Independent State of Papua New Guinea
Department of Petroleum and Energy
PNG Power Ltd.

THE PROJECT FOR FORMULATION OF RAMU SYSTEM POWER DEVELOPMENT MASTER PLAN AND LAE AREA DISTRIBUTION NETWORK IMPROVEMENT PLAN

FINAL REPORT

PART A : POWER DEVELOPMENT MASTER PLAN OF RAMU POWER SYSTEM

September 2016

Japan International Cooperation Agency

NEWJEC Inc.

PN
JR
16-003

The Project for Formulation
of
Ramu System Power Development Master Plan
and Lae Area Distribution Network Improvement Plan

FINAL Report
Part A : Power Development Master Plan of Ramu Power System

Table of Contents

List of Figures

List of Tables

List of Pictures

Abbreviations

Symbol	Abbreviations
3LG	3 Line to Ground Fault
AC	alternating-current
ACSR	Aluminum Conductor Steel Reinforced
ADB	Asian Development Bank
AIE	Allied Industrial Engineering
APDL	Application for PDL
APePL	Application for PPL
APLL	Application for PLL
APPFL	Application for PPFL
APPL	Application for PPL
APRL	Application for PRL
AVR	Automatic Voltage Regulator
AZE	alliance for zero extinction sites
BDGs	Business Development Grants
BDMT	Bone dry metric ton
BOP	Biodiversity Offset Plan
BOS	Board of Survey
BWR	Bureau of Water Resources
CB	Circuit Breaker
CEA	country environmental analysis
CEMP	Construction Environment Management Plan
CEPA	Conservation and Environment Protection Authority
CF	Capacity Factor
CFB	Circulating Fluid Bed
CITES	Convention on International Trade on Endangered Species of Flora and Fauna
CO_2e	Carbon dioxide equivalent
COD	Commercial Operation Date
CPD	center of plant diversity
CPS	Country Partnership Strategy
CSO	Community Service Obligation
CSSU	Cooperate Services Group, Community Support Service Unit
DEC	Department of Environment and Conservation
DG	Diesel Generator
DHS	Demographic and Health Survey
DLPP	Department of Lands and Physical Planning
DME	Department of Minerals and Energy
DPE	Department of Petroleum and Energy
DPEnt	Department of Public Enterprises
DSP	Development Strategic Plan
E/F	Earth Fault

Symbol	Abbreviations
E/M	Electro-Mechanical
EA	Executing agency
ED-DPE	Energy Division of the Department of Petroleum and Energy
EIA	Environmental Impact Assessment
EIB	European Investment Bank
EIP	Electricity Industry Policy
EIR	Environmental Inception Report
EIS	Environmental Impact Statement
ELCOM	PNG Electricity Commission
EMC	Electricity Management Committee
EMP	Environmental Management Plan
ENSO	the El Niño Southern Oscillation phenomenon
EPC	Engineering, Procurement, Construction
ERC	Electricity Regulatory Contract
EROP	Electrification Roll-Out Plan
EUE	Expected Unserved Energy
F/S	Feasibility study
FA	Forest Authority
FAO	Food and Agriculture Organization of the United Nations
FO	Forced Outage
FOB	Free on Board
FSL	Full Supply Level
FYPDP	Fifteen Year Power Development Plan
GDP	Gross Domestic Product
GE	Gas Engine
GEE	General Electrics
GENROU	round rotor generator model
GoPNG	Government of Papua New Guinea
GPSA	as purchase and sales agreement
GSA	Gas Sales Agreement
GT	Gas Turbine
GTA	Gas Transportation Agreement
GTCC	Gas Turbine Combined Cycle
HFO	Heavy fuel oil
HPP	Hydropower Plant
IA	Implementing Agency
IAEA	International Atomic Energy Agency
IBA	important bird area
ICCA	indigenous and community conservation area
ICCC	Independent Consumer and Competition Commission
IEE	Initial Environmental Examination
IFC	International Finance Corporation
IGCC	Integrated Gasification Combined Cycle
ILG	Incorporated Land Group

Symbol	Abbreviations
ILO	International Labor Organization
IPBC	Independent Public Business Corporation
IPDP	Indigenous Population Development Plan
IPP	Independent Power Producer
IRC	Internal Revenue Commission
IRENA	International Renewable Energy Agency
ITTO	International Tropical Timber Organization
JaCC	Japan Crude Cocktail
JCC	Joint Coordination Committee
JICA	Japan International Cooperation Agency
JV	Joint Venture
KBA	key biodiversity area
KCH	Kumul Consolidated Holdings
KPH	Kumul Petroleum Holdings
L/Os	Land Owners
LDC	Load Dispatch Center
LLG	Local Level Government
LNG	Liquefied Natural Gas
LOLE	Loss of Load Expectancy
LRMC	Long-run Marginal Cost
MDB	Multilateral Development Bank
MOH	Major Overhaul
MOL	Minimum Operating Level
MOM	Minutes of Meetings
MOU	Memorandum of Understanding
MRA	Mineral Resources Authority
MRDC	Mineral Resources Development Corporation
MTDP	Medium Term Development Plan
MWAP	Maximum Weighted Average Price
NEC	National Executive Council
NGO	Non-Governmental Organization
NOx	Nitrogen Oxide
O&M	Operation and Maintenance
O&MBU	operating and maintenance business unit
O/C	Over Current
OCCD	Office of Climate Change and Development
OFR	Operation Fault Report
OGA	Oil and Gas Act
OJT	On the Job Training
ONAF	Oil Natural Air Forced
ONAN	Oil Natural Air Natural
P/P/P	Policy, Plan and Program
P/S	Power station
PAD	Petroleum advisory board

Symbol	Abbreviations
PDL	Petroleum Development License
PDP	Power Development Planning
PePL	Petroleum Prospecting License
PFP	PNG Forest Product
PGDP	Power Generation Development Plan
PIREP	Pacific Island Renewable Energy Project
PL	Petroleum Pipeline License
PMF	Probable Maximum Flood
PNG Dam	PNG Dams Ltd
PNGFP	PNG Forestry Products Co. Ltd
PNGSEL	PNG Sustainable Energy Limited
POM	Port Moresby
POP	persistent organic pollutant
PPA	Power Purchase Agreement
PPFL	Petroleum Processing Facilities License
PPL	PNG Power Limited
PPP	Public Private Partnership
PPRP	Power Purchase Reference Price
PRL	Petroleum Retention License
PSC	Product Sharing Contract
PV	Photovoltaics
RC	Reserve Capacity
REA	rapid environmental assessment
REV	Regulated by reservoir
ROR	Run- of-river
ROW	Right of Way
Ry	Protection relay
S/S	Substation
SAIDI	System Average Interruption Duration Index
SB	Stand-By
SC	Static Capacitor
SCADA	Supervisory Control And Data Acquisition
SEA	Strategic Environmental Assessment
SIA	Social Impact Assessment
SMEC	nowy Mountains Engineering Corporation
SNCR	selective non-catalytic reduction
SOPAC	Pacific Islands Applied Geoscience Commission
SOx	Sulfur Oxide
SPM	Suspended Particle Matters
SPREP	Secretariat Pacific Regional Environmental Program
SPSS	Statistical Package for Social Sciences
STATCOM	Static Synchronous Compensator
STG	Steam Turbine Generator
SVC	Static Var Compensator

Symbol	Abbreviations
SW/S	Switching Station
TA	Technical Assistance
TDSVIU	Transmission and Distribution Sectors of Vertically Integrated Utilities
TMAXOL	Turbine Maximum Operating Level
TMINOL	Turbine Minimum Operating Level
TOH	Top Cylinder Heads Overhaul
TPP	Thermal Power Plant
UBSA	Benefit Sharing Agreements
UN	United Nations
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNIDO	United Nations Industrial Development Organization
VIU	Vertically Integrated Utilities
WASP	Wien Automatic System Planning
WB	The World Bank
UAGO	Union Attorney General Office
WHO	World Health Organization
WMA	Wildlife Management Areas
YTOD	Yonki Toe of Dam

CHAPTER 1

INTRODUCTION

CHAPTER 1 INTRODUCTION

1.1 BACKGROUND

Papua New Guinea (hereinafter referred to as "PNG") maintains high economic growth rate, which means domestic power demand is also forecast to increase in future. Conversely, the country is also subject to chronic power shortages due to aging power facilities and a lack of maintenance.

In particular, in the Ramu System, supplying power to rural cities which covers from the Highland Region through Momase Region is unstable and subject to frequent power interruptions. The largest city which consume electricity from the Ramu System is the Lae City. Although the diesel generators are installed in the city, the city is facing the problems of frequent accident caused by aging generators, blackouts and frequent regional brownouts caused by other reasons.

To cope this situation, PNG Power Ltd. (hereinafter referred to as "PPL") is constructing and rehabilitating power sources such as hydropower plants, etc. and they also have plans to reinforce transmission lines. Conversely, in terms of long-term, as the mining development is in progress, which will be a major power consumer in the future, also the expansion of commercial area in Lae area, a comprehensive power development master plan, including generation and transmission lines of Ramu System, must be established considering future increases of power demand.

In addition, the necessity to improve the distribution network, including small-scale generation facilities in the Lae area, is one of the major prior tasks of PPL in the perspectives of urgency and necessity. Thus, the formulation of the distribution network improvement plan in Lae area is needed as well.

1.2 OBJECTIVE OF THE STUDY

The objectives of the study are to help stabilize future power supply by formulating the Ramu System Power Development Master Plan (from 2016 to 2030) and the Lae Area Distribution Network Improvement Plan.

1.3 OUTLINE OF THE STUDY

Item	Formulating the Ramu System Power Development Master Plan	Lae Area Distribution Network Improvement Plan
Objective	Establishing an integrated power supply system in the Ramu System and stabilizing the long-term status of the power supply in Lae and surrounding areas	
Outputs	Power development master plan for the Ramu power system, comprising the power generation development plan, power network (transmission) expansion plan for the period between 2016 and 2030 is developed.	A distribution network improvement plan in the Lae Area for 2016 and 2030 is developed.
Target and Coverage Area	Ramu System Coverage Provinces (Morobe, Madang, East Highland, West Highland, Chimbu, South Highland, Enga)	Lae Area (Lae City and Nadzab, Erap, Taraka, etc.)
Implementing Agency	Department of Petroleum and Energy (DPE) PNG Power Ltd (PPL)	PNG Power Ltd. (PPL)
Scope of the Services	Formulation of a Ramu System Power Development Master Plan	Lae Area Distribution Network Improvement Project

1.4 IMPLEMENTATION STRUCTURE FOR THE STUDY

PPL and DPE oversee the implementation of the Study as counterpart agencies and officers from each organization are assigned to the Study. A member list of counterpart officials is shown in Table 1.4-1 and the implementation structure of the Japan International Cooperation Agency (JICA) Study Team is shown in Fig. 1.4-1.

Table 1.4-1 Member List of Local C/Ps

Organization	Name	Position
DPE, Energy Division	Mr. Idau Kopi	Acting Director, Energy Planning & Marketing Development
	Mr. Martin Bonou	Acting Director, Technical Regulation & Licensing
	Mr. Alan Lari	Acting Director, Rural Electrification
	Mr. Kila Kone	Acting Engineer, Electricity Management Secretariat
PPL Head Office	Mr. Chris Bais	Director, Strategic Planning & Business Development
	Mr. Francis Uratun	Infrastructure Manager
	Mr. Andrew Yuants	Network Planning Engineer
	Mr. Kero Tom	Financial Expert
	Mr. Damien Sonny	Renewable Energy & Carbon Specialist
	Mr. Maira Pulayasi	Distribution Engineer
	Mr. Titus Tsigese	Environmental Expert

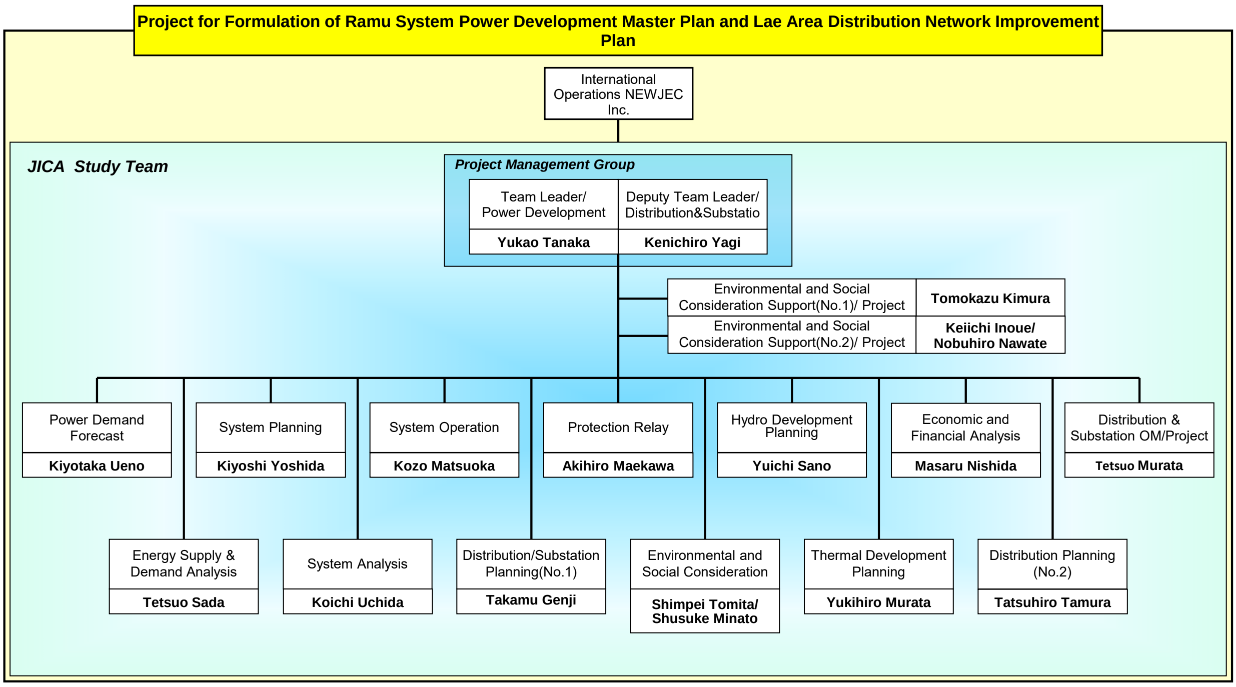


Fig. 1.4-1 Implementation Structure of JICA Study Team

1.5 OVERALL WORK SCHEDULE OF THE STUDY

The Study is roughly divided into three stages, namely "Collection of information on the power sector and analysis of current condition", "Formulation of an alternative scenario for the power development plan" and "Formulation of an optimum power development plan". The major work items and timing are shown in Fig. 1.5-1 and the Main Study Components and Schedule are presented in Fig. 1.5-2.

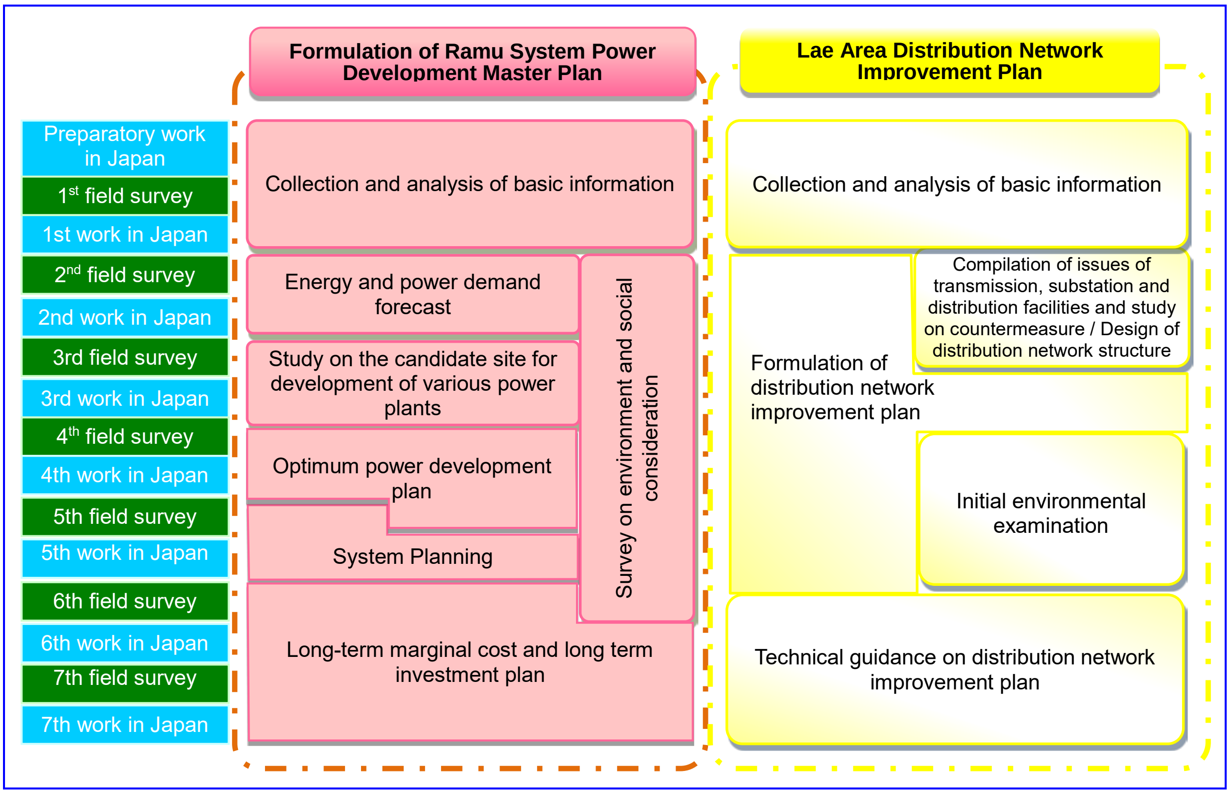


Fig. 1.5-1 Overall Work Flowchart

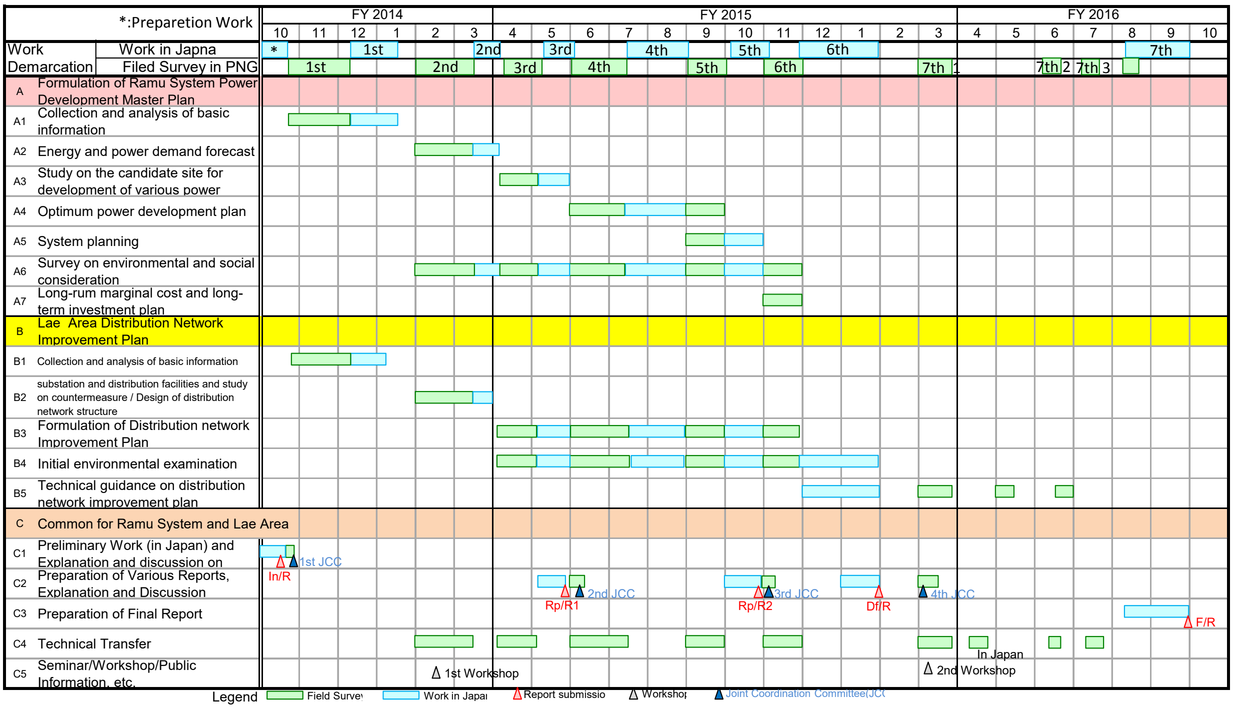


Fig. 1.5-2 Main Study Components and Schedule

1.6 TECHNICAL TRANSFER PROGRAM

As the technical knowledge which are several investigation, analysis, data management, basic knowledge concerning planning of power development, transfer to the C/P, technical transfer was given to C/P through the daily works, workshops and Joint Coordinating Committee (hereinafter referend to as "JCC") through the Study for the purpose of continuous utilization of future organization formulation. The Technical Training Program in Japan was conducted in April, 2016 as well.

(1) The Kick-Off Meeting

The Kick-Off meeting was held on October 27, 2014 at the Board Meeting Room of PPL, attended by Mr. John Tangit, CEO of PPL, Mr. Vore Veve, Director and Deputy Secretary of Energy and other officials from PPL and DPE. JICA Study Team made a presentation on the outline of the Study and methodology on each work items briefly to the participants.

Table 1.6-1 Agenda of Kick-Off Meeting in PNG

Program
Opening Address by Mr. John Tangit, Chief Executive Officer, PPL
Address by Mr. Vore Veve, Acting Deputy Secretary of Energy, Energy Planning & Market Development
Introduction of PNG and Japanese Participants
Presentation by Mr. Yukao Tanaka, Team Leader for JICA Study Team
Question & Answers
Closing Remarks by Mr. Chris Bais, Director, Strategic Planning & Business Development

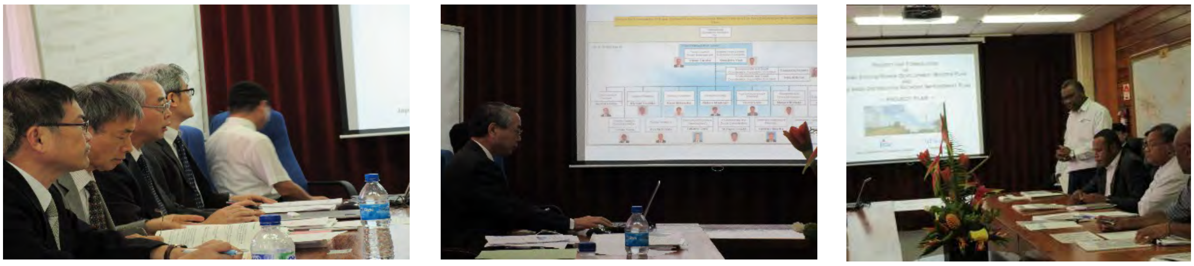


Fig. 1.6-1 Photos of the Kick-Off Meeting

(2) First JCC

The first JCC was held on October 29, 2014 at the conference room of the hotel in Port Moresby (POM). After the Opening Address and Remarks by Mr. John Tangit (Chief Executive Officer, PPL), Mr. Alan Lari (Acting Director, Rural Electrification, Energy Division of DPE) and Mr. Shigeru Sugiyama (Chief Representative, JICA PNG Office), JICA Study Team made a presentation on the outline and objectives of the Study to participants from PPL, DPE and JICA.

Table 1.6-2 Agenda of the First JCC in PNG

Program
Registration and Morning Tea
Welcome and Opening Prayer
Opening Address by Mr. John Tangit, Chief Executive Officer, PPL
Address by Mr. Alam Lari, Acting Director, Rural Electrification, Department of Petroleum & Energy
Remarks by Mr. Shigeru Sugiyama, Chief Representative, JICA PNG
Introduction of PNG and Japanese Participants
Presentation by Mr. Yukao Tanaka, Team Leader for JICA Study Team
Question & Answers
Explanation of the Meeting Minutes of JCC
Signing of Meeting Minutes by Representatives of DPE, PPL, JICA PNG Office, JICA Study Team
Closing Remarks by Mr. Chris Bais, Director, Strategic Planning & Business Development
Luncheon

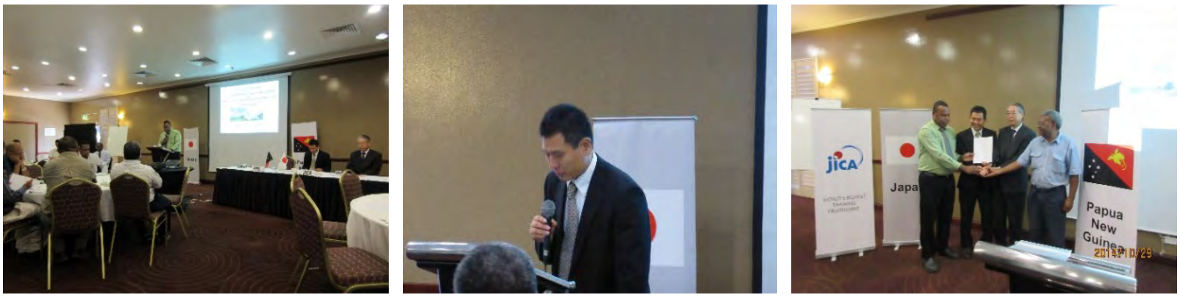


Fig. 1.6-2 Photos of the First JCC Meeting

(3) First Workshop

The first workshop was held on February 17, 2015, respectively to explain about the outline and objectives of the Study and its progress conducted by JICA Study Team and to obtain the consensus of PPL and DPE. Attended by Mr. Vore Veve, Director and Deputy Secretary of Energy, Mr. Chris Bais, Director, Strategic Planning & Business Development and other officials from related departments. JICA Study Team made a presentation of the outline of the Study, methodology of each work items and study progress to the participants.

Table 1.6-3 Agenda of the First Workshop

Program
Registration and Morning Tea
Welcome and Opening Prayer
Opening Address by Mr. Chris Bais, Director, Strategic Planning & Business Development
Address by Mr. Vore Vere, Director Energy Division & Deputy Secretary of Energy Department of Petroleum & Energy
Remarks by Mr. Shigeru Sugiyama, Chief Representative, JICA PNG
Introduction of PNG and Japanese Participants
Presentation by Mr. Yukao Tanaka and Experts of JICA Study Team
Question & Answers
Closing Remarks by Mr. Chris Bais, Director, Strategic Planning & Business Development
Luncheon

Fig. 1.6-3 Photos of the First Workshop

(4) Second JCC

The second JCC was held on June 16, 2015, respectively to explain about the outline of Progress Report No.1 and undertake discussion for the future draft study policy of the Study and to obtain the consensus of PPL and DPE. The JCC was attended by Mr. Chris Bais, Director, Strategic Planning & Business Development, JICA PNG office and the other officials from related departments. JICA Study Team made a presentation of the Progress Report No.1 by each study areas to the participants.

Table 1.6-4 Agenda of the Second JCC

Program
Registration and Morning Tea
Welcome and Opening Prayer
Opening Address by Mr. Chris Bais, Director, Strategic Planning & Business Development
Remarks by Mr. Shigeru Sugiyama, Chief Representative, JICA PNG
Presentation by Mr. Kenichiro Yagi and Experts of JICA Study Team
Question & Answers
Closing Remarks by Mr. Chris Bais, Director, Strategic Planning & Business Development
Luncheon

Fig. 1.6-4 Photos of the Second JCC

(5) Third JCC

The third JCC was held on November 10, 2015, respectively to explain the Progress Report No.2 and undertake discussion for the future draft study policy of the Study and to obtain the consensus of PPL and DPE. The JCC was attended by Mr. Vore Veve, Director, Energy Division and Deputy Secretary Energy Department of Petroleum & Energy, Mr. Chris Bais, Director, Strategic Planning & Business Development, JICA PNG Office, and the other officials from related departments, WB/IFC and ADB. JICA Study Team presented the study progress on each study areas to the participants.

Table 1.6-5 Agenda of the Third JCC

Program
Registration and Morning Tea
Welcome and Opening Prayer
Opening Address by Mr. Chris Bais, Director, Strategic Planning & Business Development
Address by Mr. Vore Veve, Director Energy Division & Deputy Secretary of Energy Department of Petroleum & Energy
Remarks by Mr. Shigeru Sugiyama, Chief Representative, JICA PNG
Presentation by Experts of JICA Study Team
Question & Answers
Closing Remarks by Mr. Chris Bais, Director, Strategic Planning & Business Development
Luncheon
Free discussion with each experts

Fig. 1.6-5 Photos of the Third JCC

(6) Fourth JCC and Second Workshop

The Fourth JCC was held on March 8, 2016 at Holiday Inn & Suites, to briefly explain on the outcome of Draft Completion Report and to obtain the consent of PNG Power and DPE. Mr. Vore Veve, Director, Energy Division, Energy & Deputy Secretary Energy, Department of Petroleum & Energy, Mr. Martin Bigiglan, Acting Chief Operating Officer, PPL, Mr. Takashi Toyama, newly assigned Chief Representative of JICA PNG, other officials of PNG Power, government body, IFC, World Bank, etc. were attended in the 4th JCC, the final committee meeting.

The Second workshop was held on March 17, 2016 at Melanesian Hotel, respectively to briefly explain on the outcome of Draft Completion Report and to obtain the consent of PNG Power (LAE). Attended by Mr. Albert Nanako, Regional Manager New Guinea Mainland.

Table 1.6-6 Agenda of the Fourth JCC

Program
Registration and Morning Tea
Welcome and Opening Prayer
Opening Address by Mr. Martin Bigiglan, Acting Chief Operating Officer
Address by Mr. Vore Veve, Director, Energy Division & Deputy Secretary of Energy, Department of Petroleum
Remarks by Mr. Takashi Toyama, Chief Representative, JICA PNG Office
Presentation by Experts of JICA Study Team
Question & Answer
Luncheon

Fig. 1.6-6 Photos of the Fourth JCC

Fig. 1.6-7 Photos of the Second Workshop

1.7 PUBLIC INFORMATION ACTIVITY

Public information activity to mass media is shown in Table 1.7-1, in close coordination with JICA for the purpose of heighten the recognition of the public. The summary and contents of the publication are shown in Appendix-1.

Table 1.7-1 Public Information Activity

Date	Name of mass media	Brief contents	Type of media
August 19, 2014	The Kensetsutsushin Shimbun	Introduction of NEWJEC awarded consulting service contract from JICA for this Study	Newspaper (Japan)
August 20, 2014	The Daily Engineering & Construction News		Newspaper (Japan)
August 21, 2014	The Denki Shimbun		Newspaper (Japan)
October 30, 2014	The National	Local newspaper introduced commissioning of the Study co-working with PPL, JICA and NEWJEC study team at the kick-off of the first JCC meeting.	Newspaper (PNG)
February 18, 2015	The National	Local newspaper introduced the study and reported that JICA and their consultants will embark on plans aimed to address issues relating to power shortages and high power losses. PNG Power Ltd director said the outcomes would provide vital information to PNG Power to improve and expand their systems in other centers. For us it's going to be a very important study as the Ramu system is our second biggest system, however, with all the developments taking place in that part of the country, the Ramu system project is going to surpass the Port Moresby system in the near future. "The outcomes of the project will provide us the data we would need for further improvement purposes." JICA PNG representative said the project is a joint effort by PNG Power,	Newspaper (PNG) & official website

Date	Name of mass media	Brief contents	Type of media
		DPE and JICA. The programs aimed to identify the most required and cost effective power distribution plans that would be used to implement a sustainable power supply system in the country.	
February 19, 2015	Wantok	Local newspaper introduced the study's commencement and reported the study outlines.	Newspaper (PNG)
June 18, 2015	The National	Local newspaper introduced that Ramu system power development master plan was expected to contribute the growth of commercial activities in Lae and in the country through financial, customer and business process perspectives. Also introduced that PPL plans to refurbish some of power infrastructures to improve services in Lae followed by this master plan study.	Newspaper (PNG) official website
November 12, 2015	The National	Local newspaper reported that PNG Power director said "The increased mining and industrial activities in the northern region and the development of Lae as the industrial hub could surpass power consumption in the Port Moresby system. We urgently need to upgrade all the hydro and thermal power stations, distribution networks, expand power generation plans, upgrade all substations, switching stations and transmission lines in the Ramu system." The Government's medium-term development goal to connect electricity to 70 per cent of the population by 2030 is unachievable, unless every rural dweller produced solar power to be sold to PNG Power Ltd, the 70 per cent target could not be achieved, according to JICA official and their study team. Deputy Secretary in the DPE said "Power was the driving force behind development. It's a mammoth task to roll out power to about 70 per cent of the population in PNG by 2030, a target set by the Government in the medium-term development goal."	Newspaper (PNG), on-line news
November 11, 2015	Post – Courier	Local newspaper introduced JCC and reported that JICA official said a planning and implementation of the project is important as electricity is the key to socioeconomic development. PNG Power director said that currently under 10 per cent of the nation had access to electricity and their 2020 goal was for 70 per cent of the nation to have access to electricity. JICA research team recommended periodical and proper maintenance of power plants is essential to operate in good condition, maximize generated energy and prolong the life-time of power plants and the immediate rehabilitation of existing hydropower plants. The research team also considered the severe dry season and recommended that energy sources such as natural gas, oil, biomass with trees and solar be used instead of just water.	Newspaper (PNG), on-line news
November 10, 2015	Loop PNG	Local online newspaper introduced JCC and reported that the study is in reaching finalization, the Ramu System Power Development plan recommends for PNG Power to look at alternative ways to generate electricity, apart from the current practice of hydro and diesel generators. Also introduced major findings of from the study.	On-line news (PNG & pacific regions)
November 10, 2015	EMTV	Local TV news introduced study outline and reported that Director of Energy Division and Deputy Secretary for DPE reiterated that the government wants to see 70 per cent of Papua New Guineans with access to reliable and affordable electricity by 2050. So far, some of the recommendations include the replacement of aging facilities as an urgent countermeasure, and the divergence of power supply such as a natural gas turbine and biomass for stable power supply. Chief Representative of JICA PNG Office said the projects will require a huge amount of investment.	TV Broadcasting & on-line news (PNG)

Date	Name of mass media	Brief contents	Type of media
March 8, 2016	NBC TV	Local TV News at 6PM reported that JCC was held to explain about the outcome of the Ramu System Power Development Master Plan. In the TV news, the remarks of Mr. Takashi Toyama, Chief Representative of JICA PNG Office was introduced that he stressed the development of power plant and transmission lien in Ramu Grid System is quite important for the economic growth for the nation.	TV Broadcasting
March 9, 2016	Post-Courier	Local newspaper reported that the progress of the Ramu system power development master plan and the Lae area distribution network improvement plan were discussed yesterday. The Ramu master plan is to optimize power generation and system expansion between 2016 and 2030, and the Lae plan is to stabilize the power supply during the same period. The Study Team recommended that in order to strengthen the power supply reliability in the Ramu System, power plants with poor fuel efficiency should be replaced or rehabilitated. In addition, they recommend that some existing hydropower plants should be refurbished or rehabilitated as short-term countermeasures to increase supply capacity. For long-term measures, it is recommended to develop a large scale hydropower plants such as Ramu 2 and Mongi-Bulum.	Newspaper
March 9, 2016	The National	Local newspaper reported that Japanese experts yesterday gave a comprehensive rundown of the Ramu System Power Development Master Plan and Lae Area Distribution Network Improvement Plan. JICA study team had made recommendations which included the rehabilitation of power plants with poor fuel efficiency, development of large-scale hydro plants such as Ramu 2 and Mongi-Bulum, and construction of high voltage transmission lines to deliver power generation in the western area to east side major power demand center, Lae.	Newspaper

Appendix 1

Public Information Activity

Appendix-1 : Public Information Activity

19/AUG/2014 The Kensetsutushin Shimbun

夏の風物詩を楽しむ

パプアニューギニアの電力開発計画受託

ニュージェック

The Kensetsu shimbun (AUG/19/ 2014)

20/AUG/2014 The Daily Engineering Construction News

マスタープラン策定を受託

パプアニューギニア電力開発2件

ニュージェック

The Daily Construction Engineering News (AUG/20/ 2014)

21/AUG/2014 The Denki Shimbun

2014年（平成26年）8月21日（木曜日）

ニュージェック

電力システム構築支援

パプアニューギニアでコンサル業務を受託

配電網計画など

文化財の電気安全守る

神社仏閣で設備点検

チラシ配布し安全啓発

担当区域の役所訪問

The Denki Shimbun (Aug/21/ 2014)

NATION

PPL power plan

Landowners wait for gravel payment

Church leaders block wharves

The National 1st JCC (OCT/30/2014)

Firm's study to help boost power system

Source:
The National, Wednesday February 18th, 2015

By Eric Balaria

A JAPANESE company will soon be working with PNG Power Ltd to improve its power networking system in the country.

NEWJEC, an integrated engineering consulting firm engaged by Japanese International Cooperation Agency (JICA), will embark on plans aimed to address issues relating to power shortages and high power losses.

The firm will conduct a study on the Ramu power system and the development of a Lae distribution network improvement plan.

The two project plans would be carried out in a 14-year period, starting next year.

Speaking at a workshop in Port Moresby yesterday, PNG Power Ltd director (strategic planning and business development) Chris Bais said the outcomes would provide vital information to PNG Power to improve and expand their systems in other centres.

"We (PNG Power) are very excited with these two projects, especially with JICA coming onboard to assist us in funding the study," Bais said.

"For us it's going to be a very important study as the Ramu system is our second biggest system, however, with all the developments taking place in that part of the country, the Ramu system project is going to surpass the Port Moresby system in the near future.

"The outcomes of the project will provide us the data we would need for further improvement purposes."

JICA PNG chief representative Shigeru Sugiyama said the project is a joint effort by PNG Power, the Department of Petroleum and Energy and JICA.

He said the programmes aimed to identify the most required and cost effective power distribution plans that would be used to implement a sustainable power supply system in the country.

Add new comment | Tags: **Business**, **Normal**

The National newspaper 1st WS (FEB/18/2015)

Wantok newspaper 1st workshop (FEB/19/2015) **The National newspaper 2nd JCC (JUN/18/2015)**

Agency: Better power services will boost development

Source:
The National, Thursday June 18th, 2015

By ERIC BALARIA
IMPROVED power services in Papua New Guinea will enhance commercial development, a Japanese aid agency official says
Japanese International Corporation Agency (JICA) chief representative Shigeru Sugiyama said a brighter PNG would make the country an attractive environment for investments if there were efficient and accessible power services available. He was speaking during a workshop hosted by PNG Power Ltd and NEWJEC, a Japanese firm engaged by JICA
to conduct studies on the Ramu power system and to develop a master plan to improve power services in Lae.
"The brighter PNG will be achieved physically by the power supply by the Ramu system to bring more light, energy and power into the region that has a large share of the population in Lae and other cities," Sugiyama said.
"The commercial importance of a brighter PNG will also be achieved economically as more improved and reliable power supply grow here and enabling an environment for doing business that would attract much needed investment to the region from sectors including mining and among others.
"Increased commercial activities in the region will be expected to benefit the people living there.
"There will be more employment opportunities, improved skills and capacity, and of the most, include house hold income."
Sugiyama said the Ramu system power development master plan, currently under study phase by NEWJEC, was expected to contribute in the growth of commercial activities in Lae and in the country through financial, customer and business process perspectives.
"In a business process perspective, the master plan does not fail to address or review this issue.
"But I believe NEWJEC can provide some useful observation as to how PPL can manage its business more efficiently as they work hand in hand with for the entire duration of this project," he said.

Add new comment | Tags: **Business, Normal**

PNG Power Ltd plans to improve infrastructure

Source:
The National, Thursday June 18th, 2015

PNG Power Ltd (PPL) plans to refurbish some of its infrastructures to improve services in Lae, a senior official says.
PPL director strategic planning and business development Chris Bais said there were several technical infrastructure issues identified at its hydropower plants and power distribution network that needed to be sorted out to improve and eliminate constant power outages in the Lae system grid.
This followed a recent study conducted by NEWJEC, a Japanese engineering consulting firm which showed that conditions of the hydropower plants at Ramu 1 (Madang/Morobe) and Paunda (Western Highlands) had deteriorated because of lack of maintenance resulting in power plants failing to operate with limited output.
"The progress of the study itself is very good indeed as it has uncovered a number of issues that is prevalent in our PPL systems," Bais said.
"We have taken note of them and we are also addressing some of those issues.
"I guess with these findings coming from an independent body that will push our management to go ahead and implement those changes.
"These are minor changes and it will basically help us a lot in minimising the outages in Lae alone." In the study NEWJEC had also proposed to PPL a K5 million short term distribution network improvement plan to improve and stabilise power supply in Lae.
"Given the scope and the quantum of the costs to be able to implement these various changes, I think PPL can allocate the use of its internal resource," Bais said.
"Some of the outages in the system is basically the transmission line which is the single grid but more so it's the distribution network.
"With what NEWJEC and JICA are doing, if it's done quickly it will definitely eliminate a lot of blackouts in the Lae systems."

Add new comment | Tags: **Business, Normal**

The National website 2nd JCC (JUN/18/2015)

The National newspaper 3rd JCC (NOV/12/ 2015)

PPL, JICA launch power plan

Source:
The National, Thursday November 12th, 2015

THE Japan International Cooperation Agency (JICA) and PNG Power Ltd have launched the project formulation for the Ramu power development master plan and the Lae Area distribution network improvement plan.
The master plan presented by a team from JICA outlined the overall work schedule to develop the Ramu power plant system to meet the demand up to 2030 in the Highlands and Momase regions.
PNG Power strategic and planning and business development director Chris Bais said the increased mining and industrial activities in the northern region and the development of Lae as the industrial hub could surpass power consumption in the Port Moresby system.
"The demand for power is increasing rapidly and putting a strain on the old power system in Ramu.
"We urgently need to upgrade all the hydro and thermal power stations, distribution networks, expand power generation plans, upgrade all substations, switching stations and transmission lines in the Ramu system."
Vore Vere, deputy secretary in the Department of Petroleum and Energy said power was the driving force behind development.
"It's a mammoth task to roll out power to about 70 per cent of the population in PNG by 2030, a target set by the Government in the medium-term development goal," Vere said. Chief JICA representative Shigeru Sugiyama said areas in the Momase and Highlands regions had huge economic potential for the country.

Add new comment | Tags: **National, Normal**

Power not achievable by '30: JICA

Source:
The National, Thursday November 12th, 2015

By TONY PALME KIP
THE Government's medium-term development goal to connect electricity to 70 per cent of the population by 2030 is unachievable, according to a Japan International Cooperation Agency official.
Environment and social consideration team member Shusuke Nimato said in Port Moresby that unless every rural dweller produced solar power to be sold to PNG Power Ltd, the 70 per cent target could not be achieved.
Nimato, while presenting a power study project formulation for the Ramu system power development master plan and the Lae area distribution network improvement plan, said political commitment was needed.
"Electricity has now become a basic human need after food, water, air and shelter," Nimato said.
"Electricity will build this nation. Government, private and public stakeholders seriously need to improve and develop power facilities and resources in the country because in 2030, the demand for power will be very high.
"We have nine provinces in Momase and Highlands regions, half of PNG's population, that depend on the Ramu system.
"Special consideration should be given to these areas because they are the economic hub of the nation.
"This master plan (2016-2030) is in line with the plan by PPL, Department of Petroleum and Energy and the Government to provide power for every Papua New Guinean.
"I think about 50 per cent of the population will have access to electricity by 2030," adding this would have to with government's support.

Add new comment | Tags: **National, Normal**

The National website 3rd JCC (NOV/12/2015)


PAPUA NEW GUINEA
Post-Courier
THE HEARTBEAT OF PNG
WEDNESDAY NOVEMBER 11, 2015

CHRISTMAS CATALOGUE IN TODAY'S Post-Courier
KENU & KUNDU FESTIVAL IN PICTURES
PAGEANT ENTRANT MISS ITALIAPREZIOSI
PPL EXEC JOHN MANGOS CHARGED

Lae in crisis

RELATED STORIES P8-P9 ■Nadzab flights cancelled; ■Governor warns Asian shop-owners; ■Knife held to 4-year-old's throat

KIA The Power to Surprise
K2700
Great Value!
Spacious loading capacity
Superior engine and brake performance
Available for immediate delivery!
BOROKO MOTORS

news

Court extends time for officers

Meeting to better power services

PNG, Bougainville working towards referendum

BUY 2 AND GET 1 FREE!
BEST PREPAID INTERNET RATES
Buy two prepaid data bundles of the same value within 24 hours and get 1 FREE!
TELIKOM PNG

Post Courier 3rd JCC (NOV/11/2015)

Japan to help Ramu power scheme

The Japan International Cooperation Agency (JICA) funded study into power generation from the PNG Power Ramu system will present its finding this morning.

The 3rd Joint Coordinating Committee held in Port Moresby will give its study outcome of two studies.

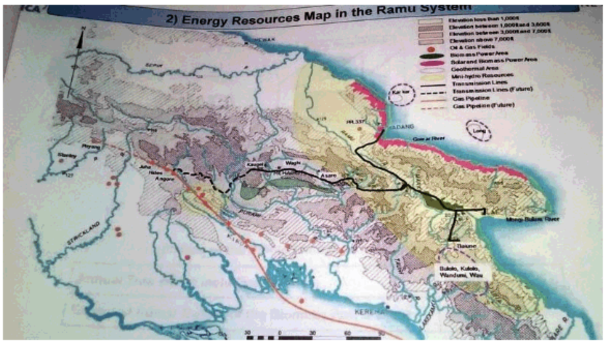
1. Project for formulation of Ramu System Power Development Master plan and;
2. Late Area Distribution Network Improvement Plan.

The study outcome will give state owned power supplier and investors a clear understanding of how the electricity power generation at the Ramu Power System can be improved using different power sources to support its grid.

Author:
Charles Yapumi

Loop PNG website 3rd JCC (NOV/10/2015)

Japan says Ramu vital to PNG development



Ramu Power station is vital in the development of Papua New Guinea says the Japan International Cooperation Agency in country chief representative.

Mr Shigerm Sugiyama from JICA PNG office said "Ramu System covers the largest area and population in the country.

"This area is a power house because of the mining development happening."

Power from the Ramu grid supplies Morobe, Madang and parts of the Highlands Region.

With mining activities happening the demand for electricity also increases, Sugiyama added.

The in-country JICA head was speaking at the presentation of a study undertaken by the Japanese Government overseas aid office on the Ramu Power grid.

Furthermore, the study outlines that a reliable power supply will attract foreign and domestic investment in business.

The current power output from the Ramu System is unstable due to the ageing machines in generation of electricity.

Author:
Charles Yapumi

Loop PNG website 3rd JCC (NOV/10/2015)

Meeting to better power services

November 11,2015, 01:39 am

Tweet

BY DAISY PAKAWA

VARIOUS stakeholders have met for the formulation of the Ramu System Power Development Master Plan and the improvement of the Lae Electricity Distribution Network.

The highlight of the workshop on Monday was the presentation of studies carried out in the past 15 years by Japanese experts.

It includes their recommendations to upgrade existing facilities to cater for the growing demand that is expected in the next 15 years.

It was attended by representatives from the Japan International Corporation Agency (JICA), PNG Power and other stakeholders.

JICA chief representative Shigeru Sugiyama says through participation stakeholders can come to an agreed conclusion to implement the two projects.

He said that planning and implementation of the project is important as electricity is the key to socioeconomic development.

PNG Power director for strategic planning and business development Chris Bais said that liaison with various stakeholders was a necessary process.

He said the final report on the two projects should be available in March.

Mr Bais said that currently under 10 per cent of the nation had access to electricity and their 2020 goal was for 70 per cent of the nation to have access to electricity.

