2	Maha 3	Loggal
1. Technical Evaluation	25.00	15.50	22.00	21.75	12.50
2. Economical Evaluation	25.00	18.75	18.75	25.00	6.25
3. Natural Environment	25.00	7.25	9.68	10.75	7.20
4. Social Environment	25.00	17.50	10.35	13.75	9.40
Total	100.00	59.00	60.78	71.25	35.35
Rank		3	2	1	4

(Source: JICA Study Team)

Table 10.8-3 Rank of Promising Site in Environmental Weighed Case

	Score Allocation	Halgran 3	Maha 2	Maha 3	Loggal
1. Technical Evaluation	15.00	9.30	13.20	13.05	7.50
2. Economical Evaluation	15.00	11.25	11.25	15.00	3.75
3. Natural Environment	35.00	10.15	13.55	15.05	10.08
4. Social Environment	35.00	24.50	14.49	19.25	13.16
Total	100.00	55.20	52.49	62.35	34.49
Rank		2	3	1	4

(Source: JICA Study Team)

As shown in Table 10.8-2 and Table 10.8-3, Maha 3 is ranked as the first in both of Even case and Environment weighed case, which is given averagely higher rank in every four large category; because it is ranked as the second in Technical Evaluation, the first in Economical Evaluation, the first in Natural Environment, and the second in Social Environment.

From view point of environmental aspect only, the difference between the first ranked site of Halgran 3 and the second site of Maha 3 is only 0.25 points, because the total of Natural environment and Social environment is 24.75 points for Halgran 3 and that for Maha 3 is 24.5 points. It is observed that Halgran 3 gains disproportionally high scores because Natural environment points is 7.25 points against 17.50 points of Social environment, while Maha 3 gains averagely high scores because Natural environment points and Social environment points are 10.75 points and 13.75 points, respectively. If the evaluation is done from Natural environment is weighed view point, the rank of Maha 3 from environmental aspect would be higher than that of Halgran 3. Table10.8-5 shows an sample of ranking study in case that the weight of “3. Natural environment” and that of “4. Social environment” is changed to 30 : 70 from 50 : 50.

Table 10.8-4 Rank of Promising Sites from Environment Aspect

	Score Allocation	Halgran 3	Maha 2	Maha 3	Loggal
3. Natural Environment	25.00	7.25	9.68	10.75	7.20
4. Social Environment	25.00	17.50	10.35	13.75	9.40
Total	50.00	24.75	20.03	24.50	16.60
Rank		1	3	2	4

(Source: JICA Study Team)

Table 10.8-5 Rank of Promising Sites from Environment Aspect (Natural weighed)

	Score Allocation	Halgran 3	Maha 2	Maha 3	Loggal
3. Natural Environment	35.00	10.15	13.55	15.05	10.08
4. Social Environment	15.00	10.50	6.21	8.25	5.64
Total	50.00	20.65	19.76	23.30	15.72
Rank		2	3	1	4

(Source: JICA Study Team)

Based on the study results as above-mentioned, Maha 3 is selected as the most promising site in this study; the main reasons are again summarized as follows;

In both cases; Even case and Environmental weighed case, it is ranked as the first.

- Any serious technical difficulties to be studied in the future have not been found.
- While it is ranked as the second by the evaluation from environmental aspect only; (“3 Natural environment + “4 Social environment”), the difference of points to the first site (Halgran 3) are very limited.
- Even in view point from environment aspect only, if Natural environment is weighed to Social environment, it is ranked as the first.

Chapter 11 Economic and Financial Evaluation

Economic and financial evaluation has been conducted for the PSPP development plan at most promising site identified in this study. The analysis tried to confirm the project's economic viability from a viewpoint of national economy, and financial profitability to CEB (financial evaluation), as well.

11.1 Economic Evaluation

11.1.1 Economic Costs of the Project

The economic costs (initial construction and replacement) of the Project were calculated from the market price as presented in Chapter 10. The method of economic pricing is (1) Exclusion of transfer items such as tax (import tax, value added tax) and subsidies; and (2) Conversion of market prices applying standard conversion factor of 0.9 for local currency. Construction costs for initial investment and replacement is summarized in Table 11.1.1-1.

Table 11.1.1-1 Factors Used for Economic Cost (construction) Calculation

Name of Input Data		Value	Unit	Remarks
A. PSPP Development				
A 1	Unit Capacity	200	MW	
A 2	Number of Unit	3	Number	
A 3	Development Cost			
A 4	*(1) Preparation*	*4,994,007*	US$	
A 5	*(2) Environmental Mitigation Cost*	*7,491,011*	US$	
A 6	*(3) Civil Works*	*249,700,365*	US$	
A 7	*(4) Hydromechanical Works*	*54,550,427*	US$	
A 8	*(5) Electro-Mechanical Works*	*194,800,000*	US$	
A 9	*(6) Transmission Line*	*3,900,000*	US$	
A10	Direct Cost Total	515,435,810	US$	
A11	Administration/Engineering Services	77,315,372	US$	15% of A10
A12	Contingency	51,543,581	US$	10% of A10
A13	Interest during Construction (IDC)	32,929,905	US$	(A10+A11+A12)*A24***0.38***A28
A14	TOTAL Cost	677,224,668	US$	A10+A11+A12+A13
A15	Unit Construction Cost	1,129	US$	A14/(A1*A2)
A16	TOTAL Cost excluding IDC	644,294,763	US$	A14-A13
A17	Base Year of Cost Estimate	2014		
A18	Replacement Cost in Yr 31st-35th	249,350,427	US$	(4) + (5) above
A19	Percentage of Foreign Currency of Direct Cost	64%		
A20				
A21	Interest Rate (Foreign)	1.40%	% p.a.	JICA Loan
A22	Percentage of Foreign Loan	85%		
A23	Interest Rate (Local)	10.00%	% p.a.	Domestic Borrowing
A24	Weighted Average Cost of Capital (WACC)	2.69%	% p.a.	A21*A22+A23*(1-A22)
A25	Standard Conversion Factor (SCF) for LKR	0.9		
A26	Economic Construction Cost after SCF	621,100,151	US$	A16*A19*1.0+A16*(1-A19)*A25
A27	Economic Replacement Cost after SCF	240,373,812	US$	A18*A19*1.0+A18*(1-A19)*A25
A28	Construction Period	5	years	
A29	Disbursement Schedule (1st - 5th; 31st-35th)			
A30	1st Year	5%		
A31	2nd Year	10%		
A32	3rd Year	25%		
A33	4th Year	40%		
A34	5th Year	20%		

(Source; JICA Study Team)

With the assumptions and parameters shown in the above, initial investment cost flow and replacement cost flow are calculated as Table 11.1.1-2 and Table 11.1.1-3.

Table 11.1.1-2 Initial Investment Cost

(Unit: US$)

Year	Initial Investment
1st Year	31,055,008
2nd Year	62,110,015
3rd Year	155,275,038
4th Year	248,440,060
5th Year	124,220,030

(Source; JICA Study Team)

Table 11.1.1-3 Replacement Investment Cost

(Unit: US$)

Year	Replacement Cost
36th Year	12,018,691
37th Year	24,037,381
38th Year	60,093,453
39th Year	96,149,525
40th Year	48,074,762

(Source; JICA Study Team)

The operation and maintenance costs of pump storage power plant consist of two components; (1) Operation and maintenance costs same as other hydro power stations; and (2) energy (electricity) cost for water pump-up.

(1) Ordinal operation and maintenance costs are calculated by multiplying the construction cost of each work item by a certain rate. This rate was determined according to the experiences with similar projects; 0.5% for civil works and 1.5% of hydraulic/electro-mechanical equipment. The calculated operation and maintenance cost of the Project is US$ 4,171,000 per year.

(2) While energy cost for water pump-up is assumed to be the cost of coal power in the Base Case, cost of LNG combined cycle (LNG-CC) for pump-up is applied in some case studies in supplemental analysis (explained later in this chapter). Two kinds of water pump-up costs i.e. from coal power and from LNG-CC power are calculated and shown in Table 11.1.1-4 and Table 11.1.1-5. Efficiency of pump-up is assumed to be 70%. The cost of water pump-up for 1kWh generation by PSPP from coal is estimated as USCts 10.29/kWh and USCts 14.96/kWh for LNG-CC.