The JICA research team also recommended periodical and proper maintenance of power plants.

is essential to operated in good condition, maximise generated energy and prolong the life-time of power plants and the immediate rehabilitation of existing hydropower plants.

The research team also considered the severe dry season and recommended that energy sources such as natural gas, oil, biomass with trees and solar be used instead of just water.

Post Courier website 3rd JCC (NOV/11/2015)

Power Study Near Completion

on Tuesday, 10 Nov 2015. Posted in Home

by Delly Waigeno – EM TV News, Port Moresby

The demand for domestic power is forecast to increase in the future as Papua New Guinea experiences growth in its economy.

The country is already facing a chronic power shortage, mainly due to aging power facilities and a lack of maintanence.

To address this, a power study has been conducted with assistance by the Japan International Cooperation Agency (JICA). It is expected to see the Ramu system developed and contribute towards an increased power supply in the Highlands and Momase regions.

The third joint committee meeting was held this morning in Port Moresby between PNG Power and JICA.

The meeting pointed out that the Ramu system, which supplies power to the Highlands region, Madang and Lae is unstable and has been subjected to frequent power interruptions.

The meeting discussed ongoing progress on the two projects funded by JICA which will help to stabilise future power supply. The two projects are the Ramu System Power Development Master Plan and the Lae Area Distribution Network Improvement Plan.

Director Energy Division and Deputy Secretary for the Department of Petroleum and Energy, Vore Veve, reiterated that the government wants to see 70 per cent of Papua New Guinean's with access to reliable and affordable electricity by 2050.

So far, some of the recommendations include the replacement of aging facilities as an urgent counter measure, and the divergence of power supply such as a natural gas turbine and biomass for stable power supply.

Chief Representative of the JICA PNG Office, Shigeru Sugiyama, said the projects will require a huge amount of investment.

The final report will be released after comments from today's meeting will be incorporated. The report will be made available on the JICA website.

EMTV TV Broadcasting & website 3rd JCC (NOV/10/2015)

PNG Power should diversify sources: Japan

BY: jkisselpar
18:43, November 10, 2015

340 READS

The final study into the Ramu System Power Development plan recommends for PNG Power to look at alternative ways to generate electricity, apart from the current practice of hydro and diesel generators.

Currently the Ramu grid power supply is inadequate to meet the demand, causing frequent blackouts to customers in Morobe, Madang and parts of the Highland grid.

Japan International Cooperation Agency, which funded the study at a cost of K8.8 million stated on its website that, "power supply to the Highlands and Momase region is unstable, interruptive and unpredictable power supply".

"In fact, the installation capacity for the Ramu System in terms of power generation stands at 188 MW but the actual capacity remains low at 89 MW today."

The major finding from the study recommended;

- Development of hydro power projects must continue as scheduled and rehabilitation work should be facilitated as well.
- The divergence of power supply sources such as natural gas turbine and biomass, etc., is preferable for stable power supply under the least cost development.
- Reinforcement of the power system especially in the Highlands area seems to be essential for enhancing the power supply reliability.
- Replacement of ageing facilities is recommended as an urgent counter measure.
- Upgrading of Lae distribution network is recommended including network design.

PNG Power director strategic planning and business development Chris Bais said the study recommendation will be circulated for input and the final draft should be handed to the Electricity Management Committee in early next year.

The committee was set up by the National Government to increase electricity access to more Papua New Guineans by 2030.

Tags:
PNG Power
Japan
Clean Energy
Author:
Charles Yapumi

Loop PNG website 3rd JCC (NOV/10/2015)

Wednesday, March 9, 2016 – The National 3

Japan agency commits to lighting up PNG

By MALUM NALU

JAPAN is committed to creating a "brighter" Papua New Guinea through improved supply of electricity, says Japan International Co-operation Agency chief representative Takashi Toyama.

Toyama, who is new in the country after taking over from his predecessor Shigeru Sugiyama, said that yesterday during a meeting on the Ramu System Power Development Master Plan, and the Lae Area Distribution Network Improvement Plan.

"I am sincerely grateful to each member of the team for your collaborative efforts so that we shape a physically and economically brighter PNG through reliability of the line system as a whole," he said.

"I'm sure that the master plans will assist in bringing energy to meet the increasing demand in the commercial capital Lae City.

"The system will be able to provide much more stable and reliable power supply in Lae."

Toyama said the plans would create a better financial perspective for Lae by reducing the frequency of blackouts in the city.

"This indicates that PPL will be able to upgrade the current facilities such as power generators and transmitters with minimal costs," he said.

"This enables PPL to provide more stable and reliable power supply for users, as well as reinvest in facilities to ensure better quality and quantity of power in the area, and financial sustainability for PPL."

He said customer satisfaction was also important.

"I'm confident that better access and reliability in the Lae area will greatly increase by 2030," Toyama said.

"The implementation of the master plans will bring a brighter PNG as well as contribute to the medium-term development plan and Vision 2050."

Petroleum and Energy Deputy Secretary Vore Vere, left, and JICA chief representative Takashi Toyama at yesterday's meeting in Port Moresby. – Nationalpic by MALUM NALU

Experts outline power plan

JAPANESE experts yesterday gave a comprehensive rundown of the Ramu System Power Development Master Plan and the Lae Area Distribution Network Improvement Plan.

The experts, who make up the Japan International Cooperation Agency study team headed by Yukao Tanaka of NEWJEC Inc, made their presentation at the fourth joint coordinating committee meeting in Port Moresby yesterday.

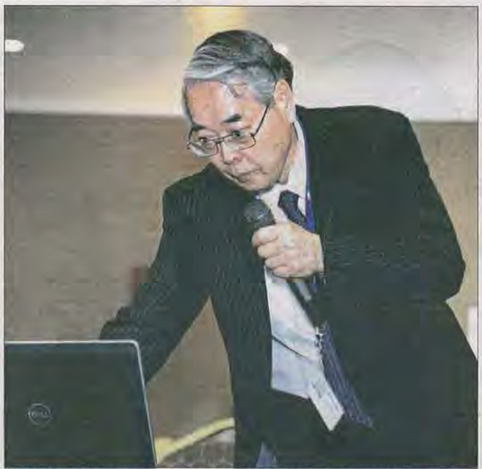
Tanaka and his colleagues, in partnership with PNG Power Ltd, made their presentation yesterday on the outcomes and findings in the course of the study.

Tanaka said the team had made recommendations which included the rehabilitation of power plants with poor fuel efficiency, development of large-scale hydro plants such as Ramu 2 and Mongi-Bulum, and construction of high-voltage transmission lines to deliver power generated in the western area to the east side major power-demand centre, Lae.

The National (MAR/09/2016)

news Post-Courier, Wednesday, March 9, 2016 www.postcourier.com.pg

Lae power plan on track



YUKAO Tanaka, team leader for the JICA study team during his presentation at the meeting yesterday.

Partners discuss progress

BY LEONNIE WAYANG

THE progress of the Ramu system power development master plan and the Lae area distribution network improvement plan were discussed yesterday by joint partners.

The Ramu master plan is to optimise power generation and system expansion between 2016 and 2030, and the Lae plan is to stabilise the power supply during the same period.

The partners which participated in the meeting were NEWJEC Inc, PNG Power Limited and the Petroleum and Energy Department.

The Japanese Government's aid group, Japanese International Corporation Agency (JICA), has provided financial assistance toward the project.

The JICA study team involved in the project is headed by Yukao Tanaka of NEWJEC Inc, and has commenced study in October, 2014.

The team recommended that in order to strengthen the power supply reliability in the Ramu System, power plants with poor fuel efficiency should be replaced or rehabilitated.

In addition, they recommend that some existing hydro-power plants should be refurbished or rehabilitated as short-term countermeasures to increase supply capacity. "For long-term measures, it is recommended to develop a large scale hydropower plants such as Ramu 2 and Mongi-Bulum.

These will result in developing power plants that utilising the natural resources of Papua New Guinea, and to construct high voltage transmission lines to deliver power generated in the western area to the east side of major power demand in Lae city."

In the Lae distribution network, the JICA study team recommend as a short-term measure to introduce a new system called the sequential switching system (SSS).

"The installation of SSS will enable to shorten the time of power failure as it can automatically detect the fault section and the power supply can be restored to the area where the distribution line is still in good condition.

"While for the long-term measure, the distribution expansion plan was formulated to cope with the power demand at the time of the year 2030."

The JICA team will complete their work in Lae by July for capacity-building of the distribution to the engineers for planning, designing and operation of distribution of the network. The meeting was to outline the progress report No 3 and undertake discussion on the future draft policy study of the project.

At a glance

POWER EXPANSION: The Ramu power system master plan is to optimise the power generation and system expansion between 2016 and 2030 and the Lae plan is to stabilise the power supply during the same period to meet the electricity demand.

JICA pleased with agencies input

THE Japanese International Co-operation Agency (JICA) chief representative Takashi Toyama has commended the work of agencies involved in developing the Ramu system power development master plan and the Lae area distribution network improvement plan.

At the fourth joint co-ordinating committee meeting held yesterday to assess the progress of the project, Mr Toyama praised the excellent achievements carried out so far to develop the master plan.

"I am sincerely grateful for each member of the team for your collaborative efforts that will contribute to shape, both physically and economically, a brighter Papua New Guinea through improving reliability of the Ramu System as a whole.

"I am sure the master plan enables the system to bring adequate light and energy to accommodate the increasing demand in Lae city as well as the province," said Mr Toyama.

Mr Toyama said he believed the master plan will guide the project efficiently and effectively upgrade and expand the existing Ramu system in Lae area to accommodate future demands.

He said he is also confident that the system will be able to provide a much more stable and reliable power supply in the Lae city area.

He said also that the agencies involved in the project have also identified a possible way of reducing the frequency of blackouts and its length in Lae.

Post Courier (MAR/09/2016)

CHAPTER 2

PRESENT STATE OF THE POWER SECTOR

CHAPTER 2 PRESENT STATE OF THE POWER SECTOR

2.1 PRESENT STATE OF THE POWER POLICY IN PNG

2.1.1 PNG National Plan

The PNG National Plan is based on a Policy to achieve the Governments goals of equity and efficiency in the supply of electricity and thus assist efforts to attain the overarching development goals of PNG.

Regarding the power development plan, the goals are defined as follows;

- The goal of equity requires an electricity industry that provides affordable power to as many citizens as possible.

- The goal of efficiency requires the supply of electricity in PNG in the most reliable, cost-effective and expeditious manner, to enhance affordability for low-income consumers and reduce costs for business using electricity as an input.

Accordingly, broad-based economic growth is encouraged to improve living standards at grassroots level in PNG.
Three strategic objectives of the Government are addressed to achieve the goal mentioned above;

- Improving accessibility to electricity;
  - Increasing the provision of electricity will help reduce poverty, partly because the lack of access to electricity is a dimension of poverty in its own right.
  - Access to electricity has urban and rural elements, both of which are addressed through this Policy.
  - The Government's intention through this Policy and the PNG Development Strategic Plan (DSP) 2010-2030 is to increase the share of the population with access to electricity to at least 70% by 2030.

- Improving reliability of the electricity supply;
  - Along with affordability and access, reliability is critical in facilitating an environment conducive to economic activity.
  - Improving reliability can thus be expected to pay significant dividends indirectly in terms of national economic growth.

- Ensuring that power is affordable for consumers.
  - It is necessary to take into account low ability to pay amongst large sections of the population.
  - There is an essential need to decrease costs in electricity supply operations by power companies by boosting efficiency.
  - It is the intention of this Policy to address problems of inefficiency and high service delivery costs in making electricity supplies affordable for all citizens and consumers of electricity in PNG.

2.1.2 Energy Policies

Energy policies of PNG comprise, a) The Oil and Gas Act 1998, b) The Oil and Gas Regulation 2002. There are also other supporting national legislations such as, c) The Environmental Act 2000, d) The Environmental Regulation 2002, e) Institutional Health, Safety and Welfare Act 1975, f) Marine Pollution (Bill) Act, g) Physical Planning 1989, h) Lands Act 1996, i) Land Disputes Settlement Act (Chapter 45), j) Companies Act 1997, k) Income Tax Act 1959, l) Organic Law on Provincial and Local Level Government (LLG), m) Public Finance Management Act 1995 and, n) Arbitration Act.

(1) The Oil and Gas Act 1998

The Oil and Gas Act 1998 (OGA) provides that ownership of petroleum (both oil and natural gas) at or below the surface of any land is vested in the State of PNG. The right to search for and recover petroleum is obtained by granting various titles and approvals from the relevant Government authorities.

The Department of DPE is responsible for regulating oil and natural gas development. The Minister of Petroleum and Energy (the Minister) performs a number of functions under the OGA.

The outstanding features of the OGA in PNG compared with other counties are as follows;

i) A licensing regime is adopted instead of a production sharing contact (PSC), which is the default global standard elsewhere (please refer to Section 3.1.3 (5) Status of gas contracts in PNG).

ii) Stakeholders in a petroleum project in PNG are the State, the developer and landowners though the landowners are usually excluded in other countries.

The participation of landowners seems to become rather complicated to proceed with the development of petroleum in PNG (please refer to 6) of this section.

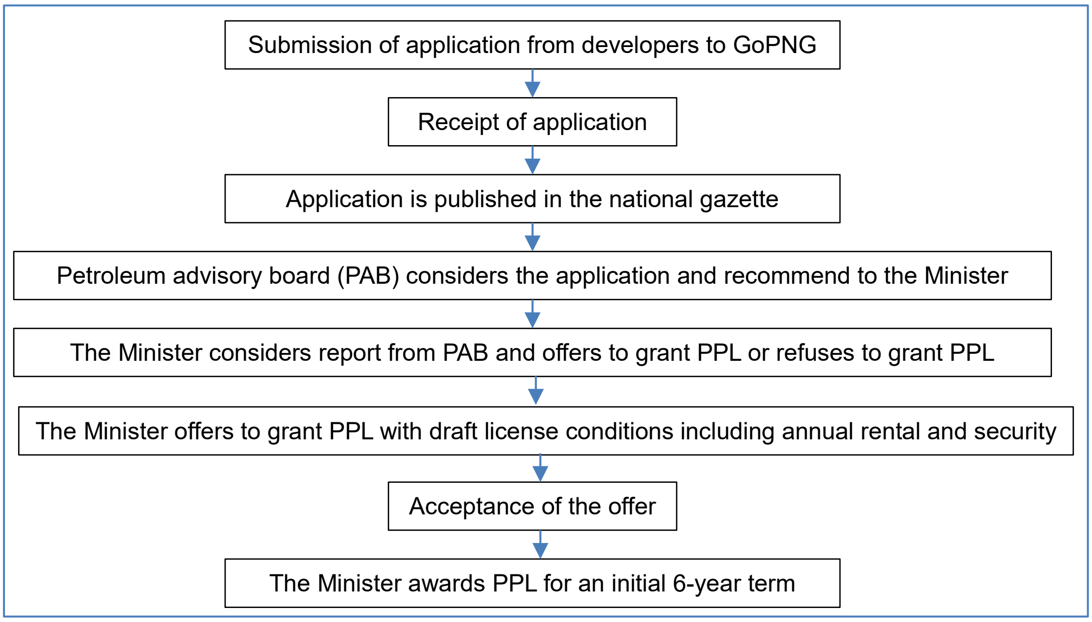
1) Petroleum Licenses

OGA provides five types of licenses as follows;

No.	Name of License	Content
1	Petroleum Prospecting License(PePL)	Exploration, 6-year term, followed by a 5-year extension term with reduction of 50% acreage.
2	Petroleum Retention License (PRL)	If the discovery is uneconomical, a retention license can be applied for. The term is 5-years plus two 5-year extensions.
3	Petroleum Development License (PDL)	Development, 25-year term plus normally 2-year or further 20-year extension reasonably required to maximize petroleum recovery.
4	Petroleum Pipeline License(PL)	25-year term plus normally a 20-year extension or less based on Ministerial opinion.
5	Petroleum Processing Facilities License (PPFL)	License would remain until canceled by the Minister under section 137 of the OGA.

2) Application and Awards Process

The flow from application to award of PPL is as follows.



3) Status of Licenses as of November 30, 2014

The recent status of licenses is summarized in Table 2.1-1.

Table 2.1-1 Status of Licenses as of November 30, 2014

Kind of License	Number
Petroleum Development License (PDL)	9
Application for PDL (APDL)	2
Petroleum Retention License (PRL)	10
Application for PRL (APRL)	1
Petroleum Prospecting License (PePL)	72
Application for PPL (APePL)	49
Petroleum Processing Facilities License (PPFL)	2
Application for PPFL (APPFL)	1
Pipeline License (PLL)	8
Application for PLL (APLL)	2

Note: From the time of this latest update to date, although the numbers have changed, confirmation for these numbers is pending from the Petroleum Registers and Master Files, which have yet to be updated.

Source: DPE

4) Benefits from Petroleum Projects

- State through Internal Revenue Committee (IRC) collects income tax.
- State has the option to acquire up to 22.5% equity in any petroleum project.
- 20.5% of this equity is taken up by the State Nominee e.g. Petromin Holding Ltd and/or Kumul Petroleum Holdings (KPH).
- 2% of this equity is given to Land Owners (L/Os) and affected LLGs in the project and managed by a trustee-Mineral Resources Development Corporation (MRDC).

- 2% of royalties are payable to affected L/Os, LLGs and Provincial Government in proportions agreed by themselves in a development forum.

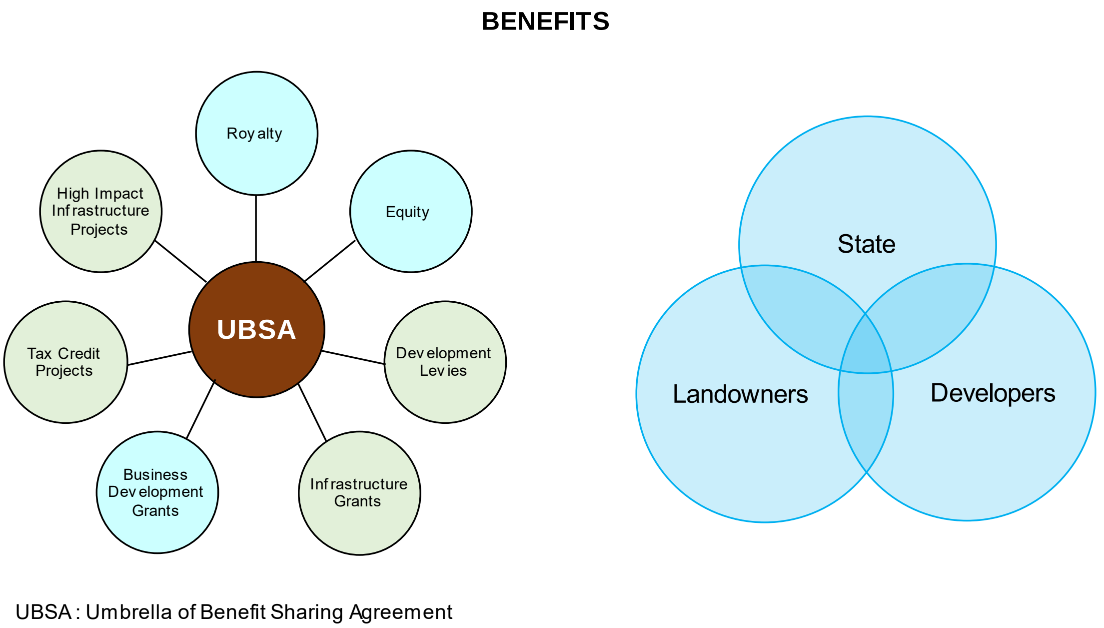
- Development Levies are payable to affected Provincial Governments.

- Business Development Grants (BDGs) are given to L/Os for business opportunities.

- Tax Credit Schemes for infrastructure projects in the project impact areas. The Project Developer establishes such infrastructure and then income is treated as income tax paid to the State.

5) Key Stakeholders in a Petroleum Project

The key stakeholders in a Petroleum Project are the State, the developer and the landowners. Each stakeholder receives benefits under the Umbrella of Benefit Sharing Agreements (UBSA) as illustrated in Fig. 2.1-1.



Source: The National Nov. 28, 2014.

Fig. 2.1-1 Benefits of Stakeholders under UBSA

6) Procedure for Landowners to receive Benefits

There are two steps for landowners to receive benefits, with the procedure relatively controversial and time-consuming.

a) Prior to signing a PDL between the Minister and developer, the Minister signs the Benefit Sharing Agreement with landowners. Landowners come from the project area, pipeline route, buffer zone and storage & loading facilities. It is not easy to conclude the agreement because there are many landowners involved who have different opinions and/or objections based on their interests.

b) On the occasion of project completion, the landowners can receive the benefits after the

Registration of Incorporated Land Groupings (ILGs). However in case of the PNG LNG project, despite the start of the exportation of the first gas from the project in May 2014, landowners have not received any benefits due to the delay of ILGs as of November 2014.

(2) The Oil and Gas Regulation 2002

It is a major complementary registration of the OGA 1998 on providing specific or detailed versions of approaches and procedures to proceed with the Act.

In Part II Administration, the roles and responsibilities between the Director Government of PNG (GoPNG) and Person-in-Charge (Operator) are stipulated on exploring oil and gas fields. Outstanding items include a) entry onto private land and b) protection of public utilities and existing pipelines.

Part III stipulates requirements for safe measures such as a) contaminated atmosphere, b) fire-fighting equipment, c) personal protective equipment, d) noise level, e) venting of flammable vapors and procedure manuals for the safe operation, etc.

Division 2 of Part III describes requirements for safe measures for offshore such as a) rescue craft, b) life jackets and buoyancy vests, c) records of arrivals and departures, d) storage of dangerous substances, etc.

Part IV stipulates electrical installation procedures in hazardous areas such as electrical wiring, earthing, lightning, generators and motors, etc.

Part V includes submission of manuals on storage, transportation and handling, etc., of explosives to the Director prior to an operator commencing geophysical or geological operational programs.

In Part VI, exploration procedures are stipulated such as a) notice of intended surveys, b) seismic operations, c) operations on roads and in inhabited areas and d) submission of data, etc.

Division 2 of Part VI describes offshore exploration mainly on offshore seismic surveys.

Part VII stipulates procedures on a) drilling, b) completion, c) recompletion, d) side track, e) major repairs and f) abandonment of wells.

Division 2 of Part VII stipulates operational requirements for a) equipment, b) pressure testing of casing strings and disposal of produced oil and gas by vented storage tank with flares on site, etc.

Division 3 of Part VII stipulates safety in drilling and workover operations, such as a) blowout prevention and b) well testing, etc.

Division 4 of Part VII stipulates requirements for rigs and associated equipment such as a) derrick and mast platform and b) safety valves and pumps, etc.

Division 5 of Part VII stipulates requirements for offshore operation, such as a) offshore drilling program, b) offshore blowout prevention, c) disposal of drilling fluid offshore and d) abandonment of offshore wells and platforms, etc.

Division 6 of Part V II stipulates requirements of air drilling such as a) delivery lines, b) fire precautions, c) sitting on compressor, c) bleed-off line and d) gas detection equipment, etc.

Division 7 of Part VII stipulates special services provided by a contractor other than the drilling contractor such as a) logging, b) formation testing and c) formation stimulation, etc.

Part VIII stipulates production requirements such as a) identification of wells and production facilities, b) applications for approval, c) measurement of production for royalty purposes, d) monitors, control mechanisms and safety devices, e) initial production tests, f) monthly production reports, g) annual production reports, etc.

Part IX, requirements for marine facilities such as a) mobile platform approval, b) application for consent to construct or install a fixed platform, c) certificate of verification of design, construction and installation of a fixed platform, d) inspections on a fixed platform, e) warning lights and sound signals, f) communication equipment and progress report of construction and installation, etc.

Part X, requirements for pipelines such as a) compliance with codes, b) construction and operational reporting, c) commissioning of pipelines and d) leakage of substances from pipelines, etc.

Part XI, reporting requirements such as a) submission of data, b) daily reports and c) well completion reports, etc.

Part XII stipulates penalties.

(3) The Environmental Act 2000

It provides specific regulatory instruments for environmental protection within the oil and gas industry. This includes Environmental Management Plans outlining impacts and measures from petroleum development activities such as exploration, petroleum facility construction, hydrocarbon waste discharges and disposals and general environmental disturbances. It also sets out requirements for environmental permits, environmental policies, environmental monitoring, reporting and non-compliance orders.

The Environmental Act requires that an Environmental Impact Assessment (EIA) shall be undertaken prior to issuing an environmental permit. The EIA is required to set out the “physical and social environmental impacts” likely to result from the proposed activities.

The application for an environmental permit must include details of the proposed activities which are consistent with EIA and any conditions required by the Minster. The Director may also impose conditions when granting the environmental permit.

(4) The Environmental Regulation 2002

It provides specific details of compliance approaches required to comply with the requirements of individual instruments as stipulated in the Environmental Act.

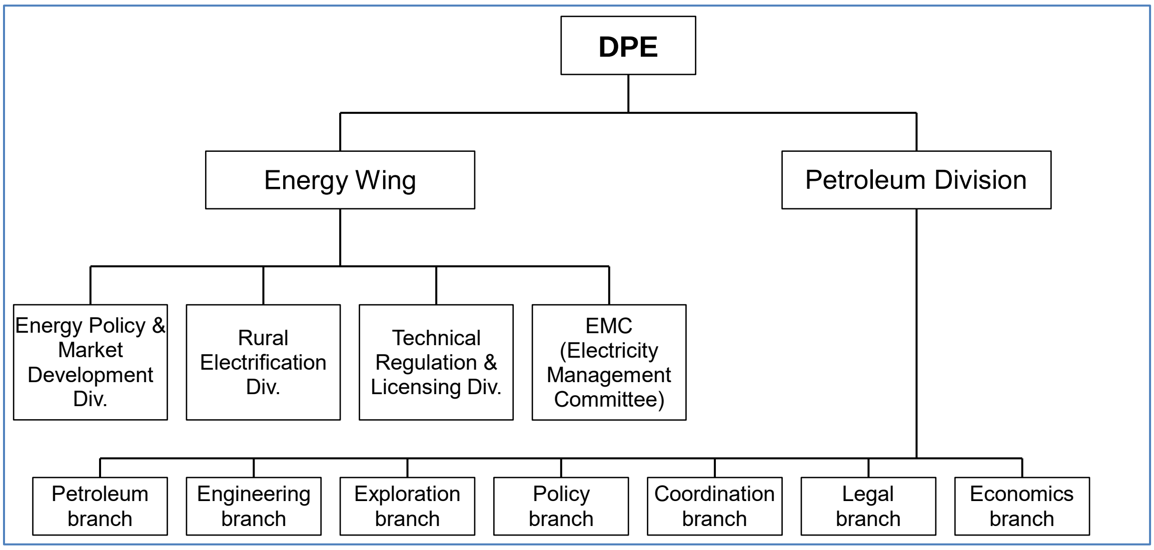
It includes a) drilling of gas and gas wells, b) manufacture of products by any chemical process in works designed to produce more than 100 tons per year of chemical products, c) manufacturing of organic chemicals requiring a petroleum processing facility license issued under the OGA , d) pipeline transport and storage using facilities capable of holding more than 0.5 million liters, e) recovery, processing, storage or transportation of petroleum products requiring the issue of a PDL or a pipeline license under the OGA and f) refining of petroleum and processing of petrochemical or liquefaction of natural gas requiring a petroleum processing facility license issued under the OGA, etc.

2.2 PRESENT STATE OF THE ENERGY SECTOR AND POWER SECTOR

2.2.1 Energy Sector Structure

(1) Structure of the DPE

The present structure of the DPE is shown in Fig. 2.2-1.



Source: DPE.

Fig. 2.2-1 Structure of DPE

(2) Gas Project Coordination Office

The PNG LNG project is the first huge project in PNG. Since many State departments and agencies were involved in this project, a Gas Project Coordination Office was set up to coordinate the activities of State departments and agencies.

The State departments and agencies involved and their roles and responsibilities are as follows

a) DPE is tasked under the OGA with screening and approving all licenses.

b) CEPA[1] is tasked under the Environmental Act with screening and approving environmental impact study reports of project operators and issuing relevant permits.

c) DT[2] is mandated to ensure all fiscal and financial requirements are in place to enable project sanctioning.

d) DJA[3] General through the State Solicitor's Office is mandated to ensure all project agreements, licenses, permits, including fiscal and financial instruments entered into between the State and project operator, are legally in order.

e) DLPP[4] is tasked under the Land Act with ensuring all land required to accommodate the

1 Conservation of Environment and Protection Authority
2 Department of Treasury
3 Department of Justice and Attorney
4 Department of Lands and Physical Planning

development of national gas projects is secured and available.

In addition, there are a number of the State departments and agencies who play key roles at different stages to ensure the State delivers on its milestone to achieve project sanctioning.

These include PNG Customer Office for matters relating to duties and levies, Taxation Office under IRC[5] for tax matters. The DFA[6] for matters relating to visas and entry permits. The State nominee companies like MRDC, Petromin Holdings Limited and Kumul Petroleum Holdings for matters relating to equity.

Due to the involvement of multiple the State departments and agencies, effective coordination to deliver on key state milestones is cumbersome at times. This is where the Gas Project Coordination Office steps in to assist in coordinating the State inputs.

2.2.2 Power Sector Structure

(1) Organizational structure of the power sector

The power sector organization in PNG is as shown in Fig. 2.2-2. PPL was established in December, 2001 by assuming the employees, debts and assets from the PNG Electricity Commission (ELCOM). Kumul Consolidated Holdings (KCH) established in 2002 owns 100% of PPLs shares.

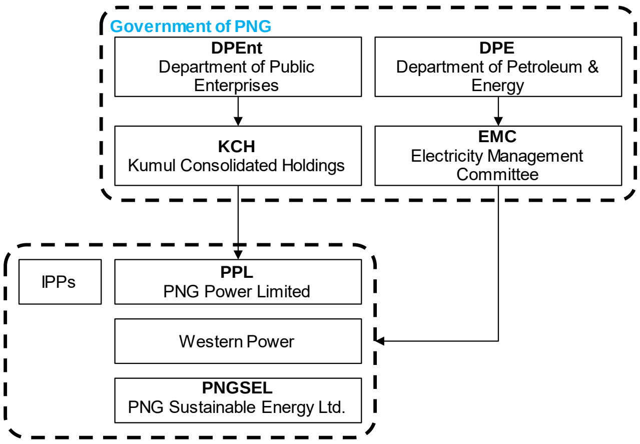


Fig. 2.2-2 Organizational Structure of Power Sector

KCH is under the jurisdiction of Department of Public Enterprises (DPEnt) and DPE is a technical regulatory organization. Further, since 2012, PPL has been under the control of the Electricity Management Committee (EMC), which is the supervisory organization for implementing the nationwide electrification expansion plan.

Power suppliers other than PPL include Western Power supplying power to the Western Province, PNG Sustainable Energy Limited (PNGSEL) and Independent Power Producers (IPPs).

(2) Structure and organization of PPL Headquarters

PPL Headquarters is located in Boroko District of POM, carrying about 1,400 permanent employees. The organization of PPL Headquarters is shown in Fig. 2.2-3 and the brief respective roles of departments are shown in Table 2.2-1.

5 Internal Revenue Commission
6 Department of Foreign Affairs

Source: PPL

Fig. 2.2-3 Organization of PPL Headquarters

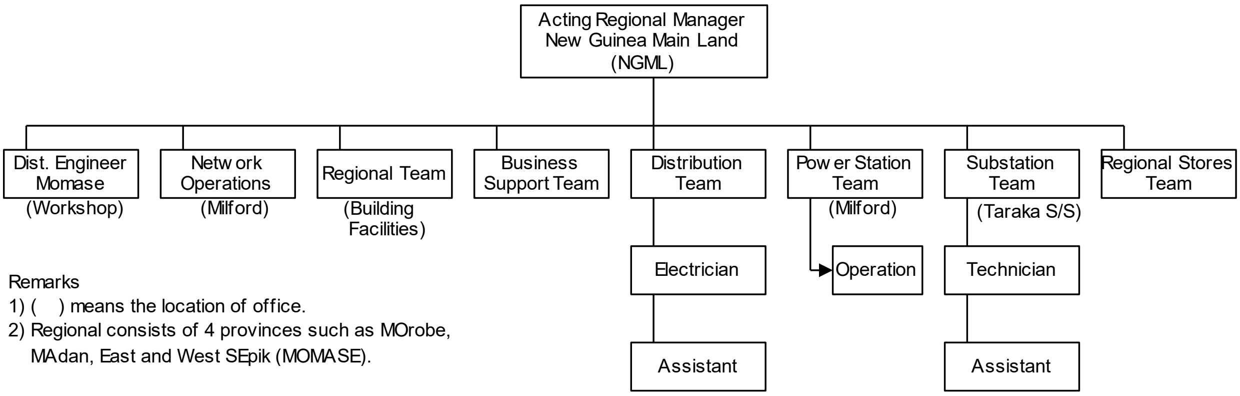
Table 2.2-1 Role of Department of PPL Headquarters

Department	Role of organization
-Strategy and Business Development	Corporate planning, managing the Regulatory contract, tariff and pricing submissions, power purchase and power supply agreements with independent power producers and major customers and the marketing of PPL .
-Finance	Financial planning, finance control, information technology and purchasing.
-General Counsel	Overseeing the internal Audit, Legal Service and Investigation and Protective Services.
-Human Resources	HR strategic planning, development and management in Areas of Workforce Planning, Leadership and Skills development, staff retention, HR polices and processes and services.
-Corporate Services	Corporate Services, Internal Audit, Legal Services, Plant & Fleet, Public Relations, Regulatory Services, Asset Security, Accommodation, Land Administration and Community Services.
-Operation	All aspects of PPLs engineering planning, design, construction, installation, testing and commissioning of generating plant and associated equipment, substation equipment and transmission lines(T/L), distribution network and regulatory services.
-Operating and Maintenance	Operating and maintaining generation, transmission, distribution and branch facilities.
-Performance Engineering	Developing maintenance plans for generation, transmission and distribution assets.
-System Operations	Safe and efficient management of the PPL power systems, particularly POM, Ramu and Gazelle systems.
-Asset Development	All Capital Works programs in generation, transmission, distribution projects.

Source: PPL

(3) Power Sector Structure of the Lae Regional Office of PPL

The Lae Regional Office of PPL is located in the center of Lae City and is the largest regional office of PPL with around 120 staff. Most of the staff oversee work related to Morobe Province, but some of the team handle the maintenance management of power facilities in other provinces, too. The organization of the Lae Regional Office is shown in Fig. 2.2-4.



Source: PPL

Fig. 2.2-4 Organization of the Lae Regional Office of PPL

Table 2.2-2 Role of the Main Team of the Lae Regional Office

Organization	Role of organization
Network Operation	In charge of Ramu system operation utilizing the Supervisory Control And Data Acquisition (SCADA system).
Regional	In charge of assets such as building facilities for 14-towers, such as Lae, Finschhafen, Wau, Madang, Goroka, Kundiawa, MT. Hagen, Mendi, Wabag, Angoram, Wewak, Maprik, Aitape and Vanimo.
Distribution	In charge of distribution facility assets, mainly Lae area network system etc.
Power Station	In charge of assets such as Taraka, Milford etc.
Substation	In charge of 9-S/S such as Taraka, Milford, Nadzab, Erap, Hiden Valley, Baiune-1/2, Meiro (Madang), Yonki (Ramu), Gusap & Dobel (Mount Hargen).

2.2.3 Power Development Plan

According to the "FIFTEEN YEAR POWER DEVELOPMENT PLAN (FYPDP)"(2014~2018), the policy for power supply is providing the a reliable electricity service and in doing so promoting a profitable, professional and growing company while contributing to the development and wellbeing of our present and future customers.

To enhance the economic and social development of Papua New Guinea through leading the development and expansion of electricity supply throughout the nation.

For achieving the above policy, the actual object of FYPDP etc. is as follows.

(1) Object of FYPDP

The main objective of this planning document is to capture the developments of the Electricity Supply Industry based on the National and Provincial Development Plans.

FYPDP aims to develop and utilize internal renewable energy sources to meet national electricity needs in line with the Electricity Industry Policy and the draft Rural Electrification Policy.

(2) Electrification Rate, SMEs and Possible Strategies to Increase the Electrification Rate

The Government's target is for 70% of the population to have electricity by 2030, which will require a comprehensive and coordinated development approach, namely

- Intensive programs; on business planning, accounting and running business
- An intensive program on agriculture extensions and farming, i.e. chicken, piggery, etc.
- Introducing cottage industries, i.e. clothing, food production including preservation methods, etc.
- Establishing markets, transport systems, storage systems, etc.

More training facilities to teach technical trade skills in rural areas targeted at rural living and rural services.

PPL will assist the Government in extending electricity services to rural areas and offers cheap technology allowing ordinary citizens access to electricity (Minimum Supply Kit and Easipay).

With Government help, PPL will investigate localized renewable and cheap power sources, including small and mini-hydro, biomass, solar, wind, etc.

(3) Ramu system

FYPDP includes the PNG Power program to meet increasing electricity demand in Ramu System and others.

Regarding the Ramu system, it has hydro stations at Ramu (5 × 15MW) and Pauanda (2 × 6MW) and serves Lae, Madang, Goroka, Mount Hagen, Kainantu, Kundiawa, Yonki, Mendi and Wabag. Diesel generators at Lae, Madang, Goroka, Kundiawa, Mendi and Wabag, Kundiawa and Goroka: supply supplementary energy during T/L outages. Power is also purchased from the privately owned Baiune Hydropower Station as required and varies between 9 to 10 MW depending on availability.

Three radial lines originating from the Ramu Hydropower Station switchyard serve Lae, Madang and the Highlands Centers. Currently Madang and the Highlands Region are supplied at 66kV and Lae at 132kV. The Highlands line, interconnected with Pauanda hydro station, supplies the townships of Kainantu, Goroka, Kundiawa, Mt Hagen, Wabag and Mendi.

1) Demand Forecast

As the demand forecast utilized for FYPDP, the demand forecasting framework uses data from the actual historical data.

For generation, transmission and distribution planning in the Ramu system, a more aggressive load forecast is used, further emphasizing the experiences of the past five years.

2) Power Development Plan

a) Generation Planning

The development of hydro-based power remains a high priority wherever economically and financially justified.

Hydro generation is a prominent feature in this FYPDP, due to the high operating and maintenance costs of diesel sets. The high costs are due to costly fossil fuels and the decline in the value of the Kina against major currencies.

Due to the difficult financial position of PLL, a “general prospectus” to develop renewable energy sources has been prepared. This “prospectus” will be distributed in due course or upon request to prospective donor governments or their agencies.

Installing new thermal units is still required to meet the forecast load growths and replace aging generating sets.

b) Transmission Planning

The fifteen-year transmission system development plans for the Ramu system provides a framework to develop existing systems to improve performance and reliability. The plans are based on projected load growth and the ability of existing systems to service increasing loads.

c) Urban Distribution Planning

The fifteen-year distribution plan provides an indication of the number of line lengths to be built and additional transformer capacities required to meet future increases in demand in urban areas.

There will be a need to extend and expand existing power reticulation as demand for electricity grows and urban areas expand. This is particularly true for the Lae systems as tie-feeders between substations, which need to be upgraded to cater for load transfers.

3) Current Major Development Plan

To meet the demand for electricity, improve current reliability and power supply quality, PPL has secured means through the following identified impact project in the Ramu system.

a) Ramu transmission system reinforcement project

The main objective of this project is to reinforce the existing 132kV T/Lbetween the Ramu 1 Hydro Power Station and Taraka substation in Lae, Morobe Province to enhance the power supply reliability and stability of the Ramu grid as illustrated in Fig. 2.2-5

In addition, the implementation of the project is urgently needed, not only to reinforce the Ramu grid, but also to secure power supply reliability to Lae, where remarkable economic development is underway and ensure power supply capability for soaring mining demand.

Fig. 2.2-5 Ramu Transmission System Reinforcement Project Route

b) Ramu 1 Rehabilitation Project

This underground Hydropower Station with 75MW-installed capacity was the first power station constructed in the Ramu Hydro System and downstream of Yonki Dam reservoir (storage 226 million m^3, catchment area 810km^2).

The power station was constructed in 1973, with an additional generating plant added in 1989.

Due to aging and other generator de-rating factors, the 5 × 15MW can no longer generate at full capacity and the generation output has declined to 45MW.

This project aims to increase the current available capacity from 45 to 60MW. This increased output and improved reliability is essential to cater for the forecast demand growth in the Ramu system.

c) Ramu 2 Hydropower Project

A 240 MW Power station is being planned below the existing Ramu 1 Power station. This is the final station in the Ramu System cascade, utilizing the flow released from the Yonki Reservoir and already used in the Toe-of-dam and Ramu 1 power stations.

By mid-2014, the preliminary design will have been completed and KCH will be investigating the various business options available for the project to be constructed.

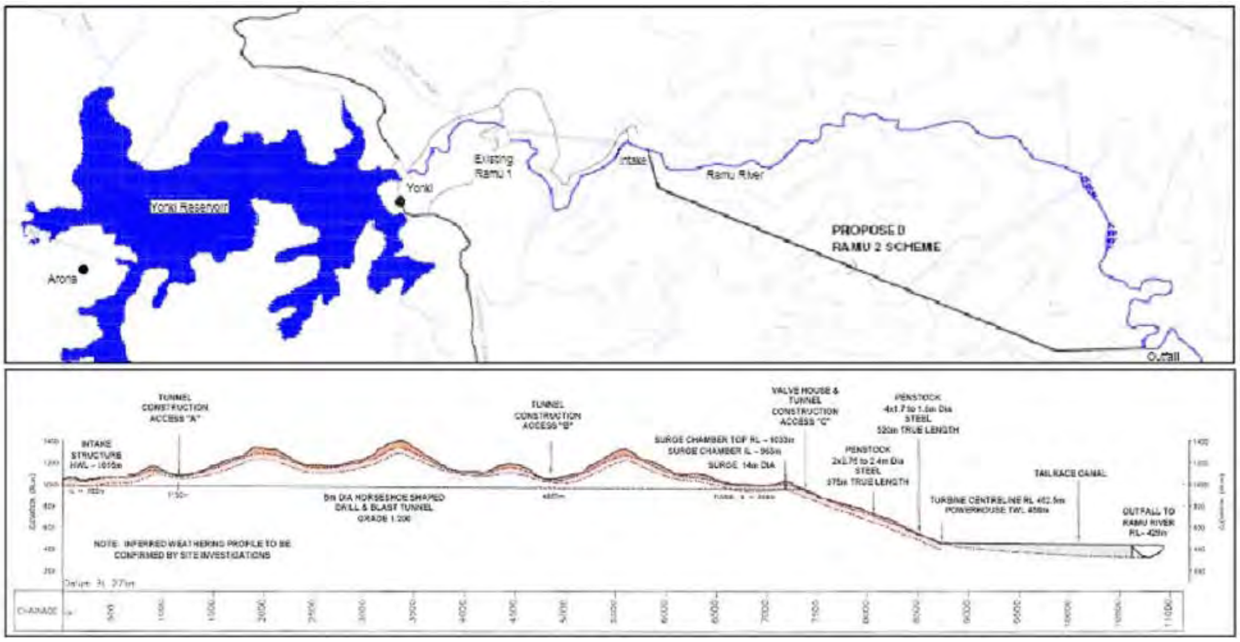


Fig. 2.2-6 Proposed Ramu 2 Hydro Power Station Layout

c) Power Infrastructure Plans

For the Ramu system, PPLs long-term power infrastructure plan includes;

- Encouraging IPPs, particularly in developing renewable energy sources (biomass in particular)
  - Markham valley (biomass)
- Investigations of hydro potentials;
  - Mongi/Bulum 120 MW hydro resource near Finschhafen, Morobe Province
  - Mini-hydro in Provinces
- Interconnection of POM and Ramu via a 275 kV T/L

2.2.4 Procurement of Fuel Oil

At present, PPL use diesel oil (light oil) to operate diesel generators. Heavy fuel oil (HFO) is not used mainly due to the environmental burden[7] though it is cheaper than diesel oil.

The POM Gas Supply Project is engaged in negotiation between the Kumul Petroleum Holdings and the MRDC to supply natural gas to the power industry (PPL, IPP) and the petrochemical industry. Accordingly, it is expected that PPL will be able to use natural gas instead of fuel oil in several thermal power stations.

(1) Fuel Oil Property

The fuel oil properties of diesel oil received by JICA Study Team in Taraka and Milford Diesel TPPs are shown in Table 2.2-3. The average heating value is 45.56 MJ/kg (10,800 kcal/kg).

7 There is another reason. Although HFO usually needs oil heating systems, particularly in highland areas, diesel oil does not require any such system. Therefore, the Operation and Maintenance (O&M) of diesel oil is easier than that of HFO.

Table 2.2-3 Fuel Oil Property

Test	Test Method	Unit	Min.	Max.	Result
Appearance	Visual/ASTM D4176 (P1)	-	C&B		C&B
Color, ASTM	ASTM D1500	Scale		2	L2.0
Acid Number, Strong	ASTM D664	mg KOH/g		Nil	Nil
Acid Number, Total	ASTM D664	mg KOH/g		0.25	0.02
Ash	ASTM D482	mass%		0.01	<0.001
Carbon Residue	ASTM D4530	mass%		0.20	<0.01
Cetane Index, Calculated	ASTM D4737		45		45.7
Cloud Point	ASTM D5773_ ASTM D2500 Equivalent	°C		+14	+6
Pour Point	ASTM 097	°C		+12	0
Copper Corrosion, 3 Hrs @100°C	ASTM D130	Grade		1	1a
Density @15°C	ASTM D4052	kg/L	0.8200	0.8700	0.8665
Distillation	ASTM D86				
90% Recovered	ASTM D86	°C		370.0	356.6
Flash Point, PMCC	ASTM D93	°C	61.5		63.5
Oxidation Stability	ASTM D2274*2	mg/L		25	-
Sulphur	ASTM D4294	mass%		0.05	0.0311
Water by Distillation	ASTM D95	vol%		0.05	<0.1
Sediment by Extraction	ASTM D473	Wt%		0.01	<0.01
Aromatics	IP 391*2	mass%		35	-
Kinematic Viscosity @40°C	ASTM D445	mm^2/s	1.900	5.000	2.818
Lubricity, (WS 1, 4) @60°C	IP 450*1	microns		460	366
Electrical Conductivity at Ambient Temp.	ASTM D2624	pS/m	50		560
Hydrogen Sulfide	IP 570*3	mg/kg		2.00	<0.60

Notes: *1 Excluded from the scope of NATA Accreditation
*2 Tested every tenth batch of tank preparation only
*3 Frequency test from Report No. 2013-MIS-033368-001, Dated 28 June, 2013, Singapore Universal Lab

Source: PPL

(2) Fuel Oil Price

Independent Consumer and Competition Commission (ICCC) announces the fuel oil prices for petrol, diesel and kerosene on the 7th day of every month, reflecting the range of values of each region. Fuel prices of POM, near the Napa Napa Refinery, are cheapest and the fuel oil price rises based on distance and accessibility. In general, fuel oil prices in highland and island areas are the highest. Table 2.2-4 shows the Indicative Retail Price Notice as of 7 October, 2014.

Table 2.2-4 Fuel Oil Prices (Toea[8]/litter)

Indicative Retail Prices Notice 7 October, 2014			
Center	Mogas (Petrol)	Diesel	Kerosene
POM (ex. Napa Napa)	352.80 - 355.97	297.78 - 300.95	289.42 - 292.59
Lae	359.23 - 361.77	304.94 - 307.48	296.27 - 298.81
Madang	360.38 - 361.30	306.10 - 307.02	297.43 - 298.35
Rabaul	358.26 - 361.51	303.97 - 307.23	295.30 - 298.56
Kokopo	363.24 - 367.56	308.96 - 313.28	300.29 - 304.61
Kimbe	359.64 - 365.36	305.36 - 311.08	296.69 - 302.41
Alotau	376.68 - 382.95	325.06 - 331.33	315.19 - 321.46
Wewak	- 373.03	- 320.43	- 310.99
Kavieng	412.77 - 417.27	365.36 - 369.86	353.66 - 358.16
Manus	- 459.26	- 419.98	- 405.25
Goroka	375.26 - 380.52	320.98 - 326.24	312.31 - 317.57
Mt. Hagen	394.58 - 397.26	340.30 - 342.98	331.63 - 334.31
Oro Bay	- 421.77	- 362.11	- 351.51
Kerema	- 402.98	- 347.96	- 339.60
Kundiawa	- 387.28	- 332.99	- 324.32
Mendi	- 403.32	- 349.04	- 340.37
Wabag	402.72 - 419.26	348.44 - 364.98	339.77 - 356.31
Vanimo	- 373.03	- 320.43	- 310.99

Note: Where a range is shown, this reflects the latest advice received for the freight charges applicable to these locations. Where the Commission has been advised of multiple freight rates, it has incorporated the rate into a range for the final retail price.

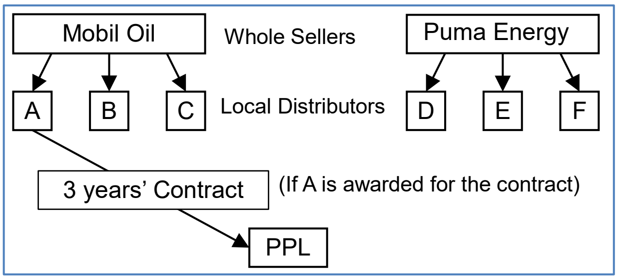
Source: PPL

(3) Fuel Oil Procurement Method

There are two whole sellers in PNG, i.e. Puma Energy[9] who own Napa Napa Refinery and Mobil Oil. Puma Energy basically sells wholesale domestic diesel oil to local distributors. Mobil oil sells wholesale domestic diesel oil or imported diesel oil to local distributors. Prices of domestic diesel oil and imported diesel oil are almost the same.

After the bidding, PPL contracts with successful local distributors for a three (3)-year period.

PPL is now considering the fact that fuel oil prices based on MOPS[10] are cheaper than fuel oil prices by ICCC, so, PPL apply to adopt MOPS's prices instead of ICCC's prices to the Minister of State-Owned Enterprise.



After receiving approval, PPL will conclude contracts based on MOPS's prices with successful local distributors with a two rather than three-year contract.

8 Toea = 0.01 Kina
9 Please refer to Section 3.1.3 (10) Napa Napa Refinery
10 MOPS is an acronym that stands for Mean of Platts Singapore, which is the average of a set of Singapore-based oil product price assessments published by Platts, a global energy, petrochemicals, metals and agriculture information provider and a division of McGraw Hill Financial. MOPS prices are FOB values, so PPL estimates fuel oil prices at MOPS + Transportation fee + Margin.

2.2.5 Rural Electrification

The rural electrification rate of PNG is currently around 15%, though official data shows a figure of around 12.4% as of 2009, based on the Demographic and Health Survey (DHS) report. These rates are calculated as "the number of electrified households by grid connection/the number of total households in PNG". Therefore, the actual rural electrification rate will increase slightly, due to off-grid and mini-grid rural electrification.

In 2009, grid electrification access of households in urban areas stood at 61.3% and 6.5% in rural areas. Over 95% of households in PNG were reportedly living in rural and remote areas.

With regard to access to modern cooking and lighting other than traditional biomass in 2009, estimated access to modern energy is based on household access to radios, given that radios need some basic form of modern energy (batteries and electricity) to operate. According to the DHS report, an estimated 29.4% of households in rural areas have access to radios, which roughly reflects the percentage of households with access to modern energy in rural areas. On the other hand, 63.9% of households in urban areas have access to radios, which roughly reflects the percentage of households with access to modern energy in urban areas.

The Government's intention, through the PNG DSP 2010-2030, is to increase the rural electrification rate to 70% by 2030 and it will progress toward achieving 100% rural electrification by 2050 in the PNG Vision 2050.

(1) Rural Electrification Activities in PNG

1) PPL Grid

PPL operates three separate grids. Two large grids, the POM system serving mainly the National Capital District and the large Ramu grid that extends into the highlands. PPL also operates the small Gazelle Peninsula grid; mainly powered by a 10 MW run-off-river hydro plant.

PPL has also recently been tasked with managing some small provincial centers (C-centers) and rural area grids because most of such facilities managed by provincial governments have deteriorated due to poor operation/maintenance.

PPL lacks the resources and capacity to be involved in directly helping rural populations with economic activities. However, with the Government's help, PPL will localize renewable and cheap power sources, including small and mini-hydro, biomass, solar and wind, etc.

Village electrification will be promoted as power lines are extended into rural areas and those adjacent to existing power lines. Standalone will be more focused in remote areas on renewable energy such as solar, wind and micro-hydro.

In early 2011, PPL agreed a USD 57.3 million power development loan from the Asian Development Bank (ADB). The aim of the project was to boost the power supply in provincial urban centers by replacing costly diesel power generation with sustainable renewable energy power generation.

The projects have to be implemented under the first tranche of funding include run-off-river Hydropower Plants in Northern Province and the Autonomous Region of Bougainville and 66-kV T/L in West New Britain.

The T/L provides access to about 1 MW of spare generation capacity from the Lake Hargy Hydropower Plant and allows connection of up to 3 MW of biomass-generated electricity from palm oil plantations.

2) Non-PPL Grid

PNG has many small- to medium-sized public and private grids (mini-grids) serving industrial and residential areas. On the other hand, GoPNG is now trying to accelerate the rural electrification rate by introducing the Electricity Industry Policy (EIP) intended to promote private-sector power generation.

a) C-centers

C-centers were established in the 1980s to electrify isolated rural areas. Initially managed by PPL, responsibilities for these centers and other tasks were then passed on to the Provinces, more specifically, to LLG Councils.

However, the transfer of responsibility for the rural electrification supply in rural areas to Provincial Government and LLG Councils saw C-centers deteriorate due to the lack of technical experiences and managerial skills at both provincial and local levels.

Some of the C-centers such as Finschafen, Samarai, Maprik and Titape are now taken care of by PPL. As for the remaining C-centers, GoPNG and DPE are now discussing how best to handle them.

What is the C-center?

In PNG, cities, towns and villages are categorized as follows;

1) A-center: Cities such as POM, Lae, Mt. Hargen, etc.
2) B-center: Large towns as provincial capitals such as Goroka, Rabul
3) C-center: Small towns and villages

C-centers are mostly un-electrified.

b) Captive Powers

In PNG, mines, plantations and other industries usually own captive power in their factories for production. Electricity is typically provided to the worker residences on their grounds as well as to the facility itself.

In addition, if the factories exert adverse impacts on the environment, such as noise, foul odor, dust scattering, well water shortages and river flooding, etc., the affected local people and local government have the right to receive free electricity as compensation from the factories. It is a kind of Community Service Obligations (CSOs).

c) IPP/PPP by Private Sector

GoPNG has begun the process of preparing EIP, which will focus on private-sector participation and competition, particularly in generation activities. EIP was adopted in December 2011, centering on efforts to attract the private sector to contribute to new power generation facilities, speed the shift toward cost-reflective pricing and transfer regulation of the sector to the DPE.

In May 2007, PNGSEL (now Western Power) was granted a license for electricity generation, distribution and supply activities in the Western Province.

An interesting feature of the PNGSEL plan involves installing solar power in about 120 isolated houses located far from the mini-grid. PNGSEL also plans to undertake a solar power project in Mbuduwan, Western Province, which will supply power to 200 dwellings, including schools, a health center, churches and family residential houses.

(2) Financial Sources for Rural Electrification

According to the "15-year Power Development Plan" by PPL, it is generally accepted that rural electrification is uneconomic in financial terms and will need to be subsidized.

Many projects can still proceed because funding is provided externally to PPL and the project is considered a socioeconomic infrastructure development rather than an economic investment. Such funding can originate from the following sources;

- National Government Budget Provision
- Provincial Government Budget Provision
- Elected National Leaders funding through Rural Action Program finance
- Aid Agency (JICA, The World Bank (WB), ADB, Church Mission, etc.)
- Major Potential Consumer (Mining, Plantation, Commercial Enterprise, etc.)

Under the recent Provisional Government reform, the emphasis has transferred to Provisional Government involvement. Several Provisional Government have accepted the challenge and made appropriate budget allocations for specific rural electrification projects. In some cases, the Provisional Government have retained direct control of these funds by constructing lines under contract with PPL adopting a supervisory and quality control role.

2.2.6 Activities of Donors

The PNG power sector is currently assisted by organizations such as the ADB, WB and European Investment Bank (EIB) as well as bilateral assistance from Japan and New Zealand. This section describes the assistance policies and projects of the ADB and WB.

(1) Asian Development Bank (ADB)

The ADB has just published its assistance policy document, Country Partnership Strategy (CPS) for 2016-2020, which basically inherits the policy set out in its predecessor, CPS2011-2015. CPSs have been planned to be in line with the PNG national development policy DSP2010-2030. DPS has set out an energy development goal for "all households to have access to a reliable and affordable energy supply and sufficient power to be generated and distributed to meet future energy requirements and demands" and also for rural development "for more than 60% of PNG's rural population to have access to electricity" as a 2030 target. ADB's CPS expands the assistance to the power sector along with transportation and communication; focusing on providing public services in rural areas, using renewable energy and utilizing private finance.

Table 2.2-5 Assistance Policy for the Power Sector in ADB's Country Partnership Strategy

	Government Sector Objectives	Sector Outcomes to which the ADB Contributes and Indicators	ADB Areas of Intervention
CPS 2011-2015	All households have access to a reliable and affordable energy supply and sufficient power is generated and distributed to meet future energy requirements and demands	- Improved conditions for commercial activity through consumption of reliable, sustainable and more affordable power supply in urban areas - 10% reduction in household expenditure on energy services from 2011 levels	- Construction of power generation to supply demand in provincial towns and the main grids - Provision of power and lighting services to unserved households
CPS 2016-2020	Improved access to a more reliable and affordable energy supply, including from renewable sources	- Sustainable and more affordable power supply in urban areas - 20 gigawatt-hours per annum additional hydro power generation in five provincial urban centers by 2020 (2014 baseline: 0) - Improved access and use of power supplies for households in rural areas - 20% of households have access to grid-connected electricity by 2020 (2014 baseline: 12%)	- Construction of power generation capacity to supply demand in provincial towns and main grids - Trial of innovative rural electrification delivery models - Support for increased private-sector investment in energy sector

Source: Country Partnership Strategy 2011-2015 and 2016-2020, ADB

The ADB projects in the power sector are described below.

Power Sector Development Plan (TA)

The current power sector policy of PNG, EIP, was drafted in 2007 and prescribes the power development to be undertaken by private initiative. At the same time, EIP states that the power development plan shall be formulated by the Department of Petroleum and Energy. Based on these provisions, GoPNG instructed the DPE to draft a master plan for the power sector.

This technical assistance (TA) project involves assisting the Energy Division of the Department of Petroleum and Energy (ED-DPE) as the Executing agency (EA) to formulate the Power Sector Development Plan.

TA Approval Date	May, 2007
TA Completion Date	June, 2009
Amount Utilized	$421,722.64

Improved Energy Access for Rural Communities (grant)

Most of the population is in rural areas and sparsely distributed in PNG, which compounds the difficulties of rural electrification. This project has PPL as EA, aiming to electrify villages by expanding T/L and improving the livelihood of villages utilizing the electricity. The project also strives to establish community-based civil works contracts for power line construction and to introduce pre-paid meters, as measures to counter the high cost of extending T/L.

Project Approval	April, 2012

Commencement (original)	January, 2012
Completion (original)	December, 2014
Budget Allocated	$5,000,000

Port Moresby Power Grid Development Project

The power system in the capital city, POM, is fed by more than half the existing national generation capacity and serves almost half of households using electricity. Steady economic development of the country fueled demand for electricity and increased the dependency on diesel-fuel generation. This situation is undesirable in view of the need to reduce consumption of imported fossil fuel and generation cost, limit any rise in electricity tariffs and provide energy security, which, in turn, underlines the importance of using renewable energy (mostly hydro) where domestically available. Also, the lack of reliability of the electricity supply, due to inadequate substation capacity, has become prominent.

This project aims to upgrade and rehabilitate hydro facilities (Rouna 1 and Sirinumu), upgrade distribution networks (expansion, extension and loss reduction) and substations (construct new substation, extend low voltage transmission and connections to substations), with KCH as EA and PPL as the Implementing Agency (IA).

Project Approval	February, 2011
Commencement (original)	January, 2013
Completion (original)	January, 2017
Budget Allocated	$5,000,000

Implementation of the Electricity Industry Policy (TA)

EIP, which came into effect in June, 2010, requires its specific implementation plan, the National Electrification Roll-Out Plan (EROP) to be realized. However, DPE, which was tasked with planning of the power sector, apparently lacks the necessary capacity. In this project, ADB will work alongside the WB to assist the DPE in formulating EROP according to EIP, build capacity and assist in identifying and implementing initial pilot projects.

Project Approval	December 2012
Budget Allocated	$1,000,000

(2) World Bank

The WB's assistance in the power sector in PNG slowed after Upper Ramu (Ramu 1) hydro in the 1970s and the Yonki Dam project in the 1980s. The Energy Sector Development Project in 2013, seems, in effect, to represent a resumption of full-scale assistance on the part of the WB in the PNG power sector.

The current assistance policy document of the WB is the Country Partnership Strategy for the Period FY2013 - 2016 (CPS13-16). Like the CPS of ADBs, CPS13-16 is based on DSP2010-2030 of GoPNG. CPS13-16 also reflects the evaluation results of the WB's own Country Assistance Strategy for the period FY08 to FY11 (CAS08-11). The power sector policy in CAS08-11 originally aimed to provide electricity in rural areas with renewable energy resources to reduce poverty and improve livelihoods. However, the GoPNG was not quite ready to cope with policy and the revision was necessary. The power sector assistance policy in CPS13-16 was drawn up upon the evaluation results and comprises two components as shown below;

Component 1 (Institution and Policy Development);
- Energy Policy Development (renewable energy and rural electrification)
- Institution and Strategy Development (socio-environmental consideration, rural electrification)
- Capacity Building of GoPNG (Power Planning and Project Management)

Component 2 (Hydro Planning Technical Assistance);
- Preparation of the Naoro-Brown hydro project
- Improvement of hydro planning in POM (3 basin inventory study, institutional development)

2.3 REFORM OF THE ENERGY SECTOR

(1) DPE

DPE has been working to convert the Department into the Petroleum and Energy Authority. In 2013, National Executive Council (NEC) approved the establishment of the Petroleum and Energy Authority and also approved funding of Kina 2.5 million under the technical assistance program for the project.

A secretariat was appointed by the Secretary of DPE soon after the NEC decision to take over the project and has since worked on all administrative tasks to engage consultants who will be directly involved in providing advice and guidance and undertake specific tasks in the authority's work program.

A total of Kina 5.39 million was appropriate to procure relevant expertise and goods and services to undertake preparatory work toward realizing the project.

The short listing and selection process, including the overall work program, were delayed given the virtual lack of any funds to carry out the tasks.

DPE will continue to push for funds to be budgeted for the project by Government to assist in implementing the project work programs.

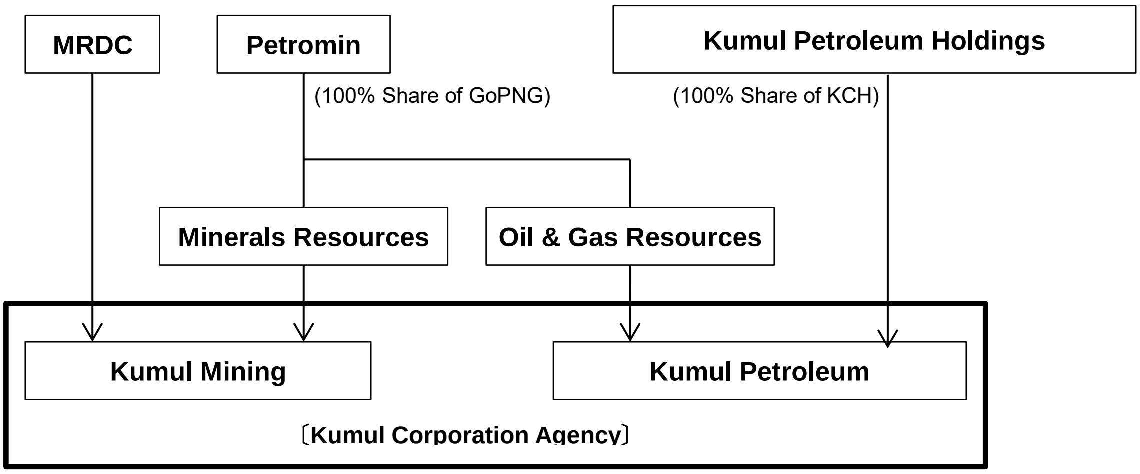
If DPE is converted into a Petroleum and Energy Authority, the Governmental office (DPE) will change to a State-Owned Enterprise (Authority). While at present, DPE receives an annual budget from the Government, the Authority can make money by business and investment and can pay tax to the Government based on profit earned.

(2) State Nominee Companies

As explained in Section 2.1.2 (1) 4), the State has an option to acquire up to 22.5% equity in any petroleum project. 20.5% of this equity is taken up by the State Nominee, e.g. Petromin Holding Ltd which is a 100% share of GoPNG and/or KPH which is a subsidy of KCH, while 2% of this equity is managed by the MRDC. Petromin Holding Ltd is also a State Nominee of the mining project.

To simplify the roles and responsibilities of these Government-related firms in the petroleum and mining projects, the Government is now considering system reform as described in Fig. 2.3-1.

Petromin Holding Ltd, Kumul Petroleum Holdings and MRDC are integrated and divided into Kumul Mining and Kumul Petroleum.



Source: DPE.

Fig. 2.3-1 Reform of State Nominee Companies

CHAPTER 3

PRIMARY ENERGY

CHAPTER 3 PRIMARY ENERGY

3.1 STATUS OF PRIMARY ENERGY IN PNG

3.1.1 Overview

PNG has abundant energy resources, particularly Hydropower and natural gas. The Hydropower potential including the 9 main river basins is estimated to be 20 GW.

Proven oil reserves total 70 Billion bbl (barrels)[1] and proven gas reserves total 15.6 TCF (trillion cubic feet), mainly from onshore oil/gas fields. While oil production is declining, gas production is soaring year by year. Gas has become the country's most important source of export revenues via supply to Asian countries, including Japan, as LNG.

The coal reserve in PNG has not been identified so far. With regard to renewable energy, PNG has abundant potential for geothermal, solar, biomass, wind[2], etc.

Table 3.1-1 Energy Resources in PNG

Resource	Reserve
Hydropower	20 GW (Potential)
Crude Oil	70 Billion bbl (Proven)
Natural Gas	15.6 TCF (Proven)
Coal	No information
Geothermal	21.92 TWh/year
Solar	160-200 Wh/cm^2 (yearly)
Wind	Under research by WB

Source: Hydropower: IRENA (Pacific Lighthouse 2013),
Oil & Natural Gas: ADB Energy Statistics (2013)
Geothermal: GEA (Geothermal Energy Association) of PNG,
Solar: Climate of Papua New Guinea by J.R. McAlpine, etc.

Fig. 3.1-1 shows the energy supply and demand balance as of 2009 according to energy statistics published by ADB in Asia and the Pacific (1990-2009) in October 2013.

The primary energy production (excluding non-commercial energy such as fuel wood) in PNG was 2,749 ktoe (kilo tons of oil equivalent). The breakdown was as follows: crude oil, 2,018 ktoe (73.4%); natural gas, 338 ktoe (12.3%); hydropower, 73 ktoe (2.7%); and geothermal, 320 ktoe (11.6%).

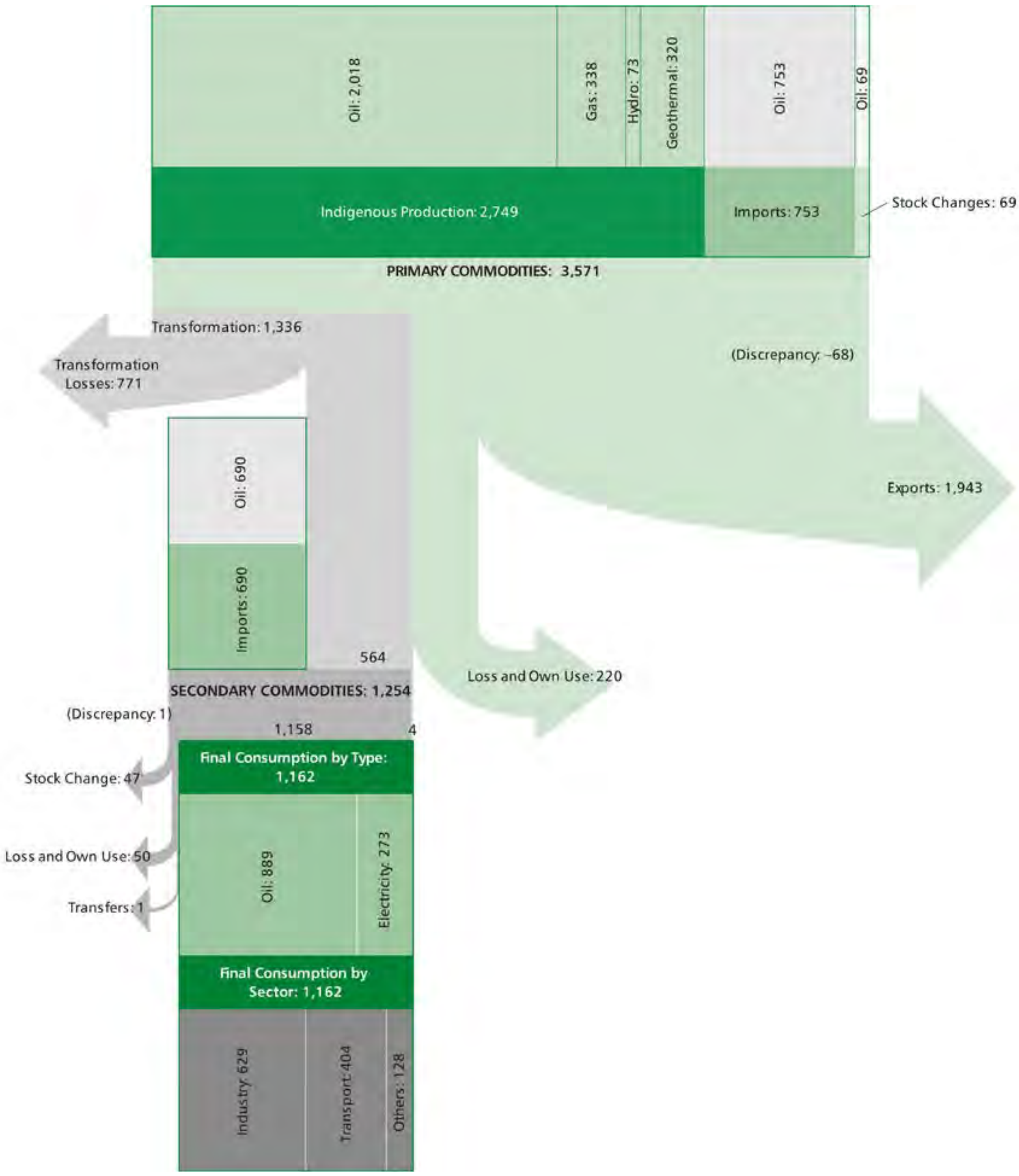
Oil imports in PNG (753 ktoe) accounted for 27.4% of total primary energy production (2,749 ktoe). As a result, total energy supply in 2009 was 3,571 ktoe, including the stock changes (69 ktoe).

On the other hand, energy exports of PNG totaled 1,943 ktoe and the final domestic energy consumption in 2009 was 1,162 ktoe, excluding loss, own use, and stock change.

Final consumption by type was as follows; oil was 889 ktoe (76.5%) and electricity was 273 ktoe

1 The figures in other literature are smaller than the figures in the ADB data.
2 There has been no known monitoring data since 1990s. The WB has implemented a wind mapping study in PNG since 2014.

(23.5%). Final consumption by sector was as follows; industry, 630 ktoe (54.2%); transport, 404 ktoe (34.8%); and other, 128 ktoe (11.0%).



Source: ADB Energy Statistics in Asia and the Pacific (1990-2009) published in October 2013

Fig. 3.1-1 Energy Supply and Demand Flow (2009)

According to Pacific Lighthouse by IRENA (International Renewable Energy Agency) in August 2013, there have been no recent studies on non-commercial energy use. The PIREP (Pacific Island Renewable Energy Project) mission in 2004 estimated that about 1,000 ktoe of wood was used annually for cooking. This figure does not seem likely to have decreased since most of this was used in areas where there is little access to other cooking fuels.

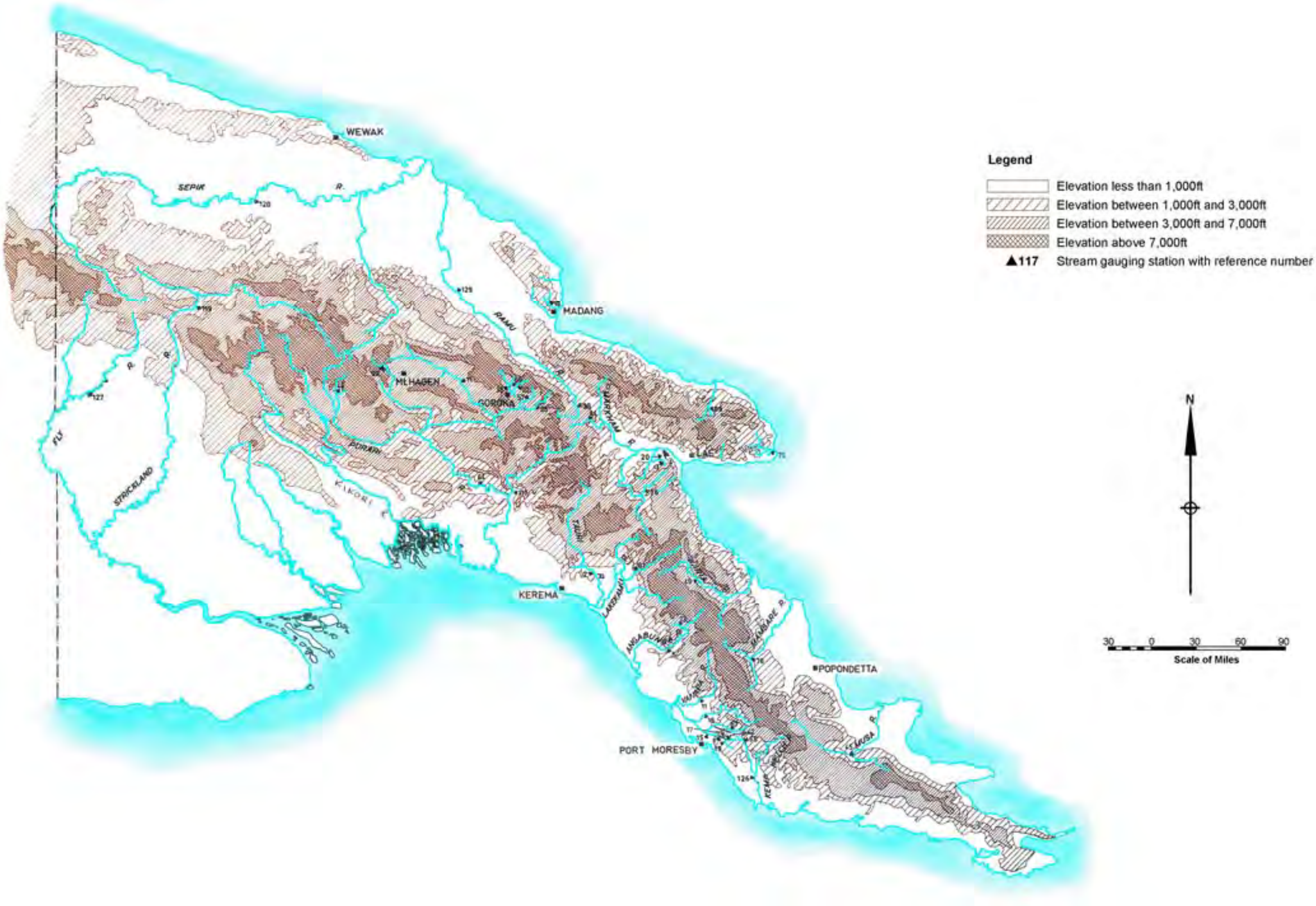
3.1.2 Hydropower

(1) Hydropower

Fig. 3.1-2 shows the locations of rivers in PNG. PNG has significant hydroelectric potential. Its land area includes 9 large hydrological drainage divisions (basins). The largest river basins are the Sepik with a catchment area of 78,000 km^2, Fly with 61,000 km^2, Purari with 33,670 km^2, and Markham with 12,000 km^2. There are other catchments of less than 5,000 km^2 in very steep areas.

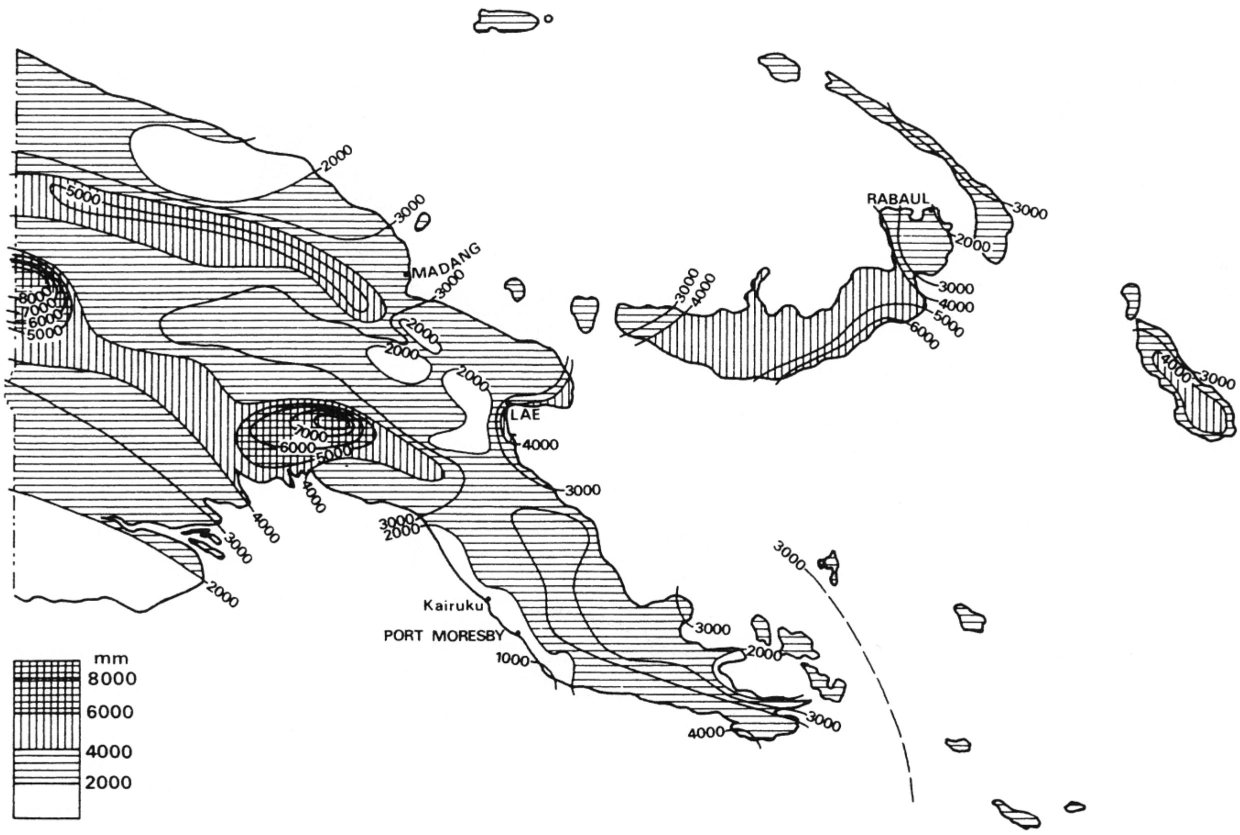
On the mainland, the annual rainfall ranges from less than 2,000 mm to 8,000 mm in some mountainous areas, while the island groups receive a mean annual rainfall of 3,000 ~ 7,000 mm. Fig. 3.1-3 shows the mean annual rainfall isohyets over PNG. The bulk of the country lies in the 2000 ~ 4000 mm rainfall zone.

The gross theoretical Hydropower potential for PNG is around 175 TWh/year. There is little economic potential for the expansion of large hydro due to the lack of substantive demand near supply sources.



Source: Assessment of Runoff and Hydro-Electric Potential by SMEC

Fig. 3.1-2 Rivers in PNG



Source: Climate of Papua New Guinea by J.R. McAlpine, etc.

Fig. 3.1-3 Rainfall Isohyets in PNG

Due to limited hydrological surveys, only approximate information on hydropower potential is available. In 1994, the WB estimated that large–scale hydro had the following potential, excluding small hydro[3] for rural communities:

Category	GW
Gross Potential	20
Technically Feasible Potential	14
Total Economically Feasible Sites	4.2

Source: IRENA (2013)

The major existing large hydropower stations in PNG are as follows;

3 Several classifications are used in hydropower. One classification is as follows:
Large hydropower (> 100MW), Medium hydropower (15 ~ 100 MW). Small hydropower (1 ~ 15 MW), Mini-hydropower (100 kW ~ 1 MW), Micro-hydropower (5 ~ 100 kW), Pico-hydropower (100 W ~ 5 kW). The classification used in this chapter is as follows:
Hydropower = Large + Medium + Small, Mini Hydropower = Mini + Micro + Pico

	Name	MW
POM	Rouna No.1 ~ No.4	36.7
	Sirinumu	1.5
Lae	Ramu No.1	78
	Pauanda	12
	YTOD	18
	Biaune (IPP)	13
	Total	**159.2**

The major large hydropower plants[4] planned are as follows;

	Name	MW
POM	Naoro Brawn	80
Lae	Ramu No.2	240
	Kaugel	90
	Mongi/Bulm	60 ~ 90
	Total	**470 ~ 500**

The total Hydropower Station output (existing + planned) as of 2014 is estimated at 629.2 - 659.2 MW, which is far below the hydropower potential of 4.2 - 20 GW in PNG. There is enough room to develop the Hydropower Stations from now on in PNG.

(2) Mini Hydropower

Mini hydropower in this chapter consists of mini-hydropower (100 - 1,000 kW), micro-hydro (5 - 100 kW) and pico-hydro (100W - 5 kW). These energy resources are usually utilized as off-grid (mini-grid) power sources for rural electrification (town and village electrification).

According to the “World Small Hydropower Development Report 2013 (PNG)” by UNIDO (United Nations Industrial Development Organization), ELCOM (now PPL) carried out numerous feasibility studies (F/S) to replace small diesel systems with small hydropower in the 1980s to 1990s, but none were developed due to high costs.

The Energy Division of DME (Department of Minerals and Energy) had assessed 45 potential hydro sites near C-centers by 1987 and had completed 14 F/S and commissioned three small hydropower systems (60 kW - 300 kW) by 1992. Apparently none have been constructed since then. Church missions, Non-Governmental Organizations (NGOs), and community organizations have built a number of small hydropower systems, but the documentation is imprecise.

The PIREP mission estimates that there may have been as many as 200 single household size pico-, micro-, and mini- hydropower systems installed in rural PNG (which perhaps 20 ~ 25% are still functioning), about 20 ~ 25 systems on Bougainville Island, and roughly the same number throughout the rest of PNG. Many more will be planned if funding can be found.

A 1985 New Zealand Aid package supported a DME assessment of mini-hydro potential near 110

4 The other large potential hydropower project is the Wabo power project in the Purari River basin, which has an estimated output of ca. 1,500 MW.

load centers in 17 Provinces. Investigations were carried out at 31 centers and the others were examined by desk study.

Although the main focus was the power generation potential in the vicinity of C-centers, the Study considered the potential in the vicinity of the nearby population centers as well. It identified 6 MW of mini-hydro potential, more than half of which was concentrated on Bougainville Island.

Other promising locations were in Madang, Morobe, Eastern Highlands, and Southern Highlands Provinces. In some locations, the economic viability was judged to be low or uncertain due to low demand and/or cheaper power through grid extension or other renewable energy sources.

A future energy scenario for PNG shows tremendous potential for future commercial energy production from renewable indigenous resources, including hydropower development. Five hundred new micro hydro systems (< 100 kW) with an average capacity of 22 kW could be realized.

The Country Partnership Strategy 2011-2015 for PNG released by ADB provides recommendations for rural electrification and technical assistance for micro hydropower projects.

3.1.3 Oil and Natural Gas

PNG commenced its first gas project as Hides gas-fired TPP (Thermal Power Plant) (62 MW) in 1991. It is still generating electricity with a 132 kV T/L for the Porgera GoldMine located 76 km north-east from the TPP.

In 1992, PNG commenced its first big oil project. This project (Kutubu) has exported over 300 million barrels of oil to date. Subsequently, smaller oil projects came on stream: Gobe 1998, Moran 2002, SE Mananda 2004, and NW Moran 2008.

In 2014, PNG began exporting LNG from its first and biggest LNG project (cost: USD 19 billion). The project was sanctioned in 2009 and has been developed extracting gas and condensate resources in Hides, Angore, and Juha fields and associated gas in the Kutubu, Agogo, Moran and Gobe Main oil fields in the southern highlands. The gas is transported to an LNG plant near POM with a capacity of 6.9 million tons per annum (mtpa). PNG LNG will be exported to various Asian countries. The first LNG was delivered to Japan in May 2014.

According to “The National” (November 28 2014), the Project Development License for the Stanley gas condensate project in the Western Provinces was issued in May 2014. The project is expected to fully operate in 2016. Other promising oil/gas fields are Elk/Antelope (gas condensate), Ketu/Elevala (gas condensate), Mananda Artic (oil), and P’nyang (gas condensate). The Elk/Antelope fields will be developed into the 2nd PNG LNG project (It is also called as the Gulf LNG project). The first LNG export from the project is expected in late 2020 or early 2021.

(1) Oil and Natural Gas Reserves

Oil and natural gas reserves in PNG are explained briefly in Table 3.1-1 and in further details in Table 3.1-2.

Other than oil and gas in Table 3.1-2, there are several other promising oil and natural gas fields in PNG such as Douglas, Pukpuk, Elevala, Ketu, Kimu, Pandra, etc. The locations of these fields are shown in (2) “Map of Oil and Natural Gas Fields.”

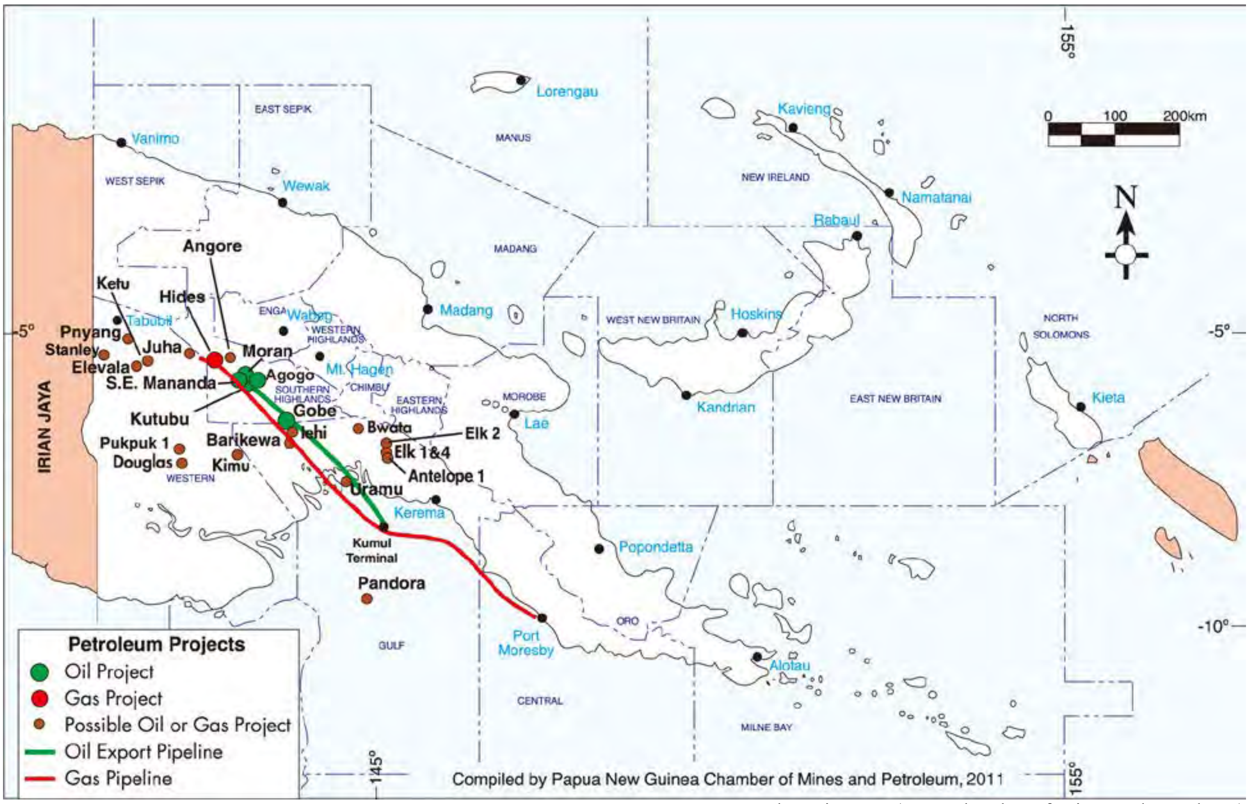
Table 3.1-2 Major Oil and Natural Gas Reserves in PNG

Location	Field	Reserves		Main Operator/ Developer
		Oil (mmbbl[5])	Natural Gas (TCF)	
Central	Hides, Angore, Juha, Kutubu, Agogo, Moran, Gobe	200	9	Esso Highlands Ltd., Oil search
Gulf	Elk/Antelope	128.9	8.6	InterOil
Western	Stanley	11.4	0.361	Horizon Oil, Talisman Energy
	P'nyang		2.5 ~ 3.0 (2C[6])*	Oil Search

Source: Petroleum in PNG (PNG Chamber of Mines and Petroleum) and *Investor Field Trip (Oil Search Limited) (Nov. 2013)

(2) Map of Oil and Natural Gas Fields

Fig. 3.1-4 shows the locations of the main oil and gas fields in PNG with oil and gas pipelines. At present, the country's oil and gas fields are concentrated in the Central highland area, Western Province, and Gulf Province. However, according to the PNG Chamber of Mines and Petroleum, there are currently 71 PePLs and over 15 applications[7]. Therefore, oil and gas fields will expand throughout the country in the future.



Source: Petroleum in PNG (PNG Chamber of Mines and Petroleum)

Fig. 3.1-4 Oil and Natural Gas Fields in PNG

5 Million barrels

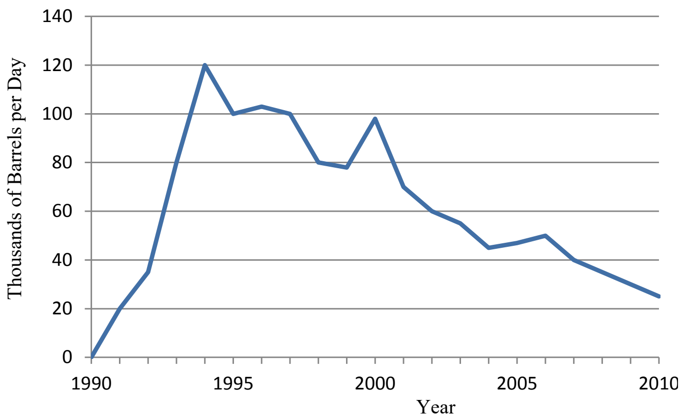
6 2C: Contingency resources with C1+C2 (C1: Proven, C2: Probable). Contingency resources are projects that are currently sub-commercial.

7 These numbers are slightly smaller than those in Table 2.1-1 "Status of Licenses as of November 30, 2014". The date of publication of "Petroleum in PNG" by the PNG Chamber of Mines and Petroleum is uncertain, but it seems to predate Table 2.1-1.

(3) Trend of Oil and Natural Gas Production

Since 1992, PNG has recovered over 400 mmbbl of light crude oil from recoverable reserves of roughly 550 mmbbl. Product will steadily decline as the resource is being depleted, as shown in Fig. 3.1-5.

On the other hand, the natural gas resource is huge (around 15.6 TCF) and equivalent to at least 2,700 mmbbl, around ten times PNG's remaining reserves of recoverable oil.



Source: Pacific Lighthouse (August 2013)

Fig. 3.1-5 Oil Production (1991-2011)

Gas demand at present is restricted mainly to the PNG LNG project. Due to lack of domestic gas demand, the Stanley condensate stripping project will recover only condensate. Dry gas will be re-injected into the reservoir and banked until required for sale.

In accordance with increased domestic gas demand in power industries and petrochemical production, gas production is expected to soar from now on. Another factor that will considerably augment gas production in the near future is the operation of the Gulf LNG project.

(4) Oil and Natural Gas Pipelines

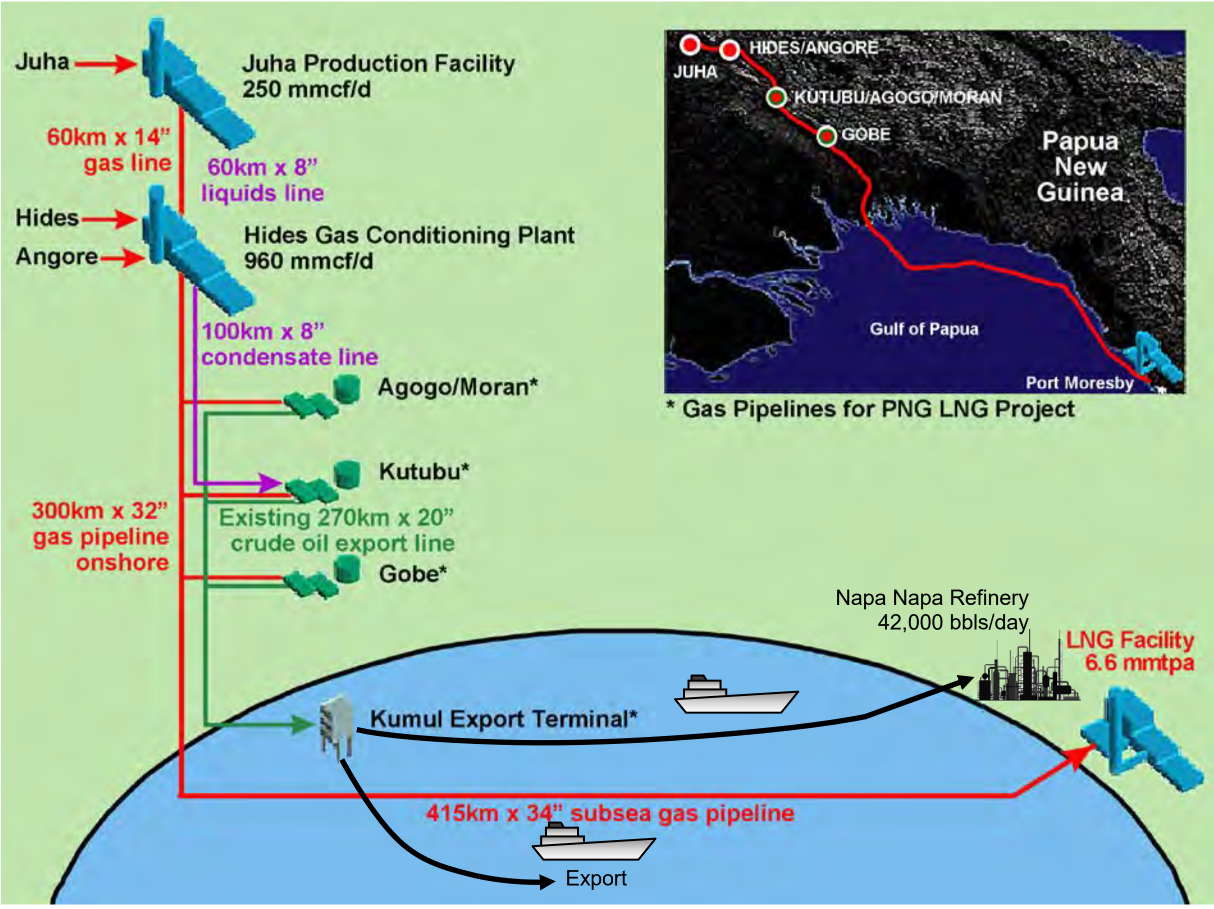
Fig. 3.1-6 shows the existing oil and natural gas pipelines in PNG. All the gas from the highland area is transported to the LNG facilities near POM. Oil is partially transported to the Napa Napa refinery and the remainder is exported.