Table 11.1.1-4 PSPP Pump-up Cost (coal power case)

Name of Input Data			Value	Unit	Remarks
D. Generation Specifications: Coal Power Plant (For Pump-up)					
	D 1	Heat Content	6,300	kCal/kg	
	D 2	Fuel Cost @ Col CIF	142.8	US$/ton	[$126/ton for Puttalam 2013]
	D 3	Fuel Cost @ Col CIF	2,267	USCts/GCal	D2/D1
	D 4	Full Load Heat Rate	2,583	kCal/kWh	
	D 5	Thermal Efficiency	33.3%		860/D4 [29.7% at Puttalam 2013]
	D 6	Fuel Cost/kWh	5.85	USCts/kWh	D3*D4 [Rs. 7.76/kWh Puttalam 2013]
	D 7	Variable OM Cost	0.56	USCts/kWh	
	D 8	Station Use	8.00%		
	D 9	Transmission Loss	3.20%		
	D 10	Pump-up cost/kWh Generation	**10.29**	USCts/kWh	(D6+D7)/((1-D8)*(1-D9))/0.7*
					*0.7= Pump-up Efficiency

(Source; JICA Study Team)

Table 11.1.1-5 PSPP Pump-up Cost (LNG-combined cycle)

E. Generation Specifications: LNGCC Plant (For Pump-up)					
	E 1	Heat Content	13,000	kCal/mmBtu	
	E 2	Heat Content	5,850	kCal/kg	E1*0.45
	E 3	Fuel Cost @ Col CIF	13.5	US$/mmBtu	
	E 4	Fuel Cost @ Col CIF	5,357	USCts/GCal	E3*3.9683
	E 5	Full Load Heat Rate	1,786	kCal/kWh	
	E 6	Thermal Efficiency	48.2%		860/E5
	E 7	Fuel Cost/kWh	9.57	USCts/kWh	E4*E5
	E 8	Variable OM Cost	0.296	USCts/kWh	
	E 9	LNGCC Generation Cost/kWh	9.86	USCts/kWh	E7+E8
	E 10	Station Use	2.70%		
	E 11	Transmission Loss	3.20%		
	E 12	Pump-up cost/kWh Generation	**14.96**	USCts/kWh	E9/((1-E10)*(1-E11))/0.7*
					*0.7= Pump-up Efficiency

(Source; JICA Study Team)

11.1.2 Economic Benefit of the Project

Economic benefit of the Project is the economic value of supplied electricity at peak time. For goods transacted in free market economy, the price shows the economic value of the goods. In case of electricity prices, it is common to make the price low from the real cost due to socio-economic policy considerations. The same is in Sri Lanka, too. Therefore, it is difficult to measure real economic value from its price instantaneously.

In this economic analysis of the Project, as used widely when evaluating hydro power projects, comparison of supplying costs for two alternatives which provide same services; namely “with project case (PSPP)”, the cost of peak electricity supply by PSPP, and “without project case (Alternative Thermal)”, the cost of peak power supply by alternative thermal. The question is which alternative is more economically advantageous than the other. Cost of without project case can be considered as the benefit of the Project.

The alternative thermal of the Project is the gas turbine generation with auto diesel fuel. The generation costs, including investment cost converted into “economic” cost, of 105MW gas turbine, which is used in Long Term Generation Expansion Plan 2013-2032 is summarized in Table 11.1.2-1.

Table 11.1.2-1 Alternative Thermal Power Plant (gas turbine 105MW auto diesel)

Name of Input Data			Value	Unit	Remarks
F. Generation Specifications: Gas Turbine 105MW (Auto Diesel)					
F 1	GT Construction Cost				
F 2		Foreign Portion	403.8	US$/kW	
F 3		Local Portion	79.2	US$/kW	
F 4	Local Discounted by SCF		71.3	US$/kW	F3*A25
F 5	Total Construction Cost		475.1	US$/kW	F2+F4
F 6	Rate of Cumulative IDC for 1.5 Years		6.51%		Interest Rate: 10% p.a.
F 7	Total Construction Cost including IDC		506.0	US$/kW	F5*(1+F6)
F 8	Station Use		2.70%		
F 9	Forced Outage		8.00%		
F 10	Scheduled Outage		8.20%		
F 11	Transmission Loss		3.20%		
F 12	kW-Value (Adjusted)		598.3	US$/kW	F7*((1-C2)*(1-C3)*(1-C4)*(1-C5))/((1-F8)*(1-F9)*(1-F10)*(1-F11))
F 13	Fixed Annual OM Cost		6.10	US$/kW	
F 14	Fixed Annual OM Cost (Adjusted)		7.2	US$/kW	F13*((1-C2)*(1-C3)*(1-C4)*(1-C5))/((1-F8)*(1-F9)*(1-F10)*(1-F11))
F 15	Heat Content		10,550	kCal/kg	
F 16	Heat Content		8,862	kCal/l	F15*0.84
F 17	Fuel Cost @ Col CIF		128.4	US$/bbl	
F 18	Fuel Cost @ Col CIF		9,112	USCts/GCal	F17/159/F16
F 19	Full Load Heat Rate		2,857	kCal/kWh	
F 20	Thermal Efficiency		30.1%		860/F19
F 21	Fuel Cost /kWh		26.03	USCts/kWh	F18*F19
F 22	Variable OM Cost		0.402	USCts/kWh	
F 23	kWh-Value (adjusted)		**27.05**	USCts/kWh	(F21+F22)*((1-C2)*(1-C5))/((1-F8)*(1-F11))

(Source; JICA Study Team)

By assuming the situation of LNG available, alternative thermal is LNG-simple cycle gas turbine, economical alternative against auto diesel. Table 11.1.2-2 summarizes the investment and generation costs by LNG-SC.

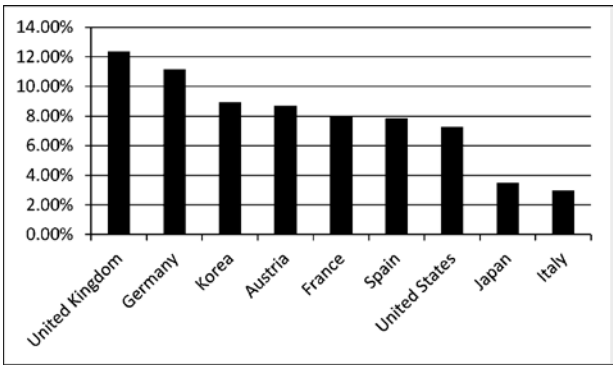
Table 11.1.2-2 Alternative Thermal Power Plant (LNG-simple cycle gas turbine)

Name of Input Data			Value	Unit	Remarks
G. Generation Specifications: Gas Turbine (LNGSC)					
	G 1	GT Construction Cost			
	G 2	Foreign Portion	403.8	US$/kW	
	G 3	Local Portion	79.2	US$/kW	
	G 4	Local Discounted by SCF	71.3	US$/kW	G3*A25
	G 5	Total Construction Cost	475.1	US$/kW	G2+G4
	G 6	Rate of Cumulative IDC for 1.5 Years	6.51%		Interest Rate: 10% p.a.
	G 7	Total Construction Cost including IDC	506.0	US$/kW	G5*(1+G6)
	G 8	Station Use	2.70%		
	G 9	Forced Outage	8.00%		
	G 10	Scheduled Outage	8.20%		
	G 11	Transmission Loss	3.20%		
	G 12	kW-Value (Adjusted)	598.3	US$/kW	G7*((1-C2)*(1-C3)*(1-C4)*(1-C5))/((1-G8)*(1-G9)*(1-G10)*(1-G11))
	G 13	Fixed Annual OM Cost	6.10	US$/kW	
	G 14	Fixed Annual OM Cost (Adjusted)	7.2	US$/kW	G13*((1-C2)*(1-C3)*(1-C4)*(1-C5))/((1-G8)*(1-G9)*(1-G10)*(1-G11))
	G 15	Heat Content	13,000	kCal/kg	
	G 16	Heat Content	5,850	kCal/l	G15*0.45
	G 17	Fuel Cost @ Col CIF	13.5	US$/bbl	
	G 18	Fuel Cost @ Col CIF	5,357	USCts/GCal	G17*3.9683
	G 19	Full Load Heat Rate	2,857	kCal/kWh	
	G 20	Thermal Efficiency	30.1%		860/G19
	G 21	Fuel Cost /kWh	15.31	USCts/kWh	G18*G19
	G 22	Variable OM Cost	0.402	USCts/kWh	
	G 23	kWh-Value (adjusted)	**16.07**	USCts/kWh	(G21+G22)*((1-C2)*(1-C5))/((1-G8)*(1-G11))

(Source; JICA Study Team)

11.1.3 Economic Evaluation of the Project and Case Studies

Operation of the Project (PSPP Project) is assumed to be 1,000 hours per year (average four (4) hours in weekdays, and shut down due to scheduled maintenance and forced outage be ten (10) days per year). Annual generation becomes 600GWh with above assumptions. A 1,000 hours operation per year is equal to 11.4% utilization rate. As a reference, PSPP's utilization rates in OECD countries[1] are shown in Figure 11.1.3-1.



(Source：Electricity Information 2014, IEA)

Figure 11.1.3-1 Utilization Rate of PSPP in OECD Countries (2012)

[1] Countries shown in Chart are the countries having more than 2,000MW PSPP capacity. Utilization of Japan and Italy is low; utilization of Japan is affected by low operations in nuclear power plants; and Italy is affected by increase of electricity import from neighboring countries after liberalization of electricity market due to high generation cost in Italy.

The cash flow of base case is shown in Table 11.1.3-1. The economic internal rate of return (EIRR) is 21.5%, and the net present value is US$ 695.4 million (at 10% discount rate). The EIRR exceeds 10% hurdle rate of opportunity cost of capital (10% is often used for projects in developing countries). Thus, economic viability of the Project is high from national economy's view point.