1) Oil Pipelines

The oil pipeline (270km × 20 inch) from the Agogo/Moran, Kutubu and Gobe oil fields to the Kumul export terminal is operating. A part of the oil is exported abroad from Kumul by oil tankers and the remaining oil is transported to the Napa Napa Refinery near POM by the same means.

2) Natural Gas Pipelines

The gas and associated liquid from Juha, Hides, and Angore gas fields are collected and separated in the Hides gas conditioning plant. The gas including the associated gas in the Angogo/Moran, Kutubu and Gobe oil fields is transported by onshore/offshore gas pipeline (32 inch and 34 inch) over a distance of 700 km to the LNG facility located approximately 20 km northwest of POM.



Source: Petroleum in PNG (PNG Chamber of Mines and Petroleum) modified by JICA Study Team

Fig. 3.1-6 Oil and Gas Pipelines in PNG

(5) Status of Gas Contract System in PNG

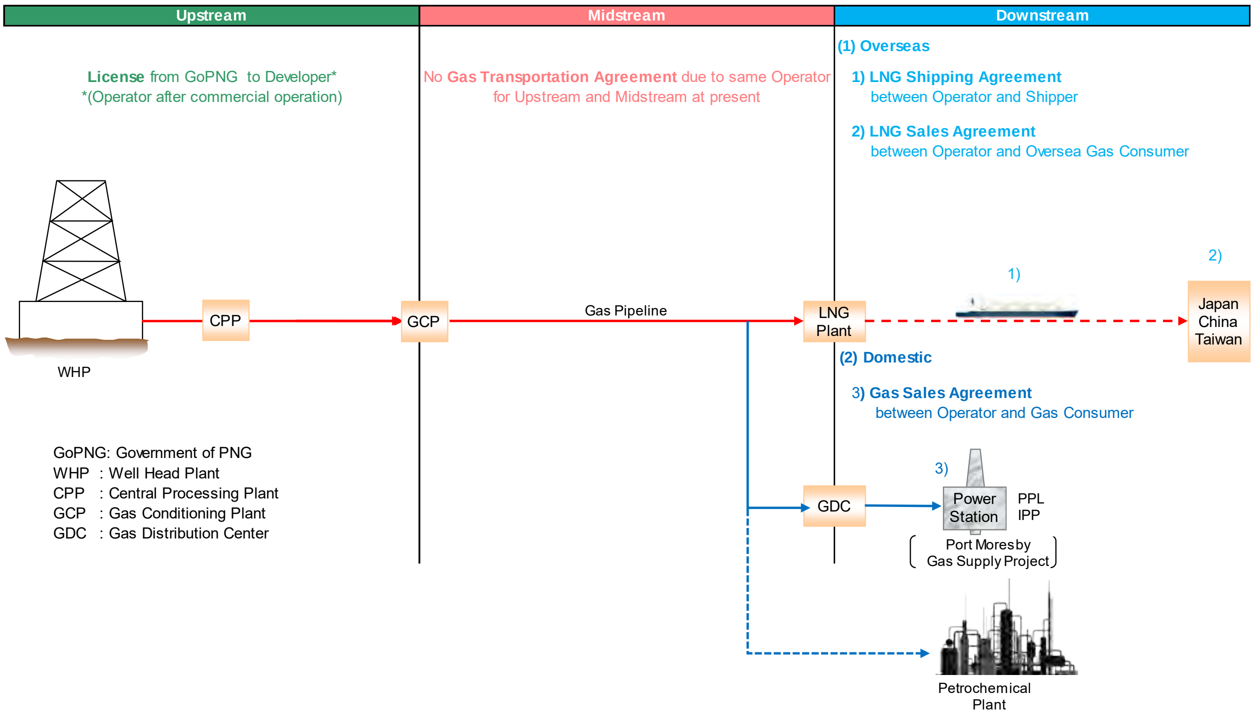
Fig. 3.1-7 shows the gas contract system in PNG. As explained in Section 2.1.2 (1) of Energy Policy, the present gas contract system in PNG is not a PSC system but a License system. A developer who is named as an operator after commercial operation of the gas field receives the licenses (PePL, PRL, PDL) from GoPNG.

There is only one gas project (PNG LNG project) at present other than the old gas project, the Hides gas-fired TPP. There is no GTA (Gas Transportation Agreement), because the same operator (Esso Highland Limited, a subsidiary of ExxonMobil Corporation) manages the upstream and midstream processes.

Downstream, Esso Highland limited has concluded an LNG shipping agreement with the shipper and LNG sales agreements with overseas gas consumers. A GSA (Gas Sales Agreement) has recently been concluded for the POM Gas Supply Project between the gas consumers in PNG and ExxonMobil Corporation.

Gas will be used in PPL and IPP for power generation from now on. Gas will be also used for petrochemical industries in the near future.

As shown in Fig. 3.1-7, the operator controls all of the agreements in PNG.

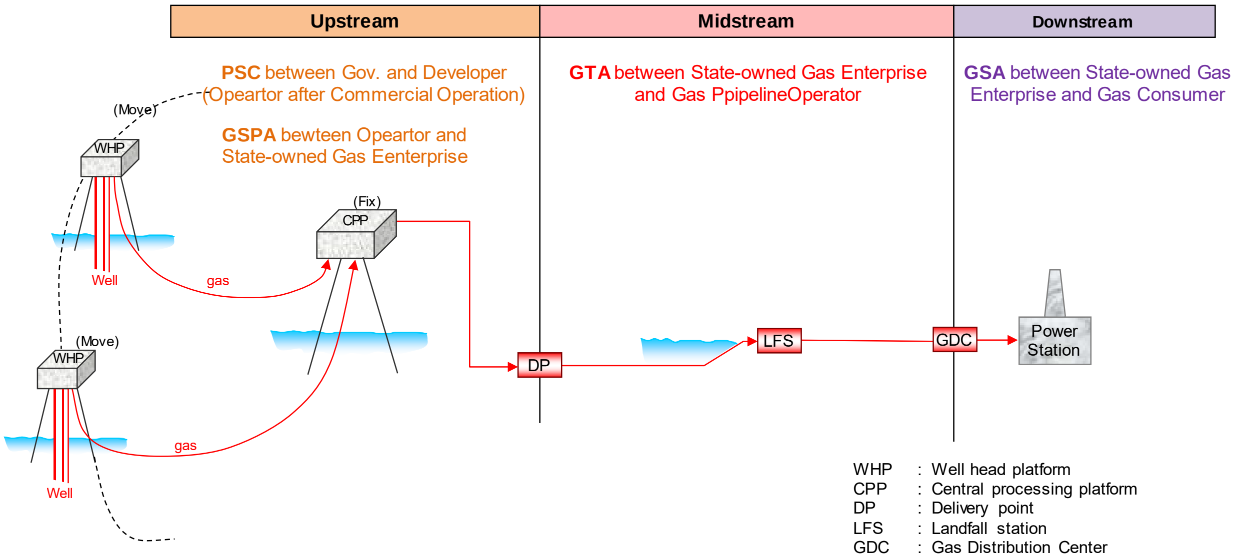


Source: prepared by JICA Study Team with hearings of DPE

Fig. 3.1-7 Gas Contract System in PNG

Fig. 3.1-8 shows a sample of the PSC gas contract system used in Vietnam, for reference purposes. Unlike the case in PNG, off-shore gas fields are major in Vietnam.

An operator who agrees PSC agreement with the Government of Vietnam enters a gas purchase and sales agreement (GPSA) with the State-Owned Gas Enterprise (Petro Vietnam). The State-Owned Gas Enterprise enters a GTA with the Gas Pipeline Operator and enters GSAs with domestic gas consumers. Unlike PNG, the State-Owned Gas Enterprise controls all of the agreements in Vietnam.



Source: prepared by JICA Study Team

Fig. 3.1-8 Gas Contract Systems in Vietnam

We have heard that PNG is considering changing its gas contract system from the present license system to PSC. For the natural gas fields exploited only for domestic purposes, the gas contract system in Vietnam is a good model for PNG.

(6) Gas Properties

Table 3.1-3 shows the properties of natural gas produced in the highland area. The gas is classified as so-called "sweet gas" with zero H_2S and small amount of CO_2, and suitable for LNG production.

Table 3.1-3 Natural Gas Properties

Content		MOL %
Water Vapor	H_2O	0.01
Nitrogen	N_2	0.74 ~1.16
Hydrogen sulphide	H_2S	0.00
Carbon dioxide	CO_2	0.71 ~2.04
Methane	C_1	83.37 ~ 89.98
Ethane	C_2	5.71 ~8.01
Propane	C_3	1.72 ~3.70
i-Buthane	iC_4	0.36 ~0.59
n-Butane	nC_4	0.40 ~0.77
i-Pentane	iC_5	0.16
n-Pentane	nC_5	0.09 ~0.10
Hexane	C_6	0.05 ~ 0.07
Heptane	C_7	0.03 ~ 0.04
Octane	C_8	0.01
Nonane	C_9	0.00

Source: DPE

Estimated caloric values for the averaged MOL (%) by the calculation of JICA Study Team are 10,567 kcal/Nm^3 (HHV) and 9.570 kcal/Nm^3 (LHV), respectively.[8]

(7) Gas Prices

It is rather difficult to foresee the gas price[9] in the highland area because there have been no recent gas sales trades there. There has been only one experience with the supply of gas to the Hides gas-fired TPP in the highland area in 1991, i.e., the Gas Turbine (GT) TPP for the Porgera Gold Mine. While the actual gas sales price is unknown, we heard that the gas price is high because a single developer without competitors monopolizes the gas supply.

The gas price in the highland area is affected not only by the aforesaid monopoly, but also by the rather small gas demand for future gas-fired TPPs in the Ramu System. The gas price in PNG is also affected by crude oil prices in the Asian Market, especially by JaCC (Japan Crude Cocktail[10],).

As explained in Section 3.2.1 (4) 4), There is an IPP proposal with small gas-fired TPPs in the highland area. Although the gas price is still under negotiation, the price level is likely to be around 11% × JaCC. The JaCC as of November 1-20, 2015 is 47.60 USD/bbl, therefore, the gas price at this moment is roughly estimated at ca.5.2 USD/MMbtu.

8 No information on measured calorific values.
9 Gas price in the highland area is almost same as wellhead gas price of the gas field in the highland area.
10 Average CIF price of crude oil in Japan. JaCC is recently declining due to crude oil surplus.

PNG has exported LNG overseas since May 2014. The recent LNG price in the Asian market is USD 11 ~ 12/MMbtu, down considerably from USD 15 ~ 16/MMbtu in the past. Although the LNG price in PNG is calculated by the bellow equation, the LNG price is also linked with JaCC which has been drastically declining due to the recent crude oil surplus.

LNG price in PNG = Wellhead gas price in the highland area + Gas pipeline transportation charge + Gas liquefaction charge + Shipping fare + Profit

It is envisaged that the gas price in the highland area and LNG price will widely fluctuate from now on in accordance with JaCC's fluctuation.

(8) LNG Projects in PNG

PNG has one (1) operating LNG project, i.e., the PNG LNG project, and 1 promising LNG project, i.e., the Gulf LNG project[11]. In addition to these, a potential LNG project may be operated in the Western Province by Talisman Energy and Mitsubishi Corporation.

1) PNG LNG Project

The construction of the first PNG LNG project started in 2010 and took more than 191 million work hours to complete. At peak, more than 21,000 people were employed by the project, including more than 9,000 Papua New Guineans.

More than 10.7 billion kina has been spent with PNG business. More than 700 km of pipeline connects the facilities, which include a gas conditioning plant in Hides and liquefaction and storage facilities near POM with project capacity of 6.9 mtpa of LNG. The facilities comprise two (2) trains and two (2) 160,000 m^3 LNG storage tanks and marine facilities to allow access for LNG tankers with capacities of 125,000 m^3 to 220,000 m^3.

The first shipment of LNG was sent out in May 2014 to Tokyo Electric Power Company in Japan. The first LNG tanker arrived at Japan on June 3, 2014.

The production of the PNG LNG project is a 6.6 mtpa integrated LNG project operated by Esso Highland Limited. The joint venture owners of the project are: ExxonMobil (33.2%), Oil Search (29.0%), Kumul Petroleum Holdings (16.6%), Santos (13.5%), JX Nippon Oil and Gas exploration (4.7%), MRDC (2.8%), and Petromin (0.2%).

LNG will provide a long-term supply to four (4) major customers in the Asian Region: Tokyo Electric Power Company (1.8 mtpa), Osaka Gas Company (1.5 mtpa), Chinese Petroleum Corporation of Taiwan (1.2 mtpa), and Unipec Asia Company (2 mtpa), a subsidiary of China Petroleum and Chemical Corporation (Sinopec).

2) Gulf LNG Project

The Gulf LNG project is planned by InterOil. The project is based on Elk/Antelope fields that have estimated resources of 8.6 TCF of gas and 128.9 mmbbl of condensate.

The project start-up configuration envisages a condensate stripping plant adjacent to the Elk/Antelope fields, 120 km of dry gas and condensate pipelines to the coast, a 3 mtpa land-based modular LNG plant, a 2 mtpa fixed floating LNG plant, LNG storage tanks, and an LNG export terminal.

11 It is also said as 2nd PNG LNG project

InterOil and Pacific LNG Operations (a shareholder of Liquid Nguni Gas, the developer of the LNG plant) have signed a Heads of Agreement for the supply of a total of 3.3 ~ 3.8 mtpa of LNG to the Noble Group (1 mtpa), Gunvor Singapore (1 mtpa), and ENN Energy Trading of China (1 ~ 1.5 mtpa).

InterOil was looking for an internationally recognized LNG operating company. In December 2013, InterOil finally selected a development partner for its Elk/Antelope fields in the Gulf Province. The French major Total SAwill pay up to USD 3.8 billion (K 9.01 billion) for a 61.3% stake in the fields. According to an InterOil announcement in 2014, Total SA acquired a gross participating interest of 40.1% in PRL 15, which contains Elk/Antelope fields.

Oil Search, one of the key players involved with the existing LNG project (namely, the ExxonMobil-led PNG LNG project), has also joined the venture by acquiring a 23% stake of the Elk/Antelope fields.

As a result of joining of Oil Search, the idea of integrating with the PNG LNG project is emerging. Oil Search believes that the PNG LNG has the potential ability to build an additional train on site with extra gas that could be supplied from the Elk/Antelope fields.

This issue does not seem to be solved so far.

(9) Napa Napa Oil Refinery

InterOil bought a crude distillate plant that was originally built by Chevron in 1963 in Alaska and operated there until 1994. The plant was dismantled and transferred to POM for construction and commissioning. All heat exchangers, coolers, pumps, tanks, piping were newly installed in 2004. Practical completion occurred in January 2005.

1) Name plate capacity of the plant: 36,000 BPD[12]

2) Products: Fuel gas, LPG, Light Naphtha, Mixed Naphtha, 91RON Unleaded Gasoline, JetA-1 (Kerosene), Diesel, Low Sulphur Waxy Residue

3) Sustainable feed rate achieved: 32,500 BPCD[13]

4) Domestic/export ratio of the product: ca. 65% for the domestic market, ca.35% for export

In July 2014, InterOil sold its refinery and petroleum products distribution business (52 service stations and 30 fuel depots, etc.) to the Singapore-based Puma Energy group.

In November 2014, Puma Energy announced an investment plan for the refinery to increase the production capacity to 42,000 BPD with installation of 10 MW GT and an additional 280,000 m^3 of new crude & refined product storage.

3.1.4 Coal

Despite having huge mineral and petroleum resources, coal deposits have never been extensively explored in PNG.

JICA Study Team has collected most of its information on coal in PNG through the internet and magazines. It has ascertained the following;

12 BPD: Barrels per day (capacity of the plant)
13 BPCD: Barrels per calendar day (annual production/365)

"In the early 1900s, patrols recorded a number of coal deposits in the upper reaches of Kikori, Purari and Eva rivers. Though initial attempts to exploit these deposits were not overcome by limitations in both access and technology.

Waterford PNG, a company dedicated to developing the coal industry in the country, conducted coal explorations towards PNG's western border in 2010.

At the same time, Oil Search tried to access the coalbed methane in the Western Province. Their exploration was fruitless, but they found coal-bearing strata and a number of petroleum wells had encountered coal measures at varying depths.

Waterford approached Mineral Resources Authority (MRA) to undertake a study of coal's potential economic benefit to the country in 2013, but the study was not realized.

A diversified mineral explorer named Mayur Resources has been exploring for coal in the Gulf Province along the Vailala and Purari rivers since 2014 with a view to solving PNG's chronic power problems.

MRA stated that coal had a long history as an effective source of power for countries throughout the world, most notably India and China. MRA would ensure that the work program of Mayur Resources is given the necessary attention in terms of providing vital regulatory services."

Based on the foregoing information, JICA Study Team tried to contact MRA through PPL to clarify the coal resources in the Ramu System. The only response was the following email message;

"The MRA has been mainly undertaking reconnaissance work on geothermal and coal potential in the country so far. For the Ramu region, there is no data/work on geothermal in the area. For coal, investigations are ongoing in an area being explored by companies within the vicinity of the Ramu basin.

It is too early at this stage to determine the coal supply and viability. More work will be required to develop the potential. The same holds true for geothermal, where we are still in the early stages of reconnaissance work for West New Britain, Morobe (Wau-Bulolo area), and Milne Bay."

3.1.5 Renewable Energy

(1) Overview

The renewable energy potential of PNG is enormous, but most of it is in remote locations where there is limited demand and where renewables are not readily exploitable.

Up to the mid-1980s, PNG was the regional leader in biomass energy for agro-processing, biogas use, biomass gasification, wood and charcoal cooking, ethanol production, solar PV implementation, and resources assessment.

Recently the private sector has been the main driver of renewable energy use. The coffee industry still uses wood-burning driers; the palm oil industry uses wastes for electricity production; and Ramu Sugar plans to use wood for combustion in its bagasse boilers to increase its energy production.

At least several thousand new solar home lighting systems are expected to be installed in the rural areas of PNG every year, overwhelmingly through private initiatives.

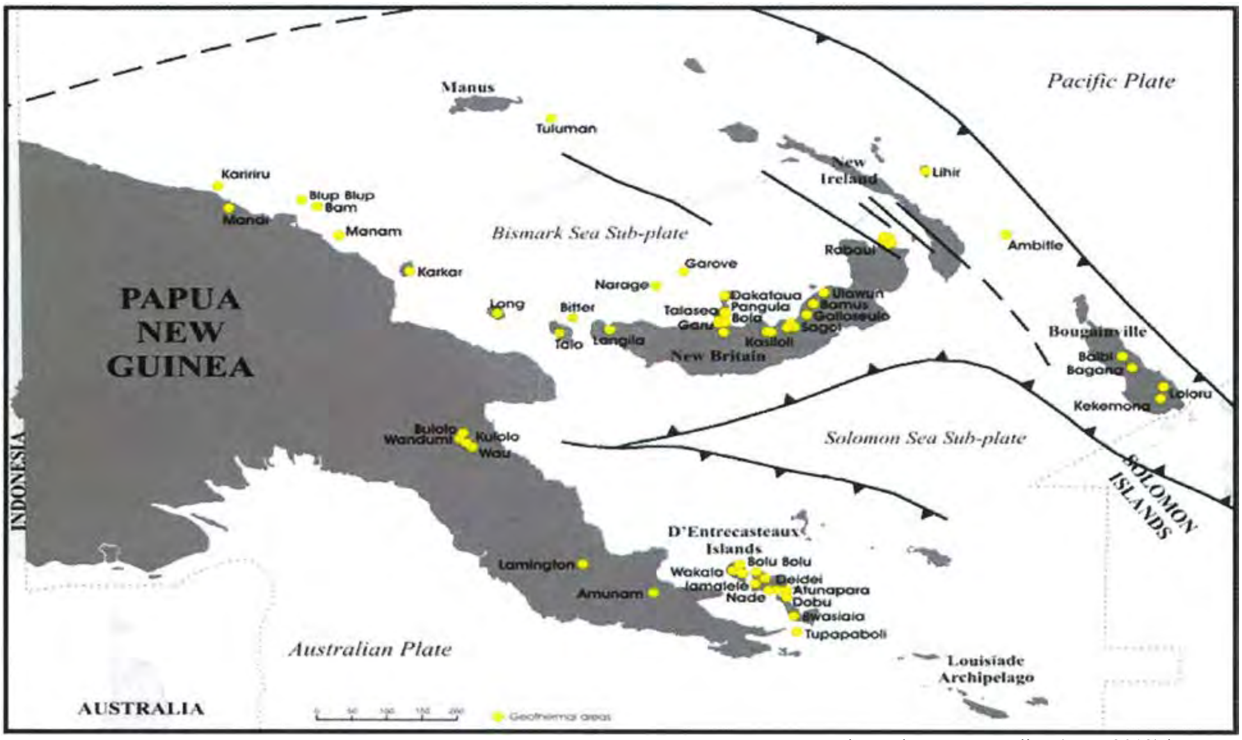
About three-quarters of mini/micro hydro systems installed are no longer in use; a high percentage of residential and public facility PV and wind systems have failed; and most C-center power systems are operating poorly, or not at all[14].

(2) Geothermal

No systematic geothermal energy assessments have been carried out, but reconnaissance studies suggest that the most promising area is the Northern coast of New Britain. At least seven (7) geothermal sites are confirmed in that area: Bamus, Galloseulo, Walo, Kasoli-Hoskins, Garbuna, Pangalu-Talasea, and Bola.

The thermal fields of Pangalu-Talasea and Kasoli-Hoskins on the north coast of New Britain are associated with a belt of recent volcanic activity. Numerous hot springs, geysers, fumaroles, and mud pools are found (temperature range: 90-101°C), many with significant levels of H_2S and CO_2. The geothermometric equilibrium temperature could be in the 300°C range, and dry steam geothermal reservoirs could underlie the region.

PNG also has several sites with geothermal potential apart from the aforementioned areas, as Fig. 3.1-9 shows;



Source: Geothermal Resource Policy (Nov. 2012) by MRA

Fig. 3.1-9 Geothermal Potential Sites in PNG

The only commercial geothermal development has been on Lihir Island, north of New Ireland. The 6 MW geothermal power plant was commissioned at Lihir Gold Ltd. (the first geothermal power facility in the Pacific islands). The facility was expanded to 52.8 MW in 2011.

14 Please refer to Section 2.2.5 Rural Electrification

Southern Energy Solution Ltd. (SESL) is now planning a 5 MW geothermal pilot project in Rabaul of East New Britain. A geological survey recently completed found that fluid temperatures were high enough (300 ~ 400°C) to adopt the flash cycle. The project is now looking for funding for test drilling.

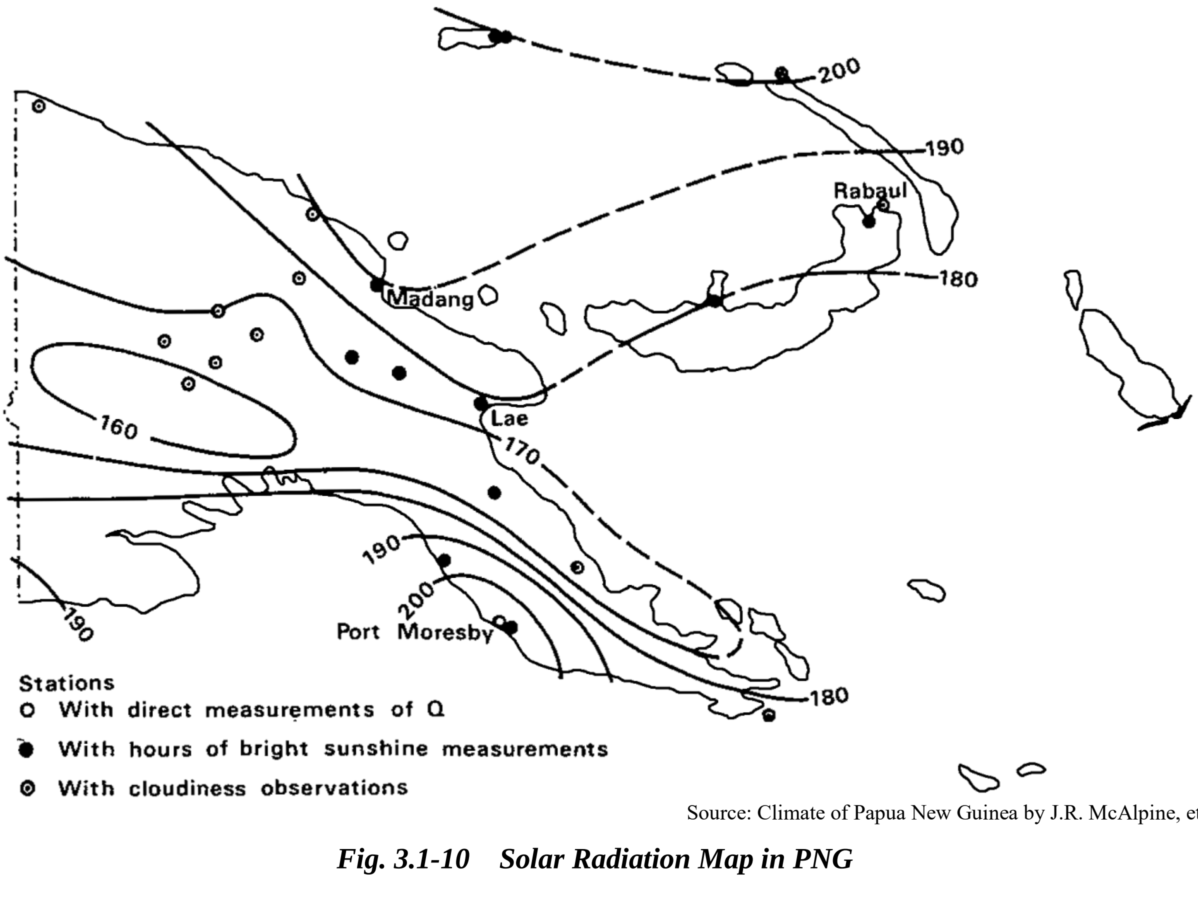
The project planners intend to connect with the PPL East New Britain grid system. The present power sources of the system consist of 5 MW of hydropower and 5 MW of Diesel Generators (DGs). The pilot project is expected to replace 5 MW of existing DGs.

The project will be developed by IPP or Public Private Partnership (PPP). The earliest (Commercial Operation Date (COD) is in 2018, provided that funds including for test drilling, etc. are available soon.

(3) Solar Energy

Solar energy is one of the large potential resources of renewable energy in PNG. The average sunshine in much of the country appears to be good, with between 4.5 ~ 8 hours daily. Due to mountainous terrain and the persistent cloud cover they cause, solar energy reaching the ground can vary greatly from place to place and cannot be easily estimated for a particular site from satellite data.

Fig. 3.1-10 shows the distribution of the total annual global solar radiation expressed as mean daily values in W-h/cm^2. Most of PNG receives from 160 to 200 W-h/cm^2 per year.



Source: Climate of Papua New Guinea by J.R. McAlpine, etc.

Fig. 3.1-10 Solar Radiation Map in PNG

Of 23 locations assessed in studies in the 1990s, POM is PNG's sunniest location, with 2,478 sunshine hours per year. The least sunny is Tambul, Western Highland, with 1,292 hours. The best locations for PV are the offshore islands and the southern regions, where there is less persistent cloud cover caused by mountains.

At least 25 small-scale applied research projects involving solar energy took place in PNG between 1989 and 1994, mostly at Unitech. The studies included solar drying, water heating, PV monitoring, and solar pumping.

Solar drying of copra, cocoa, and coffee was widespread in the 1980s, particularly by smallholders. Also in the 1980s, the government supported a solar water heating retrofit program for commercial users, industry, and households with at least 3,000 household systems installed. At least 7,000 homes in POM used solar water heating in 2004.

PV has spread gradually in PNG over the past 30 years, with small independent solar systems marketed by private suppliers mainly for lighting and communications use. Some 3,000 solar home lighting systems were sold to individuals between 1998 and 2002, and about 1,000 new systems have probably been sold each year since.

PNG Telecom has hundreds of solar sites, with a total capacity of over 200 kWp[15]. The expansion of the mobile phone system into rural areas is rapidly increasing solar use of telecommunications and increasing demand for solar-powered phone chargers. A major problem, however, is protecting these facilities against vandalism and theft.

At least a dozen PV pumping systems and a dozen PV-powered refrigerators were installed at health centers in the 1980s. A Japanese-supported project of around USD 11.3 million provided solar electrification for 320 schools in all PNG provinces in 1997-1998. By 2004, however, only a few of the panels installed were still operating.

Several problems contributed to the lack of long-term success, including poor installation quality, inadequate maintenance and support, difficulties in transportation of spare parts, and security issues leading to numerous thefts of panels.

About 200 solar and Liquefied Petroleum Gas (LPG) based vaccine refrigerators have been installed in health facilities since 2000. Many, however, have been poorly designed or maintained, and many of their solar panels have been stolen.

As in the case with Fiji, the presence of a larger hydro generation capacity has kept PNG's electricity prices much lower than in all-diesel generating countries in the region. Grid-connected solar and wind are less cost effective, which makes it rather difficult to attract private sector investment in solar and wind power systems for grid connection.

(4) Wind Energy

There have apparently been no systematic estimates of wind energy since the 1990s, when the best potential was estimated to be in parts of the Central, Western, Milne Bay, and New Ireland Provinces and the POM area. These estimates were based on modeling with very little actual wind gauging.

Several wind turbines were installed in Morobe Province after independence but no wind

15 kWp: Peak output of the solar panel under the conditions where: 1) the radiation strength is 1 kW/m^2, 2) the panel surface temperature is 25°C, 3) the air mass is 1.5 (sunshine absorption rate in the atmosphere).

monitoring has yet begun. In 2002, the Chinese government donated 50 small combined wind/solar generators to PNG. A number of them have been installed in various coastal locations.

Although full details were not available, the Chinese government has also reportedly provided around 1 MW in small wind systems to the Duke of York Islands of New Britain to power local hospital and other facilities.

The WB has started an investigation project to identify the wind power potential in PNG. Eight 80-m-tall observation towers will be constructed at different locations[16] in PNG to measure the wind direction, wind speeds, etc.

(5) Biomass

1) Categorization of Biomass Energy

The biomass energy resources provided vary widely in terms of utilization methods, system configurations, and available raw materials.

The utilization methods for biomass are roughly categorized as a) power generation, b) heat generation, and c) fuel production.

The power and heat yielded from biomass are generated by direct combustion and biogas. Biogas is further divided into two types, which produced through biochemical processes and which produced through thermochemical processes.

The available raw materials for biomass power generation and heat generation are categorized as follows; a) plantation produce (trees, tree waste) b) wood and wood waste (bark, sawdust, woodchip, etc.), c) agriculture waste (bagasse, palm kernel shell & fiber waste, empty fruit bunch, coffee husk, rice husk, etc.), d) garbage (food waste, waste oil, paper waste, etc.), e) livestock dung, and f) waste water.

With regard to fuel production (bioethanol and biodiesel), agriculture produce such as sugar cane, corn, bean, potato, cassava, copra, oil palm, nipa palm, sago palm, jatropha, etc. are used as available raw materials.

Table 3.1-4 shows the matrix among the utilization methods, system configurations and available raw materials.

16 A maximum of 10 locations if the WB permits.

Table 3.1-4 Matrix of Biomass Utilization

Utilization Methods		System Configurations	Available Raw Materials
Power	Direct Combustion	Boiler → (Steam) → STG → Electricity	Plantation Produce (Trees, Tree waste)[17] Wood waste (bark, sawdust, woodchip) Agriculture waste (bagasse, PKS & fiber waste, EFB, coffee husk, rice husk) Garbage (food waste, paper waste, waste oil)
Power – Biogas	Biochemical Process	Digester → (CH_4) → GE → Electricity Digester → (CH_4) → (Gas) → Cooking	Livestock dung, Agriculture waste, Garbage, Wastewater (sewage sludge)
Power – Biogas	Thermochemical Process	Gasifier → Cleaner → (CO, H_2, CH_4) → GE → Electricity	Wood waste, Agriculture waste, Garbage
Heat	Direct Combustion	Kitchen, Stove → Heat for cooking, warming Boiler → Steam to process product	Wood & Wood waste Agriculture waste Garbage
Heat	Biogas	Gasifier → Cyclone Combustor → Heat to dry product (Heat Gasifier)	Wood waste, Agriculture waste, Garbage
Biofuel	Bioethanol	Estification Reactions → Bioethanol (mixing with gasoline)	Sugar cane, Corn, Cassava, Nipa palm, Sago palm
Biofuel	Biodiesel	Estification Reactions → Biodiesel (substitute for diesel oil)	Bean, Copra, Oil palm, Jatropha, Waste oil

STG: Steam Turbine Generator, GE: Gas Engine, PKS (Palm Kernel Shell), EFB (Empty Fruit Bunch)

Source: prepared by JICA Study Team

2) Present Situation in PNG

According to "Independent State of Papua New Guinea (2012) - Policy and Regulatory Overviews – Clean Energy" by Renewable Energy and Energy Efficiency Partnership (REEEP) Policy Database, although two-thirds of PNG is forested, much of the biomass is inaccessible or unsuited for energy use. An estimated 58% of the land is subject to strong or severe erosion and 18% is permanently inundated or regularly flooded.

a) Power and Heat by Biomass

While no recent surveys have been done to document its use, traditional biomass (mainly fuel wood) probably accounts for over 50% of PNG's national energy consumption in 2010. Wood is largely used for cooking in PNG. Although there have been several attempts to introduce efficient wood stoves and charcoal stoves, most cooking continues to be done on open fires.

Some electricity and process heat are produced from biomass waste in the oil palm, sugar milling, and wood processing industries.

17 At present, the plantation produce is not yet utilized for power in PNG. In the future, however, it has the potential to produce power as shown in Section 3.2.1 (9) "Biomass."

Log exports come to about 2 million m^3 per year, but very little is processed locally, leaving only relatively small amounts of biomass waste for energy. There are 18 major wood-processing facilities in PNG, but the amount of residue produced and available for energy use is unknown.

b) Power and Heat by Biogas

Although current use is unknown, in 1990 about 80 gasifiers were installed for the use of biomass waste in the copra, cocoa, and tea industries as a replacement of imported fuels.

In the 1970s and 1980s, several biogas systems operated for a short time at the Lae City Council and at a coffee plantation in Mt. Hagen. A small biogas system using the waste from 20 pigs was constructed in Central Bougainville in early 2004, but the results of the project are unavailable.

There have been proposals to incinerate municipal waste in POM for energy, but Secretariat Pacific Regional Environmental Program (SPREP) study concluded that waste incineration was unsuitable for POM as it would require complex technology and sophisticated operations and management and would likely produce unacceptable emissions.

New Britain Palm Oil Ltd. is constructing two large biogas digester facilities, one in Mosa and one in Kubango. Both use palm oil mill effluent to produce electricity and provide gas for cooking at company residences and for mill processing. Table 3.1-5 shows the electricity generated from palm oil production as of August 2013.

c) Biofuel

Ethanol (alcohol) can be produced from sugar-cane molasses, sago palm, nipa palm and other crops and blended with petrol to fuel vehicles. Reportedly, between 200 million liters and 1,100 million liters of fuel alcohol per year could be produced from sago palm in the Gulf Province alone and over 250 million liters could be produced from nipa palm from the Purari Basin.

Ramu Sugar Mills, which produced about 4 million liters of ethanol per year in the 1980s, uses bagasse (sugar-cane waste) as a fuel for its operations. Ramu Sugar Mills is establishing a plantation to grow fuelwood to supplement bagasse as a fuel.

It operates about 8,000 hectares of cane plantations and produces over 80% of PNG sugar production. The company currently produces around 0.3 million liters of ethanol, most of which is exported to Australia.

With additional processing, almost any vegetable oil (biodiesel) in PNG can be used as a liquid fuel to blend with diesel fuel, but the practical potential of biodiesel depends on the oil's value as an export commodity compared to the price of diesel fuel. PNG produces about 330 million liters of crude palm oil per year and about 33 million liters of coconut oil.

According to Madang Provincial Administration, Madang Provincial Government is piloting a biodiesel project in Karkar Island to generate electricity from the coconut oil. The biodiesel has been produced for 5 years from coconut with 100% power generation.

Table 3.1-5 Electricity from Palm Oil Production[18]

Site	Name of Plant Owner	Electricity Generation Capacity in MW
Mosa – WNBP	New Britain Palm Oil LTD.	1~ 1.5
Kubango – WNBP		1~ 1.5
Numondo - WNBP		1~ 1.5
Kapiura – WNBP		1~ 1.5
Higaturu – Oro		1~ 1.5
Sumberipa – Oro		1~ 1.5
Mamba – Oro		1~ 1.5
Hagita- MBP		1~ 1.5
Poliamba – NIP		1~ 1.5
Kimbe (new const.)		2
Hargy – WNBP	Hargy Oil Palms LTD.	1~ 1.5
Navo – WNBP		1~ 1.5

Source: Pacific Lighthouse in August 2013

(6) Ocean Energy

Ocean energy consists of tidal power, wave power, ocean thermal power[19], etc. Among these, a 2-MW class tidal power pilot plant has been operating at some locations around the world since 2008.

Little is known about PNG's potential for tidal power, wave power, or ocean thermal power. The tidal range is 2.7 m/s near POM versus 1.1 - 1.6 m/s in most of the country. There is reportedly a 6 m/s range in parts of the Torres Strait. There have been very preliminary proposals to tap tidal currents (peaking at 7 - 11 km/hour) at Buka Passage, Bougainville.

18 All palm oil mills in PNG generate part of their electricity from palm kernel shell & fiber waste and mainly uses energy for palm oil processing. Higaturu also supplies some nearby residences with electricity.
19 Power generation utilizing water temperature differences between the sea surface and sea bottom.

3.2 OUTLOOK ON PRIMARY ENERGY FOR THE RAMU SYSTEM TOWARD 2030

Based on the information on Section 3.1 “Status of Primary Energy in PNG,” we focus on the promising energy resources for the power generation in the Ramu System in this section.

3.2.1 Evaluation of Each Energy Resource

(1) Hydropower

Fig. 3.2-7 (attached in Section 3.2.3 “Energy Resources Map in the Ramu System”) shows the Energy Resources Map in the Ramu System. The blue lines indicate rivers. There are two big rivers in the Ramu System, i.e., the Ramu River and Markham River. There are also many medium size rivers suitable for Hydropower Plants.

In the east coast of the Morobe and Madang Provinces, Hydropower Plants are either in place or being planned in the Gowar Rivers, the Mongi-Blunm River, and Bainune Creek. In the highland area, Hydropower Plants are being planned at sites along the Waghi River, Asoro River, and Kaugel River.

Therefore, the hydropower is one of the promising sources of electricity supply to the Ramu System.

(2) Mini Hydropower

As explained in Section 3.1.2 (2) “Mini Hydropower,” the Madang, Morobe, Eastern Highlands and Southern Highlands Provinces belong to the Ramu System are endowed with a lot of mini hydro potential. The capacity of mini hydro, however, is usually within 1 MW and suitable for rural electrification.

Mini hydro is not considered a feasible energy source of electricity supply to the Ramu System in this Feasibility Study because its capacity is too small to connect the grid. It is rather suitable for mini-grid to promote the rural electrification.

(3) Oil

Diesel oil is now widely used for the diesel generators in the Taraka and Milford Power Stations, etc. and has recently been introduced for use to drive the GT in the Lae wharf.

While diesel oil is available as an energy source for power generation in the Ramu System, it is costly and imposes a significant environmental burden. It should therefore be used on a limited basis for peak/backup power and/or short relief until the large Hydropower Plants begin operating.

(4) Natural Gas

There are currently four potential natural gas resources for the Ramu System: 1) Natural gas in the highland area, 2) the Stanley gas field in the Western Province, 3) Natural gas in the Madang Province and 4) An IPP project in the highland area.

1) Natural gas in the highland area

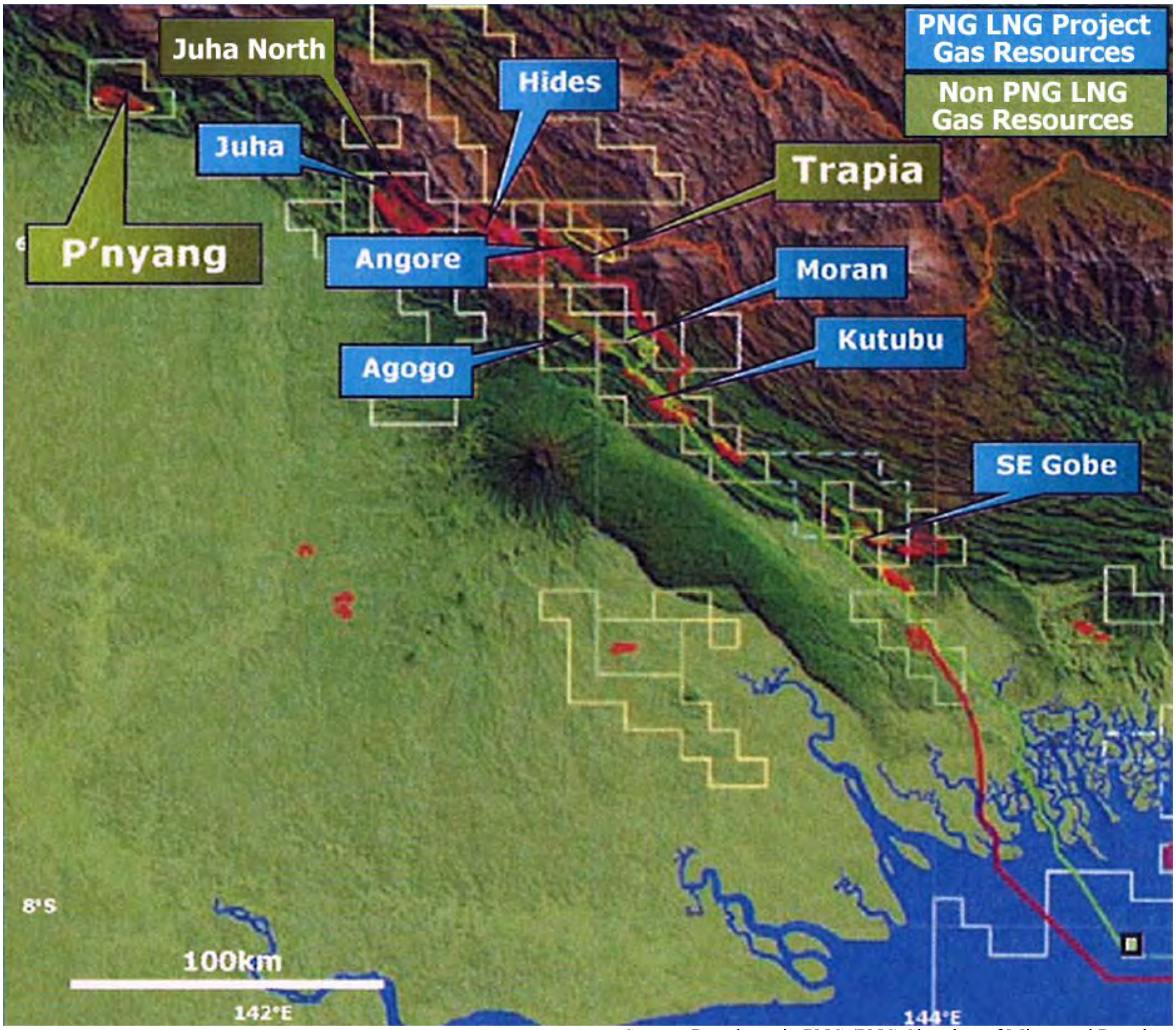
As shown in Fig. 3.2-1, there are ample gas reserves in the highland area. The oil/gas fields marked in blue are contracted with the PNG LNG project, while those marked in green are not yet contracted.

Among the gas fields marked in green, P'nyang (in the Western Province) has relatively huge gas reserves. According to the report from Oil Search, the total 2C recoverable gas in P'nyang is estimated at 2.5 ~ 3.0 TCF. If 15% of the gas reserve can be used for domestic purpose and the lifetime of a gas-fired TPP is assumed to be 25 years, the available gas quantity for gas-fired TPP is estimated at 41 ~ 49 mmcfd.

The table on the rights shows estimates of available MW for each type of gas-fired TPP based on the expected plant efficiency for each unit capacity.

Type[20]	Possible MW
GT (26 MW)	236 ~ 282
GE (1.5 MW)	272 ~ 325
GTCC (41 MW)	352 ~ 421

Due to differences in plant efficiencies, the Gas Turbine Combined Cycle (GTCC) plant produces almost 1.5 times more output than the GT with the same gas consumption.



Source: Petroleum in PNG (PNG Chamber of Mines and Petroleum)

Fig. 3.2-1 Gas Fields in the Highland Area

20 The efficiencies of these generators are varied along with their outputs (MWs). The efficiencies corresponded to MWs in parentheses are used to estimate possible MWs.

There is a precedent gas-fired TPP in the highland area. Picture 3.2-1 shows GT TPP (62 MW) in Hides for the Porgera Gold Mine. Its initial operation was in 1991, hence it has already operated for 24 years.

According to the Oil Search report, there is a plan to replace the obsolete GT TPP with a GTCC TPP.

Source: Oil Search

Picture 3.2-1 GT TPP (62 MW) in Hides for the Porgera Gold Mine

2) Stanley Gas Field in the Western Province

The Stanley gas field is being developed through a joint venture between Horizon Oil and Talisman Energy in the Western Province, as shown in Fig. 3.2-2. The condensate stripping project is ahead until the gas pipelines are installed. The dry gas could supply domestic and large industry consumers in the region. Any dry gas not sold will be re-injected into the reservoir and banked until required for sale.

In February 2012, GoPNG announced that the Cabinet had approved a proposal by PNG Energy Development for a gas power plant at Stanley. This could supply the OK Tedi mine and the possible mine development at Frieda River, as well as potential consumers across the border in West PNG. The key social objective of the Study is to supply power to the rural area in the Western Province.

There is another plan to develop gas for the PNG's third LNG project together with gas from Elevala/Ketu gas fields while they are currently in PePLstate.

A study will be required with regard to the power supply to the Ramu system using the Stanley gas, because the gas field is far from the Ramu grid system.