Table 11.1.3-1 Cash-flow of Base Case and Its EIRR

(US$,000)

Year	PSPP Cost				Revenue				Net Cash	NPV disc	NPV disc
	Investment	Fixed OM	PumpCost	Total	Investment	Fixed OM	Fuel+Vari.	Total	Flow	@IRR	@10%
-4	31,055			31,055				0	-31,055	-67,682	-45,468
-3	62,110			62,110				0	-62,110	-111,408	-82,668
-2	155,275			155,275				0	-155,275	-229,230	-187,883
-1	248,440			248,440				0	-248,440	-301,861	-273,284
0	124,220			124,220	359,003			359,003	234,783	234,783	234,783
1		4,171	61,741	65,911		4,328	162,286	166,614	100,702	82,881	91,548
2		4,171	61,741	65,911		4,328	162,286	166,614	100,702	68,213	83,225
3		4,171	61,741	65,911		4,328	162,286	166,614	100,702	56,142	75,659
4		4,171	61,741	65,911		4,328	162,286	166,614	100,702	46,206	68,781
5		4,171	61,741	65,911		4,328	162,286	166,614	100,702	38,029	62,528
6		4,171	61,741	65,911		4,328	162,286	166,614	100,702	31,299	56,844
7		4,171	61,741	65,911		4,328	162,286	166,614	100,702	25,760	51,676
8		4,171	61,741	65,911		4,328	162,286	166,614	100,702	21,201	46,978
9		4,171	61,741	65,911		4,328	162,286	166,614	100,702	17,449	42,708
10		4,171	61,741	65,911		4,328	162,286	166,614	100,702	14,361	38,825
11		4,171	61,741	65,911		4,328	162,286	166,614	100,702	11,820	35,296
12		4,171	61,741	65,911		4,328	162,286	166,614	100,702	9,728	32,087
13		4,171	61,741	65,911		4,328	162,286	166,614	100,702	8,006	29,170
14		4,171	61,741	65,911		4,328	162,286	166,614	100,702	6,589	26,518
15		4,171	61,741	65,911		4,328	162,286	166,614	100,702	5,423	24,107
16		4,171	61,741	65,911		4,328	162,286	166,614	100,702	4,464	21,916
17		4,171	61,741	65,911		4,328	162,286	166,614	100,702	3,674	19,923
18		4,171	61,741	65,911		4,328	162,286	166,614	100,702	3,023	18,112
19		4,171	61,741	65,911		4,328	162,286	166,614	100,702	2,488	16,466
20		4,171	61,741	65,911	359,003	4,328	162,286	525,617	459,706	9,349	68,332
21		4,171	61,741	65,911		4,328	162,286	166,614	100,702	1,686	13,608
22		4,171	61,741	65,911		4,328	162,286	166,614	100,702	1,387	12,371
23		4,171	61,741	65,911		4,328	162,286	166,614	100,702	1,142	11,246
24		4,171	61,741	65,911		4,328	162,286	166,614	100,702	940	10,224
25		4,171	61,741	65,911		4,328	162,286	166,614	100,702	773	9,294
26		4,171	61,741	65,911		4,328	162,286	166,614	100,702	637	8,449
27		4,171	61,741	65,911		4,328	162,286	166,614	100,702	524	7,681
28		4,171	61,741	65,911		4,328	162,286	166,614	100,702	431	6,983
29		4,171	61,741	65,911		4,328	162,286	166,614	100,702	355	6,348
30		4,171	61,741	65,911		4,328	162,286	166,614	100,702	292	5,771
31	12,019	4,171	61,741	77,930		4,328	162,286	166,614	88,684	212	4,620
32	24,037	4,171	61,741	89,949		4,328	162,286	166,614	76,665	151	3,631
33	60,093	4,171	61,741	126,005		4,328	162,286	166,614	40,609	66	1,748
34	96,150	4,171	61,741	162,061		4,328	162,286	166,614	4,553	6	178
35	48,075	4,171	61,741	113,986		4,328	162,286	166,614	52,628	58	1,873
36		4,171	61,741	65,911		4,328	162,286	166,614	100,702	91	3,258
37		4,171	61,741	65,911		4,328	162,286	166,614	100,702	75	2,961
38		4,171	61,741	65,911		4,328	162,286	166,614	100,702	61	2,692
39		4,171	61,741	65,911		4,328	162,286	166,614	100,702	51	2,448
40		4,171	61,741	65,911	359,003	4,328	162,286	525,617	459,706	190	10,157
41		4,171	61,741	65,911		4,328	162,286	166,614	100,702	34	2,023
42		4,171	61,741	65,911		4,328	162,286	166,614	100,702	28	1,839
43		4,171	61,741	65,911		4,328	162,286	166,614	100,702	23	1,672
44		4,171	61,741	65,911		4,328	162,286	166,614	100,702	19	1,520
45		4,171	61,741	65,911		4,328	162,286	166,614	100,702	16	1,382
46		4,171	61,741	65,911		4,328	162,286	166,614	100,702	13	1,256
47		4,171	61,741	65,911		4,328	162,286	166,614	100,702	11	1,142
48		4,171	61,741	65,911		4,328	162,286	166,614	100,702	9	1,038
49		4,171	61,741	65,911		4,328	162,286	166,614	100,702	7	944
50		4,171	61,741	65,911		4,328	162,286	166,614	100,702	6	858
								IRR =	21.5%	0	695,395

(Source; JICA Study Team)

Economic evaluation results of base case and cases of sensitivity analysis, which tries to measure the impact on EIRR and NPV by changes in cost and/or benefits caused by various reasons, are summarized in Table 11.1.3-2. Assumed cases are as follows;

Case E-1 Base case

Case E-2 Initial construction cost increase by 10%

Case E-3-1 PSPP generation (kWh) increase by 10%

Case E-3-2 PSPP generation (kWh) decrease by 10%

Case E-4 Coal price for pump-up generation increase by 10%

Case E-5 Diesel fuel price for alternative gas-turbine thermal decrease by 10%

Table 11.1.3-2 Results of Economic Sensitivity Analysis

Case	Description	EIRR (%)	NPV (US$ Mil)
E-1	Base Case	21.5%	695.4
E-2	Initial Construction Cost 10% Up	19.3%	624.0
E-3-1	Generation 10% Up	22.8%	795.1
E-3-2	Generation 10% Down	20.1%	595.7
E-4	Coal Price for Pump-up 10% Up	20.7%	634.2
E-5	Fuel Price for Alternative Thermal Gas-turbine 10% Down	19.2%	534.5

(Source; JICA Study Team)

The results of sensitivity analysis show that relatively large impacts on EIRR and NPV are observed by 10% increase in initial construction cost (Case E-2), and by 10% decrease in diesel price for alternative gas-turbine (Case E-5), while relatively small impacts seen by PSPP generation volume changes (Case E-3-1, E-3-2), and coal price increase (Case E-4). In any case, impacts on results of economic analysis caused by changes in key factors are not significant.

11.2 Financial Evaluation

11.2.1 Financial Cost and Benefit

(1) Financial Cost

Financial cost consists of initial investment cost, equipment replacement cost, and operation and maintenance (O&M) cost, expressed in tax excluded market price. Initial investment cost and replacement cost are taken from Chapter 10 as follows;

Table 11.2.1-1 Initial Investment Cost (financial)

(Unit: US$)

Year	Initial Investment
1st Year	32,214,738
2nd Year	64,429,476
3rd Year	161,073,691
4th Year	257,717,905
5th Year	128,858,953

(Source; JICA Study Team)

Table 11.2.1-2 Replacement Investment Cost (financial)

(Unit: US$)

Year	Initial Investment
36th Year	12,467,521
37th Year	24,935,043
38th Year	62,337,607
39th Year	99,740,171
40th Year	49,870,085

(Source; JICA Study Team)

The operation and maintenance cost (O&M cost) consists of;

1) O&M cost of hydropower plant is usually estimated as certain percentage of initial investment cost. From similar projects in the past, annual O&M cost is calculated as 0.5% of civil work cost and 1.5% of hydro-mechanical and electro-mechanical works cost. Annual O&M cost is calculated as US$ 4,171,000.
2) In the base case, electricity for water pump-up will be generated by coal power plant. Pump-up cost is as shown in Table 11.1.1-4. Generation efficiency of PSPP is assumed as 70%. One kWh generation from PSPP requires US cents 10.29/kWh of coal power generation cost. To generate 600GWh of PSPP, the cost for coal power generation is US$ 61.7 million.

(2) Financial Benefit

The financial benefit of the Project is revenue from electricity sales. The average revenue of CEB was LKR 18.23/kWh in 2013. It is justifiable to use peak-time tariff, which is fixed higher than day-time tariff and off-peak tariff, for revenue calculation. Though PUCSL has its tariff road map to introduce peak/off-peak tariff for all consumer categories, peak tariff is applied only for high voltage consumers at this moment. PUCSL, in its Decision on Electricity Tariffs 2013, states that peak adjustment factor (ratio of peak tariff of 18:30-22:30 against day-time tariff of 05:30-18:30) is determined as 1.25. Based on this determination, calculated peak tariff of LKR 22.79/kWh (18.23 * 1.25) is used for average peak tariff. It is converted to US cents 17.65/kWh by applying average US$/LKR exchange rate of 2013 (LKR 129.11/US$).

From the generated 600GWh by PSPP per annum, 537GWh is salable after deducting gross loss of 10.5% (gross loss value of 2025 in LTGEP 2013-2032). Estimated annual revenue from PSPP electricity is US$ 94.8 million.

(3) Financial Evaluation

With the above explained assumptions, FIRR on investment (all equity finance basis) was calculated as 2.8%, and NPV with 10% discount rate was US$ minus (-) 464.1 million, as shown in Table 11.2.1-3. FIRR is merely above weighted average interest rate of 2.69%, consisting of JICA ODA loan of 1.4% for 85% investment cost and local loan of 10% for 15% investment cost. The Project does not make loss but only a small profit. Low profitability of peak supply may be considered inevitable, because of higher cost and not high enough peak-time electricity tariff.

It is worth to note that cost for alternative generation by gas-turbine is US cents 34.08/kWh[2] as against the expected revenue of US cents 17.66/kWh. This makes a loss of more than 16 cents per kWh sales. Thus, PSPP is much better option than gas-turbine in terms of financial aspects. The Transmission License issued to CEB includes a condition of electricity supply obligation[3]. CEB, therefore, does not have an option not to supply electricity due to financial non-attractiveness. The conclusion is that PSPP, though not very good return of investment from present tariff level, is the rational selection under demand fulfill obligation.

[2] It consists of US cents 27.05/kWh auto diesel fuel, and capital cost of US cents 7.03/kWh. Capital cost is calculated by using F12 figure of Table 11.1.3-1 (598.30

[3] Section 17 Special conditions of transmission licensees; Without prejudice to generality of section 15, a transmission license issued to a licensee shall include conditions – (b) requiring the licensee to forecast future demand, to plan the development of the licensee's transmission system and to procure the development of new generation plant to meet reasonable forecast demand , Sri Lanka Electricity Act, No. 20 of 2009

Table 11.2.1-3 Cash-flow of Base Case and Its FIRR

(US$,000)

Year	Cash Outflow				Inflow	Net Cash	NPV disc	NPV disc
	Investment	Fixed OM	PumpCost	Total	Sales	Flow	@IRR	@10%
-4	32,215			32,215		-32,215	-36,012	-47,166
-3	64,429			64,429		-64,429	-70,046	-85,756
-2	161,074			161,074		-161,074	-170,304	-194,899
-1	257,718			257,718		-257,718	-264,999	-283,490
0	128,859			128,859		-128,859	-128,859	-128,859
1		4,171	61,741	65,911	94,779	28,867	28,074	26,243
2		4,171	61,741	65,911	94,779	28,867	27,303	23,857
3		4,171	61,741	65,911	94,779	28,867	26,553	21,688
4		4,171	61,741	65,911	94,779	28,867	25,823	19,717
5		4,171	61,741	65,911	94,779	28,867	25,114	17,924
6		4,171	61,741	65,911	94,779	28,867	24,424	16,295
7		4,171	61,741	65,911	94,779	28,867	23,753	14,814
8		4,171	61,741	65,911	94,779	28,867	23,100	13,467
9		4,171	61,741	65,911	94,779	28,867	22,465	12,243
10		4,171	61,741	65,911	94,779	28,867	21,848	11,130
11		4,171	61,741	65,911	94,779	28,867	21,248	10,118
12		4,171	61,741	65,911	94,779	28,867	20,664	9,198
13		4,171	61,741	65,911	94,779	28,867	20,096	8,362
14		4,171	61,741	65,911	94,779	28,867	19,544	7,602
15		4,171	61,741	65,911	94,779	28,867	19,007	6,911
16		4,171	61,741	65,911	94,779	28,867	18,485	6,282
17		4,171	61,741	65,911	94,779	28,867	17,977	5,711
18		4,171	61,741	65,911	94,779	28,867	17,483	5,192
19		4,171	61,741	65,911	94,779	28,867	17,003	4,720
20		4,171	61,741	65,911	94,779	28,867	16,535	4,291
21		4,171	61,741	65,911	94,779	28,867	16,081	3,901
22		4,171	61,741	65,911	94,779	28,867	15,639	3,546
23		4,171	61,741	65,911	94,779	28,867	15,210	3,224
24		4,171	61,741	65,911	94,779	28,867	14,792	2,931
25		4,171	61,741	65,911	94,779	28,867	14,385	2,664
26		4,171	61,741	65,911	94,779	28,867	13,990	2,422
27		4,171	61,741	65,911	94,779	28,867	13,606	2,202
28		4,171	61,741	65,911	94,779	28,867	13,232	2,002
29		4,171	61,741	65,911	94,779	28,867	12,868	1,820
30		4,171	61,741	65,911	94,779	28,867	12,515	1,654
31	12,468	4,171	61,741	78,379	94,779	16,400	6,914	854
32	24,935	4,171	61,741	90,846	94,779	3,932	1,612	186
33	62,338	4,171	61,741	128,249	94,779	-33,470	-13,347	-1,441
34	99,740	4,171	61,741	165,652	94,779	-70,873	-27,485	-2,774
35	49,870	4,171	61,741	115,782	94,779	-21,003	-7,921	-747
36		4,171	61,741	65,911	94,779	28,867	10,588	934
37		4,171	61,741	65,911	94,779	28,867	10,297	849
38		4,171	61,741	65,911	94,779	28,867	10,014	772
39		4,171	61,741	65,911	94,779	28,867	9,739	702
40		4,171	61,741	65,911	94,779	28,867	9,472	638
41		4,171	61,741	65,911	94,779	28,867	9,211	580
42		4,171	61,741	65,911	94,779	28,867	8,958	527
43		4,171	61,741	65,911	94,779	28,867	8,712	479
44		4,171	61,741	65,911	94,779	28,867	8,473	436
45		4,171	61,741	65,911	94,779	28,867	8,240	396
46		4,171	61,741	65,911	94,779	28,867	8,014	360
47		4,171	61,741	65,911	94,779	28,867	7,793	327
48		4,171	61,741	65,911	94,779	28,867	7,579	298
49		4,171	61,741	65,911	94,779	28,867	7,371	270
50		4,171	61,741	65,911	94,779	28,867	7,169	246
					IRR =	2.8%	0	-464,148

(Source; JICA Study Team)

11.2.2 Sensitivity Analysis

Financial evaluation results of base case and cases of sensitivity analysis, which tries to measure the impact on FIRR and NPV by changes in cost and/or benefits caused by various reasons, are summarized in Table 11.2.2-1. Assumed cases are as follows;

Case F-1 Base case

Case F-2 Initial construction cost increase by 10%

Case F-3-1 PSPP generation (kWh) increase by 10%

Case F-3-2 PSPP generation (kWh) decrease by 10%

Case F-4 Coal price for pump-up generation increase by 10%

Case F-5 Peak tariff index (ratio against day-time tariff) to 1.50 from base case value of 1.25

In Case F-5, that is to change peak tariff index from 1.25 to 1.50, FIRR improves to a certain degree. This may be a realistic option to improve financial viability of the Project due to the following reasons; (i) while peak tariff index of general purpose is 1.23, the same of industry and hotel is from 1.6 to 2.3 under current tariff structure. Thus, higher peak tariff index exists and accepted by certain category of consumers; (ii) consumer category not implemented peak tariff is domestic consumers, who may not be ready to accept high peak tariff index at beginning. But, gradual increase of peak tariff index in order to familiarize the new tariff system is a reasonable approach.

Table 11.2.2-1 Results of Financial Sensitivity Analysis

Case	Description	FIRR (%)	NPV (US$ Mil)
F-1	Base Case	2.8%	-464.1
F-2	Initial Construction Cost 10% Up	2.3%	-538.2
F-3-1	Generation 10% Up	3.5%	-431.4
F-3-2	Generation 10% Down	2.1%	-496.9
F-4	Coal Price for Pump-up 10% Up	1.4%	-525.4
F-5	Peak Tariff Index Increase from 1.25 to 1.50	6.2%	-276.2

(Source; JICA Study Team)

The above financial analysis and sensitivity test shows that financial low return is an issue, and it can be improved to FIRR 6.2% by increasing peak-time tariff by average 20% (from 1.25 to 1.50). But the expected financial improvement is not high enough. Therefore, to compensate financial low profit, it is recommended to mobilize highly concessional loan such as JICA ODA loan.

Chapter 12 Conclusion and Recommendation

12.1.1 Outline of the Most Promising Site

Figure 12.1.2-1 shows the location of Maha 3 site, which was selected as the most promising candidate site. Regarding the access to the lower dam site, total distance from Colombo is around 110 km, and the dam site is reached through A1, A21, B136, B278 and a path of the distance around 6.2 km. In this regard, it was confirmed in the site survey conducted by the study team that direct approaching from the lower dam site to the upper dam site is difficult for vehicles due to narrow width of the said path. However, the accessibility of the upper dam site itself is good even by vehicles due to newly constructed road and so on.