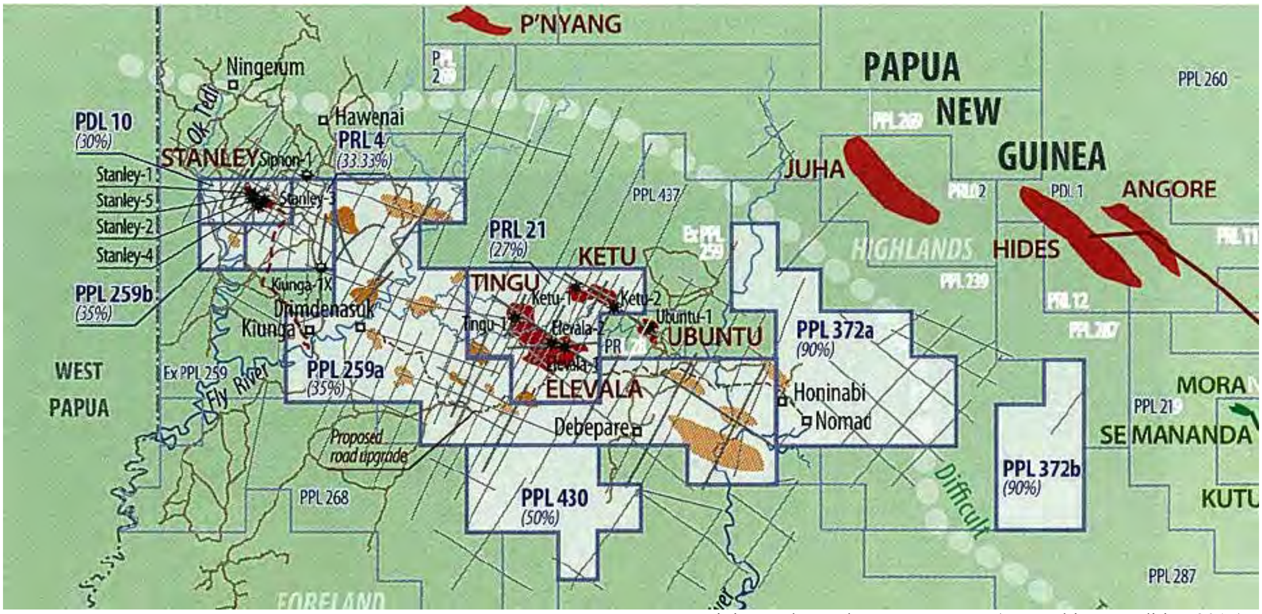
According to "Petroleum in PNG" reported by PNG Chamber of Mines and Petroleum, the contingent resources of Stanley gas field are 361 BCF[22] of gas. If 15% of the gas reserve can be used for domestic purpose and the lifetime of the gas-fired TPP is assumed to be 25 years, the available gas quantity for the gas-fired TPP is estimated at 5.9 mmcfd.

The table on the right shows estimates of available MW for each type of gas-fired TPP based on the expected plant efficiency for each unit capacity.

Type[21]	Possible MW
GT (26 MW)	34
GE (1.5 MW)	39
GTCC (41 MW)	51

21 The efficiencies of these generators are varied along with their outputs (MWs). The efficiencies corresponded to MWs in parentheses are used to estimate possible MWs.

22 According to "Mining and Petroleum Investment" by PNG (Thirteenth Edition 2015), the gross proven and probable contingent resources (2C) in discovered fields together with prospective resources in potential field extensions total 1.4 TCF. Therefore, the contingent resources might increase in the future.



Source: Mining and Petroleum Investment (PNG Thirteen Edition 2015)

Fig. 3.2-2 Location of the Stanley Gas Fields

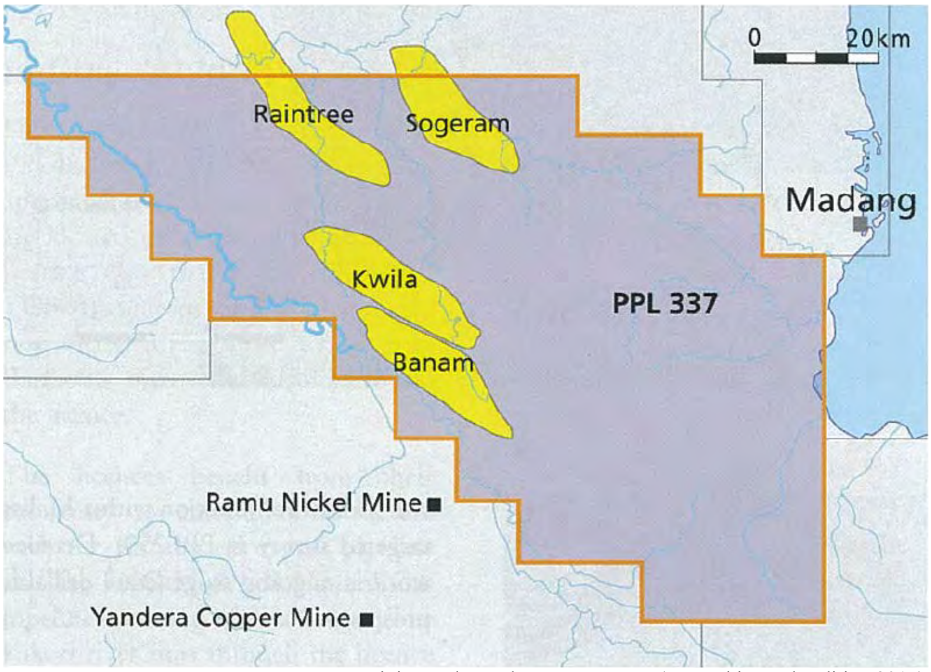
3) Natural gas in the Madang Province

As shown in Fig. 3.2-3, PePL 337 is located near Madang and developed by Heritage[23]. According to Profile (Thirteenth Edition 2015) by Chamber of Mining and Petroleum Investment, the presence of gas seeps within the license indicates an active petroleum system. Four prospects have been identified on the license to date.

The license has good access by road and is located near potential local gas markets, i.e., the gas supply to the gas-fired TPPs for the Ramu Nickel Mine (ca. 80 MW) and Yandera Copper Mine (ca. 100 MW).

The location is also suitable for LNG export because of its close proximity to the deep water port of Madang.

23 Heritage was founded in 1992 with initial interest in offshore Angola. Since then it has had exploration success with the discovery of the M'Boundi oil field in Congo. Heritage is now a privately owned company following the acquisition by al Mirqab on June 30, 2014. Heritage is expanding into SE Asia with the farm-in into four licenses in PNG.



Source: Mining and Petroleum Investment (PNG Thirteenth Edition 2015)

Fig. 3.2-3 Location of the PePL 337 Prospect

Two prospects proposed for drilling are the Kwila and Raintree prospects. Initial well planning has commenced to enable the testing of these prospects by the drilling of two shallow wells in Q4 2014/Q2 2015.

4) An IPP project in the highland areas

According to the latest information, a developer is now presenting Power Purchase Agreement (PPA) on an IPP proposal with a project for small gas-fired TPPs in the highland area. The gas source for the gas-fired TPPs is not yet revealed. If the gas source is different from the P'nyang gas field, the potential of the gas-fired TPP in the highland area will be further increased.

(5) Coal

Although there is some movement to explore the coal mines in PNG, long lead times are required to produce coal in the country. Hence, coal production does not seem to be in time by the project target year of 2030.

On the other hand, PNG is close to Indonesia and Australia, two of the world's major coal exporters. However, there is no plan to import coal from these countries so far.

The following enumerates the merits/demerits of coal-fired TPP compared with gas-fired TPP.

1) Merit

In general, the electricity generation cost of a coal-fired TPP is cheaper than that of a gas-fired TPP.

Coal-fired TPP: around USC 9.0/kWh

Gas-fired TPP: around USC 10.5/kWh

2) Demerits

a) CO_2 emission from a coal-fired TPP is almost twice as high as that of a gas-fired TPP.

b) Nitrogen oxides (NOx) emission from a coal-fired TPP is more than threefold higher than that from a gas-fired TPP.

c) A gas-fired TPP emits no SOx.

d) A coal terminal must be constructed in the wharfs of Lae or Madang if a coal-fired TPP is constructed in the Ramu System.

Weighing the pros and cons, a coal-fired TPP does not seem to be superior to a gas-fired TPP for the Ramu System. In conclusion, coal will not be a feasible energy resource for the Ramu System by 2030.

(6) Geothermal

According to Fig. 3.1-9, there are several geothermal resources in the Ramu System: 1) Bulolo, Kulolo, Wondumi, Wau in Morobe and 2) Karkar Island, Long Island in Madang.

However, no site investigations for these potential locations have been done so far. Given the long lead time required to operate a geothermal TPP from the investigation stage onward and the project target year of 2030, geothermal has little chance of becoming an energy resource for the Ramu System in time.

With regard to the geothermal resources in Madang, the transfer of the generated power to the Ramu System presents another problem, because these potential sites are in the islands. It would be technically possible to install T/L through the sea, but the installation costs would be huge.

Considering the foregoing situation, geothermal is not likely to be a feasible energy resource for the Ramu System up to 2030.

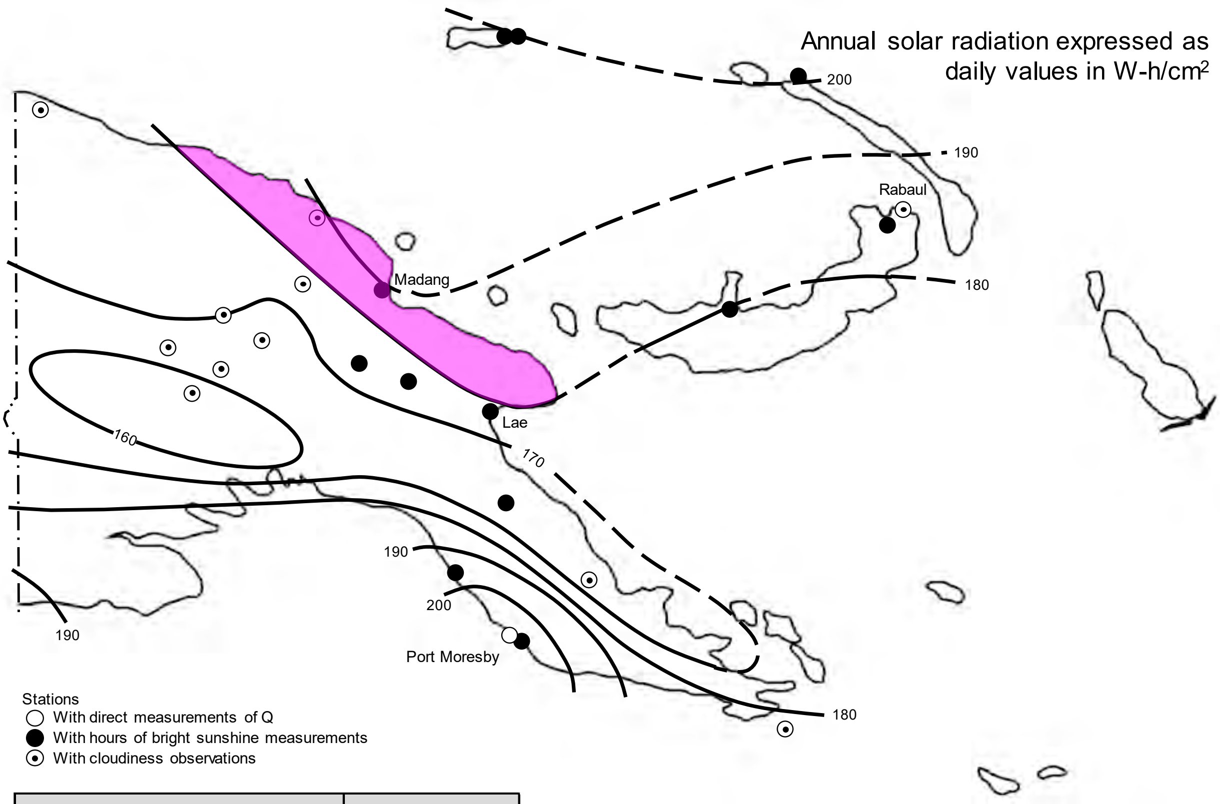
However, as geothermal is one of the most promising energy resources in PNG, it cannot be completely denied the case that the geothermal resources in Morobe are suddenly developed by the governmental or overseas fund in near future.

(7) Solar Energy

As shown in Fig. 3.2-4, the annual solar radiation level of PNG approaches that of sun belt areas in the Middle East, Africa, etc. and exceeds that of Japan.

POM and New Ireland are the most suitable areas for solar power in PNG, followed by the east coast of the Madang and Morobe Provinces. Hence, the area marked in pink in Fig. 3.2-4 is the suitable area for solar power in the Ramu System.

Although the pink zone includes parts of the lower montane forest area and the lowland rainforest area, those zones are excluded from Fig. 3.2-7 in view of the difficulty of constructing solar power plants in these areas.



Location	W-h/cm^2
Sun belt (Middle East, Africa, India, Mexico, Austrarlia, etc.)	200 ~ 250
Japan	100 ~ 150

Source: Climate of Papua New Guinea by J.R. McAlpine, etc.

Fig. 3.2-4 Candidate Location for Solar Power in the Ramu System

Mega solar power is now popular in Japan. The in Picture 3.2-2 shows a 10 MW solar power station of Kansai Electric Power Company in Japan.

Although the unit price (USD/kW) of solar power plants exceeds the unit prices several other renewable energy power plants, the price is declining around the world year by year.

Given that the solar power potential in PNG exceeds that of Japan, solar power is considered a feasible energy resource for the Ramu System.

Picture 3.2-2 Mega Solar (10 MW) in Japan

(8) Wind Energy

As explained in Section 3.1.5 (4) "Wind Energy," the WB has started an investigation project to identify the wind power potential in PNG.

The project is implemented in three phases:

Phase I : Mesoscale Wind Modeling Analysis (completed)

Phase II : Reflecting Phase I results, the installation of meteorological masts were commenced at the end of July 1015, and the data acquisition will be carried out over 2 years

Phase III : Review of the mesoscale wind modeling analysis compared with the data actually acquired by meteorological masts will be conducted, and as the results, the wind mapping in PNG will be completed by 2017

According to Interim mesoscale wind modeling report issued in August 2015, in regard to the Ramu System, there are two potential locations; 1) higher modelled winds in the straight between New Britain and Morobe and 2) in Highlands enhanced by their elevated exposure.

The feasibility of wind power for the Ramu System should be determined based on the evaluation results of the final report by the WB.

(9) Biomass

As shown in Table 3.1-5 in Section 3.1.5 (5) “Biomass” the utilization of biomass is roughly categorized as a) power generation, b) heat generation, and c) fuel production.

Among them, b) “heat generation” falls outside of the project objective and c) “fuel production” is mainly used for transportation and export purposes and is too small in quantity to be used for power generation.

Two types of a) “power generation” are available, i.e., a direct combustion system and gasification system. The gasification system is further divided into bio-chemical processes and thermochemical processes.

The present capacity[24] of the gasification system is generally small, on a level suitable for rural electrification. Hence, a direct-combustion biomass power plant is selected for biomass power generation in this study.

With regard to raw material for the biomass generation, plantation produce (trees, tree waste, etc.), wood waste (bark, sawdust, woodchip, etc.), agriculture waste (bagasse, palm kernel shell & fiber waste, empty fruit bunch, coffee husk, rice husk, etc.), and garbage (food waste, paper waste, etc.) are examined.

As explained in Section 3.1.5 (5) “Biomass,” agriculture waste is already utilized in PNG for self-use power generation and/or for steam to process products, and for heat for drying and cooking. Garbage, meanwhile, is too low in quantity to be used power generation.

Therefore, the possible raw materials for power generation in the Ramu System are limited to plantation produce and wood waste. These candidates are further examined as follows;

According to Pacific Regional Energy Assessment 2004 (Papua New Guinea National Report

24 If IGCC (Integrated Gasification Combined Cycle) by biomass is utilized in the future, a large-capacity gasification system is expected to be realized. However, realization by the target year of 2030 would be difficult in PNG.

Volume 10), as a rule of thumb, for each m^3 of log extracted in the plantation, about the same amount stays in the bush (i.e., the same amount is unavailable for productive use): for each m^3 of processed timber produced, at least the same amount remains as waste. In total 200 m^3 of logs cut generate about 100 m^3 of logs extracted, which generate about 45 m^3 of useful processed wood and 55 $m^3$of waste.

Only a small percentage of the wood extracted in PNG is processed locally, and much of the portion processed locally goes to chip mills in neighboring cities. The bulk is exported as logs and only a small amount is processed in PNG, leaving a relatively small amount available in practice for potential energy production.

The major timber processing plants in the Ramu System areas (Morobe, Madang, the highland areas, etc.) are listed below;

kind	Facilities	Location
Sawmills	Madang Timbers Limited	Madang
Plywood Factory	PNG Forest Product	Bulolo, Morobe
Woodchip Mill	Jant Limited	Madang
Furniture Factory	Phillco Joinery Limited	Lae, Morobe
	PI Logging	Taraka, Lae, Morobe
	Timber saw	Lae, Morobe

Source: Pacific Regional Energy Assessment 2004

According to PNG Forest Authority (PNG FA), the wood waste from above-listed facilities is already utilized for self-use power generation, for steam to process products, and for heat for drying and cooking. Too little is left over for use for power generation.

GoPNG is now encouraging the timber industry to export processed products instead of logs. There is therefore a possibility that wood waste will be augmented in the future. Yet even if the amount of local timber process increases, the utilization of the wood wastes for self-use is expected to increase accordingly. Therefore, the power-generating potential of wood waste for the Ramu System does not seem to reach a significant level.

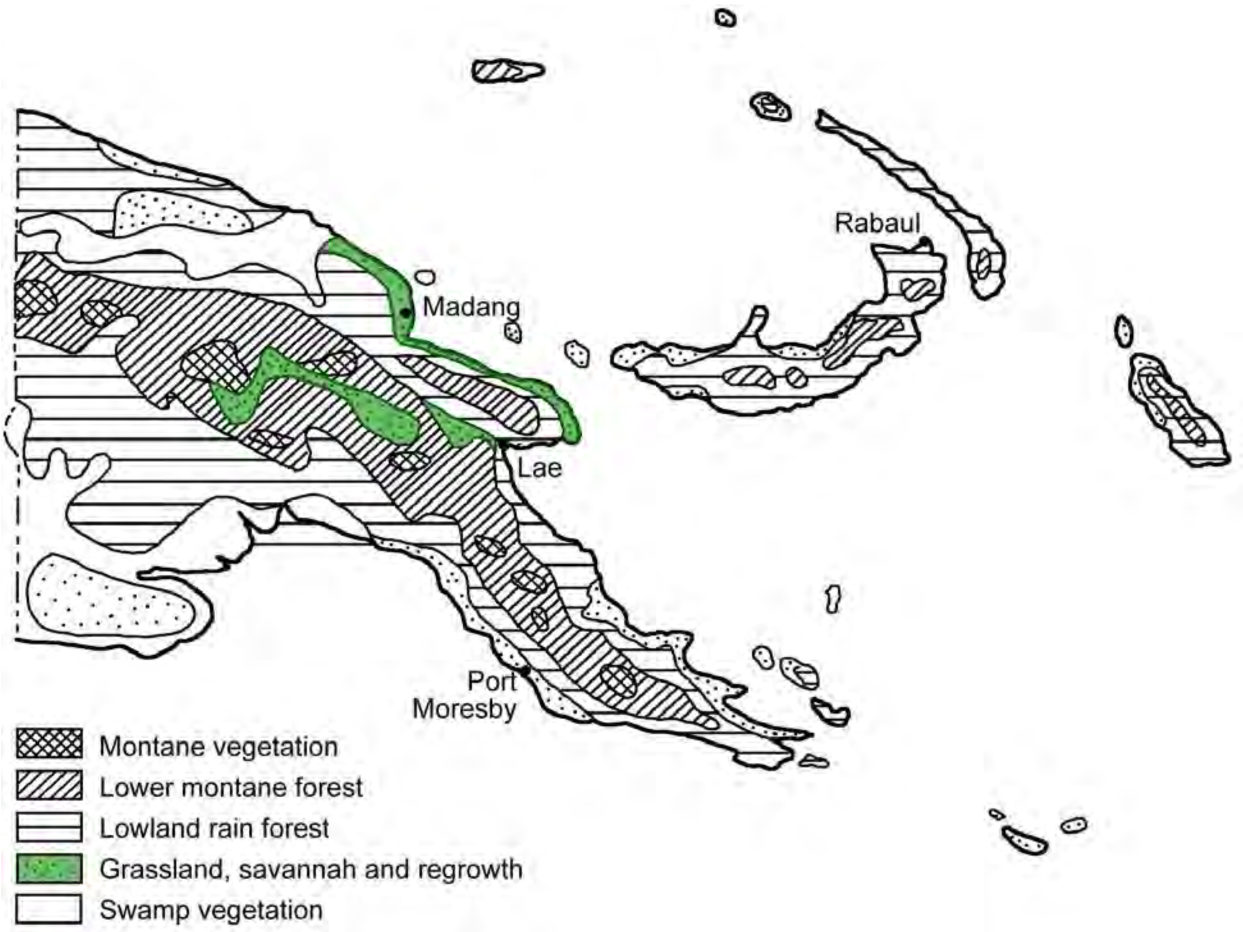
On the other hand, the plantation produce (both trees and tree waste) seems likely to become a feasible source of power generation for the Ramu System in the future.

1) Power Generation with Plantation Trees

Oil Search is proceeding with a 30 MW (15 MW × 2 units) Biomass Power Generation Project in the Markham Valley in the Morobe Province. The specifications are described in Section 5.3.2 “Biomass Power Plant.”

Oil Search has already concluded Memorandum of Understanding (MOUs) over 22,000 ha with local landowners. At the site inspection in November 2014, JICA Study Team found that eucalyptus pellita grew to around 5-m in height (see the picture to the right).

As shown in Fig. 3.2-5 the suitable locations for power generation with plantation trees are the east coast of the Morobe and the Madang Provinces and the highland areas categorized as grassland, savannah and regrowth (mostly uncultivated areas), in addition to the Markham Valley.



Source: Climate of Papua New Guinea by J.R. McAlpine, etc.

Fig. 3.2-5 Candidate Locations for Biomass Power in the Ramu System

2) Power Generation with Plantation[25] Tree Waste

As explained above, the same amount of plantation waste[26] extracted as logs is currently burnt without reuse. There is therefore a substantial potential to utilize this waste for power generation in the Ramu System.

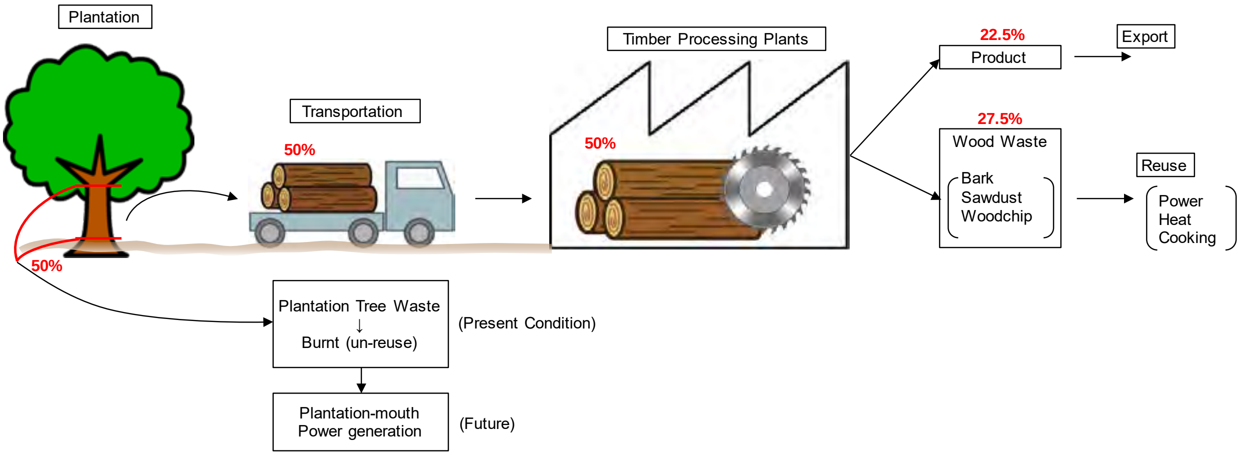
Given the high cost of transporting the tree waste to demand sites such as neighboring cities, the construction of plantation-mouth power stations seems to be suitable in this case.

Fig. 3.2-6 shows the flow of utilization of the plantation tree waste. Around 50% of grown

25 According to PNG FA, plantation areas are operated and managed by PNG FA. On the other hand, concessioner areas are operated by private companies and managed by PNG FA. Concessioner areas are much wider than plantation areas in PNG. In this F/S report, plantation areas mean plantation areas + concessioner areas

26 Thinning is regarded as a part of plantation waste

trees in the plantation can be used as fuel for the plantation-mouth power station.



Source: prepared by JICA Study Team

Fig. 3.2-6 Power Generation with Plantation Tree Waste

To grasp the power generation potential by utilizing tree waste, JICA Study Team have got the data on amount of the tree waste from the Bulolo Plantation in Morobe through PNG FA as follows;

Annual tree waste including thinning[27] = 60, 000 m^3/year

Preliminary estimation on the potential power generation by the tree waste in the Bulolo Plantation is carried out by the following assumptions;

Average density of the tree waste based on air-dry basis:	0.5 ton/ m^3
Average calorific value of the tree waste based on air-dry basis:	3,000 kcal/kg
Plant efficiency of the biomass power plant with the tree waste:	15%
Capacity factor of the biomass power plant with the tree waste:	80%
Expected power output of the biomass power plant:	2.2 MW

2.2 MW seems to be well worthy to supply power to the Ramu System as single power sources. However, aforementioned assumptions should be reviewed through the actual site inspection of the Bulolo Plantation. On top of that, there seem to be very few pre-existing projects for the plantation-mouth power plants with tree waste elsewhere in the world. It will therefore be required to carry out a feasibility study to select the feasible site and to estimate more accurate possible MWs and to study the plant process, technical specifications, EIA, economic/financial analysis, etc.

(10) Ocean Energy

There is a potential for tidal power at the Vitiaz Strait near the east coast of the Morobe Province, where relatively high tidal speeds are observed.

Overall, however, it seems premature to consider ocean energy as a promising energy resource in the Ramu System by 2030, given that tidal power is in a pilot plant stage even in developed countries.

27 According to PNG FA, the tree waste in the Bulolo Plantation is not burnt but left as it is.

3.2.2 Table Summarizing the Promising Energy Resources in the Ramu System toward 2030

Table 3.2-1 briefly summarizes the evaluation results on the foregoing (1) ~ (10). Fourteen energy resources are examined and five energy resources are selected as promising energy resources for electricity supply to the Ramu System by 2030.

Table 3.2-1 Table Summarizing the Promising Energy Resources in the Ramu System (up to 2030)

No.	Type of Energy	Availability/Feasibility	Explanation
1	Hydropower	○	There are many large and medium-size rivers in the Ramu System suitable for hydropower power generation: e.g., Ramu and Markham Rivers (large), Gowar, Mongi-Bulum, Baiune, Waghi, Asoro and Kaugel Rivers (medium)
2	Mini Hydropower	△	There are rich mini-hydro resources in the Madang, Morobe, and Highland areas, but the capacity of mini hydro is usually up to 1 MW rather suitable for mini-grid to promote the rural electrification.
3	Oil	○	Diesel oil is widely used for DGs and a GT in the Ramu System.
4	Natural Gas	○	There are currently four potential gas resources to supply power to the Ramu System, i.e., P'nyang and Stanley gas fields in the Western Province, PePL 337 in the Madang Province, and gas-fired IPP project in the Highland area.
5	Coal	×	There is no plan so far to import coal to PNG or develop coal mines as an energy resource to supply power to the Ramu System.
6	Geothermal	△	There are several potential geothermal resources in the Ramu System, i.e., Bulolo, Kulolo, Wondumi, Wau in Morobe and Karkar Island, Long Island in Madang. No survey, however, has been conducted so far. Considering long lead time to the operation, geothermal does not seem to be in time as a source of power supply to the Ramu System by 2030. But narrow hope to develop until 2030 remains as it is one of the most promising energy resources in PNG.
7	Solar Energy	○	The eastern coastlines of Madang and Morobe Provinces receive high solar radiation and are suitable for solar power plants, including mega-solar systems.
8	Wind Energy	?	There is no known wind monitoring data since 1990s. The WB is starting an investigation project to identify the wind power potential in PNG. The feasibility of wind energy has to be judged from the study results.
9	Biomass with Plantation Trees	○	Oil Search is developing a 30 MW project with plantation (Eucalyptus) in the Markham Valley. There are other suitable areas for biomass power generation in the Ramu System.
10	Biomass with Plantation Tree Waste	?	There seem to be prospects on the utilization of plantation tree waste for the power generation in the Ramu System. However, the final conclusion requires the implementation of a feasibility study for the candidate plantation site.
11	Agriculture/Wood Wastes	×	The amount of biomass waste is not enough to supply power to the Ramu System. Most of the waste already utilized for self-use.
12	Biogas	×	The capacity of the gasification systems (both bio-chemical process and thermochemical process) is usually small and better suited for mini-grid to promote the rural electrification.
13	Biofuel	×	Biofuel is used not for power generation but for export and vehicles in PNG.
14	Ocean Energy	×	The detailed potential in PNG is unknown. It would probably be premature to select the ocean energy for power generation in the Ramu System by 2030, given that power generation by ocean energy is still in a pilot plant stage even in developed countries.

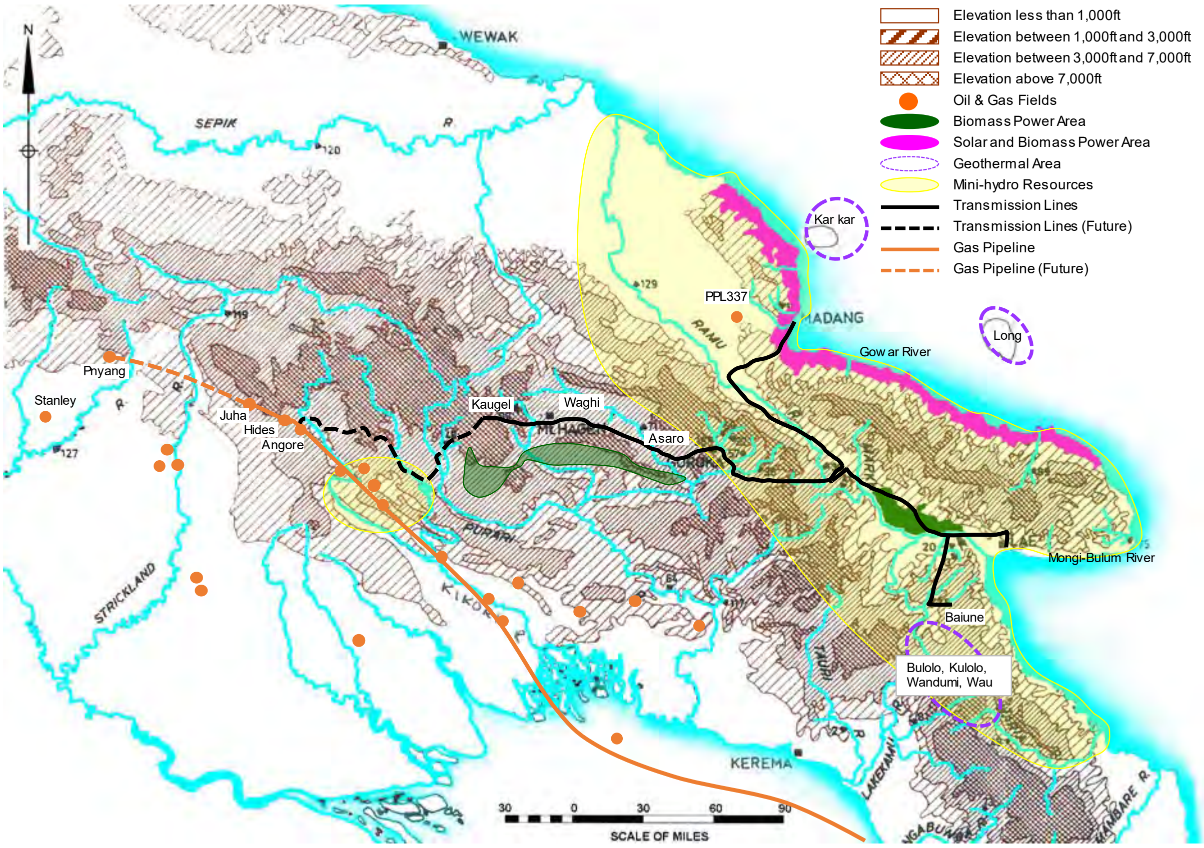
○: Available & Feasible △: Not so feasible ×: Not feasible ?: Further study is needed

Source: Prepared by JICA Study Team

In conclusion, the promising energy sources for power generation in the Ramu System by 2030 are hydropower, natural gas, solar, and biomass with plantation trees, along with oil on a limited basis for peak/backup and/or short relief until the operation of hydropower goes online because of high oil prices and environmental considerations.

3.2.3 Energy Resources Map in the Ramu System

Fig. 3.2-7 shows the energy resources map in the Ramu System reflecting the evaluation results on the foregoing (1) ~ (10).



Source: prepared by JICA Study Team

Fig. 3.2-7 Energy Resources Map in the Ramu System

3.3 CONCLUSIONS AND RECOMMENDATIONS

3.3.1 Conclusion

The promising energy resources for power generation in the Ramu System toward 2030 are hydropower, natural gas, solar power, and biomass with the plantation trees, along with oil on a limited basis for peak load/backup power and/or short relief until the Hydropower plants go online due to high diesel oil prices and environmental considerations.

The availability of wind power should be evaluated after the investigation by the WB. The prospects for biomass with plantation tree waste should be determined after the feasibility study results in the future.

3.3.2 Recommendation

(1) Energy Resources

Through the F/S, available and possible energy resources in the Ramu System up to 2030 are identified. Based on the identification, adopted energy resource and its generation capacity (MW) in the Ramu System should be properly reflected on the Optimal Power Generation Development Plan with consideration of the results of Power Demand Forecast.

Apart from the identification, there are several unidentified energy resources for power generation in the Ramu System at present. Therefore, we recommend ongoing investigation of the following two energy resources from now on and revisions of Table 3.2-1 “Table Summarizing the Promising Energy Resources in the Ramu System (up to 2030)” and Fig. 3.2-7 “Energy Resources Map in the Ramu System” if required.

The availability of wind power should be determined based on the evaluation in the final report by the WB to be issued in 2017 (scheduled).

Biomass with plantation tree waste has considerable potential and is currently unused in PNG. It will be necessary to carry out a feasibility study for the candidate site to evaluate the feasibility and then to proceed with estimations of the possible MWs, study of the plant process, technical specifications, EIA, and economic/financial analysis, etc.

(2) Gas Contract System

The present gas contract system in PNG is based on the license system. As explained in Section 3.1.3 (5), for the natural gas fields exploited only for domestic use, we recommend that PNG consider the adoption of the similar gas contract system used in Vietnam, a more beneficial model for PNG.

CHAPTER 4

POWER DEMAND FORECAST

CHAPTER 4 POWER DEMAND FORECAST

4.1 POWER DEMAND FORECAST OF THE RAMU SYSTEM

4.1.1 Background

In PNG, the political situation has been stable since 2012 when President O'Neill came to power. From an economical perspective, real Gross Domestic Product (GDP) growth level has hovered between 6 and 9%, outperforming East South Asian countries, due to the satisfactory agricultural and mining sector. In particular, new resource industry promotion based on LNG is expected to be a huge catalyst for economic growth. In an LNG project worth 19 billion US$ by Exxon Mobil, exports of LNG commenced in 2014.

Under these circumstances, domestic electric demand is also expected to increase in future. According to the FYPDP 2014-2028, published by PPL, energy sales and peak demand of PPL, 944GWh and 225MW as of 2013, will increase to 1,468GWh and 456MW as of 2028. In the Ramu System, which supplies electricity from Highland regions to Momase regions, such as Lae, Madang, Mt. Hagen, peak demand is forecast to increase from 88MW as of 2013 to 147MW as of 2028.

In response, the PNG government requested technical support from the Japanese government to establish a master plan for the Ramu System and Lae city distribution system. This plan would implement a demand forecast, with the result reflected in a power generation development plan and power system plan.

4.1.2 Current Power Demand Status

(1) Historical data

Peak demand of the Ramu System stopped at around 40 MW from 1999 to 2007, but rose to around 50 MW from 2008, around 60 MW from 2010, 81.8MW as of 2013 and 87.8MW as of 2014, with peak demand steadily increasing. The average growth rate in energy sales, excluding the mining sector, from 2009 to 2013 has been 4.6%. Recent steady growth is due not only to steady growth in the Base Load, such as the commercial, industrial and domestic sectors, but also the impact of the Hidden Valley mining load, which started to operate from 2011. Fig. 4.1-1 shows a historical transition in energy sales from 2009.

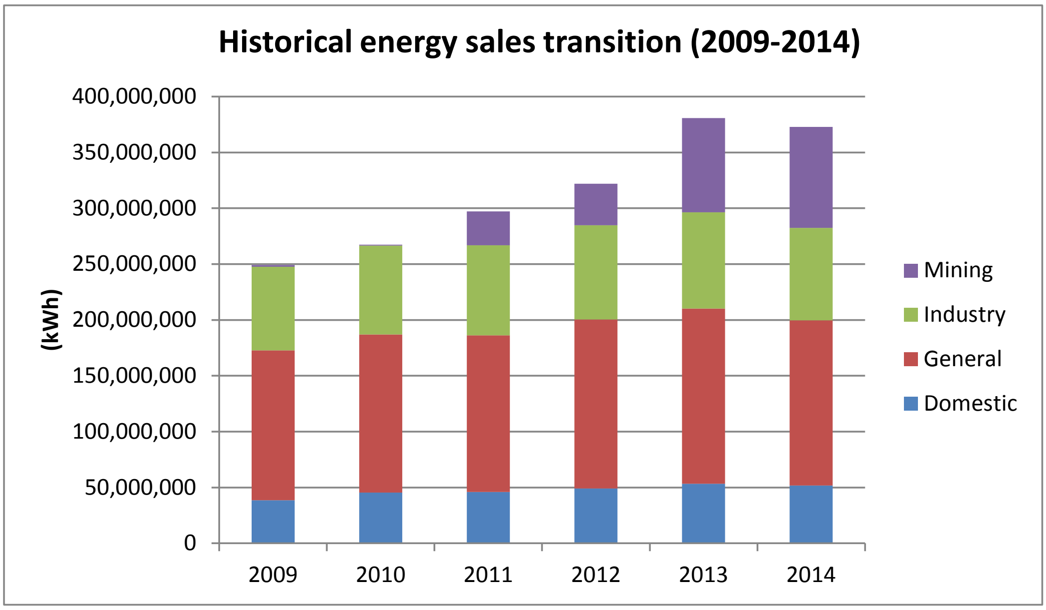


Fig. 4.1-1 Historical Energy Sales Transition

(2) Each Sector

Consumers are categorized into four sectors such as industrial, general supply (mainly commercial), domestic sector and public lighting, each of which is defined as follows;

1) Industrial

Consumer with contracted capacity exceeding 200kVA, whose price comprises demand price and utilization price

2) General supply (Mainly commercial)

Consumers with contracted capacity under 200kVA
Excluding consumers residing in buildings for domestic use.
Including consumers who lease buildings for domestic use and do not live there.

3) Domestic

Consumers who occupy buildings for domestic use

4) Public lighting

Organizations which install public lighting, such as city or state governments

In the demand analysis, consumers are categorized into three sectors, where general supply includes public lighting. Fig. 4.1-1 shows the energy sales transition of each sector and the summation.

The growth rate of energy sales in each sector between 2009 and 2013 was 3.5% for industrial, 4.0% for general supply and 8.4% for domestic respectively. The growth rate in total energy sales, excluding mining, was 4.6% between 2009 and 2013, which showed steady growth. However, total energy sales in 2014 were slightly below those of 2013.

(3) Each region

The Ramu System area includes 15 service centers, collectively known as ‘Center’.

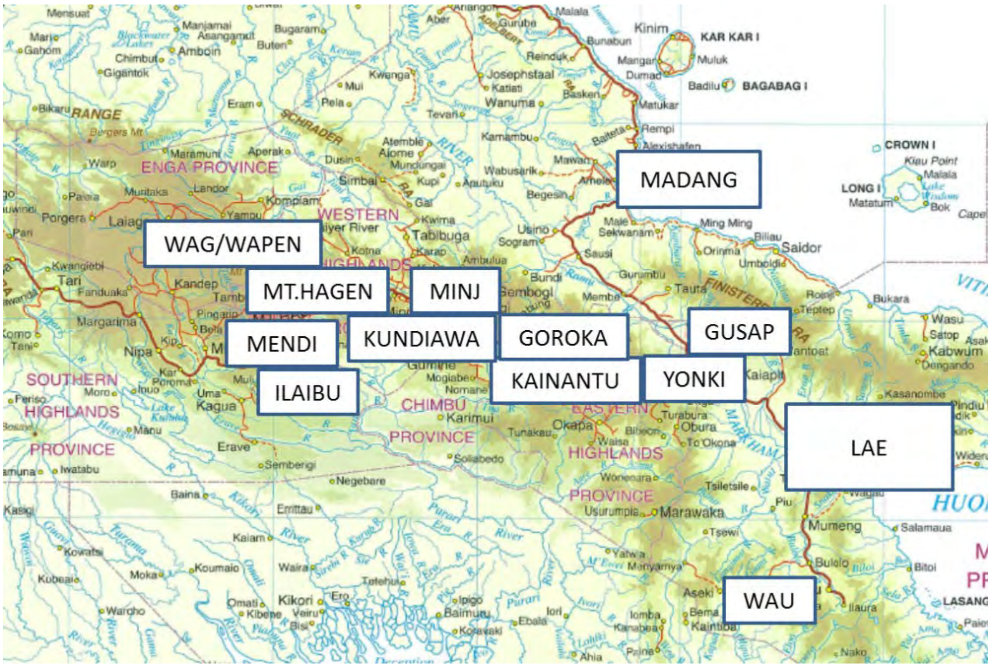
From the eastern region of the Ramu System area, the name of each Center is enumerated below, based on Customer Service at PPL’s headquarters.

LAE, FINSCHAFFEN, MUMENG, WAU, MADANG
GUSAP, YONKI, KAINANTU, GOROKA, KUNDIAWA
MINJ, MT.HAGEN, MENDI, ILAIBU, WAG/WAPEN

Here, FINSCHAFFEN and MUMENG have only a little demand and are located near the Lae region, so in the analysis, these two centers are to be included in Lae Center and the total number of centers in the Ramu System area will be 11.

Fig. 4.1-2 shows the transition in annual energy sales at each Center, while Fig. 4.1-3 shows the peak demand percentage of each center in 2014. Recently, that of Lae Center was the largest, followed by Wau, where Hidden Valley mining is located, 3rd Madang, 4th Mt. Hagen and 5th Goroka. Other centers - except for the top five centers located in the western Highland region, have little energy sales compared to the top 5.

In the Ramu System, the growth rate of energy sales between 2009 and 2013, is 5.1% for Lae and 6.1% for Madang, where industry and commerce are developing steadily. This is remarkable compared to other centers.



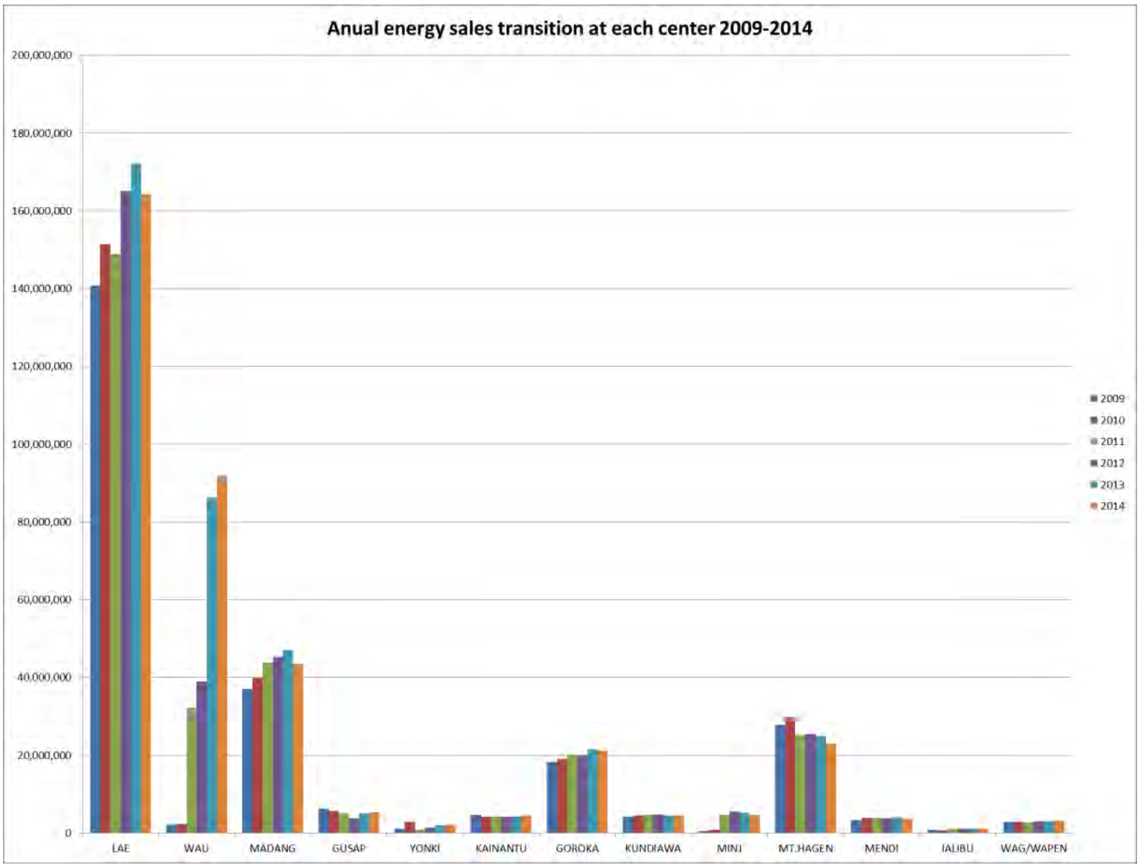


Fig. 4.1-2 Annual Energy Sales Transition at Each Center 2009-2014

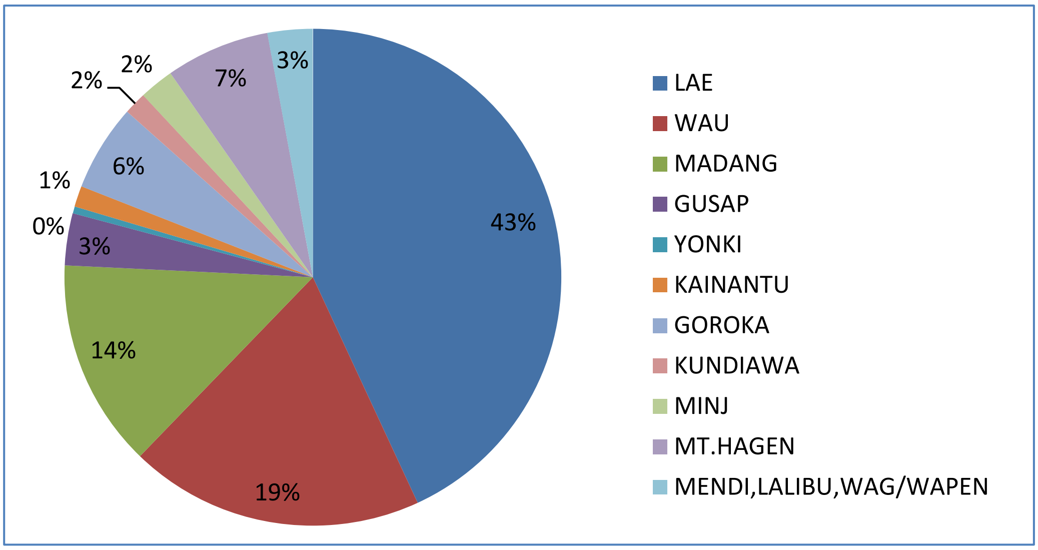


Fig. 4.1-3 Peak Demand Ratio of Each Center in 2014

4.1.3 Methodology for Demand Forecast

The demand forecast until 2030 in the Ramu System is based on the methodology adapted in FYPDP and settled by PPL. The reason is that the power demand forecast is to be revised by PPL according to the changes in surrounding circumstances and the revision work is expected to be smooth based on the same methodology in future. Clarifying the power demand forecast simulation conditions and simulation algorithm is crucial and allows the power demand forecast result to be general purpose and applicable.