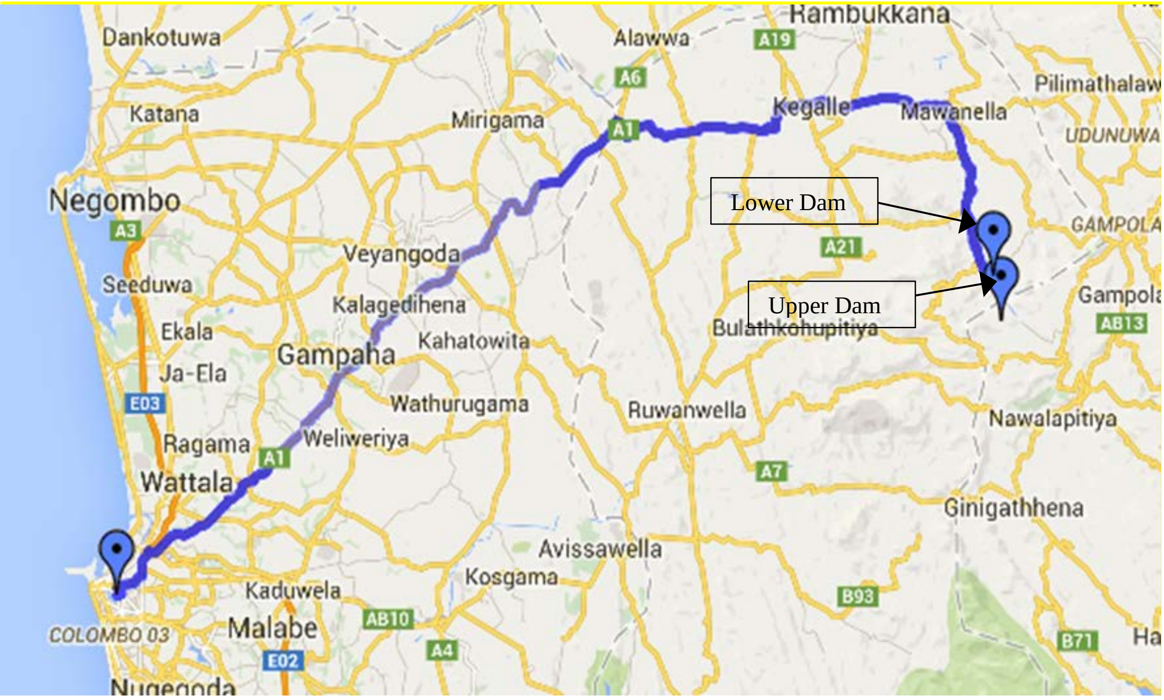


Figure 12.1.2-1 Location of Maha 3 Site

In Maha site, 1/1,000 topographic survey covering the upper reservoir area and the lower reservoir area was conducted. Based on the outcome of 1/1,000 survey, the pumped storage scheme is reviewed. Table 12.1.2-1 shows the general features of Maha 3.

Table 12.1.1-1 General Features of Maha 3 Scheme

Candidate Site		unit	Maha 3 case1	Maha 3 case2
Installed Capacity		MW	600	600
Unit Capacity		MW	200	150
Number of Units		unit	3	4
Peak Generating Time		hours	6.14	6.17
Gross Head		m	521.04	521.44
Rated Head		m	493.37	483.95
Rated Discharge		m^3	142.64	147.10
Upper Pond	Latitude		7°06'23"	7°06'23"
	Longitude		80°28'49"	80°28'49"
	Catchment Area	km^2	1	1
	Reservoir Area	km^2	0.22	0.22
	Crest Elevation	E.L.-m	821.0	820.5
	High Water Level	E.L.-m	815.0	814.5
	Low Water Level	E.L.-m	794.5	791.3
	Drawdown	m	20.5	23.2
	Sediment Level	E.L.-m	782.3	782.3
	Gross Capacity	MCM	3.71	3.60
	Available Capacity	MCM	3.15	3.27
	Dam Height	m	59	59
	Crest Length	m	260	260
Lower Pond	Latitude		7°07'50"	7°07'50"
	Longitude		80°28'49"	80°28'49"
	Catchment Area	km^2	35	35
	Reservoir Area	km^2	0.24	0.24
	Crest Elevation	E.L.-m	298.5	297.5
	High Water Level	E.L.-m	292.5	291.5
	Low Water Level	E.L.-m	276.4	273.0
	Drawdown	m	16.1	18.5
	Sediment Level	E.L.-m	263.2	263.2
	Gross Capacity	MCM	6.22	5.78
	Available Capacity	MCM	3.20	3.30
	Dam Height	m	73.5	72.5
	Crest Length	m	380	380
Headrace Tunnel				
	Inner Diameter	m	5.60	4.00
	Length	m	960	960
	Nos. of lines	-line	1	2
Penstock Tunnel				
	Inner Diameter	m	4.30	3.10
	Length	m	993	996
	Nos. of lines	-line	1	2
Tailrace Tunnel				
	Inner Diameter	m	6.10	4.40
	Length	m	415	415
	Nos. of lines	-line	1	2
Access Tunnel to PH				
	Length	m	900	900

(Source: JICA Study Team)

Table 12.1.4-1 shows both construction costs for the scheme 3 units of 200 MW and that for 4 units of 150 MW.

Table 12.1.4-2 Maha 3 Construction Costs

	Item/Project	200MW 3units (US$)	150MW 4units (US$)	Remarks
1.	Preparation and Land Acquisition	4,994,007	5,125,380	
	(1) Access Roads			@550,000US$/km
	(2) Compensation & Resettlement			
	(3) Camp & Facilities	4,994,007	5,125,380	3. Civil Works * 2%
2.	Environmental Mitigation Cost	7,491,011	7,688,070	3. Civil Works * 3%
3.	Civil Works	249,700,365	256,268,986	
4.	Hydromechanical Works	54,550,427	57,433,434	
5.	Electro-Mechanical Equipment	194,800,000	202,500,000	
6.	Transmission Line	3,900,000	3,900,000	
	Direct Cost	515,435,810	532,915,870	
7.	Administration and Engineering Service	77,315,372	79,937,381	Direct Cost * 15%
8.	Contingency	51,543,581	53,291,587	Direct Cost * 10%
9.	Interest during Construction	32,929,905	34,046,663	Σ(1-8)*0.38*i*T
	Total Cost	677,224,668	700,191,501	
	Power Output (kW)	600,000	600,000	
	USD per kW	1,129	1,167	

(Source: JICA Study Team)

12.2 Recommendations

In case the electric power development mainly of coal thermal power plants, which have no advantage in load following capability, would be executed in accordance with the LTGEP 2013-2032, the following troubles might occur in the Sri Lankan power supply system.

- Trouble in stable power supply such as power outage during peak demand time
- High cost operation of gas turbine and diesel generation using oil for peak power demand

In order to avoid the troubles, it is necessary to line up a dedicated power source at a fair rate for peak demand, and the pumped storage power plant is selected as the optimal power generation for peak power demand in this report (refer to Chapter 8). Consequently, recommendations for project implementation plan and next stage studies toward realization of the project are made in the following clauses.

12.2.1 Project Implementation Plan

In order to implement the project on time, it is recommended to proceed with the implementation schedule shown in Figure 12.2.1-1.

Feasibility study, the construction planning including deployment of temporary facilities, which may has impacts on the environment in the site, is to be studied by the commencement of EIA to reflect it into the environment assessment. Also, the topographical survey and the geological investigation are to be executed in the earlier stage for basic design in the later stage; therefore, total 2 years are estimated as the study period. In addition, the period for supporting environment clearance is added according to CEB's request.

Total duration of the detailed design is estimated as 2 years, so that the detailed technical study is to be conducted in the earlier stage, and tendering including tender document preparation is to be conducted in later stage.

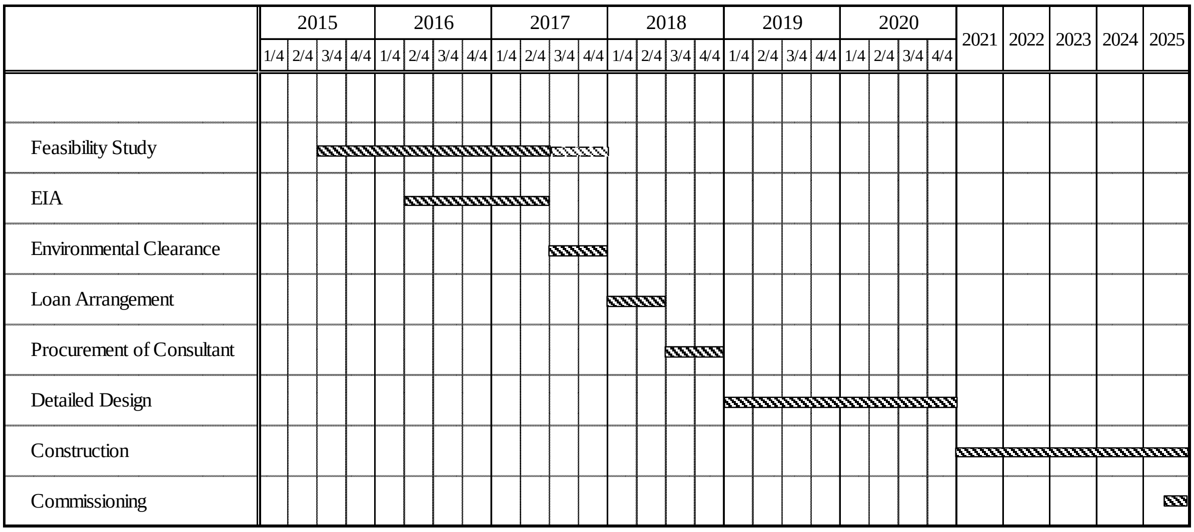


Figure 12.2.1-1 Draft Overall Implementation Schedule of Development of PSPP in Sri Lanka

12.2.2 Recommendation for the Next Stage Study

(1) Topography and geology survey

1) Topography survey

The 1:5,000 (5m inter contour) scale and 1:1,000 (1m inter contour) scale survey were made for the Maha 3 upper and lower reservoir.

The studies at the next stage require site surveys of construction material candidate sites, temporary construction sites, or temporary access roads, also the surveys along the whole water route with 1:1,000 to 1:5,000 scale.

2) Geology survey

The left dam abutment where the certain thicknesses of the talus with possible mass movement was not considered to determine upper dam axis, but the details information was not known for the whole reservoir areas.