Fig. 4.1-4 shows the configuration of the methodology, with each part explained in the following section;

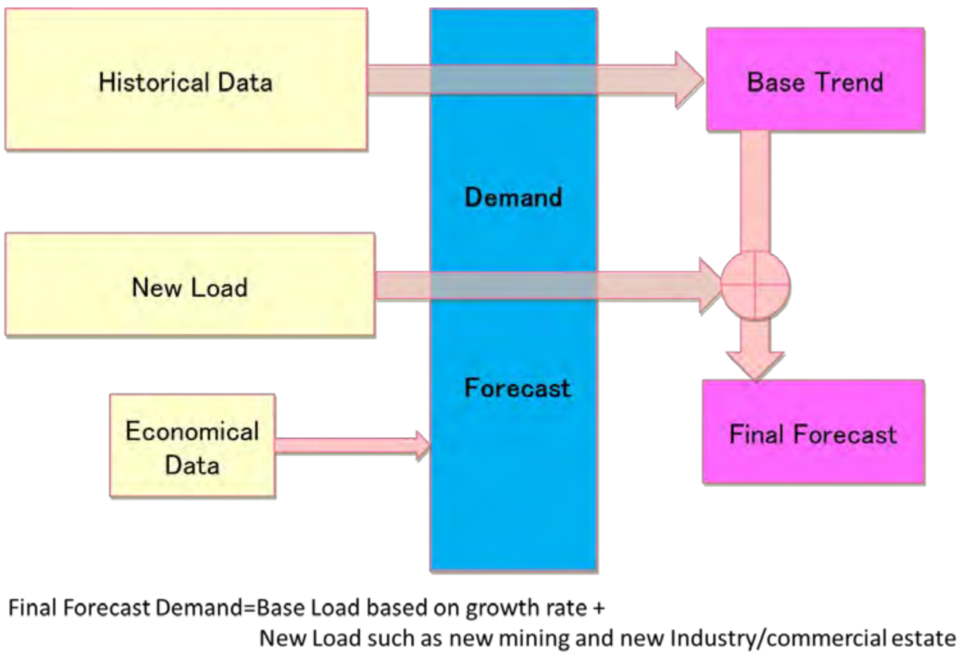


Fig. 4.1-4 Configuration of Demand Forecast Methodology

(1) Trend forecast

Based on historical data of total power demand, the future growth rate is calculated and total power demand is forecasted from a macro perspective. Conversely, the power demand of each sector is forecasted and integrated by calculating each sector's future growth rate, where the impact factors impacting demand forecasts such as rural electrification and outage rates, are considered. Consequently, the top forecast total power demand is verified.

Moreover, the power demand of each center is forecasted and integrated by calculating each center's growth rate in future and the top forecast total power demand is divided to each center. The result is reflected to the facility plan of each region such as substation and distribution line.

(2) New Load

The upper power demand forecast based on historical data trends is called 'Base Load'. Conversely, power demand for projects such as new mining and industrial/commercial estate, which is independent of historical data, is called 'New Load'. New Load is listed in the inventory informed by the project developer or PPL. Some projects are feasible and others uncertain, thus, the choice of project reflected in the demand forecast is discussed with PPL. The listed New Loads are then summed up to the forecast Base Load and the result is the total power demand of the Ramu System.

(3) Economical index

Power demand and supply are closely connected and economical parameters such as GDP are the key when making power demand forecasts. PPL also takes GDP into consideration for demand forecasting. Based on GDP published by each relevant organization and the GDP growth rate, the power demand forecast result is verified, whereby elasticity, which constitutes the ratio of growth rates in 'GDP' and 'Power demand', is a key parameter. Leveraging elasticity, which is calculated based on historical data, the future growth rate of power demand can be verified.

As mentioned in the top part, the demand forecast is implemented through complex methods such as trend forecasts of the total Ramu System from a macro perspective, trend forecasts of each sector/region, and considerations of New Load and economical indexes. Consequently, the power demand forecast result is verified.

4.1.4 Demand Forecast Results

(1) Demand forecast condition

1) Base Load

(a) Total Ramu System

Based on historical energy sales data between 2008 and 2014, the maximum value of 5 year's growth rate of Base Load, where mining is subtracted from energy sales, is 4.6%.

With reference to the 'PNG Vision 2050', the growth rate of GDP in the base case is estimated at 4.6%, which is equivalent to the top value.

Conversely, with reference to the 'IMF Economic Outlook Oct. 2014', the growth rate for real GDP between 2015 and 2019 was 3.5%. There is no regional GDP data, therefore national GDP is adapted instead of the data. From historical data, elasticity, as defined by the ratio of growth rate in 'GDP' and growth rate in 'Power demand', is 1.6, which constitutes a maximum of 5 year's average value between 2005 and 2014. Therefore, the future growth rate is estimated at 5.6% which is equal to 3.5% multiplied by 1.6.

As mentioned in the top part, the growth rate is verified and estimated at between 5.0 and 6.0%.

(b) Each sector

The growth rate for energy sales excluding mining between 2009 and 2013 was 4.6%, where domestic comprises 8.4%, general supply 4.0 and industry 3.5%.

Conversely, peak demand (MW) can be estimated from energy sales (MWh) using the following parameters;

Loss rate (%) = Energy sales (MWh) / Generation energy (MWh) × 100

Load factor (%) = Generation energy (MWh) / (Peak demand (MW) × 8760 hours) × 100

From historical data between 2005 and 2014, the average value is estimated as follows;

Loss rate : 22.0%
Load factor : 68.8%

2) New Load

(a) Mining load

In the Ramu System, three new mining projects are planned.

- Wafi Golpu mining facility (Morobe Joint Venture (JV) Company, Gold/Copper)
- Ramu Nico mining facility (The China Metallurgical Group Corporation, Nickel/ Cobalt)
- Yandera mining facility (Marengo Company, Copper/Gold/Molybdenum)

Wafi Golpu's information is from Morobe JV Company.
Ramu Nico's information is from the Chamber of Mine and Petroleum
Yandera's information is from the Chamber of Mine and Petroleum and PPL

Table 4.1-1 shows the demand forecast for each new mining project.

Table 4.1-1 Demand Forecast of New Mining

(Unit: MW)

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Ramu Nico ( ):By captive power			(36.2)	(80)	(80)	(80)	(80)	80	80	80	80	80	80	80	80	80	80
Wafi/ Golpu							35	35	35	35	35	80	80	80	80	80	80
Yandera							100	100	100	100	100	100	100	100	100	100	100
OK Tedi (Expansion)												80	80	80	80	80	80

On Wafi Golpu mining facility, information from the interview as of Nov. 2014 with Morobe Mining JV Company is as follows;

- The current situation is Pre F/S (Feasibility Study). F/S is to commence on Dec. 2014. Underground mine
- Power demand and power source

  2015-2020: 10-20MW Captive power to be used for construction
  (Via a diesel generator, which is to be used for emergencies after 2020)

  2020-2025: 35MW PPL to be used for operation
  (Reception from Erap substation via 66kV T/L around 20km)

  2025-2030: 80MW (estimation)

  After 2030: 150MW (Max.)

- Above mentioned T/L to be paid by MMJV and constructed by PPL

- Drilling survey is implemented currently

Continuous operation day and night to be implemented after operation

- Product and investment
  2020-2025: 5 million tons per year 2-3 billion USD (Development almost certain)
  2025-2030: 10 million tons per year (Development depends on F/S result)
  After 2030: 22 million tons per year 10 billion USD

- Electric power is to be used for processing, pumping, ventilation and chiller

- Electric power cost to comprise 30% of total operation cost

Reliability and low price of electric power is to be an issue

- Power source candidates are as follows;
  PPL gas turbine 35MW
  IPP hydropower 10MW (near Baiune hydropower)
  IPP biomass power 30MW
  IPP Ramu 2 hydropower 150MW (construction period of over a decade will be required)
  IPP gas power station, etc.

- MMJV is a joint venture between Harmony Gold Company (South Africa) and Newcrest Company (Australia)

- MMJV has no plans to invest in IPP

Fig. 4.1-5 shows the location map of the Wafi Golpu mining facility.

Information of operating Hidden Valley mining, which is owned by MMJV, is as follows in the interview.

- Operating from 2010
  Open pit mine of gold and copper

- Power demand: 15-17MW No extension plan
  Reception from Erap substation via a 132kV T/L
  Continuous operation day and night

- Generator for emergency: Diesel generator 20MW (1MW × 20)
  Manufacturer: Caterpillar
  Before operation, used for construction
  Fuel: Diesel

- Outages of a few hours are frequent.
  The reliability of the power supply is problematic

- Electricity price under 20 US cent/kWh

- Production: 4 million tons per year

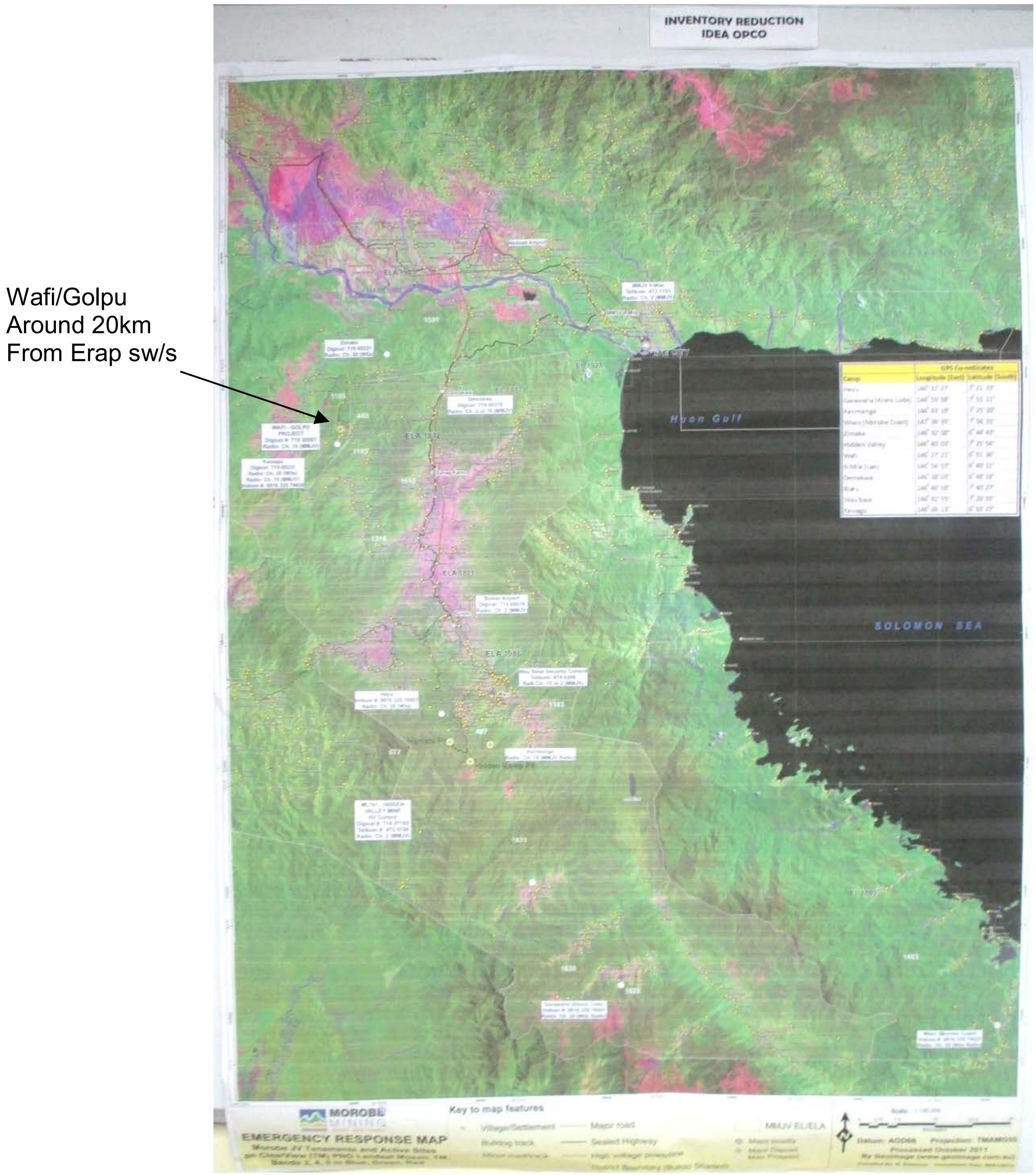


Fig. 4.1-5 Location of Wafi Golupu Mining Facility

On Ramu Nico mining facility, information from an interview as of March 2015 with the Chamber of Mines and Petroleum is as follows;

- Operating from the end of 2012. Open pit mine of Nickel and Cobalt.
- Power demand (Installed capacity)
  Kurumbukari Mine Site: about 20MW (Present demand about 6.2MW)
  Basamuk Processing Plant: about 60MW (Present demand about 30MW).
- Generator for operation: Diesel generator 40-50MW
  Manufacturer: Wartsila.

- In future, economical electricity from Ramu 2 hydropower is expected. The year depends on Ramu 2 hydropower coming into operation.
- Since production levels have reached around 85%, it seems there is considerable overcapacity built into the project due to the interviewer's opinion.
- Previously, operation stopped due to rejection of people around the site, but it is currently operating as normal.

Fig. 4.1-6 shows the location of the Ramu Nico mining facility.

Fig. 4.1-6 Location of the Ramu Nico Mining Facility

On Yandera mining facility, information from the interview as of March 2015 with Chamber of Mines and Petroleum is as follows;

- A big mining project scheduled in future. Open pit mine of Copper, Gold and Molybdenum
  Launch year still unclear, but around 2025 (estimated)
  Power demand still unclear, but about 100 MW (estimated)
- Drilling survey is currently implemented
- Location is near to Ramu Nico, south side about 20km

(b) New industrial/commercial estate load

New industrial/commercial estate projects are planned in the Lae and Madang regions due to interviews from PPL. Table 4.1-2 shows the project name and peak demand each year. Based on PPL's opinion, since the feasibility of these planned projects remains unclear, how to reflect the projects in the forecast master plan is discussed with PPL.

Moreover, concerning projects planned by local government or personal companies, except the top table, since the feasibility and starting year remain unclear, they are not reflected in the demand forecast of the master plan based on discussion with PPL.

Table 4.1-2 Demand Forecast for the New Industrial/Commercial Estate Project

(Unit: MW)

		2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Madang	Madang Marine Park		10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Lae	Taiheiyou Cement													3	3	3	3	3
	Prima						1	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
	News Port									4	4	4	4	4	4	4	4	4
	Portion 508										8	8	8	8	8	8	8	8
	KK Kingstone						1	1	1	1	1	1	1	1	1	1	1	1
	BOC					1	2	2	2	2	2	2	2	2	2	2	2	2
	MMJV											10	10	10	10	10	10	10
	Goodman					1.5	1.5	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
	Majestic					1	1	1	1	1	1	1	1	1	1	1	1	1
	Nambawan					2	4	4	4	4	4	4	4	4	4	4	4	4
	Dong Won					1	2	2	2	2	2	2	2	2	2	2	2	2
	Haili Sheng						1	2	2	2	2	2	2	2	2	2	2	2
	Paradise Food					1	1	1	1	1	1	1	1	1	1	1	1	1
	SP Brewery					0.5	1.2	2.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2

Table 4.1-3 Conditions for Demand Forecast

<table>
<tr><th>Analysis Step</th><th colspan="2">Conditions for the forecast</th><th>Reference</th></tr>
<tr><td rowspan="3">Base Load Variable Setting</td><td>Historical Data</td><td>4.6%</td><td>5 year's growth rate from 2009 to 2013
(Maximum of 5 year's growth rate between 2008-2014)</td></tr>
<tr><td>GDP</td><td>3.5%</td><td>IMF"Economic Outlook"Oct 2014, Average of annual growth rate 2015- 2019</td></tr>
<tr><td>Elasticity</td><td>1.6</td><td>Maximum of 5 year's average value between 2005 and 2014</td></tr>
<tr><td>Base Load Power Consumption Forecast</td><td>Growth Rate</td><td>5.0 ~ 6.0%</td><td>Historical data and GDP×Elasticity are considered,
which includes rural electrification and outage impacts</td></tr>
<tr><td rowspan="2">Base Load Peak Demand Forecast</td><td>Power Loss Rate</td><td>22.0%</td><td>The average from result of 2005-2014</td></tr>
<tr><td>Load Factor</td><td>68.8%</td><td>The average from result of 2005-2014</td></tr>
<tr><td>New Load Peak Demand</td><td>Power Loss Rate Mining</td><td>4.0%</td><td>FYPDP</td></tr>
<tr><td rowspan="2">Total Peak Demand Forecast</td><td rowspan="2">Scenario</td><td>High Case</td><td>Base load growth rate:6.0%
Whole Feasible New Loads are added</td></tr>
<tr><td>Normal Case</td><td>Base load growth rate 5.0%
Certain New Loads are added</td></tr>
<tr><td>Allocation to Center/Substation</td><td>Historical Data</td><td></td><td>Forecasted total peak demand is allocated to each center based on growth rate of each center by historical data</td></tr>
</table>

(2) Demand forecast on Normal Case

Based on the abovementioned conditions, a demand forecast with high feasibility is known as a 'Normal Case', with forecasting implemented under the following conditions;

- The growth rate of the Base Load is 5.0%
- Certain New Loads are added

Fig. 4.1-7 shows the demand forecast result until 2030, where the Base Load forecast from historical data and New Load, including Ramu Nico mining facility, Wafi Golpu mining facility, half the industrial estate load in the Lae region and the commercial estate load in Madang are all summed up.

In the Normal Case, peak demand of Base Load in the Ramu System is 118MW as of 2020, 192MW as of 2030. Total peak demand, where Base Load and New Load are summed up, is 174MW as of 2020, 400MW as of 2030.

Conversely, to verify the Base Load forecast result, the peak demand forecast result analyzed from each sector's demand forecast until 2030 is shown in Table 4.1-4. In the analysis, energy sales until 2030 calculated from the growth rate of each sector, are forecast and the peak demand is forecast taking loss rate and load factor into consideration. Consequently, the peak demand, which is the summation of each sector, was 149MW as of 2030. Total peak demand considering rural electrification and captive power, is 192MW which is the forecast result from a macro perspective.

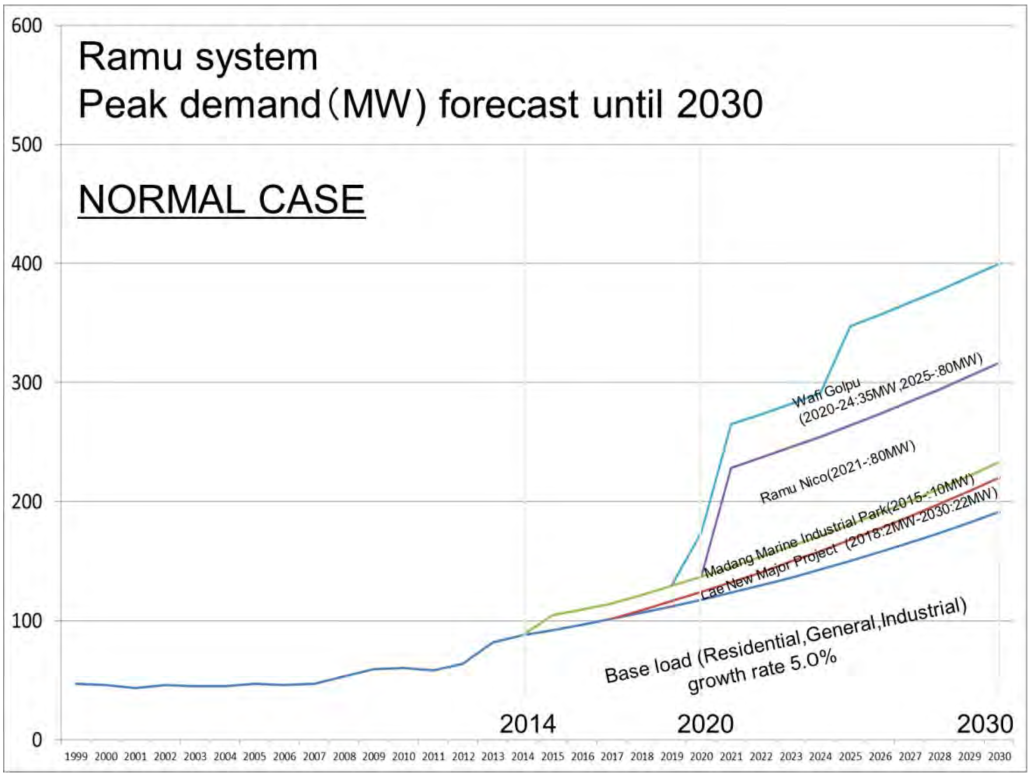


Fig. 4.1-7 Peak Demand Forecast until 2030 (Normal Case)

Table 4.1-4 Demand Forecast (Normal case)

	Unit	Growth rate	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Base Load (A)	MW	1.050	88	92	97	102	107	112	118	124	130	136	143	150	158	166	174	183	192
Ramu nico mining	MW									80	80	80	80	80	80	80	80	80	80
Wafi/Golpu mining	MW								35	35	35	35	35	80	80	80	80	80	80
Total Mining Load (Load side)	MW								35	115	115	115	115	160	160	160	160	160	160
Loss	-								0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Total Mining Load (Generation side) (B)	MW								36	120	120	120	120	167	167	167	167	167	167
Madan marine industrial park	MW			10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Morobe new commercial project	MW						1.72692	3.45385	5.18077	6.90769	8.63462	10.3615	12.0885	13.8154	15.5423	17.2692	18.9962	20.7231	22.45
Total Industrial Load (Load side)	MW			10	10	10	11.7269	13.4538	15.1808	16.9077	18.6346	20.3615	22.0885	23.8154	25.5423	27.2692	28.9962	30.7231	32.45
Loss	-			0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22
Total Industrial Load (Generation side) (C)	MW			13	13	13	15	17	19	22	24	26	28	31	33	35	37	39	42
Peak demand (A)+(B)+(C)	MW		88	105	110	114	122	129	174	265	273	282	291	347	357	367	378	389	400
(Referrence:Base Load by sum up)																			
Domestic	MWh	1.084	51,729	56,074	60,784	65,890	71,425	77,425	83,929	90,979	98,621	106,905	115,885	125,619	136,171	147,610	160,009	173,450	188,019
General	MWh	1.040	147,891	153,806	159,959	166,357	173,011	179,932	187,129	194,614	202,399	210,494	218,914	227,671	236,778	246,249	256,099	266,343	276,996
Industry	MWh	1.036	82,745	85,724	88,810	92,007	95,320	98,751	102,306	105,989	109,805	113,758	117,853	122,096	126,491	131,045	135,763	140,650	145,714
Mining	MWh	1.000	90,376	90,376	90,376	90,376	90,376	90,376	90,376	90,376	90,376	90,376	90,376	90,376	90,376	90,376	90,376	90,376	90,376
Total energy sales	MWh		372,741	385,981	399,929	414,631	430,132	446,484	463,740	481,958	501,200	521,533	543,028	565,762	589,816	615,280	642,246	670,818	701,105
Loss	-		0.236	0.220	0.220	0.220	0.220	0.220	0.220	0.220	0.220	0.220	0.220	0.220	0.220	0.220	0.220	0.220	0.220
Generation energy	MWh		487,881	494,847	512,730	531,578	551,451	572,415	594,538	617,895	642,564	668,633	696,190	725,336	756,175	788,820	823,393	860,024	898,853
Load factor	-		0.634	0.688	0.688	0.688	0.688	0.688	0.688	0.688	0.688	0.688	0.688	0.688	0.688	0.688	0.688	0.688	0.688
Base Load by sum up(D)	MW		88	82	85	88	91	95	99	103	107	111	116	120	125	131	137	143	149

(3) Demand forecast on High Case

In contrast with the Normal Case, the feasible maximum demand forecast is called 'High Case'. The forecasting is implemented under the following conditions;

- The growth rate of the Base Load is 6.0%
- All feasible New Loads are added

Fig. 4.1-8 shows the demand forecast result until 2030, where the Base Load forecast from historical data and New Load including Ramu Nico mining facility, Wafi Golpu mining facility, Yandera mining facility, Ok Tedi mining facility (80MW 2025-), an industrial estate load in the Lae region and a commercial estate load in Madang, are summed up.

In the High Case, the peak demand of Base Load in the Ramu System is 125MW as of 2020 and 223MW as of 2030. Total peak demand where Base Load and New Load are summed up, is 345MW as of 2020 and 534MW as of 2030.

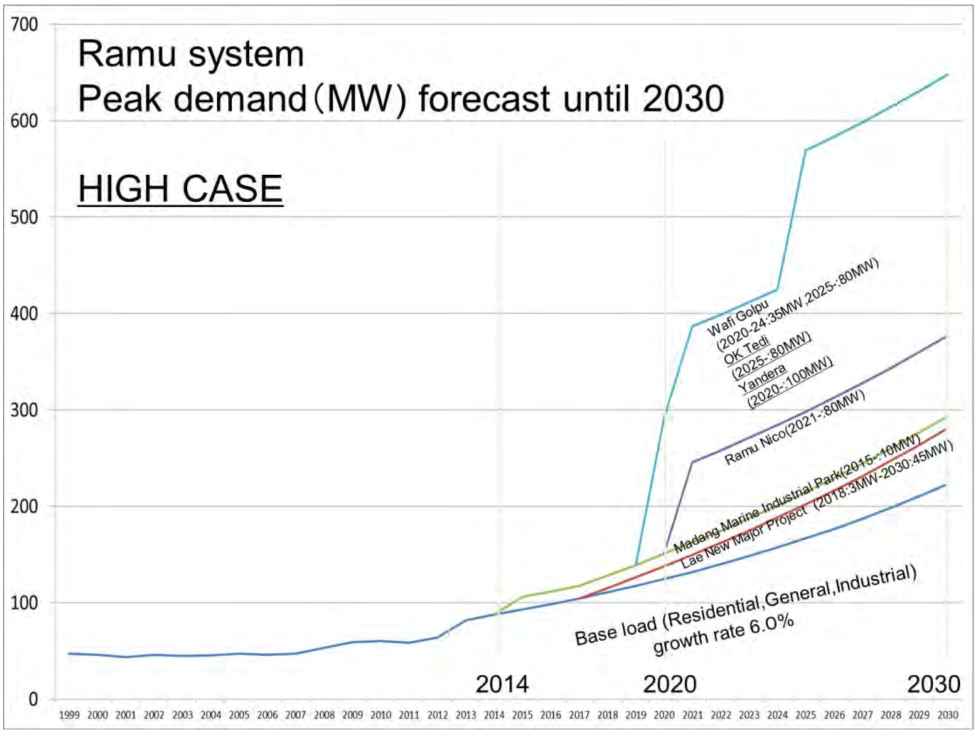


Fig. 4.1-8 Peak Demand Forecast until 2030 (High Case)

Table 4.1-5 Demand Forecast (High case)

	Unit	Growth rate	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Base Load (A)	MW	1.060	88	93	99	105	111	117	125	132	140	148	157	167	177	187	199	210	223
Ramu nico mining	MW									80	80	80	80	80	80	80	80	80	80
Wafi/Golpu mining	MW								35	35	35	35	35	80	80	80	80	80	80
Yandera mining									100	100	100	100	100	100	100	100	100	100	100
OK Tedi mining														80	80	80	80	80	80
Total Mining Load (Load side)	MW								135	215	215	215	215	340	340	340	340	340	340
Loss	-								0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Total Mining Load (Generation side) (B)	MW								141	224	224	224	224	354	354	354	354	354	354
Madan marine industrial park	MW			10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Morobe new commercial project	MW						3	7	10	14	17	21	24	28	31	35	38	41	45
Total Industrial Load (Load side)	MW			10	10	10	13	17	20	24	27	31	34	38	41	45	48	51	55
Loss	-			0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22
Total Industrial Load (Generation side) (C)	MW			13	13	13	17	22	26	31	35	39	44	48	53	57	62	66	70
Peak demand (A)+(B)+(C)	MW		88	106	111	117	128	139	291	387	399	412	425	569	584	599	614	631	648

(4) Demand forecast for each region

To establish a facility plan such as a substation and distribution line, the demand forecast for each region in the Ramu System is important. Here, the demand forecast of each Center, where each service center is located, is implemented until 2030. The analytical steps are as follows;

- Each Center's growth rate is estimated from historical data
- Each Center's peak demand is estimated from historical data
- Each Center's peak demand is divided into each existing substation, where the summing up of each Center's peak demand is accordance with the peak demand of Base Load in the Normal Case.

The Base Load's peak demand of each Center estimated result until 2030 is shown in Fig. 4.1-9 and the Base Load's peak demand ratio of each center in 2030 is shown in Fig. 4.1-10.

On Base Load as of 2030, the peak demand of Lae Center is the biggest, followed by Madang Center. In the forecast, the peak demand of Lae Center is 50% of the total Base Load and Madang is 18%.

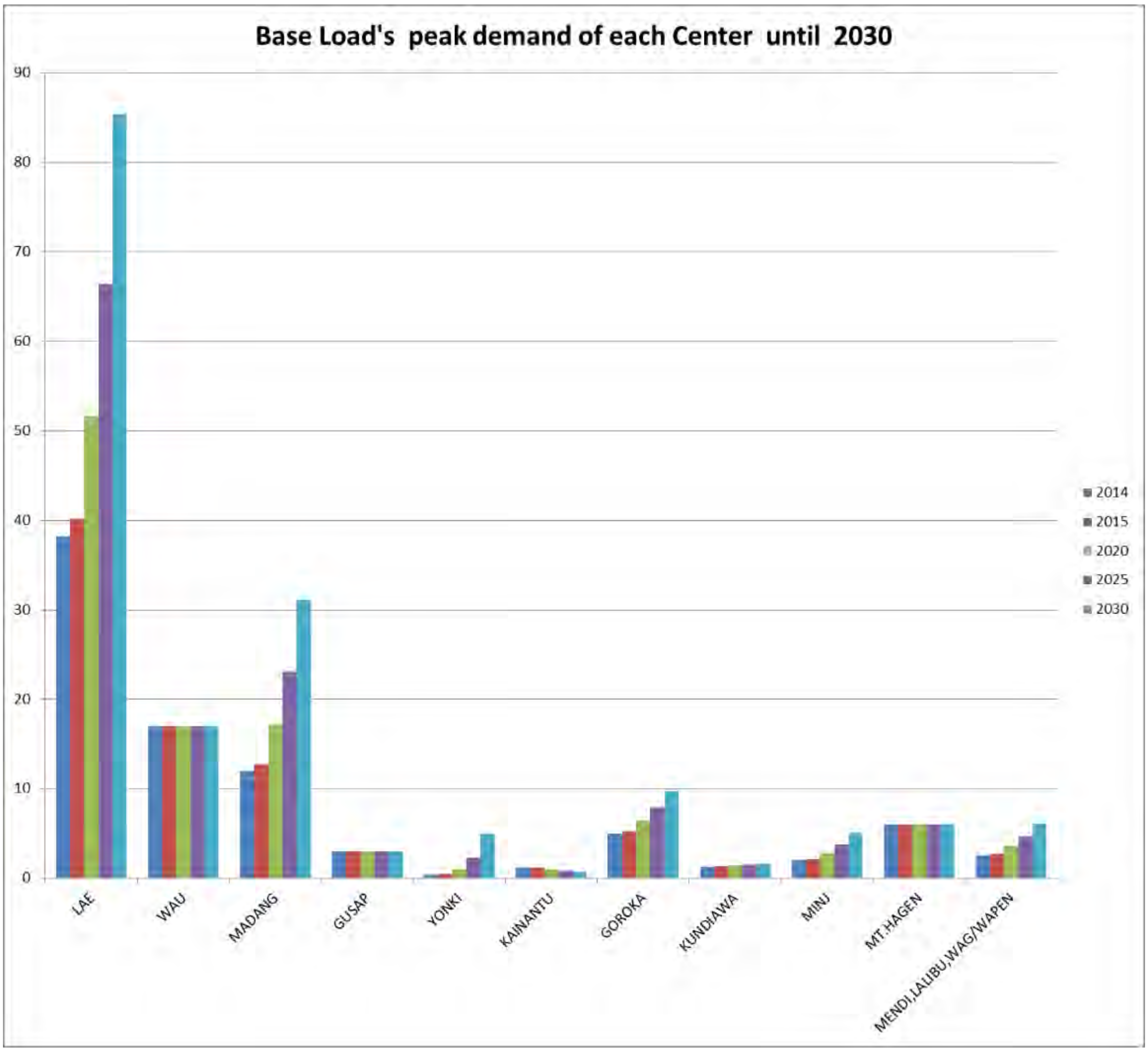


Fig. 4.1-9 Base Load's Peak Demand of Each Center until 2030(Normal Case)

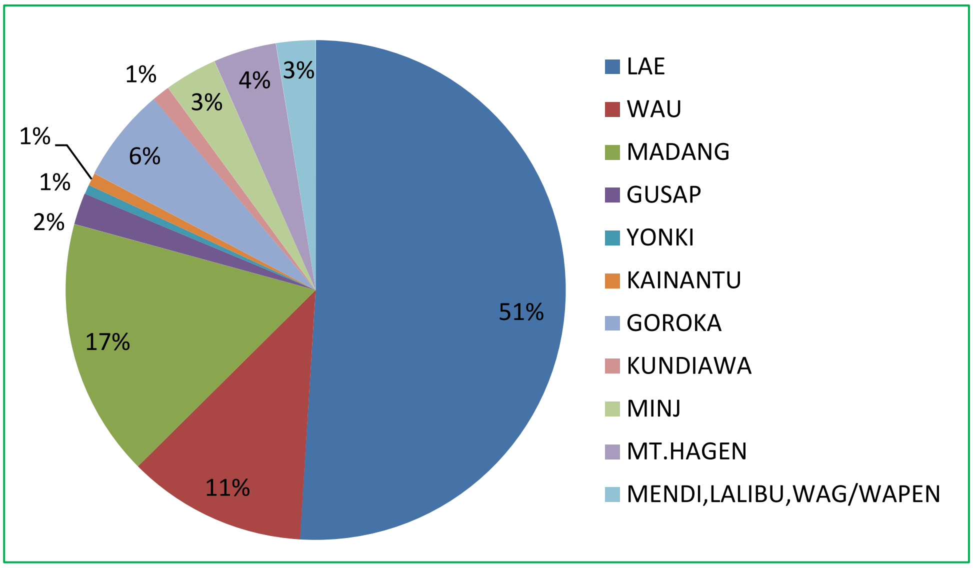


Fig. 4.1-10 Base Load's Peak Demand Ratio of Each Center in 2030 (Normal Case)

(5) Load curve

Information on daily and annual load change is crucial for power generation operation and a power generation developing plan.

The daily load curve for the peak demand recorded date in 2014 is shown in Fig. 4.1-11.

As shown in Fig. 4.1-11, the feature of the daily load curve in the Ramu System is that peak demand is monitored at around 1100 and the difference between minimum and maximum loads is small, at about 1.4. The annual load factor is around 70%, which is an average for the past decade. Generally, as economic activity increases in developing country, power demand in the commercial and industrial sector rises accordingly. Consequently, daytime operation has a tendency to increase.

However, from historical data, power demand in the commercial and industrial sector is around 70% of total power demand. As of 2030, the ratio is forecast to be around 60%. Conversely, from a daily load curve as of 2010, the daytime load peak was already monitored. Therefore, the development of the commercial and industrial sector is estimated as stable.

Moreover, though the new mining load, with a basic load, is expected to increase the load factor, Hidden Valley mining's load factor is presently around 60 and the percentage will increase following steady operation to around 70%, which is the total system's load factor.

Consequently, the load factor and curve are expected to be stable in future and they are to be forecast from historical data.

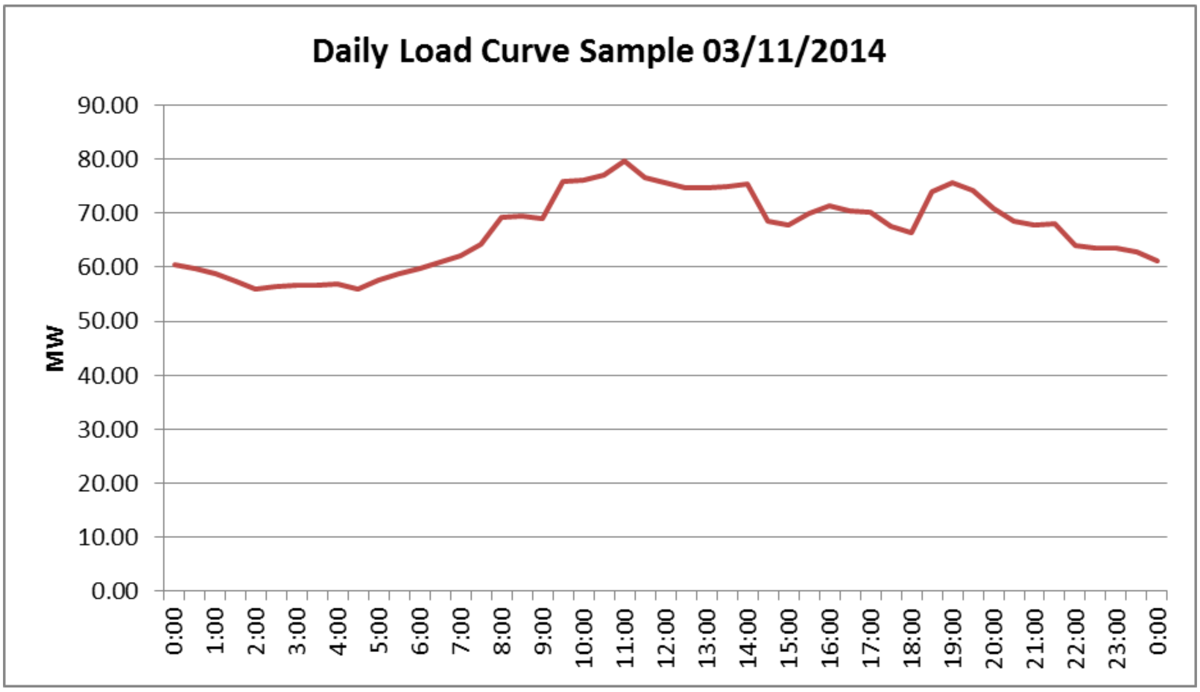


Fig. 4.1-11 Daily Load Curve Sample

4.1.5 Considerations

(1) Comparison with FYPDP by PPL

The forecast result for the Master Plan and FYPDP are shown in Fig. 4.1-12.

In FYPDP, the growth rate for power demand is 5.0%, which is the same as the master plan. Because of the lower estimated peak demand in 2013, the demand forecast of FYPDP is transited to be lower than the master plan.

However, if peak demand in 2014 were reflected in FYPDP, the demand forecast would be the same as the master plan.

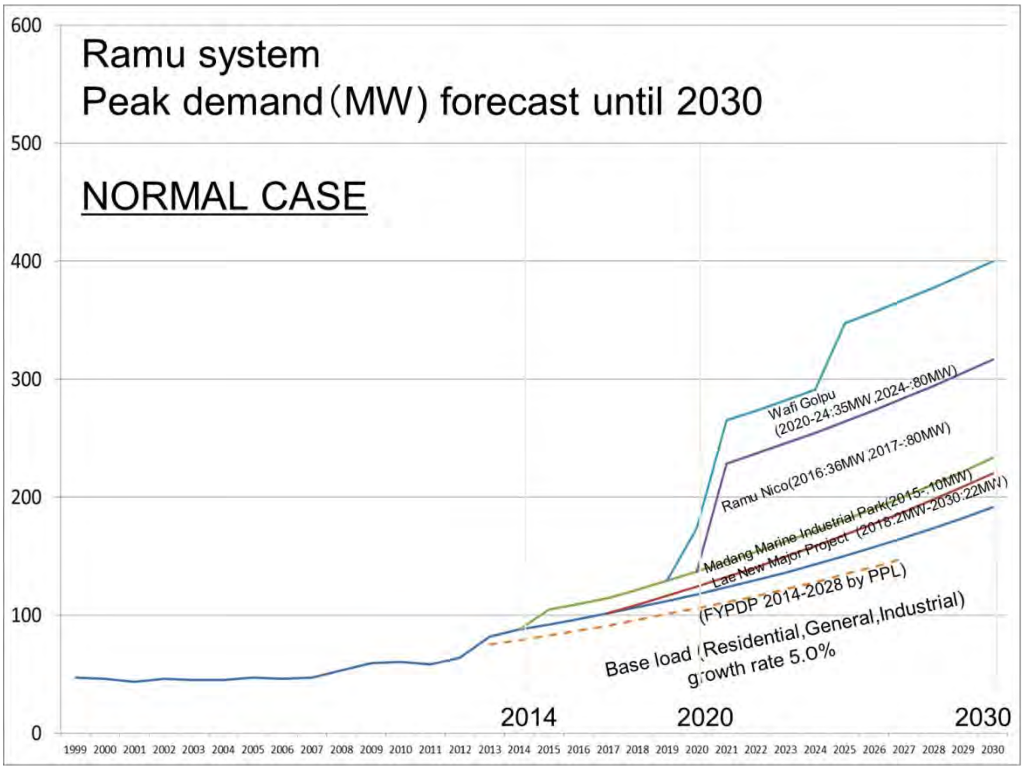


Fig. 4.1-12 Comparison of the Master Plan's Forecast Result and FYPDP's Forecast Result

(2) Comparison with the ADB plan

In reference, the 'Power Sector Development Plan; Draft Final Report Jan. 2009' by ADB technical support is the most precise report in demand forecast. Here, the peak demand in the Ramu System as of 2027 is forecasted to be 468 MW in the High Case (which is called 'Optimistic case' in the report). Although the New Load estimated differs between them, the result nearly coincides with the peak demand of 367MW-599MW MW cited in the master plan as of 2027.

4.1.6 Issues and Recommendations

(1) Impact of new mining load and the power supply

In demand forecast of the master plan result, as of 2030, the new mining load constitutes 42% of total peak demand in the Normal Case and 55% in the High Case. Peak demand and the launch year of the new mining load, impact power generation development plan and power system plan are linked to a probable risk with facility investment. In the demand forecast of the master plan, a new mining load as a New Load can be separated from the Base Load, which is based on historical data. Therefore, reducing the impact of the new mining load on the total master plan is desirable and the demand forecast is flexible where the New Load can be separated easily. It is desirable that the power supply to new mining loads can be separated from the supply to Base Load by assigning independent power source such as IPP and PPP to new mining loads.

JICA Study Team recommends that a new mining load be separated from total peak demand according to the methodology of the master plan when the demand forecast is to be revised under the supposedly changing conditions.

(2) Data unified management

Historical data for the demand forecast of the master plan was obtained from System Operations of PPL concerning generations and substations and from Customer Service concerning consumers. FYPDP and the base documents were referred for settlement of the demand forecast of the master plan. When FYPDP is revised, it is desirable to use historical data obtained in the master plan and we recommend data unified management such as an annual report is stored and succeeded.

(3) Periodical demand forecast revision

The demand forecast for the master plan was settled based on information as of February 2015 and the result was explained at a workshop (17 February, 2015) and basically approved by the Minutes of Meetings (MOM).

Under supposed conditions changing after settlement of the master plan, we recommend that the demand forecast be periodically revised based on the latest historical data and an economical index using the master plan's methodology and data; the result of which would be used for FYPDP.

CHAPTER 5

STUDY FOR THE DEVELOPMENT SITES FOR EACH CANDIDATE POWER PLANT

CHAPTER 5 STUDY FOR THE DEVELOPMENT SITES FOR EACH CANDIDATE POWER PLANT

5.1 HYDRO POWER

PPL is currently responsible for the operation of 17 systems at various centres. Three of these systems are hydro-based with generation capacity in excess of 10 MW; namely, the POM, Ramu and Gazelle Peninsula systems. Twelve of the remaining 14 systems are thermal-based, and the other two adopt mini hydro schemes supplemented with diesel power.

PNG has large hydropower (HP) potential estimated at about 15,000 MW. Out of the total generating capacity of 580 MW throughout PNG at present, developed hydropower capacity accounts for only about 220 MW.

(Source: Baseline Data Collection Survey in Power Sector Final Report, June 2010, JICA)

The GoPNG is working to resolve chronic power problems and associated power shortages. KCH has initiated the promotion of two hydropower projects, i.e., the Naoro Brown Hydropower Project (80 MW) in POM grid and the Ramu 2 Hydropower Project (180 MW) in the Ramu system. Both schemes are to be developed as PPP/IPP schemes.

5.1.1 Current Status of Hydropower Facilities

(1) Existing Hydropower Plants in Ramu System

1) Outline of Existing Hydropower Plants

HPPs, especially the Ramu 1 HPP, are major generation sources in the Ramu system. Most of the HPPs have operated for around 30 years. Maintenance works have not been conducted properly, so the power plants often become inoperative or operate with limited output.

HPPs supply around 90% of the total generated energy. Total installed capacity of HPPs (PPL) is around 100 MW, but the available maximum output is only around 60 MW (60%) due to design flaws and inappropriate maintenance. The Baime HPP is operated by IPP, which supplies most of the electricity to Hidden valley mine and sells the surplus electricity to PPL. The existing HPPs in the Ramu system are listed in the following table.