The left bank at upper streams and lower streams of the present dam axis shall be investigated for their subsurface conditions. At minimum 1 hole each at upper and lower area are recommended so as to clarify the rock basement features. The areas of investigations may range 250m to upstream and 300m to downstream as there are anticipated solid rock basement in shallow depths with some steep ridges on the left bank heading towards river bed. (The site in 250m upstream may be inferior to that of 300m downstream from the comparison of the right ridges shape)

Also, drilling surveys at intake, outlet, water route, seismic surveys along whole water route, drilling surveys at the power house, construction material surveys are required in due course.

(2) Environmental Considerations Study

1) EIA Process for the F/S

The EIA process follows the National Environmental (Amendment) Act No. 56 of 1988.

The outline of the Project needs to be presented and explained at the Scoping Committee. Since a pumped storage power plant development has never been planned and realized in Sri Lanka.

Contents of the TOR from the Committee are general. If comments from JICA need to be incorporated in the EIA study, it is suggested to hold a meeting with the PAA and then the contents should be changed. For the Project, it is likely that CEA is the PAA. According to the Act, it takes 30 days to issue a TOR, but it might take two to three months. In conclusion, it could take six to nine months to start the EIA study of the Project after starting the F/S.

The Project site includes dam, reservoir, power plant, dumping site, quarry, switch yard, access road and transmission line.

In Sri Lanka, project alternatives are usually discussed and examined in its EIA study. But the alternatives of the Project have already been examined in its master plan stage. It is therefore sufficient to briefly describe the conclusion of the examination of the alternatives in the EIA report. It is not necessary to discuss and examine the alternatives at the F/S stage.

The PI (draft), scoping (draft) and TOR (draft) for the EIA are attached as Appendix 12.2, Appendix 12.3, and Appendix 12.4 in Final Report.

2) Natural environment

The Project does not give direct impacts to protected areas, and impacts to the natural environment are expected to be less than a project with big dam / reservoir because of the small scale of the Project site, and there are no Ramsar sites in its downstream. Impacts to the natural environment in the downstream area are expected to be small.

It is, however, unavoidable for the endangered species[1] recorded in the site to receive impacts of which scale are yet unclear. According to the Asian Development Bank[2], an important criterion is whether a development site is a "critical habitat" for an endangered species or not. But it is not known whether the Project site is critical habitats for the recorded endangered species. In addition, there is a possibility that there are more endangered species in the Project site. This is because the survey period is short in its master plan study.

At the F/S of the Project, it is recommended: a) to study the endangered species of the site for at least one year; and, b) to formulate a conservation plan to avoid, mitigate and compensate the impacts to the natural environment (especially the endangered species) based on the results of the study.

It is important to involve the Sri Lankan experts to discuss the conservation plan and to receive constructive suggestions in collaboration with the JICA Study Team, which leads the sustainability of the conservation activities at the site.

3) Social environment

The biggest impact to the social environment is expected to be induced by an involuntary resettlement. The Project formulates a resettlement action plan based on the Sri Lankan National Involuntary Resettlement Policy to mitigate the impacts as much as possible. There are, however, gaps between the Policy and the JICA Guidelines (2010). The Project fulfills the gaps based on the Guidelines. The following points are particularly considered: (a) that the compensation scheme is based replacement costs; that there is a mechanism to compensate persons who do not have the right for the land; that persons who lose livelihoods by the Project receive the compensation; and that there is a grievance redress mechanism. If they are not functional, it is necessary to identify measures to deal with these points.

The more detailed social study is conducted in and around the Project site for an adequate and sufficient resettlement action plan. The Project also studies other cases in Sri Lanka to try to formulate the plan which fits in the current conditions in the country.

4) SHM

In Sri Lanka, comments from the public are collected after the formulation of an EIA report but SHMs at and around the site are not required. In particular, there is not an opportunity to collect comments from local affected persons before project starts. The Project applies the JICA Guidelines (2010) and holds two SHMs at the site – one at the scoping stage, and the other at the stage of the EIA report (draft). The main objectives of the SHMs are to collect comments from affected persons, local governmental organizations and NGOs and to reflect their comments to

[1] For their details, refer to "The National Red List 2012 of Sri Lanka – Conservation Status of the Fauna and Flora (Ministry of Environment, Sri Lanka, 2012)".
[2] Safeguard Policy Statement（Asian Development Bank, 2009）

the Project as much as possible.

(3) Civil Works

The construction cost in this study was calculated with the method prescribed in Guideline and Manual for Hydropower Development (JICA, 2011) (hereafter the guideline manual); therefore, it should be studied more detail in the next stage.

Especially, the cost of dam construction occupies the large part in the civil works. At the next stage, it is a requisite that advantageous dam type; especially the unit price of a concrete type and that of a rock-fill type, should be studied in more detail. Availability of embankment material in the vicinity of the site will be essential for suitable dam type selection.

As for the waterway and the powerhouse cavern layout, the setting elevation of pump-turbine was determined considering a suction head shown the guideline manual which tends to give more affordable one. The elevation of a pump-turbine affects much the waterway layout, so that suction head and total layout of the waterway should be reviewed more detailed in the next stage. In this regard, if a required suction head is reduced, the setting elevation of pump-turbine; the powerhouse cavern, can be set at more higher; accordingly it affects total construction period because the length of access tunnel to the powerhouse become shorter, which is on the critical path of the overall construction schedule.

(4) Electrical Equipment

The adjustable speed system can bring a lot of benefits on the enhancement of the power system quality with more effective frequency control and voltage control, as well as on reducing the risks which may be caused by unexpected incidents.

Even though the cost of the adjustable speed system will be higher than that of the conventional system, it is recommended to study more definitely on application of the adjustable speed system for the project.

(5) Transmission Line

Two-circuit PI connection to Kotmale - Kirindiwela T/L is selected as the connecting transmission lines from Maha site to the power grid. Following i) Definite transmission line route, ii) Definite connecting point, and iii) construction planning would be main subjects.

Determination of the definite transmission line route needs to consider detailed conditions (such as, topographical conditions, types of land-uses, and locations of houses and other buildings, etc.) under transmission line route area. ii) Definite Connecting Points needs to consideration to design conditions of existing transmission line towers, such as locations of tension-type towers, allowable horizontal angles of towers, and design loads of towers, etc. And, Construction work needs to consider planning for construction works of T/L, in consideration with required time periods for outage works, and possible outage periods of Kotmale - Kirindiwela T/L.

(6) Construction Planning

In this study, the detailed construction planning was not studied. In the next stage, it is necessary to study on the layout, scale and development of the temporary facilities, as well as to study the detailed construction plan. In this regards, those studies should be conducted in the early timing in the next study and the results should be reflected to the environmental survey in the next stage. Following temporary facilities should be included in the construction planning;

1) Temporary yards for construction activities (including stock yards for construction materials)
2) Quarries and borrow area
3) Yards for concrete plants
4) Access roads
5) Penstock assembly yards
6) Disposal areas
7) Office yards for project owners and contractors

(7) Development Scale

In this study, 600 MW of the installed capacity and 6 hours of the equivalent peaking duration were set in every pumped storage scheme planning case. As for the installed capacity, it was determined considering required peak demand at the timing of the first pumped storage project installation in Sri Lanka. On the other hand, as for the equivalent peaking duration, it was determined to be flexible to possible changes of load patterns in the future in spite of assumed peaking time of around 3 hours in 2025. Also, it was considered that, in general, from 6 to 8 hours are set as an equivalent peaking duration at planning stage of pumped storage schemes.

Figure 12.2.2-1 shows a relationship among equivalent peaking duration, construction costs, and EIRR of Maha 3 of 3 units of 200 MW. According to this figure, it seems that larger scale (herein the equivalent peaking duration) gives larger economic performance; however, more detailed study from demand side requirement should be considered to determine the optimal development scale.

In the next stage, it is recommended that more detailed study should be done for the optimization of development scale, (i.e.: installed capacity and equivalent peaking duration).