Table 5.1-1 Existing Hydropower Plants in Ramu System

Plant Name	Type	Rated Output	Available Output	Date Comm.	Owner	Remarks
Ramu 1	REV	#1-#3: 15 MW × 3 units #4, #5: 16.5 MW × 2 units Total Max output: 78 MW	45 - 50 MW	#1-#3: 1976 #4-#5: 1990	PPL	#1-#3 turbines were replaced in 1991.
Pauanda	ROR	6 MW × 2 units	8 - 10 MW	1983	PPL	
YTOD	REV	9.3 MW × 2 units Total: 18.6 MW	6 MW	2013	PPL	
Baime	ROR	Upper Baime: #1: 2 MW #2, #3: 4.7 MW × 2 Total: 11.4 MW	8 - 10 MW	2013	IPP (PFP*1)	Mainly supplies to Hidden valley mine, Max 16 MW
		Lower Baime #1 - #5: 0.7 MW × 5 Total: 3.5 MW		2006	IPP (PFP*1)	

Note: REV: Regulated by reservoir
ROR: Run- of-river
PFP: PNG Forest Products, generated energy mainly supplies to Hidden valley mine (Max. 16 MW)

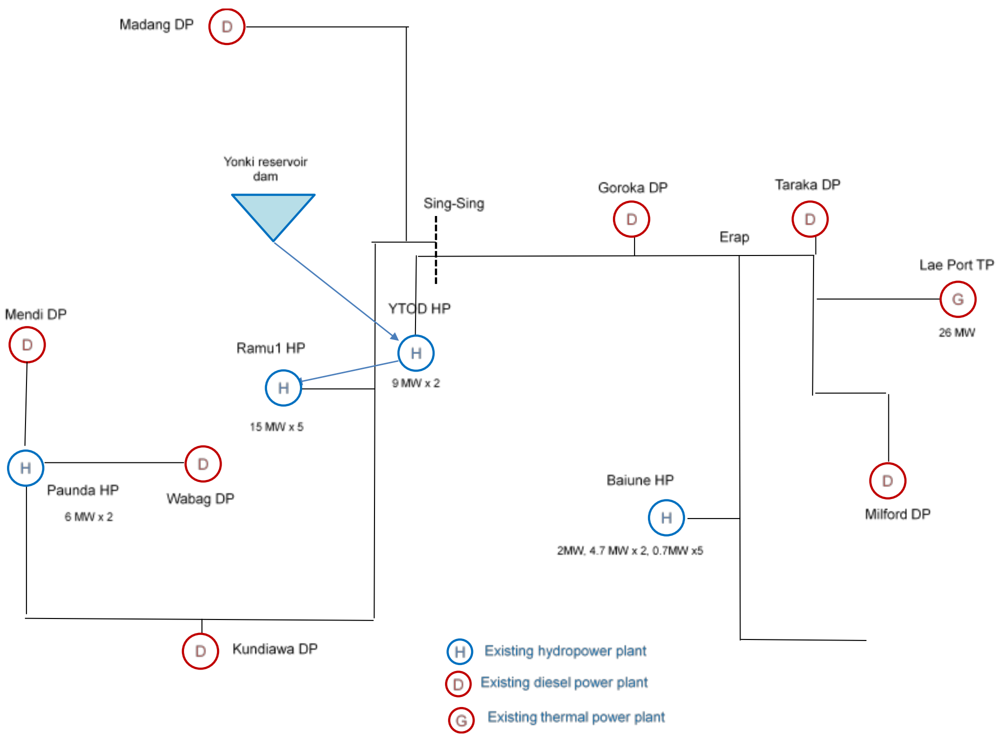


Fig. 5.1-1 Image of Existing Plants in Ramu System

2) Locations of Existing Hydropower Plants

The Yonki Toe of Dam (YTOD) HPP is located at the toe of the Yonki dam. The Ramu 1 HPP is located around 2 km downstream of the dam in Morobe province. The Pauanda HPP is located in the Western Highlands Province and connected to Ramu 1 HP through a 66 kV T/L running a distance of about 260 km. The Baime HPP is located in Morobe Province, is operated by IPP, and mainly supplies electricity to the Hidden Valley mine. The following map shows the locations of the existing HPPs.

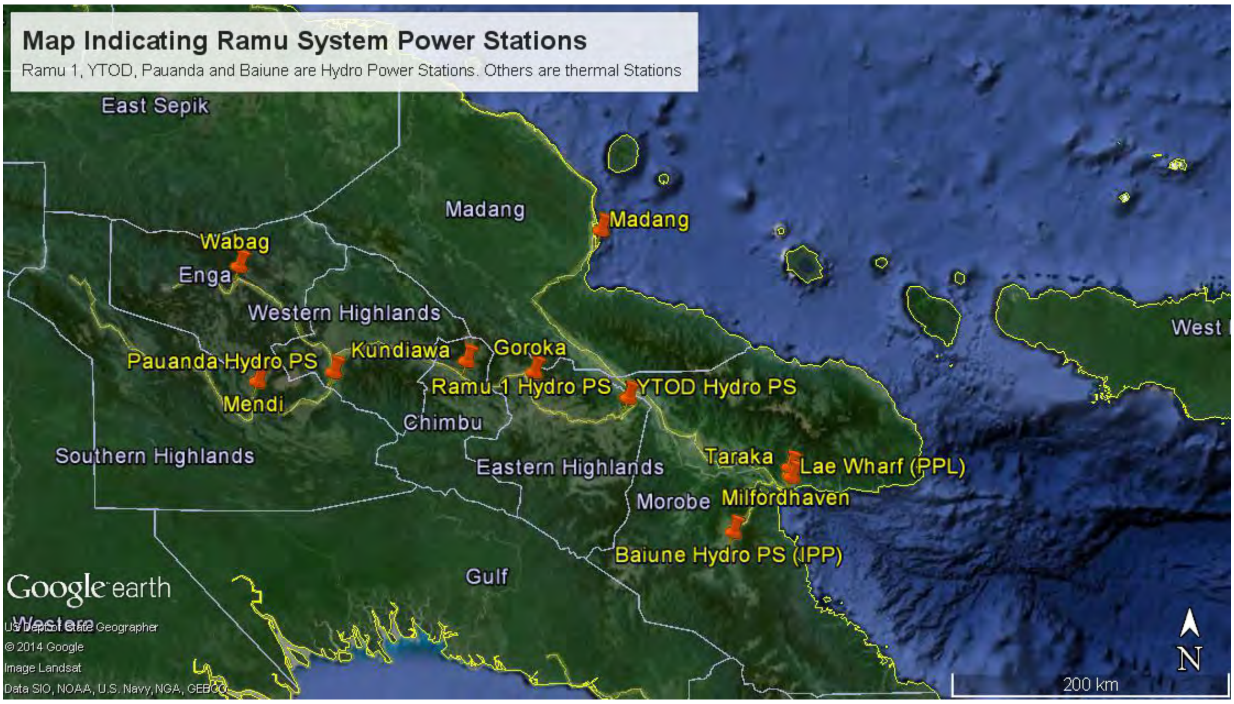


Fig. 5.1-2 Location Map of Existing Plants in Ramu System

(2) Operation Status of Existing Hydropower Plants

1) Annual Operation Status of Existing Hydropower Plants

The total generated energy in 2014 was 487.9 GWh, including purchased energy. HP energy totaled 372.5 GWh and accounted for 76% of total energy. Thermal plant energy totaled 47.4 GWh (10%) and purchased energy totaled 68.1 GWh (14%).

HP energy was increased by 98.4 GWh (136%) over the last ten years, while the sum of thermal energy and purchased energy increased markedly by 110.2 GWh. This trend has appeared from 2011. The share of HP energy has decreased because the available capacity of Hydropower Plants (HPPs) has not provided a sufficient margin against the system demand. In the Ramu system no HPPs have been constructed in the more than 30 years since the construction of the Ramu 1 and Pauanda HPPs. The YTOD HPP commenced generation with a maximum capacity of 18 MW in November 2013, but available output has so far been limited to 6 to 7 MW due to design flaws.

The annual generated energy and purchased energy of Ramu grid from 2005 to 2014 are given in the following table and figure.

Table 5.1-2 Annual Generated Energy and Purchased Energy in the Ramu System (2005 to 2014)

Unit: MWh/year

year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Ave
Hydropower energy	274,071	281,269	304,145	299,062	293,474	310,891	335,228	345,942	382,503	372,478	319,906
Thermal power energy	5,278	3,145	3,660	7,058	29,606	23,293	36,914	50,121	25,160	47,385	23,162
PPL total energy	279,348	284,414	307,805	306,121	323,080	334,185	372,142	396,063	407,664	419,863	343,068
Ratio of hydro energy	98%	99%	99%	98%	91%	93%	90%	87%	94%	89%	94%
Purchased energy (IPP, Hydro)	0	756	1,547	5,993	6,586	12,511	10,326	8,976	74,539	68,073	18,931
System Total	279,348	285,170	309,352	312,114	329,666	346,696	382,468	405,039	482,203	487,936	361,999
Ratio of hydro energy	98%	98%	98%	96%	89%	90%	88%	85%	79%	76%	88%

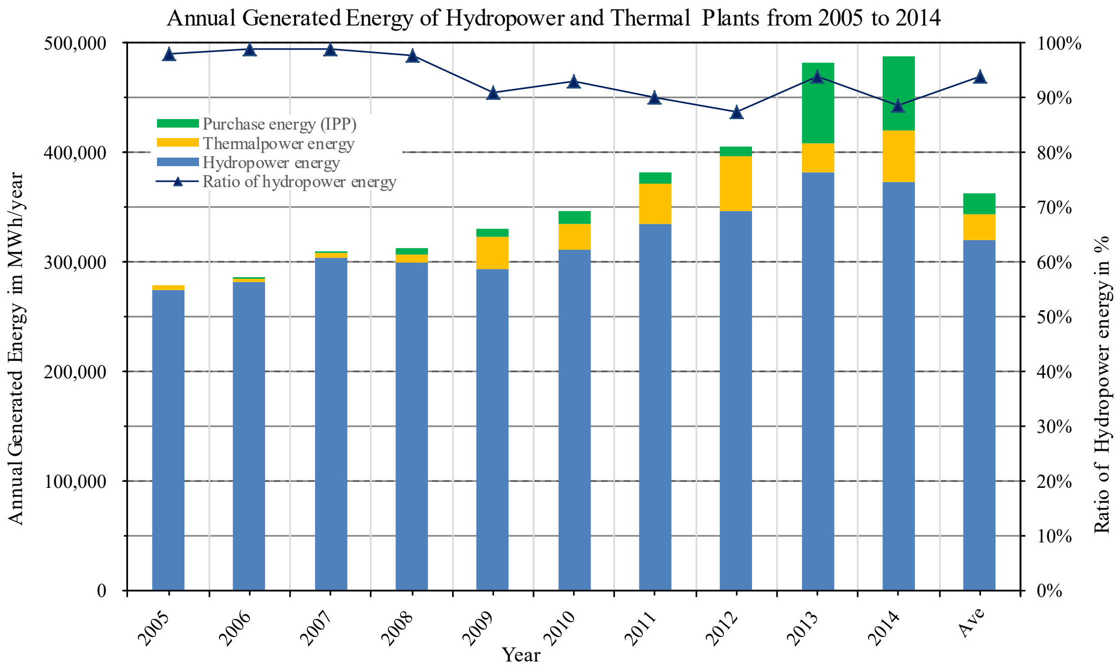


Fig. 5.1-3 Annual Generated Energy and Purchased Energy of Ramu System (2005-2014)

The Ramu 1 HPP (installed capacity of 75 MW) is the major power plant of the Ramu system. In 2014 annual energy generated by Ramu 1 HP totaled 290.7 GWh, which accounted for around 78% of the total HP energy and 60% of the total system energy. The Ramu 1 HP clearly has an important role in the Ramu system. The following tables and figures list the annual generated energy of each HPP.

The available energy of each HPP at present is estimated based on records of operation over the last 10 years, as follows;

- Ramu 1 HP: 320 GWh/year (CF=76%, Pmax=48 MW)
- Pauanda HP: 70 GWh/year (CF=80%, Pmax=10 MW)
- YTOD HP: 50 GWh/year (Installed capacity is 9 MW × 2 units, but available output is 6 to 7 MW) (CF=82%, Pmax=7 MW)

Table 5.1-3 Annual Generated Energy of Each Hydropower Plant in the Ramu System (2005 to 2014)

Unit: MWh/year

Year	RAMU 1 HYDRO	YONKI TOD	PAUANDA HYDRO	TOTAL RAMU HYDRO	TOTAL RAMU THERMAL	Total Hydro+ Thermal	TOTAL RAMU Purchased	TOTAL RAMU
2005	225,333	0	48,738	274,071	5,278	279,348	0	279,348
2006	228,967	0	52,302	281,269	3,145	284,414	756	285,170
2007	251,445	0	52,700	304,145	3,660	307,805	1,547	309,352
2008	245,710	0	53,353	299,062	7,058	306,121	5,993	312,114
2009	236,998	0	56,476	293,474	29,606	323,080	6,586	329,666
2010	255,377	0	55,514	310,891	23,293	334,185	12,511	346,696
2011	269,529	0	65,699	335,228	36,914	372,142	10,326	382,468
2012	275,853	0	70,089	345,942	50,121	396,063	8,976	405,039
2013	327,764	*8,148	46,591	382,503	25,160	407,664	74,539	482,203
2014	290,675	51,501	30,303	372,478	47,385	419,863	68,073	487,936
Ave.	260,765	51,501	53,176	319,906	23,162	343,068	18,931	361,999
Min.	225,333	51,501	30,303	274,071	3,145	277,216	0	277,216
Max.	327,764	51,501	70,089	382,503	50,121	432,624	74,539	507,163

Note: *: total of 2 months of operation

Source: PPL

The Average Capacity Factors of the Ramu 1 HP, YOTD HP, and Pauanda HP are around 62%, 84% and 61%, respectively. The Capacity Factor (CF) of each HPP is calculated as given in the following table.

The CF of the Ramu1 HP is around 60% on average for an available maximum output of 48 MW. It will be possible to raise the CF up to around 80%, which will increase the additional energy to about 60 GWh/year on average. The CF of the Pauanda HP (run-of-river type) is around 60% on average and has an available maximum output of 10 MW in the wet season. Energy generated at the Pauanda HP in the dry season decreases to around 80% of the energy in the wet season (8 MW). In 2014 generated energy decreased to 30 GWh/year, a level equivalent to a CF of only 35%, due to serious trouble with the turbines.

Table 5.1-4 Capacity Factor of Each Hydropower Plant in the Ramu System (2005 to 2014)

Year	CF of Ramu 1	CF of YTOD	CF of Pauanda	CF (Total)	Ratio of Ramu 1 to all hydro	Ratio of YTOD to all hydro	Ratio of Pauanda to all hydro
2005	53.6%		55.6%	41.2%	82.2%	0.0%	17.8%
2006	54.5%		59.7%	42.2%	81.4%	0.0%	18.6%
2007	59.8%		60.2%	45.7%	82.7%	0.0%	17.3%
2008	58.4%		60.9%	44.9%	82.2%	0.0%	17.8%
2009	56.4%		64.5%	44.1%	80.8%	0.0%	19.2%
2010	60.7%		63.4%	46.7%	82.1%	0.0%	17.9%
2011	64.1%		75.0%	50.4%	80.4%	0.0%	19.6%
2012	65.6%		80.0%	52.0%	79.7%	0.0%	20.3%
2013	78.0%		53.2%	57.5%	85.7%	2.1%	12.2%
2014	69.1%	32.7%	34.6%	55.9%	78.0%	13.8%	8.1%
Ave.	62.0%	32.7%	60.7%	48.1%	81.5%	1.6%	16.9%
Min.	53.6%		34.6%	41.2%	78.0%	0.0%	8.1%
Max.	78.0%		80.0%	57.5%	85.7%	13.8%	20.3%
Avg. Capacity (MW)	48.00	7.00	10.00	65.00			

Source: PPL

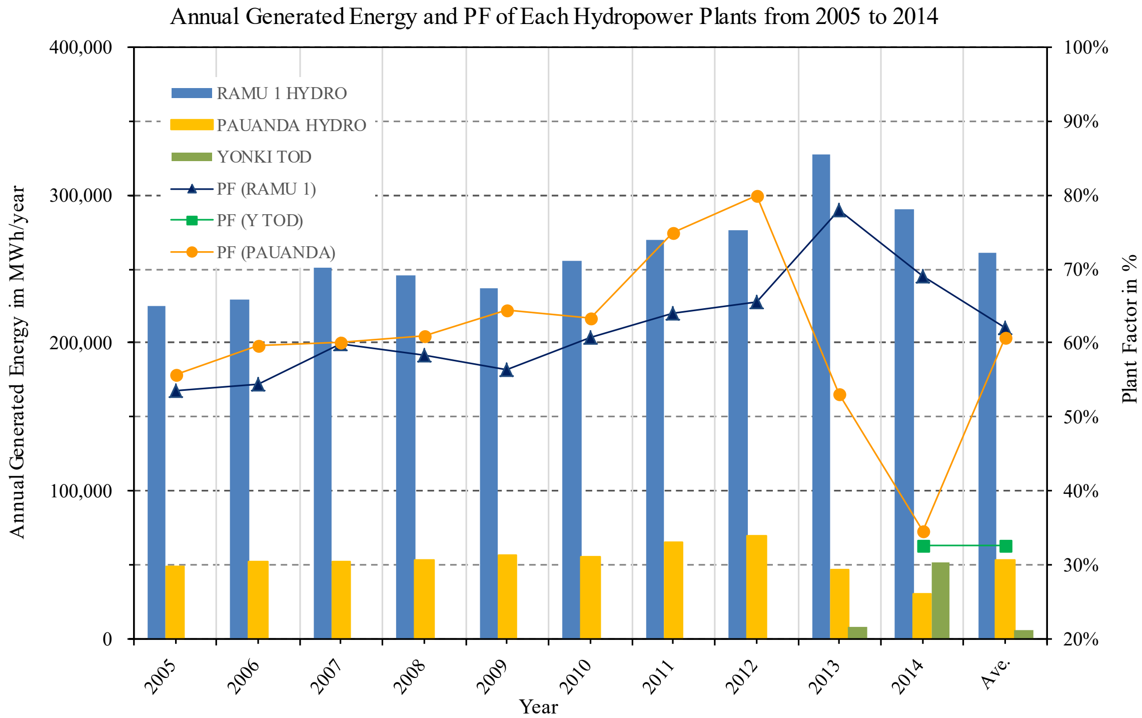


Fig. 5.1-4 Annual Generated Energy of Each Hydropower Plant of Ramu System (2005 to 2014)

A comparison of generated energy between the wet seasons (January to March and October to December) and dry season (April to September) at each HPP is shown in the following figure. As the figure shows, there are no remarkable differences between the energy generated in the dry and wet seasons.

According to the hearing with PPL, the generated energy of the Pauanda HP in the dry season is estimated to be around 80% of that in the wet seasons, but there are no records of river discharge. On the other hand, the Ramu 1 HP and YTOD HP are not influenced by river flow fluctuation because both plants can be operated using regulated water released from the Yonki reservoir dam.

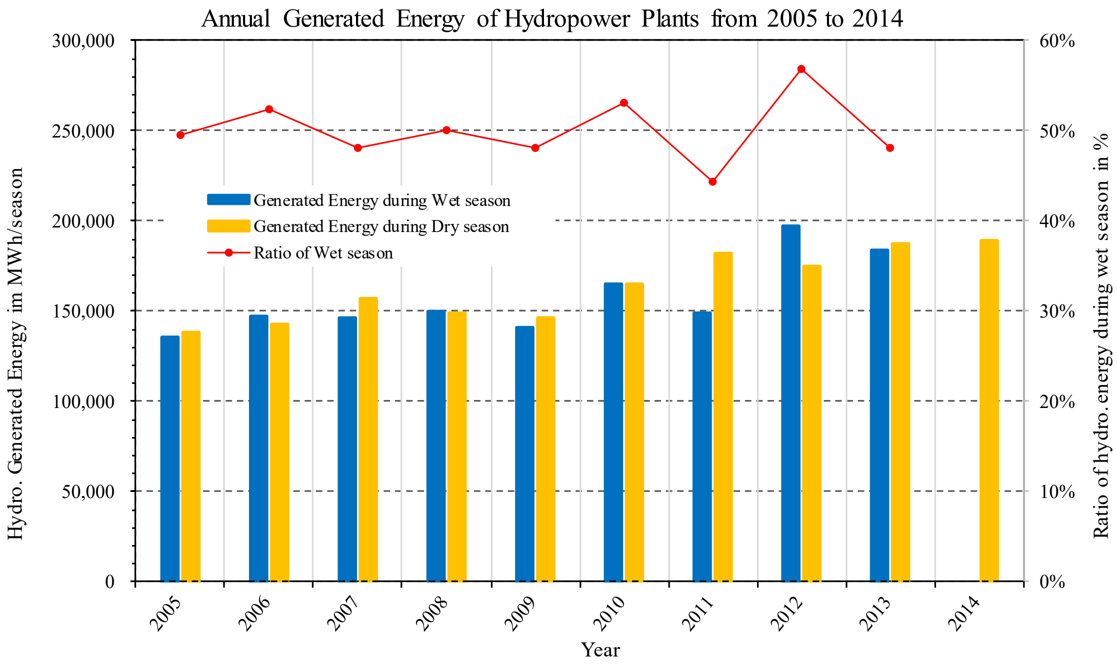


Fig. 5.1-5 Comparison of Generated Energy between the Wet Seasons and Dry Season in Hydropower Plants

2) Monthly Operation Status of Existing Hydropower Plants

The monthly energy from each HPP from 2005 to 2014 and the monthly average, maximum, and minimum energy outputs from the HPPs are given in the following figures. According to these figures, the monthly average HP energy is almost constant, at around 25 GWh/month, and available energy is around 35 GWh/month.

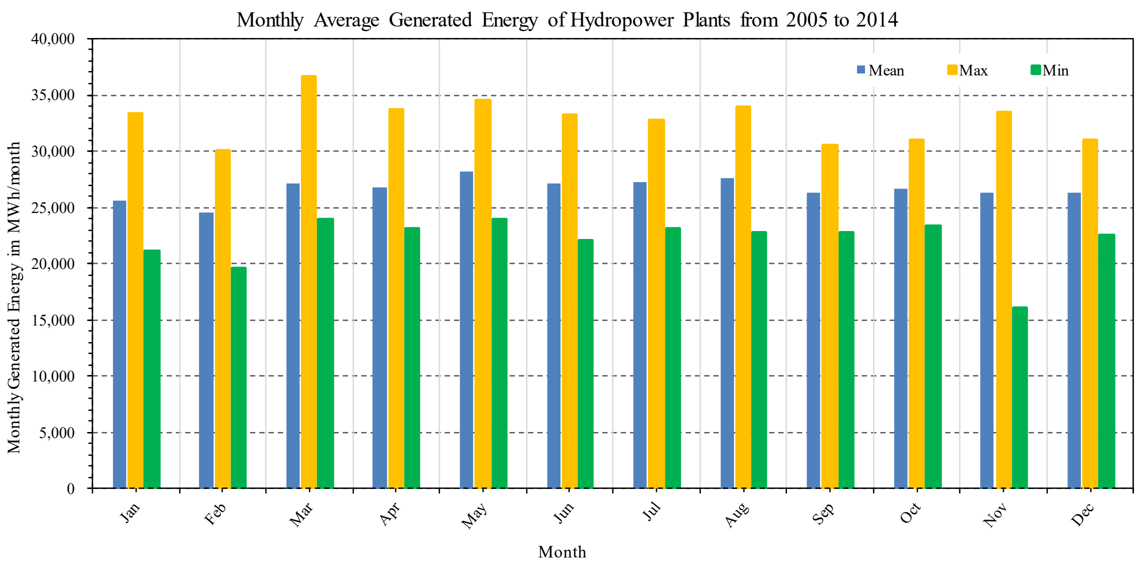
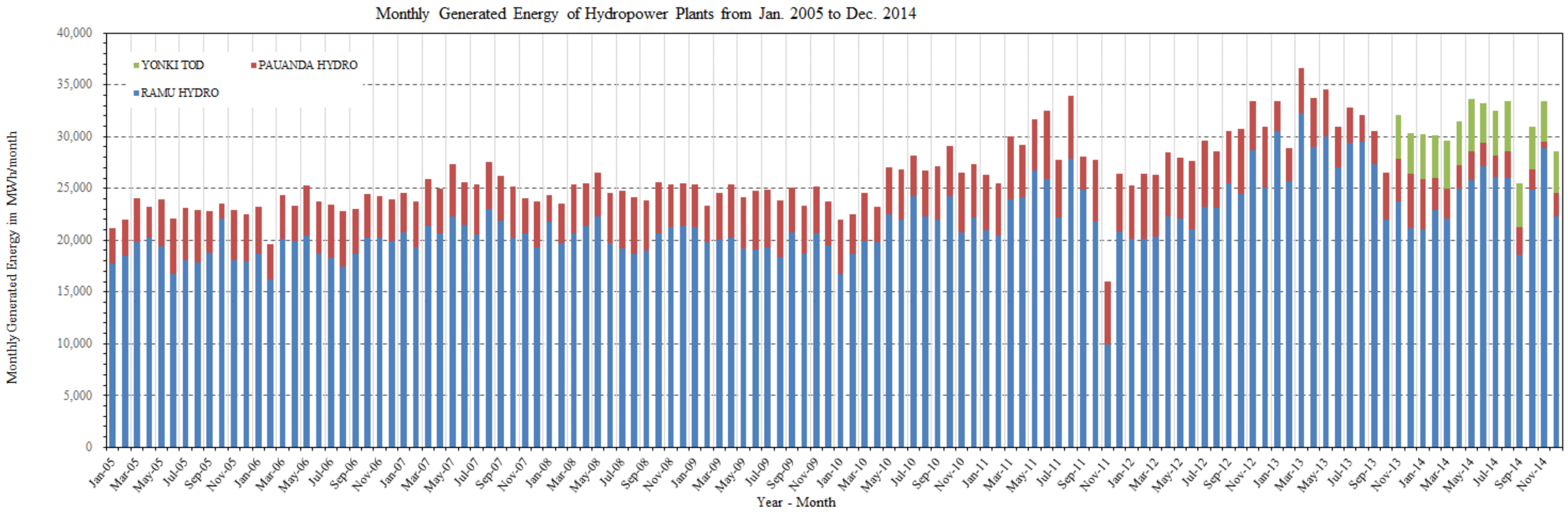


Fig. 5.1-6 Monthly Average, Maximum, and Minimum Energy Outputs from the Hydropower Plants



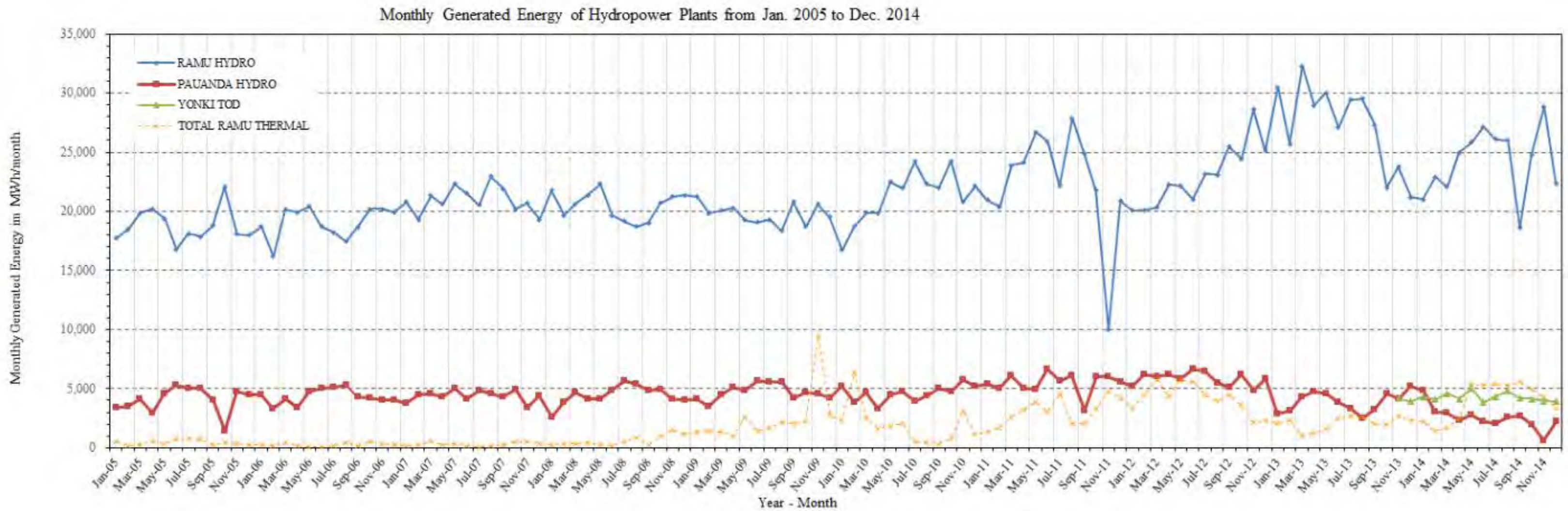
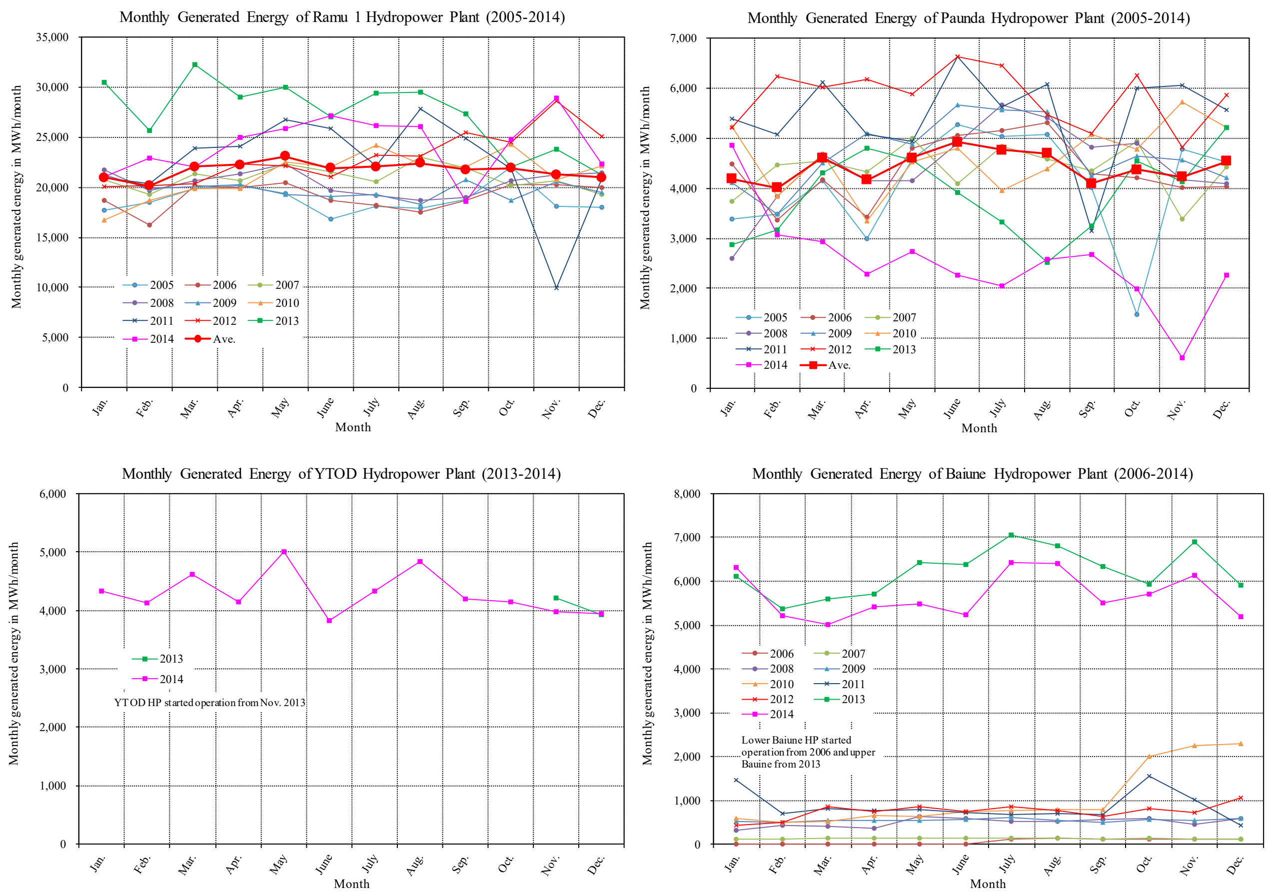


Fig. 5.1-7 Monthly Energy of Each Hydropower Plant (from Jan. 2005 to Dec. 2014)

The following figures show the fluctuations of monthly energy from each HPP. The Ramu 1 and YTOD plants are reservoir-type and the Pauanda and Baime plants are run-of-river types.



(Upper Baime with installed capacity of 11.4 MW started operation in 2013)

Fig. 5.1-8 Fluctuation of Monthly Energy from Each Hydropower Plant (from 2005 to 2014)

3) Operation Status of Existing Hydropower Plants in 2013 and 2014

The following table shows the HP operation status of each unit in 2013 and 2014. The YTOD HPP (installed capacity: 18 MW) started generation from November 2013, but maximum output has been limited to no more than 6 to 7 MW due to a large impulse of the waterway.

The annual rate of operation hours of each unit of the Ramu 1 hydropower plant varied between 30% and 90% and averaged 70%. The reduced capacity of a tailrace tunnel limited the available power discharge to around 30 m^3/sec, which was equivalent to a maximum power discharge of 3 units only. Therefore, 1 unit is always on stand-by. The average output is calculated as the daily generated energy divided by the operation hours per day.

Table 5.1-5 Rate of Operation Hours and Average Output of Each Hydropower Plant Unit (2013 & 2014)

Plant	unit	Rate of operation hr.		Average output (MW)		remarks
		2013	2014	2013	2014	
Ramu 1 HP	#1	80.5%	81.8%	9.54	8.99	
	#2	93.7%	89.8%	10.59	9.63	
	#3	80.8%	47.9%	9.44	5.08	
	#4	32.2%	77.7%	4.90	11.14	
	#5	76.6%	45.2%	8.96	7.44	
	Mean/Total	72.8%	68.48%	43.43	42.29	
Pauanda HP	#1	41.8%	16.2%	3.22	1.89	
	#2	85.2%	87.4%	4.01	3.29	
	Mean/Total	63.5%	51.8%	7.23	5.18	
YTOD HP	#1	50.6%	87.9%	6.04	5.43	
	#2	42.7%	28.6%	5.89	5.27	
	Mean/Total	46.7%	58.3%	5.97	5.73	

Table 5.1-6 Monthly Generated Energy of Hydropower and Thermal Power Plants of Ramu System (2013)

Unit: MWh/month

plant	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Ave
Ramu 1	27,657	25,489	32,276	28,952	24,651	27,081	29,441	29,121	26,980	21,397	21,157	21,197	315,399	26,283
Pauanda	2,120	2,347	4,203	4,789	3,143	4,542	3,137	2,488	3,237	4,307	4,024	4,660	42,997	3,583
YTOD											4,218	3,930	8,148	4,074
Hydropower energy	29,778	27,836	36,478	33,740	27,794	31,622	32,579	31,609	30,217	25,704	29,399	29,787	366,544	30,545
Thermal power energy	1,606	2,200	1,177	1,026	1,135	4,026	2,758	2,800	3,371	2,178	2,342	1,309	25,928	2,161
PPL total energy	30,794	30,036	37,655	34,767	28,929	35,648	35,337	34,409	33,588	27,882	31,741	31,096	392,472	32,657
Ratio of hydropower energy	97%	93%	97%	97%	96%	89%	92%	92%	90%	92%	93%	96%	93%	94%
Baime HP (IPP)	6,113	5,372	5,596	5,719	6,425	6,374	7,059	6,819	6,341	5,930	6,888	5,904	74,539	6,212

Source: PPL

Table 5.1-7 Monthly Generated Energy of Hydropower and Thermal Power Plants of Ramu System (2014)

Unit: MWh/month

plant	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Ave
Ramu 1	21,030	22,898	22,752	24,990	25,821	27,128	26,112	26,016	18,610	24,819	28,872	22,323	291,371	24,281
Pauanda	4,332	4,301	4,619	4,149	4,825	3,820	4,325	4,836	4,043	4,148	3,981	3,920	51,299	4,275
YTOD	4,854	3,070	3,063	2,286	2,744	2,255	2,048	2,574	2,651	1,994	608	2,265	30,409	2,534
Hydropower energy	30,216	30,269	30,434	31,425	33,390	33,203	32,484	33,426	25,305	30,960	33,460	28,507	373,079	31,090
Thermal power energy	1,790	1,054	1,171	2,678	4,996	5,045	4,828	5,008	4,898	4,638	4,249	2,821	43,174	3,598
PPL total energy	32,006	31,323	31,605	34,102	38,385	38,249	37,312	38,434	30,202	35,598	37,709	31,328	416,254	34,688
Ratio of hydropower energy	94%	97%	96%	92%	87%	87%	87%	87%	84%	87%	89%	91%	90%	90%
Baime HP (IPP)	6,306	5,217	5,018	5,424	5,485	5,228	6,426	6,407	5,517	5,716	6,129	5,200	68,073	5,673

Source: PPL

4) Daily Operation pattern of Hydropower Plants

The daily operation pattern of the Ramu system is hydro-based operation. Thermal power plants supply electricity during peak hours in the afternoon (PM 2:00 – PM 5:00) and night-time (PM 7:00 – PM 10:00) on weekdays. On weekends, peak hours only fall in night-time (PM 7:00 – PM 10:00).

The following figures show the daily operation status of hydropower and thermal power plants on September 4, 2014 (Thursday) and September 7, 2014 (Sunday). On these days, the Ramu 1 HP supplied around 60% of total daily energy and covered the base and middle base loads.

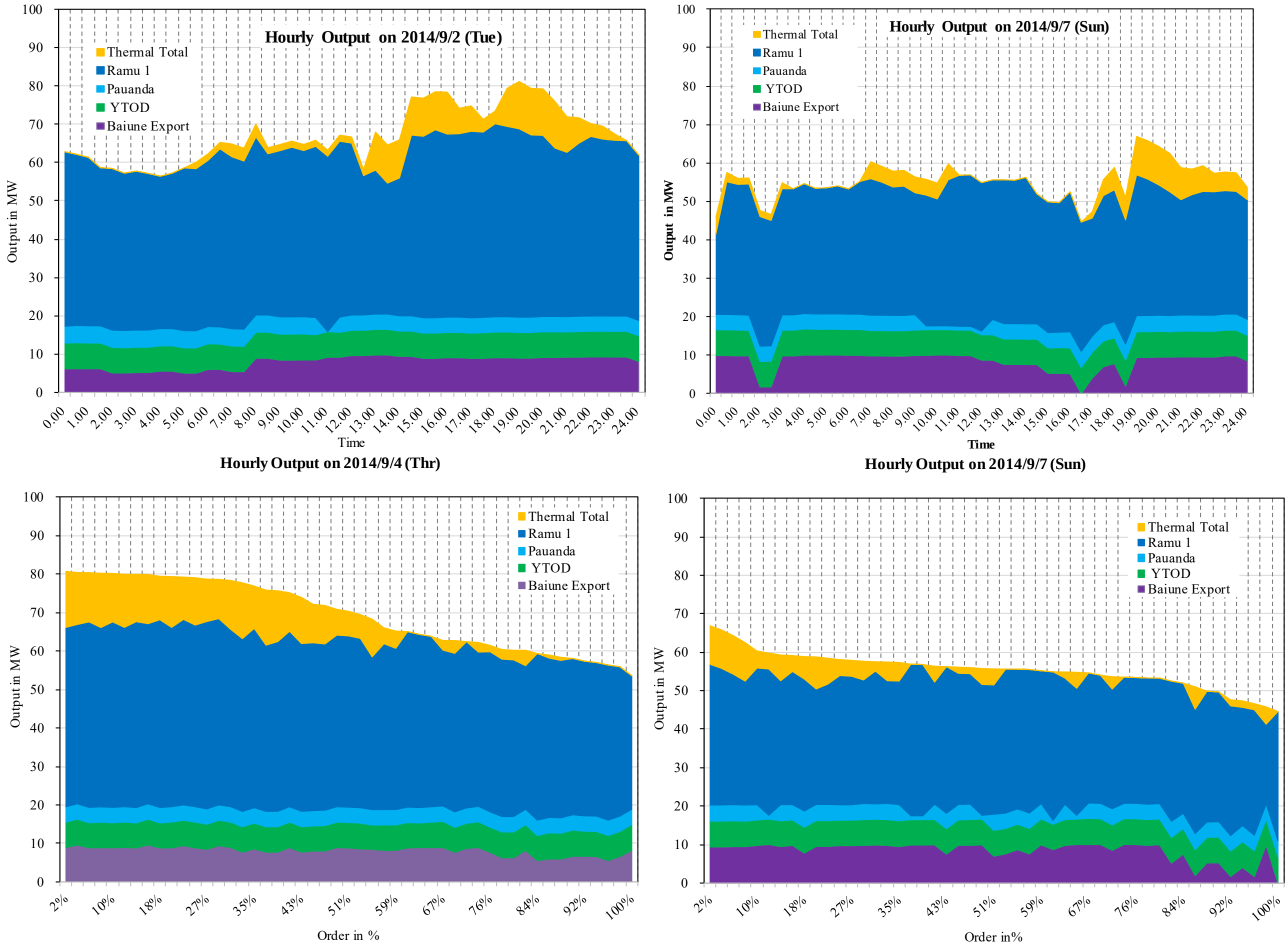


Fig. 5.1-9 Daily Operation Weekday and Weekend Patterns on Sept. 4, 2014 (Thursday) and Sept. 7, 2014 (Sunday)

Table 5.1-8 Daily Operation Weekday and Weekend Patterns on Sept. 4, 2014 (Thursday) and Sept. 7, 2014 (Sunday)

Sept. 4, 2014 (Thursday)

item	unit	Ramu 1	Pauanda	YTOD	Baime (IPP)	Hydro total	Thermal total	System total
Energy	MWh/day	1,051.1	96.0	158.4	195.0	1,500.5	167.4	1,667.8
	rate	63.0%	5.8%	9.5%	11.7%	90.0%	10.0%	100.0%
Max	MW	48.8	4.0	6.8	9.6	68.4	14.6	80.7

Sept. 7, 2014 (Sunday)

item	unit	Ramu 1	Pauanda	YTOD	Baime (IPP)	Hydro total	Thermal total	System total
Energy	MWh/day	809.1	76.9	152.3	223.3	1,261.6	104.0	1,365.6
	rate	59.2%	5.6%	11.2%	16.4%	92.4%	7.6%	100.0%
Max	MW	48.5	4.0	6.8	11.4	67.3	15.9	69.3

(3) Details of Existing Hydropower Plants

1) Ramu 1 Hydropower plant

The Ramu 1 HPP located in the Ramu River in Morobe province was completed in 1976. Three hydro turbine units were installed in Phase-1, and an additional 2 turbine units were installed in Phase-2 in 1990. Ramu 1 HP was originally a run-of-river type scheme. The Yonki reservoir dam (storage volume of around 340 million m^3) was constructed about 2 km upstream of Ramu 1 HP in 1992. Since the completion of the Yonki dam, the Ramu 1 HP has used the release water regulated by the Yonki dam, i.e., operated as a reservoir type. The YTOD HPP was completed at the toe of the Yonki dam and started generation in November 2013. The layout of Ramu 1 HP is shown in the Attachment.

The poundage volume of the diversion weir of Ramu 1 HP is only 190,000 m^3/sec, which is equivalent to only a few hours of operation for Ramu 1 HP. The flow from Yonki dam cannot be controlled by this poundage.

The intake is connected to a vertical pressure shaft of 210 m in length 3.05 m diameter, and a horizontal pressure tunnel of the same diameter. Both shafts are lined with concrete, and a part of the horizontal tunnel near the underground powerhouse is lined with steel and has a diameter of 2.51 m.

The five generating units of the Ramu 1 HP are housed in an underground cavern and the control house is located on the surface near the diversion intake. The tailrace tunnel, surge shaft, and surge tunnel are arranged downstream of the powerhouse. The tailrace tunnel is 2,290 m long, with a horse-shoe shape measuring 3.4 m in width and 3.4 m in height. The length of the concrete-lined section is 1,470 mm, and one of the unlined sections has a length of 820 m (excluding an invert portion). The slope is 1:450. A surge shaft with a horizontal tunnel is provided about 60 m downstream of the powerhouse.

Original runners of units 1, 2 and 3 were replaced by new runners in 1991 due to heavy cavitation after operation of units 4 and 5. The major features of the hydro machines of the Ramu 1 HP are given in the following table.

Table 5.1-9 Major Features of the Hydro Machines of Ramu 1 Hydropower Plant

Ramu 1 HP		Turbine					Generator					
unit	Date Comm.	maker	Type	Rated Speed rpm	Rated Head m	Max. flow m^3/sec	maker	type	Voltage	AMPS	kVA	kW
#1	1974 -75	Litostroj	V/Francis	750	198.6	9.80	Rade Koncar	Synch	11,000	1,017	16,660	15,000
	1991	Refurbished by Boving	V/Francis	750	198.6	9.80						
#2	1974 -75	Litostroj	V/Francis	750	198.6	9.80	Rade Koncar	Synch	11,000	1,017	16,660	15,000
	1991	Refurbished by Boving	V/Francis	750	198.6	9.80						
#3	1974 -75	Litostroj	V/Francis	750	198.6	9.80	Rade Koncar	Synch	11,000	1,017	16,660	15,000
	1991	Refurbished by Boving	V/Francis	750	198.6	9.80						
#4	1989	Boving	V/Francis	750	198.6	8.94	Elin	Synch	11,000	1,017	18,000	17,000
#5	1989	Boving	V/Francis	750	198.6	8.94	Elin	Synch	11,000	1,017	18,000	17,000
total						47.28						79,000

Source: PNG Power, Fifteen Year Power Development Plan, 2014 - 2018

Refurbishment works for the E/M equipment of all five units have been conducted by Andriz Hydro (Austria) since 2011. The work for units 3, 4 and 5 was completed in 2014. The remaining work for units 1 and 2 was postponed due to budgetary problems of PPL.

The total maximum output of 75 MW cannot be achieved due to limited capacity of the tailrace tunnel under the present condition, and the total available output is about 45 to 50 MW. The actual flow capacity of the tailrace tunnel is only about 25 - 30 m^3/sec (the total required for the five units in full operation is 47 m^3/sec), which is only equivalent to the sum of the maximum power discharge of 3 hydro turbines (10 m^3/sec per turbine).

When three turbines were operating in phase-1, open channel flow ran in a tailrace tunnel. When the additional 2 turbines were installed in phase-2, it was assumed that the tailrace tunnel would function as a pressure flow channel in order to increase flow capacity of the tunnel. The alignment of the tailrace tunnel is convex, so air remains in an inflection point and negative pressure occurs in case that hydraulic pressure is higher than the alignment.

2) Pauanda Hydropower Plant

The Pauanda HPP is located near the highway between Mt. Hagen and Mendi in Western Highlands Province, around 40 km far from Mt. Hagen. The Pauanda HP commenced generation in March 1983.

The Pauanda HP is a run-of-river type with a total rated output of 12 MW (6 MW × 2 units). The Pauanda HP is connected with the Ramu 1 HP through a 66 kV transmission line of 260 km in length.

The diversion weir is constructed in the Pauanda creek, the tributary of the Kaugel River. The weir is about 20 m in length and the foundation of the weir is solid rock. The intake structure is located on the right bank and connected with the de-silting basin. Abundant sediment materials are transported from upstream after every flood in the wet season.

The basin is surrounded by a high vertical rock wall, so the steel beam gratings are installed to protect it against large falling rocks. The headrace tunnel connects the basin with the forebay, which is around 1 km in length. A penstock of 310 m in length and 2.3 m in inner diameter is installed between the forebay and powerhouse. The forebay and upper penstock are constructed on the terrace, as the forebay tends to both slide and settle. As a result, the penstock upstream has been heavily deformed and repaired (cutting and welding of the steel).

The hydro turbines and generators were manufactured in Ebara and Shinko Denki, Japan. These hydro machines have been used for more than 30 years. The major features of the hydro machines at the Pauanda hydropower plant are given in the following table.

Table 5.1-10 Major Features of the Hydro Machines at Pauanda Hydropower Plant

Pauanda HP		Turbine					Generator					
unit	Date Comm.	maker	Type	Rated Speed rpm	Rated Head m	Max. flow m^3/sec	maker	type	Voltage	AMPS	kVA	kW
#1	1983	Ebara	H/Francis	500	109.5	6.23	Sinko Elec.	Synch	11,000	656	7,500	6,000
#2	1983	Ebara	H/Francis	500	109.5	6.23	Sinko Elec.	Synch	11,000	656	7,500	6,000
total						12.43						12,000

Source: PNG Power, Fifteen Year Power Development Plan, 2014 - 2018

3) Yonki Toe of Dam (YTOD) Hydropower Plant

The YTOD HPP is located just downstream of Yonki reservoir dam, about 2 km upstream of the Ramu 1 HP.