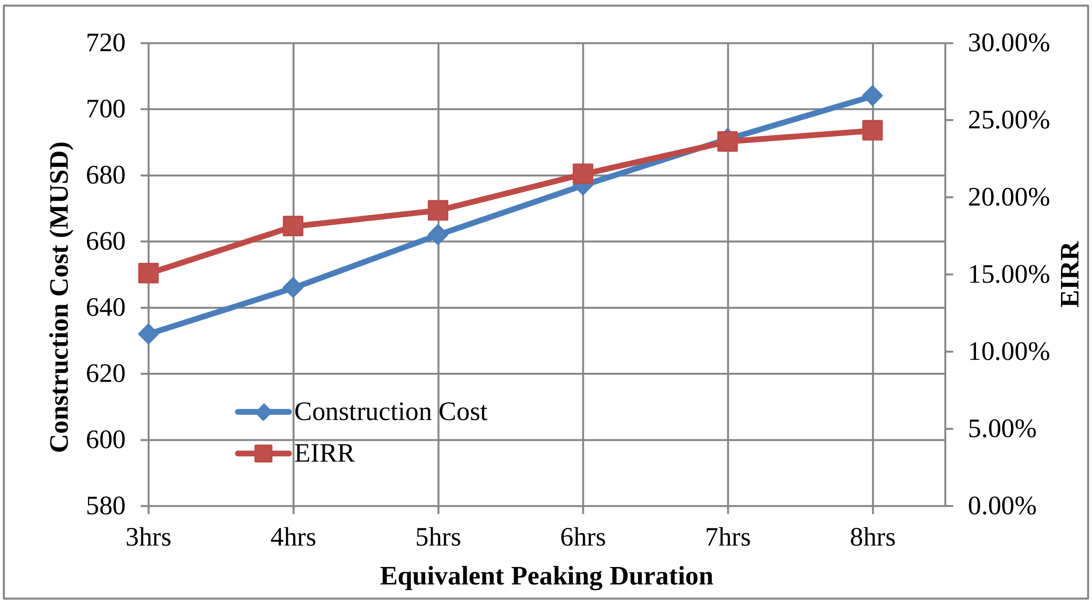
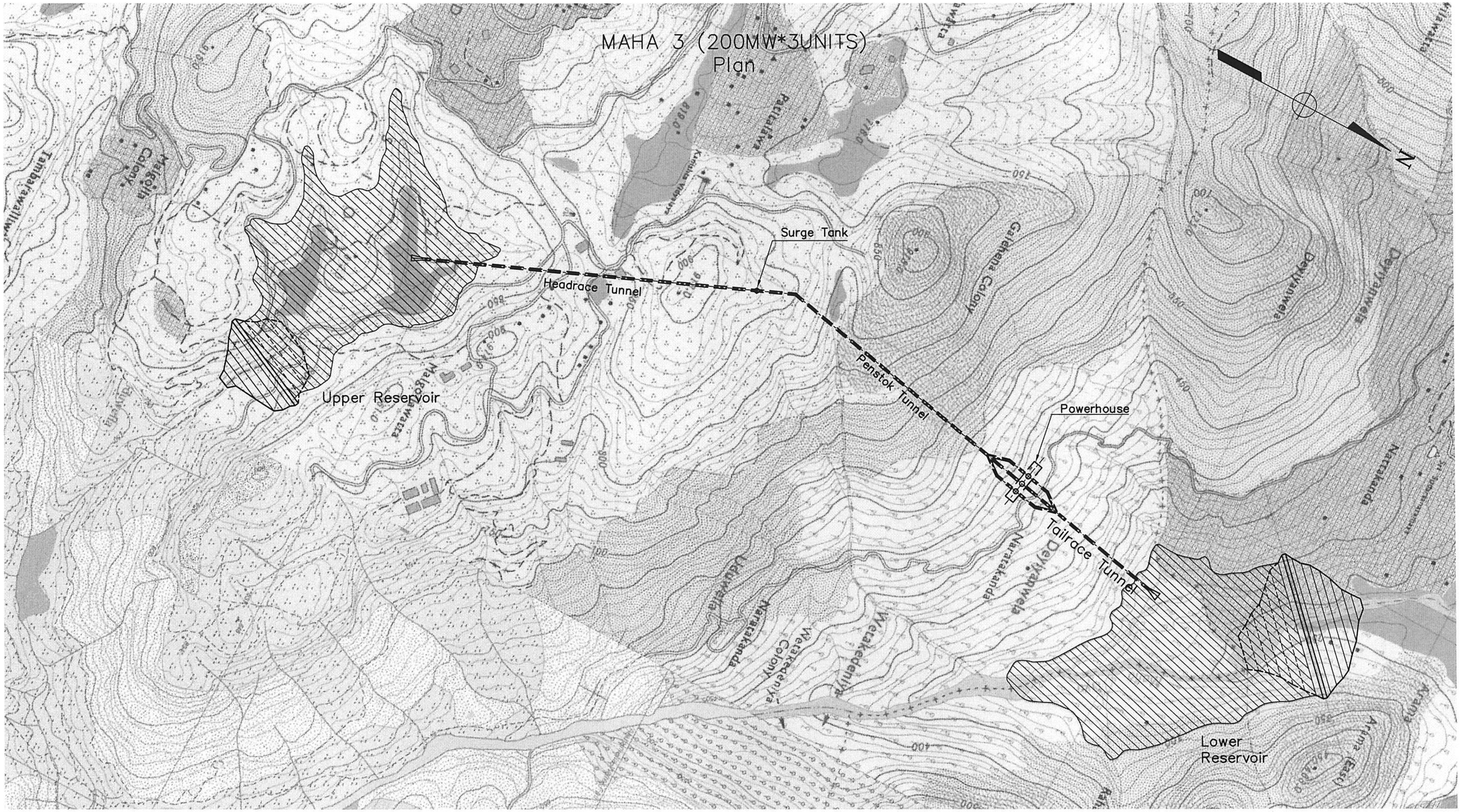


Figure 12.2.2-1 Relationship among Equivalent Peaking Duration, Construction Costs, and EIRR

Appendix

List of Appendix



Upper Reservoir (200MW×3units)		
Latitude		7°06'23"
Longitude		80°28'49"
Catchment Area	km^2	1
Reservoir Area	km^2	0.22
Crest Elevation	E.L.-m	821.0
High Water Level	E.L.-m	815.0
Low Water Level	E.L.-m	794.5
Drawdown	m	20.5
Sediment Level	E.L.-m	782.3
Gross Capacity	MCM	3.71
Available Capacity	MCM	3.15
Dam Height	m	59
Crest Length	m	260

Lower Reservoir (200MW×3units)		
Latitude		7°07'50"
Longitude		80°28'49"
Catchment Area	km^2	35
Reservoir Area	km^2	0.24
Crest Elevation	E.L.-m	298.5
High Water Level	E.L.-m	292.5
Low Water Level	E.L.-m	276.4
Drawdown	m	16.1
Sediment Level	E.L.-m	263.2
Gross Capacity	MCM	6.22
Available Capacity	MCM	3.20
Dam Height	m	74
Crest Length	m	380

Waterways (200MW×3units)			
Headrace Tunnel			
	Inner Diameter	m	5.60
	Length	m	960
	Nos. of lines	-line	1
Penstock Tunnel			
	Inner Diameter	m	4.30
	Length	m	993
	Nos. of lines	-line	1
Tailrace Tunnel			
	Inner Diameter	m	6.10
	Length	m	415
	Nos. of lines	-line	1
Access Tunnel to PH			
	Length	m	900

0 500m

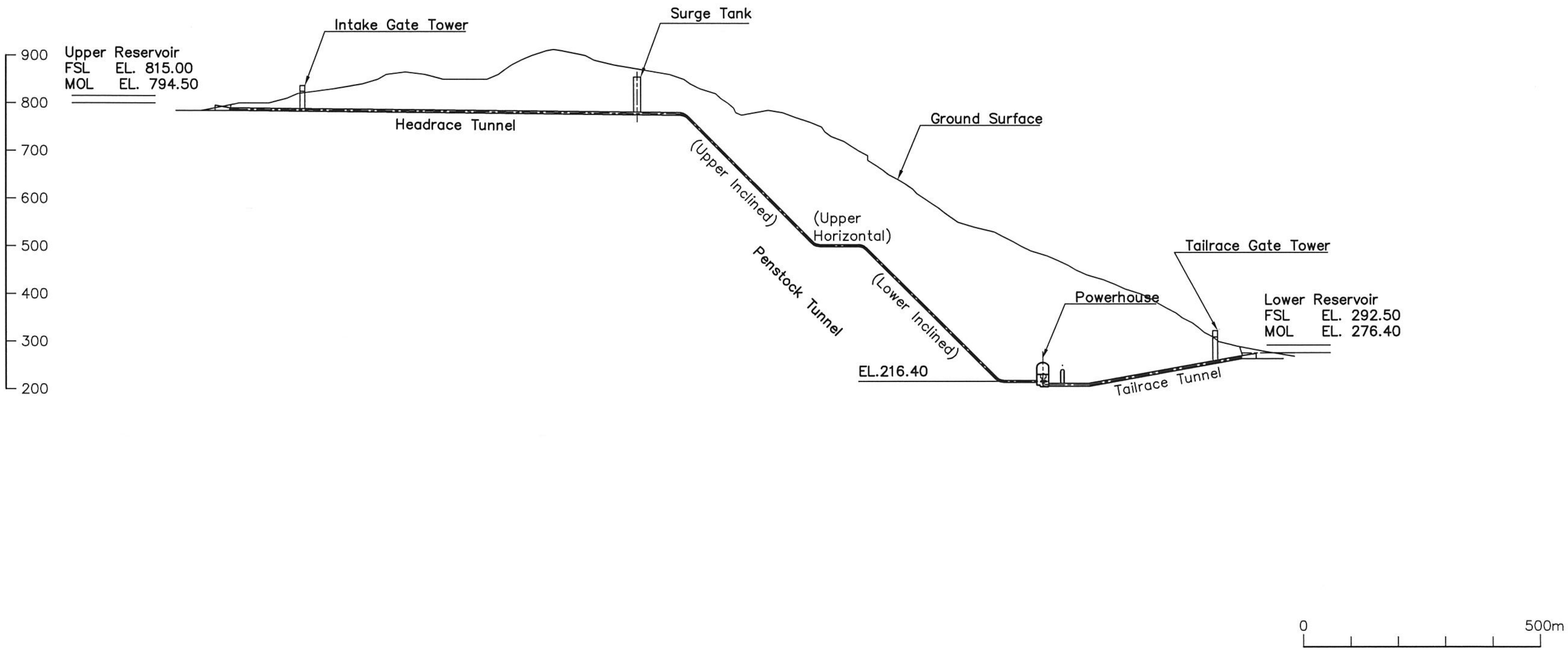
Electric Power Development Co., Ltd

MAHA 3
200MW/unit*3unit
Plan

Appendix 12.1-1

January, 2015

MAHA 3 (200MW*3UNITS)
Profile

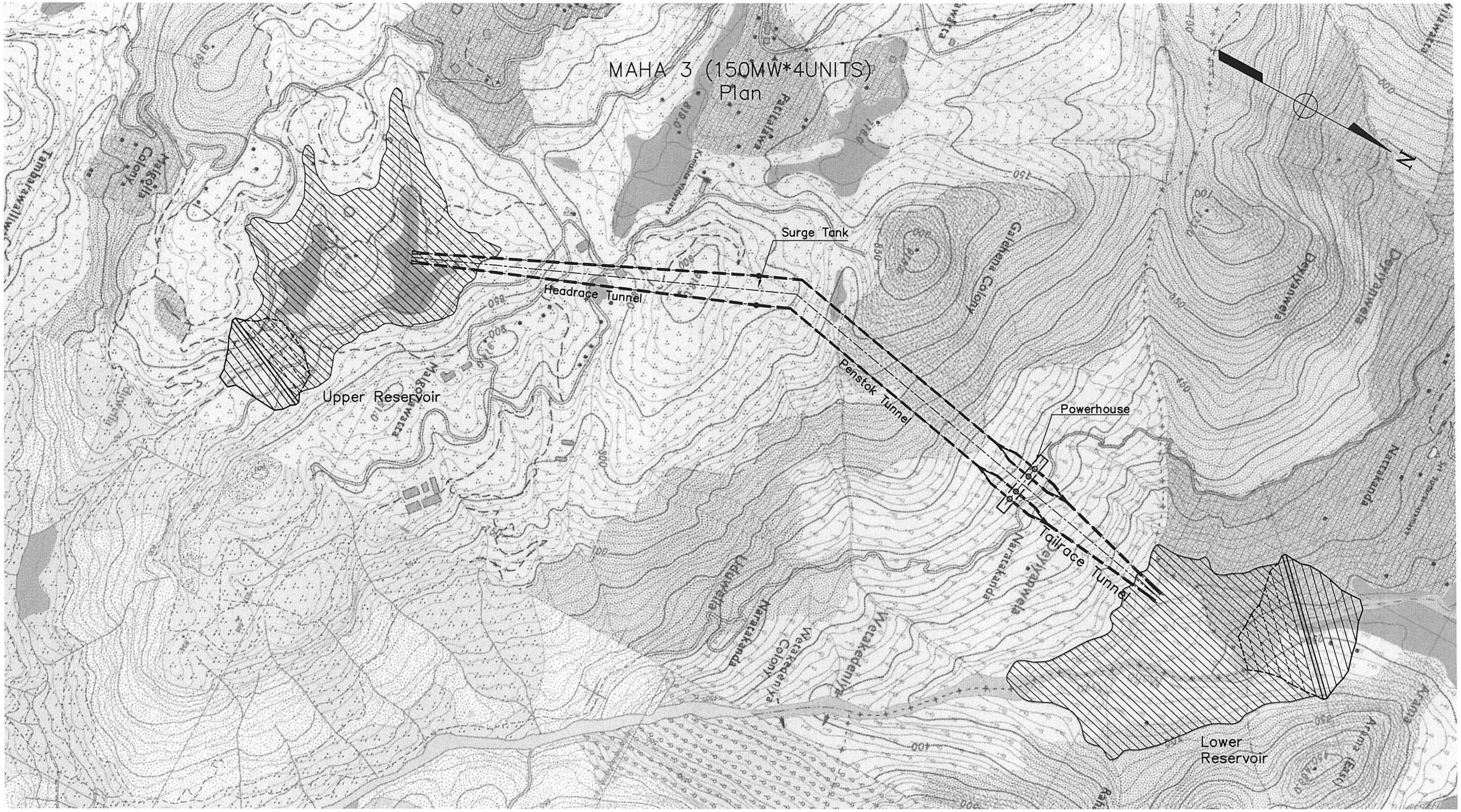


Electric Power Development Co., Ltd

MAHA 3
200MW/unit*3unit
Profile

Appendix 12.1–2

January, 2015



Upper Reservoir (150MW×4units)		
Latitude		7°06'23"
Longitude		80°28'49"
Catchment Area	km^2	1
Reservoir Area	km^2	0.22
Crest Elevation	E.L.-m	820.5
High Water Level	E.L.-m	814.5
Low Water Level	E.L.-m	791.3
Drawdown	m	23.2
Sediment Level	E.L.-m	782.3
Gross Capacity	MCM	3.60
Available Capacity	MCM	3.27
Dam Height	m	59
Crest Length	m	260

Lower Reservoir (150MW×4units)		
Latitude		7°07'50"
Longitude		80°28'49"
Catchment Area	km^2	35
Reservoir Area	km^2	0.24
Crest Elevation	E.L.-m	297.5
High Water Level	E.L.-m	291.5
Low Water Level	E.L.-m	273.0
Drawdown	m	18.5
Sediment Level	E.L.-m	263.2
Gross Capacity	MCM	5.78
Available Capacity	MCM	3.30
Dam Height	m	73
Crest Length	m	380

Waterways (150MW×4units)			
Headrace Tunnel			
	Inner Diameter	m	4.00
	Length	m	960
	Nos. of lines	-line	2
Penstock Tunnel			
	Inner Diameter	m	3.10
	Length	m	996
	Nos. of lines	-line	2
Tailrace Tunnel			
	Inner Diameter	m	4.40
	Length	m	415
	Nos. of lines	-line	2
Access Tunnel to PH			
	Length	m	900

0 500m

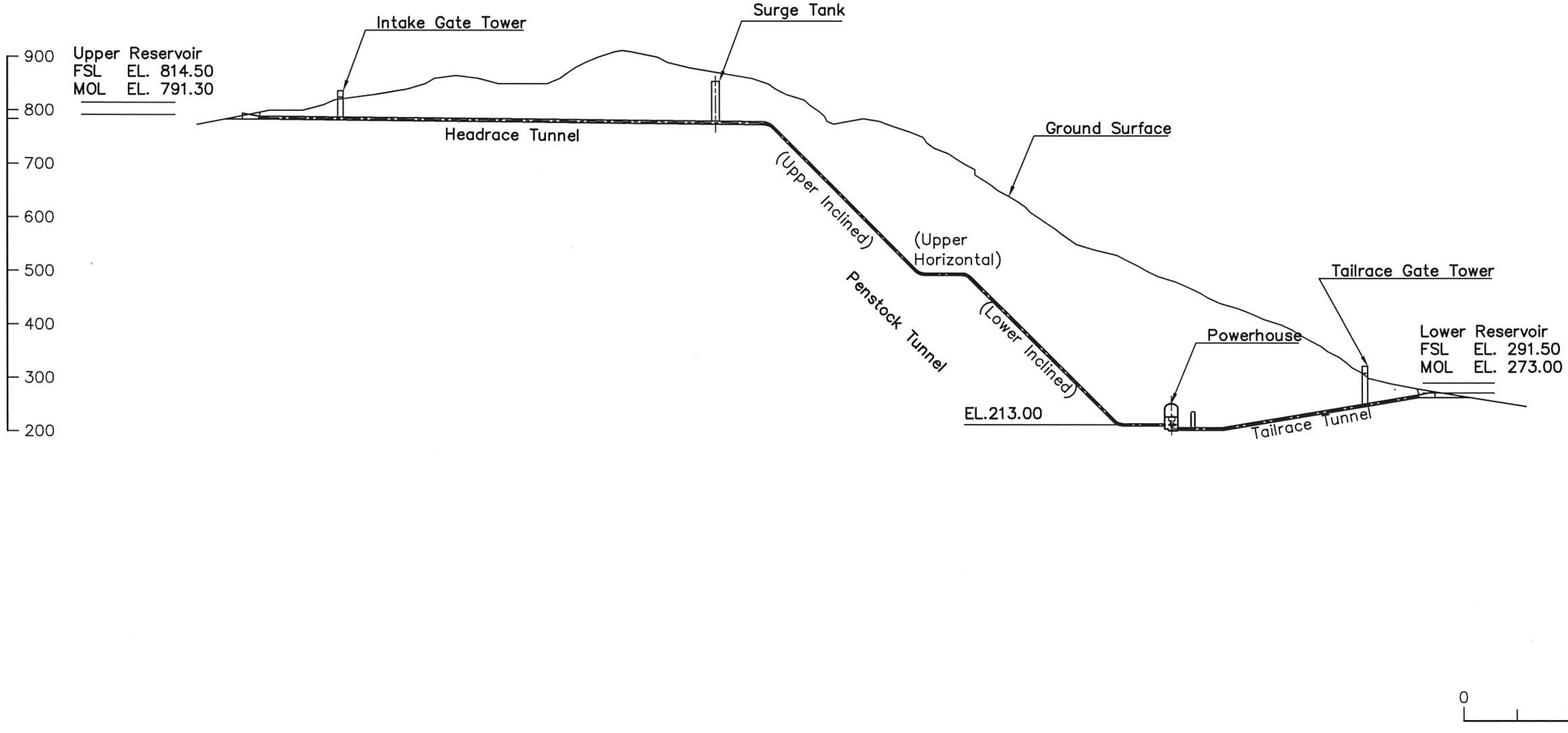
Electric Power Development Co., Ltd

MAHA 3
150MW/unit*4unit
Plan

Appendix 12.1-3

January, 2015

MAHA 3 (150MW*4UNITS)
Profile



Electric Power Development Co., Ltd
MAHA 3 150MW/unit*4unit Profile
Appendix 12.1–4
January, 2015