The YTOD HP uses around 50 m of unutilized head between the existing the Yonki dam (earth dam, 60 m height) and the intake of the Ramu 1 HP. Design and bid documents of the YTOD HP were made byPB Power. Construction works of the YTOD HP were commenced under the Engineering, Procurement, Construction (EPC) contract between PPL and CNEC, a Chinese Contractor, in 2008. Later, PPL terminated the contract because of non-performance by the Contractor. PPL then directly managed the project and established the PPL Project Team incorporating Nippon Koei as the project site managers. The Project Team has handled remaining works such as the penstock, powerhouse building, turbine and generator installation, tailrace, and so on since June 2011. PPL contracted Daiho Corporation, Japan, as a civil contractor and Andriz Hydro, Austria, as an Electro-Mechanical (E/M) plant contractor. The YTOD HP started to supply electric power to the Ramu grid from November 2013. The project was funded by a consortium of local banks.

After operation commenced, a large impulse struck during shutdown of the turbines. It was then judged that the turbines and structures were at a high risk of damage by impulses of a similar magnitude in the future. Since the commencement of generation, the operators have therefore run the plant at less than half of the maximum power discharge and maintained a constant output of 6 to 7 MW, well below the design (original) maximum output of 18 MW (9 MW, 2 units).

Another factor impeding higher output is a rise in generator temperatures whenever the output surpasses 6 to 7 MW. The cooling water supply system needs to be improved (a change from an open type to closed type is recommended).

At present, single units are alternated in turns, keeping a constant output of around 6 to 7 MW and power discharge of 16 to 20 m^3/sec. A discharge of 5 to 9 m^3/sec is released through the bypass valves (capacity of 47 m^3/sec) during operation. The total power discharge of 25-30 m^3/sec required for the Ramu 1 HP is released from the Yonki dam.

The major features of the hydro machines of the YTOD HPP are given in the following table.

Table 5.1-11 Major Features of Hydro Machines of YTOD Hydropower Plant

YTOD HP		Turbine					Generator					
unit	Date Comm.	maker	Type	Rated Speed Rpm	Rated Head m	Max. flow m^3/sec	maker	type	Voltage	AMPS	kVA	kW
#1	2014	Harbin electric Machinery	V/Francis	300	43.0	24.40 (23.98)	Harbin electric Machinery	Synch	11,000	556	10,600	9,300
#2	2014	Harbin electric Machinery	V/Francis	300	43.0	24.40 (23.98)	Harbin electric Machinery	Synch	11,000	556	10,600	9,300
total						48.80						18,600

( ) rated discharge (nameplate) Source: PNG Power, Fifteen Year Power Development Plan, 2014 - 2018

Table 5.1-12 Major Features of YTOD Hydropower Plant

Hydrology	
Catchment Area at Yonki Dam	850 km^2
Mean Annual Inflow	983 mcm = 31.2 m^3/s = 1,160 mm/year
Max Flood Flow observed	610 m^3/s
Probable Maximum Flood (PMF)	Inflow at 10,610 m^3/s & outflow at 6,573 m^3/s
100-yr flood	Inflow at 850 m^3/s & outflow at 500 m^3/s
Yonki Reservoir	
Reservoir level at PMF	El. 1,268.0 masl
Turbine Maximum Operating Level	El. 1,259.2 masl
Full Supply Level (FSL)	El. 1,258.0 masl
Turbine Minimum Operating Level	El. 1,239.0 masl
Minimum Operating Level (MOL)	El. 1,230.0 masl
Gross Capacity at FSL	332 mcm
Gross Capacity at MOL	18.4 mcm
Effective Storage	313.6 mcm
Surface Area at FSL	21.2 km^2
Dam & Intake (existing)	
Type of Dam	Zoned earthfill
Dam Crest Level / Crest Length	El. 1,270.0 masl / 680 m
Height	60 m
Dam Embankment Volume	2.75 mcm
Elevation at Spillway Crest	EL. 1258.0 masl
Length of Overflow Crest	85 m
Waterways	
Rated Discharge	24.4 m^3/s × 2 units = 48.8 m^3/s
Penstock Pipe	Length : 727.271 m (= 621.370 m + 105.901 m)

Penstock Pipe Diameter	4.0 m - 3.6 m – 2.75 m
Powerhouse & Tailrace	
Type	Surface
Length / Width	33.8 m / 36.1 m
Normal Tailwater Level	EL. 1206.0 masl at 50 m^3/s
Minimum Tailwater Level	EL. 1205.0 masl at 0 m^3/s
Tailrace Channel	Open channel
Power Generating Equipment Turbines	
Turbine	
Type	Vertical-shaft Francis
Rated Output	9.3 MW × 2 units
Rated Head	43.0 m
Rated Discharge	24.4 m^3/s
Generators	
Rated Voltage	11 kV
Rated Output	10.6 MVA × 2 units
Main Transformer	
Type	Three-phase, oil immersed type
Rated Voltage	132 kV/11 kV
Rated Power	21.6 MVA × 1 set
Transmission line	132 kV line (YTOD Switchyard to the 132 kV Switchyard of Ramu-1 PS)
Length	1,845 m
Type	Overhead, single circuit with OPGW
Energy Generation	
Mean Annual Energy Generation	83.4 GWh (FS 1989)

(Source: Yonki, Dam Project Final Design Report, 1991.1, SMEC)

4) Yonki reservoir dam Operation

The Ramu intake storage is too small to absorb the daily fluctuations required to follow the power system load. The Yonki dam will make it possible to match the flows with the expected generation, avoid spills, maximize the effective use of the river flow for hydropower generation, and additionally provide a sustained river flow during the dry season.

The maintenance of the water resources, dams, and reservoirs was transferred to an independent corporation, PNG Dams Ltd. (PNG Dam). PNG Dams was incorporated by NEC in July and thereupon took over the Sirinimu Dam, Yonki Dan, and related assets and liabilities from ELCOM. However, PNG Dams is not functioning at present and no staff is assigned.

According to the hearing with PPL, no operation rule has been established for the Yonki reservoir dam. As a basic rule, the daily power discharge targets are aligned with the average monthly river flow to avoid water spills from the spillway of the Ramu 1 HP. Daily minor adjustments to increase or decrease the water released from the Yonki dam can be absorbed by the Ramu 1 HP poundage according to the instructions of system operators.

PPL was provided with reference document on Reservoir operation of the Yonki dam prepared by Snowy Mountains Engineering Corporation (SMEC) in April 1989. It seems that this is not a practical manual and not used at the Ramu HP.

The following figures show the fluctuations of the water level of the Yonki dam in 2012, 2013, and 2014. The turbine operation level is between Turbine Minimum Operating Level (TMINOL) 1,239.0 m and Turbine Maximum Operating Level (TMAXOL) 1,259.2 m. Under the present conditions, the required power discharge is limited to 25 to 30 m^3/sec due to insufficient capacity of a tailrace tunnel of the Ramu 1 HP. There is therefore no need to follow an optimum annual reservoir operation rule. After rehabilitation for recovery of the maximum output of 75 MW of the Ramu 1 HP, however, it will be essential to control the reservoir water level of the Yonki dam in order to effectively supply electricity according to the demand and maximize generation of the Ramu 1 and YTOD HPs. Furthermore, after the Ramu 2 hydropower project (the largest-capacity project among the three cascade hydropower projects) is introduced at the furthest point downstream, it will be more important to develop an optimum reservoir operation rule to maximize the total hydropower energy of the three HPPs.

Yonki Reservoir	
Reservoir level at PMF	EL. 1268.0 masl
Turbine Maximum Operating Level (TMAXOL)	EL. 1259.2 masl
FSL)	EL. 1258.0 masl (335 mcm)
Turbine Minimum Operating Level (TMINOL)	EL. 1239.0 masl
MOL)	EL. 1230.0 masl (18.4 mcm)
Gross Capacity at FSL	332 mcm
Gross Capacity at MOL	18.4 mcm
Effective Storage	313.6 mcm

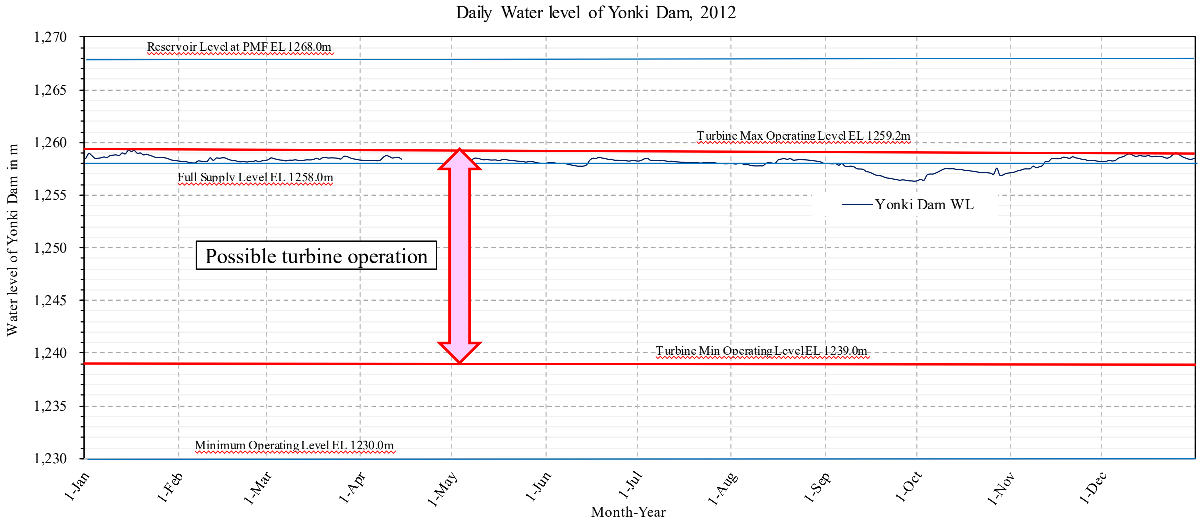
5) Sedimentation of Yonki Reservoir

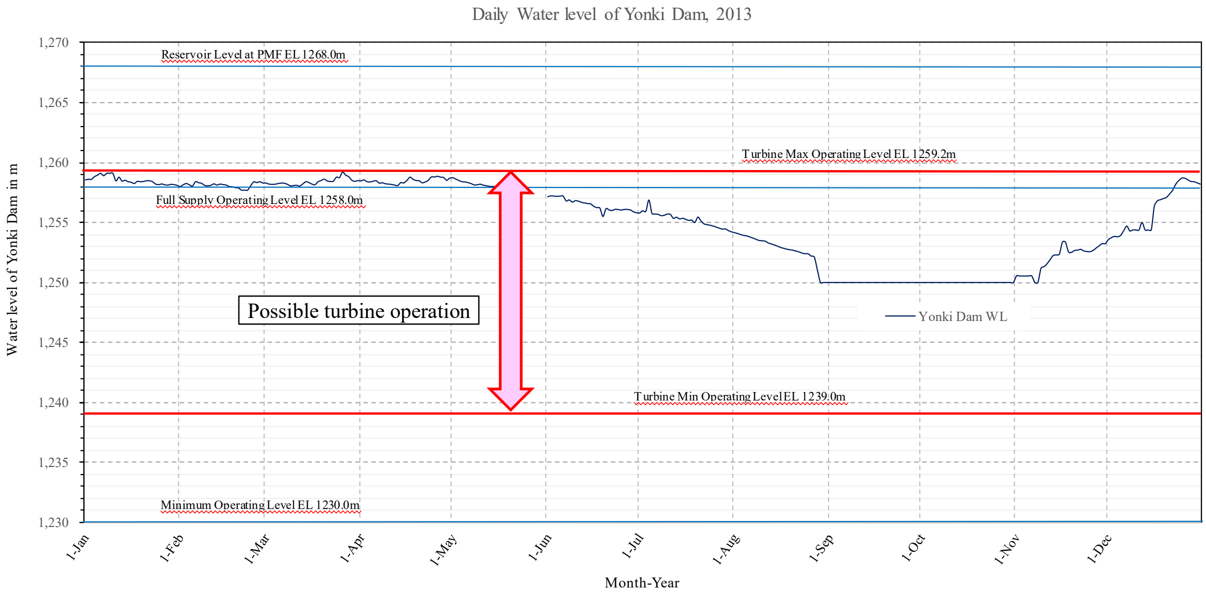
Sedimentation survey of Yonki Reservoir was conducted in 2007 and 2013, it is estimated about 2.4 million m^3 of sediment had been deposited between the period of the 2 surveys, 2007 and 2013.

Based on the current model for storage volume, the active volume now under sediment would represent approximately 0.7% of the active volume.

It is found that sedimentation is restricted to the immediate area surrounding the Ramu intake area judging from analysis of bathymetric survey results and satellite imagery.

(Reference: Sedimentation survey of Yonki Reservoir, SOPAC Technical Report (PR191), 2013)





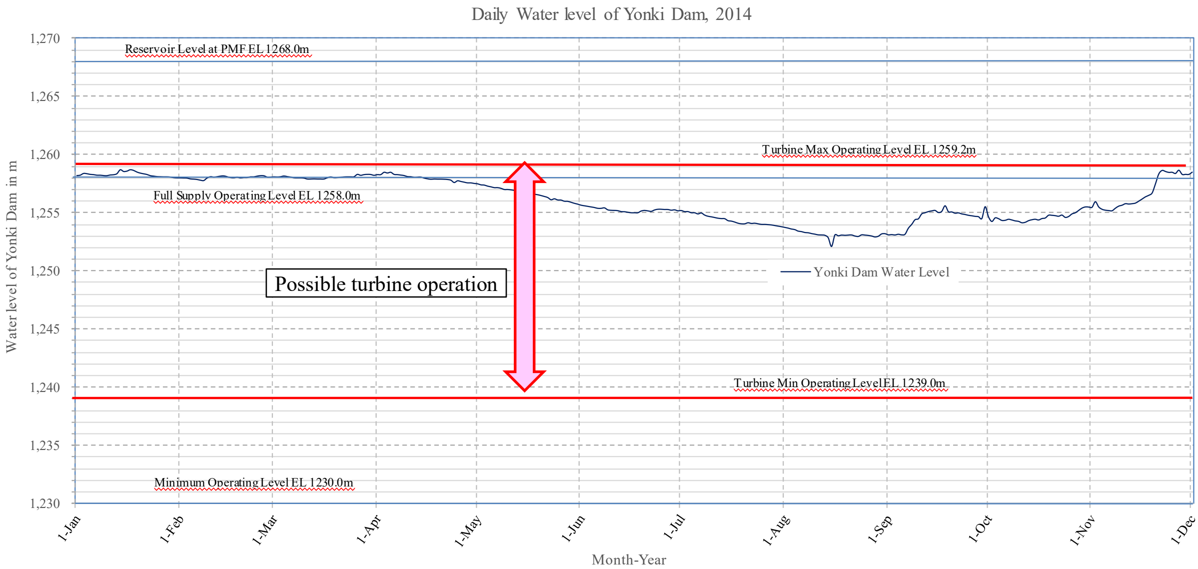
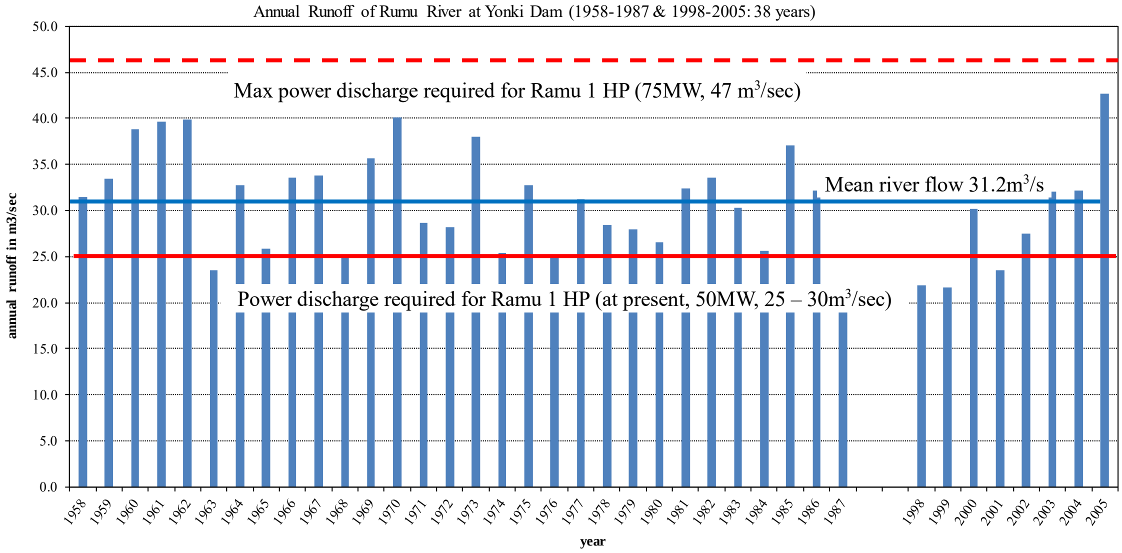


Fig. 5.1-10 Water Level of Yonki Reservoir Dam (2012, 2013 and 2014)



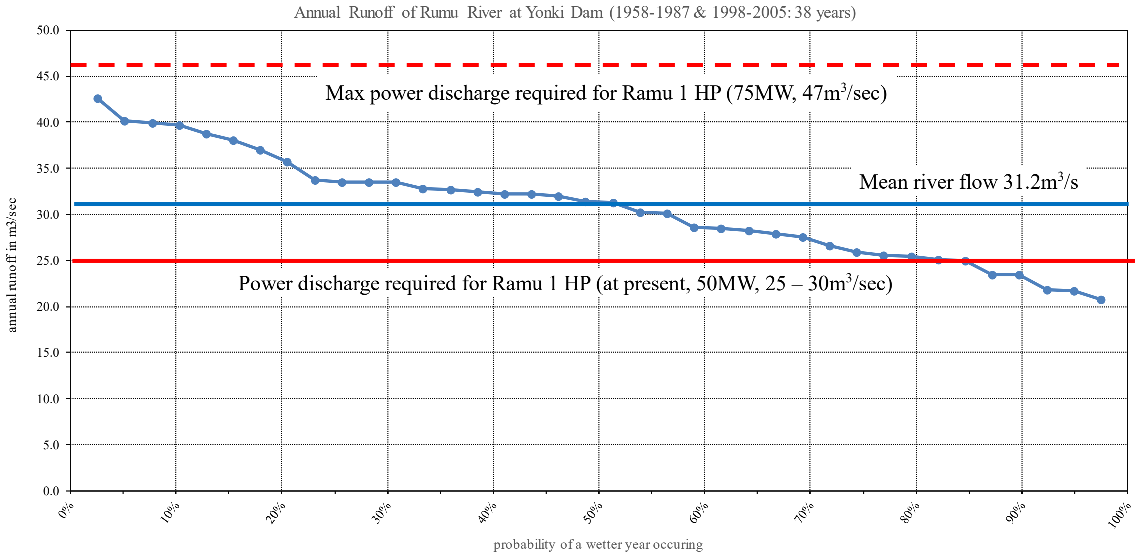


Fig. 5.1-11 Annual Runoff of Ramu River at Yonki Dam (from 1998 to 1987 & 1996 to 2005)

5) Baime Hydropower Plant (IPP)

The Baime HPP is owned by PNG Forest Product Ltd., which supplies electric power mainly to the nearby Hidden Valley Mines (maximum demand: 16 MW). Surplus energy is sold to PPL.

The Baime HP consists of Upper Baime completed in 2013 and Lower Baime completed in 2007. Both power plants are run-of-river types. Under a PPA between PPL and the IPP, the unit generated energy cost is set to be 0.37 PGK/kWh as of 2015.

Power plant	others	Unit capacity	Total capacity	Actual capacity
Upper Baime HP	Run-of-river type	1 MW × 2 units, 4.7 MW × 2 units	11.4 MW	
Lower Baime HP	Run-of-river type	0.7 MW × 5 units	3.5 MW	
Total			14.9 MW	Wet season: 10 MW Dry season: 8 MW

Source: system control, PPL

(4) Field Investigation of Existing Hydropower Plants

During the 1st site visit in November 2014, a field investigation was conducted at existing HPPs on the following dates with the PPL Counterpart.

Table 5.1-13 Field Investigation of Existing Hydropower Plants during the 1st Site Visit

Date	route	activities	Attendant
Nov. 01, 2014	POM – Lae		
Nov. 02, 2014	PPL Lae – Taraka S/S – Milford S/S	Visit to Substation (S/S)	
Nov. 03, 2014	Nadzab S/S – Erap SW	Visit to S/S, SW	
Nov. 04, 2014	Lae – Ramu 1	Visit to Ramu 1 HP control room	PPL: Mr. D. D. Sonny JICA team: Sano, Tomita
Nov. 05, 2014	YTOD, Ramu1	Investigation of YTOD and Ramu 1 HPs	
Nov. 06, 2014	Yonki dam - Lae	Investigation of Yonki dam, Ramu 2 site	
Nov. 07, 2014	Lae - POM		
Nov. 11, 2014	POM – Mt. Hagen		PPL: Mr. D. D. Sonny JICA team: Sano
Nov. 12, 2014	Mt. Hagen – Pauanda HPP	Investigation of Pauanda HP	
Nov. 13, 2014	Mt. Hagen - POM		

1) Ramu 1 Hydropower Plant

The major civil structures of the Ramu 1 HP consist of an intake dam, vertical/horizontal pressure shaft, underground powerhouse, tailrace tunnel, surge tunnel, and shaft. The only underground structure that could be inspected was the powerhouse. Visual inspections of the turbines, generators, control equipment, etc., of all of the units were conducted in the underground powerhouse. The unit #3 turbine was shut down due to replace worn out brake parts. The wall and arch portions of the cavern are covered with concrete lining and shotcrete because of the sound rock condition and a little leakage.

The information and findings collected at the site were as follows;

- Refurbishment works consisting of a turbine governor upgrade and improvements of the cooling water supply system, control system, etc., were commenced by Andriz Hydro in 2013 for units #3, #4 and #5. The works for units #1 and #2, however, were not yet commenced. Remaining refurbishment works for units #1 and #2 will be restarted once the budget is allocated by PPL.

- The capacity of a tailrace tunnel is limited (estimated at around 25 ~ 30 m^3/sec). At present it corresponds to the maximum power discharge of 3 units, which results in around 45~50 MW of power output at maximum. Required works to maximize power output and energy production are proposed by the Consultant.

- The investigation by PPL in 2011 revealed a large concrete failure and flush in an elbow portion of an intake pressure shaft and voids behind units #4 and #5 draft tubes due to poor placement of backfill concrete. Repair works based on detailed investigation are urgently required to maintain safe operation and a longer operation period.

2) Pauanda Hydropower Plant

The major civil structures of the Pauanda HP consist of a weir, intake, de-silting basin, headrace tunnel, forebay, penstock, open powerhouse, and outlet.

The information and findings collected at the site are as follows;

- Unit #1 has been out of order due to failures of turbine bearings since May 2014. Spare parts were ordered from the POM head office but have not yet been delivered.

- Unit #2 has a problem with its cooling water supply system. The power output was therefore reduced to keep below the specified temperature for the turbine bearings (around 1 MW). Technical staff from POM office will be dispatched to conduct a detailed investigation in response to requests.

- Overhaul is recommended for all of the E/M equipment and replacement (renewal) is recommended for the governor system, control system, exciter system, etc. All of these components are aged (over 30 years) and do not function properly.

- Abundant sediment materials deposit in front of the intake after every big flood. Sediment therefore has to be removed by heavy equipment, which requires plant shutdown. According to the hearing with the staff, the sediment flushing gate functions poorly because the levels of the intake screen and flushing gate are almost the same.

- The forebay slides and settles because the structure was built on terrace deposits that are both unstable and watery. This results in serious deformation of the penstocks. Large deformation of an expansion joint beyond the allowance was discovered, and a damaged penstock portion has been cut and welded with steel banding four times so far to adjust the alignment with the penstock. Periodical monitoring of the settlement and sliding and substantial countermeasures are required to avoid further sliding and settlement of the forebay as soon as possible.

3) YTOD Hydropower Plant and Yonki Reservoir Dam

The major civil structures of the YTOD HP consist of an intake tower, pressure shaft, penstock, open powerhouse, and outlet. The underground structures could not be inspected, so visual inspection of the powerhouse and E/M equipment, etc., was conducted. The YTOD HP has operated since November 2013.

The information and findings collected at the site are as follows;

- The power plant is operated within only about half of the original maximum power output, in order to avoid possible failures of structures and turbines due to large water pressure pulses during shutdown. (P=6 ~ 7 MW)

- The cooling water supply system operates insufficiently.

- A bid for additional surge chamber works to improve the available maximum capacity up to 18 MW was completed in 2014. The bid evaluation is in progress. Prior to contract and construction, approval from PPL and the KCH boards will be required.

- There are no problems with the structures of the Yonki reservoir dam.

Intake: The intake screen is blocked by a lot of debris.

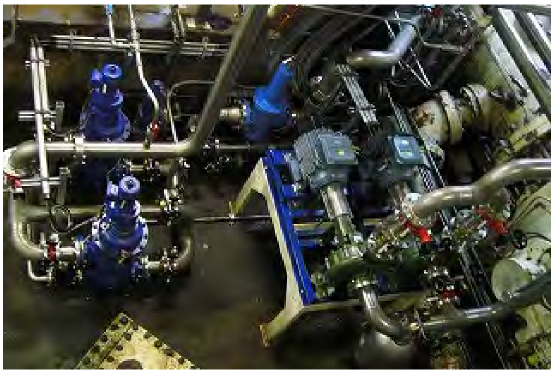
Unit #1 turbine

Unit #4 turbine

Unit #3 turbine: out of order

Unit #4 Generator

Unit #2 Generator



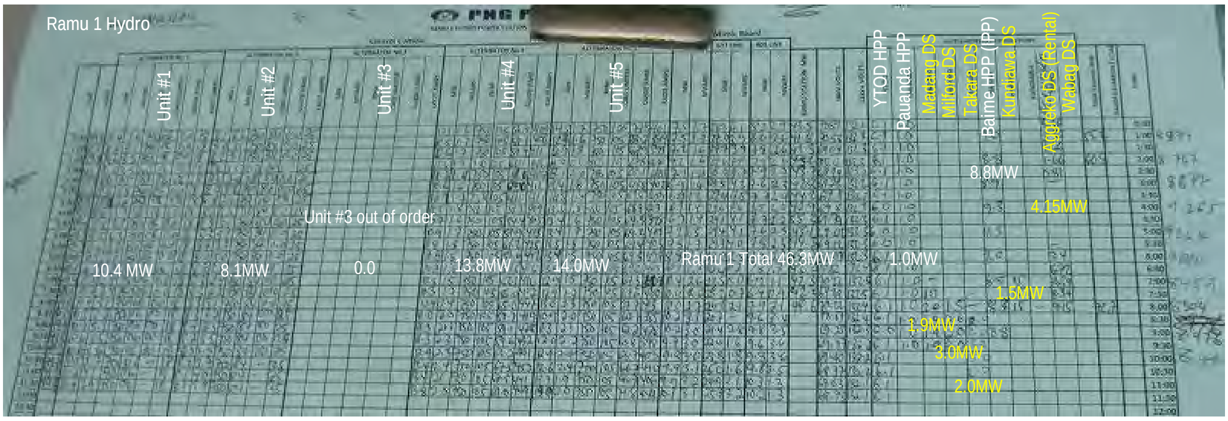
The water cooling system was replaced
(Units #1, #2 and #3).

Unit #5 turbine

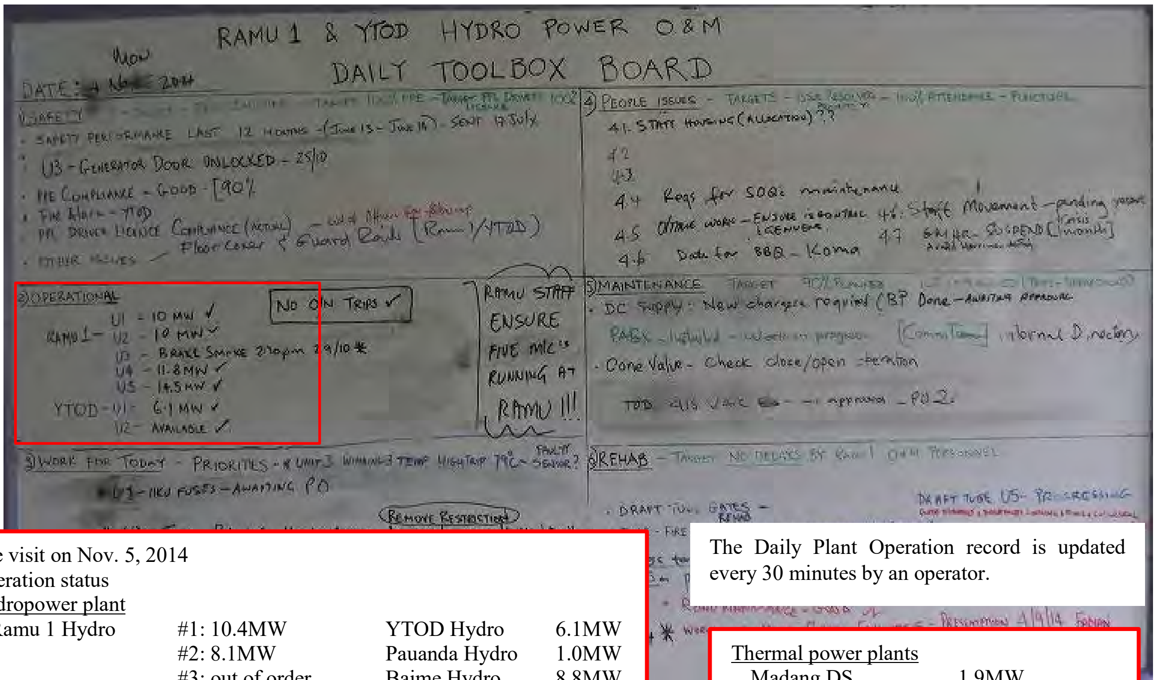
Underground powerhouse

Control house

Picture 5.1-1 Ramu 1 Hydropower Plant (Nov. 6, 2014)



Daily Operation Records at Ramu 1 Hydropower Plant Control Center (Nov. 5, 2014)



Site visit on Nov. 5, 2014
Operation status
Hydropower plant

Ramu 1 Hydro	#1: 10.4MW	YTOD Hydro	6.1MW
	#2: 8.1MW	Pauanda Hydro	1.0MW
	#3: out of order	Baime Hydro	8.8MW
	#4: 13.8MW		
	#5: 14.0MW		
	total: 46.3MW		

The Daily Plant Operation record is updated every 30 minutes by an operator.

Thermal power plants

Madang DS	1.9MW
Milford DS	3.0MW
Taraka DS	2.0MW
Aggreko DS (rental)	4.15MW


Intake weir


Intake: Abundant sediment materials are deposited in front of the Intake.


Sediment materials are frequently removed by heavy equipment.


Intake gate


Forebay


The forebay is unstable due to sliding and settlement.


Gap of forebay structure


Gap of forebay structure

Deformation of the saddle-fixed portion

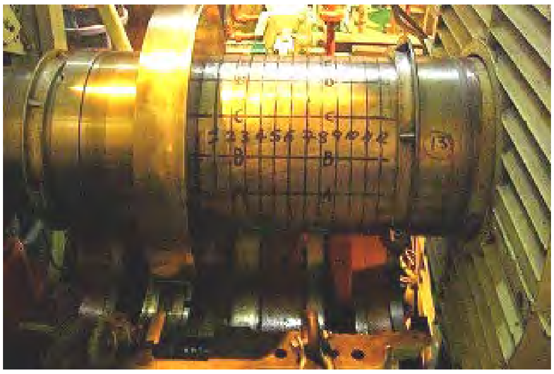
Deformation of the saddle-fixed portion

Upper concrete lining portion: Penstock

Repaired portion of deformed penstock

Unit #1 Turbine: failure of water cooling system

Unit #2 Turbine: damaged turbine bearing



Unit #2 Turbine

Pauanda Hydropower Plant

Picture 5.1-2 Pauanda Hydropower Plant (Nov. 12, 2014)

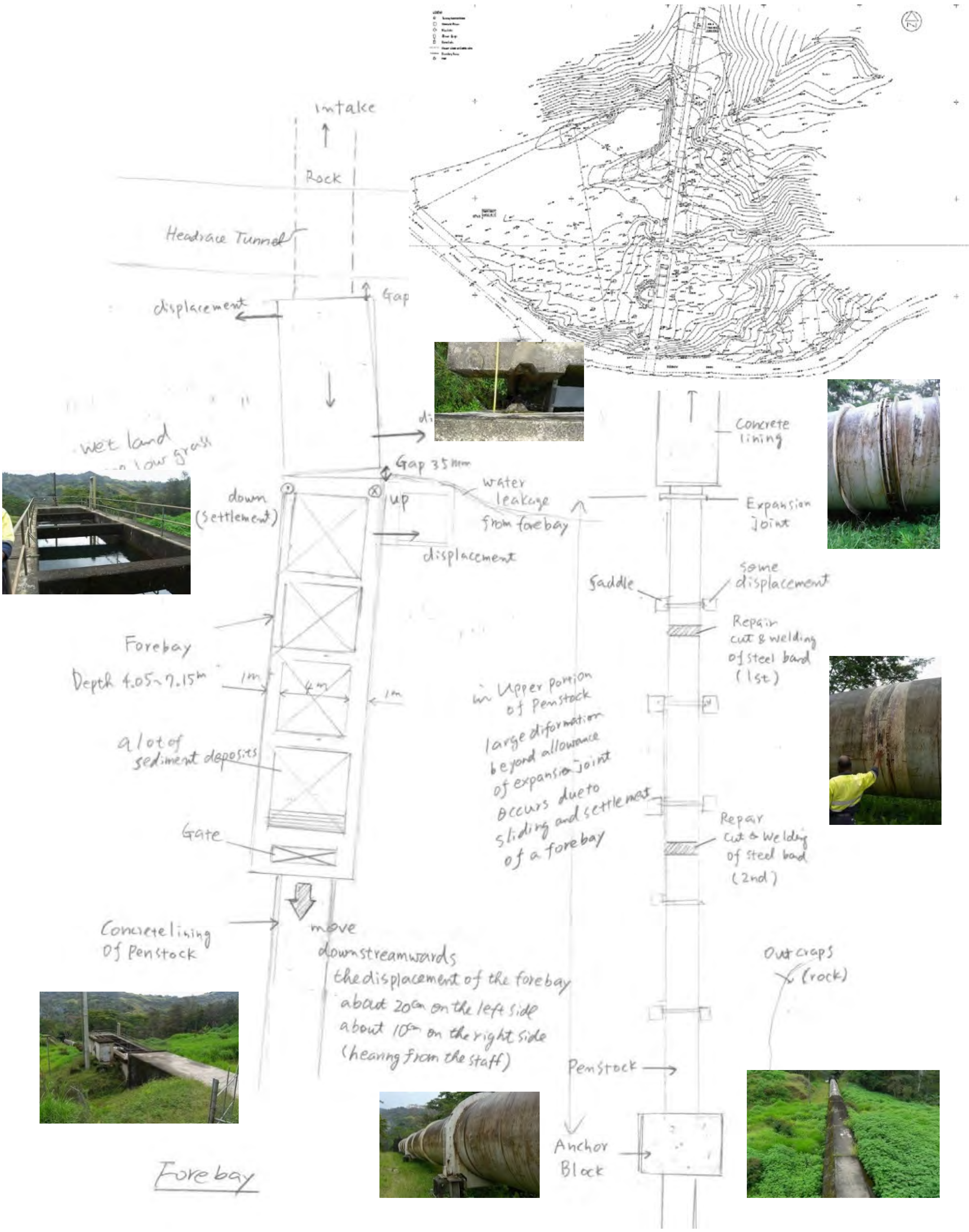


Fig. 5.1-12 Sliding and Settlement of Forebay and Deformation of Upper Penstock

Yonki dam: Upstream view

YTOD Hydropower: Intake tower gate

Yonki dam: Spillway

Outlet of Bypass valve

Additional Surge Chamber to be connected to the open penstock

Open penstock

Electro-mechanical equipment

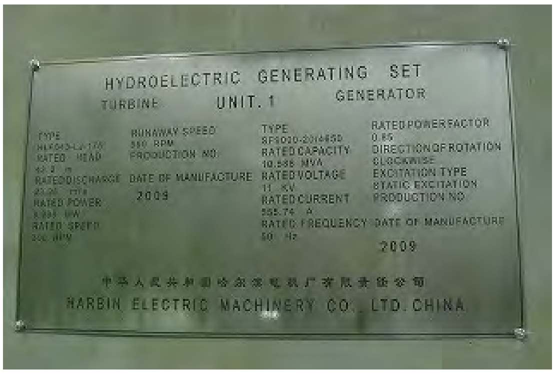
Inlet valve

Unit #1 Governor

Unit #1 Turbine

Unit #1 Generator

Water supply system: it functions insufficiently



Nameplate of the Turbine and Generator: Harbin Electric Machinery, China

Control Room In

Powerhouse Building

Powerhouse exterior

Outlet

Picture 5.1-3 YTOD Hydropower Plant and Yonki Reservoir Dam (Nov. 6, 2014)

5.1.2 Operation and Maintenance of Hydropower Facilities

(1) General

Proper operation and maintenance of power plants are essential to sustain the output of power generation. Many HPPs are aged, and most are maintained improperly. Spare parts are not replaced for long periods, and no overhauls have been done for the last three decades due to fund shortages. In frequent cases, periodical maintenance for the power plants has also been cancelled. The lifetime of a HPP is longer than 50 years under proper operation and maintenance, and more benefits can be obtained from today's cheaper O&M costs.

(2) Operating and Maintenance business unit (O&MBU), POM Head Office

The organizational structure of the operating and maintenance business unit (O&MBU) in the POM head office was revised in May 2013 to enable the delivery of services effectively and efficiently, as shown in the following figure.

A Hydro Maintenance Team (4 positions), Transmission and Distribution Maintenance Team (3 positions), and Civil Maintenance Team (3 positions) were established and overseen by a General Manager of O&M. It is very difficult for these staff members to maintain all power facilities all over PNG by themselves, because only 4 E/M engineers and 3 civil engineers have to conduct maintenance, inspection, design, procurement and supervision of repair works in 11 hydropower plants all over the country.

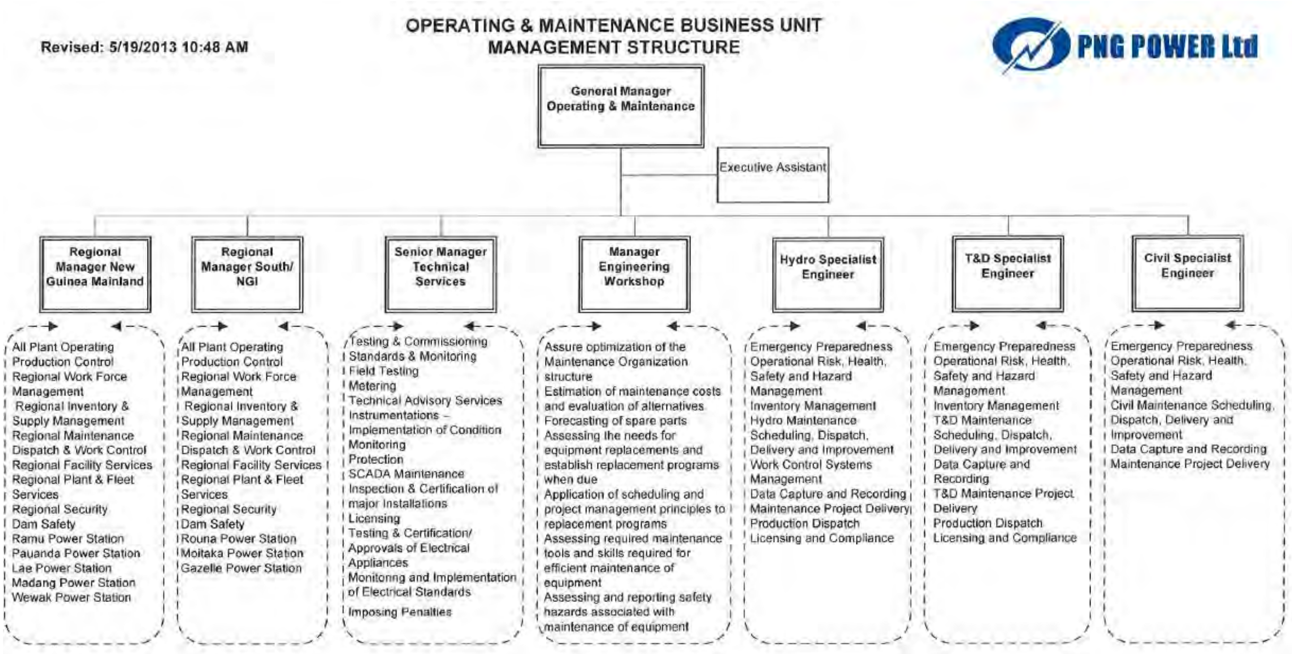
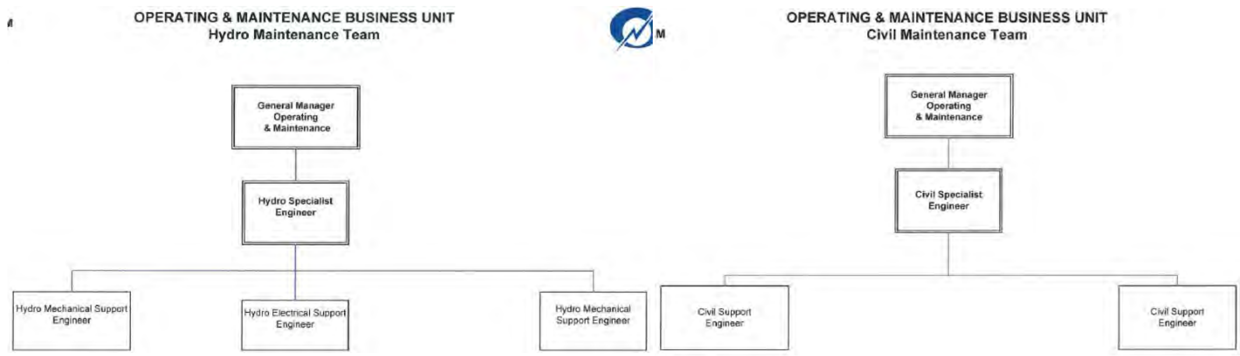


Fig. 5.1-13 Organization of the Operating and Maintenance Business Unit

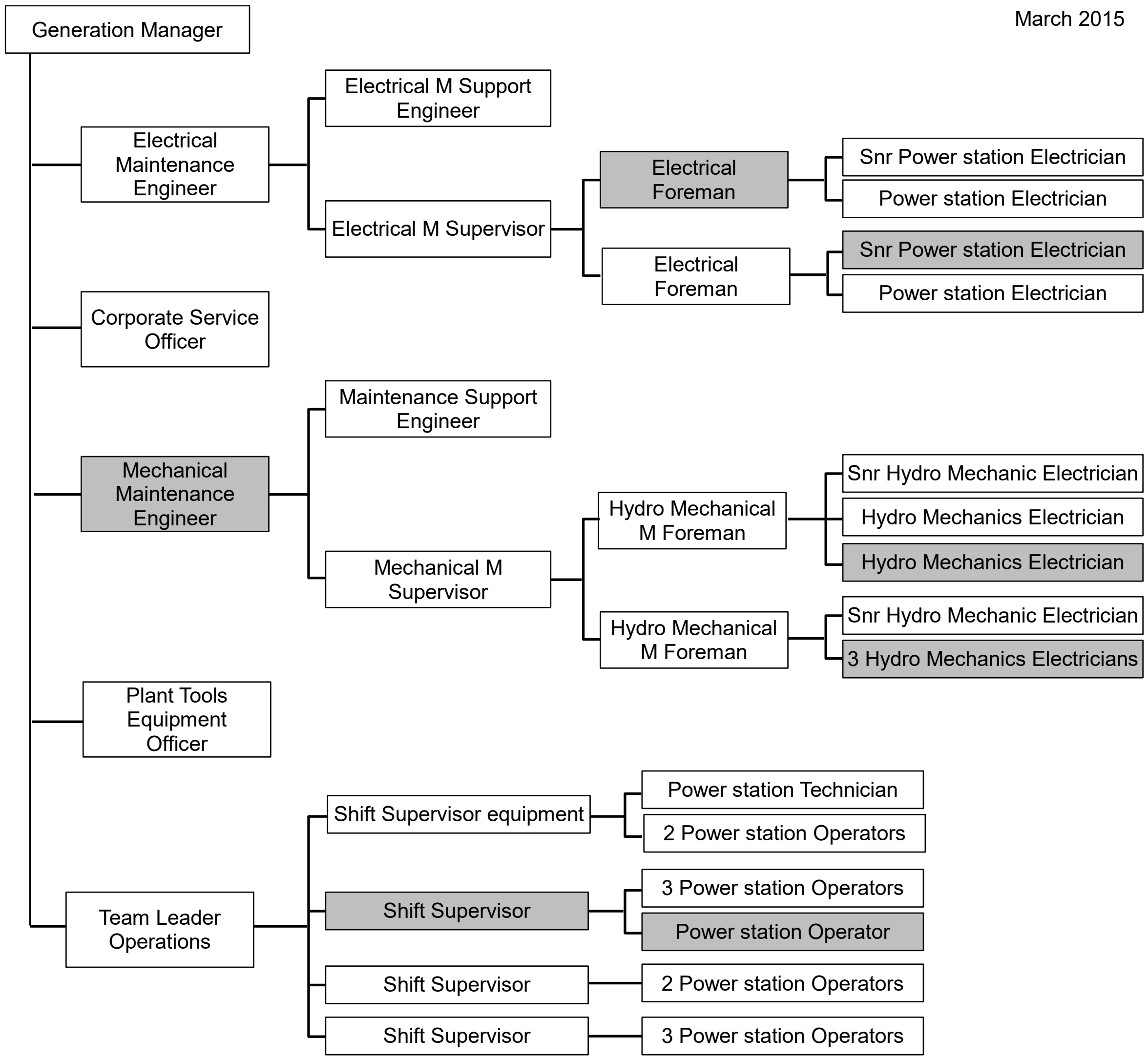
(Source: Revised Organizational Structures – O&MBU, PPL)



(Source: Revised Organizational Structures – O&MBU. PPL)

Fig. 5.1-14 Organization of the Hydro Maintenance Team and Civil Maintenance Team

(3) Ramu 1 Hydropower Plant



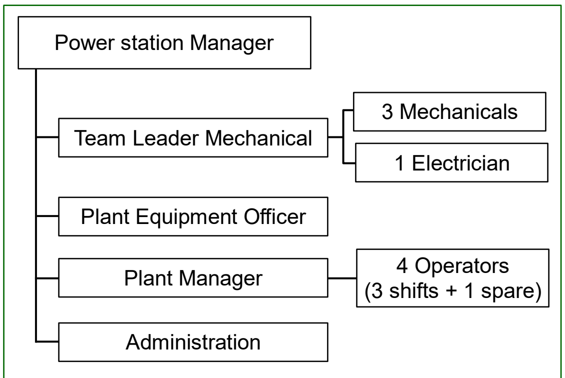
(Source: hearing with O&M Business, PPL)

Fig. 5.1-15 Organization Chart of Ramu 1 Hydropower Plant

The operation and maintenance of the Ramu 1 HP are carried out by 31 staff members in total, and the number of vacant positions is 10. Separate sections are set up to handle electrical maintenance, mechanical maintenance, and operation. The operation section is divided into four groups that work in three shifts. Each group consists of 2 to 3 staff members. One operator works at the YTOD HPP and the staff of the Ramu 1 HPP is responsible for the maintenance of the YTOD HP. A SCADA system is provided between the YTOD HP and Ramu 1 HP operation room. The organization structure of the Ramu 1 HP is given in Fig. 5.1-15.

(3) Pauanda Hydropower Plant

The operation and maintenance of the Pauanda HPP are carried out by 13 staff members in total. Four operators work in three shifts (1 spare). All of the staff members are experienced technicians and work well. The organization structure of the Pauanda HP is given in Fig. 5.1-16.

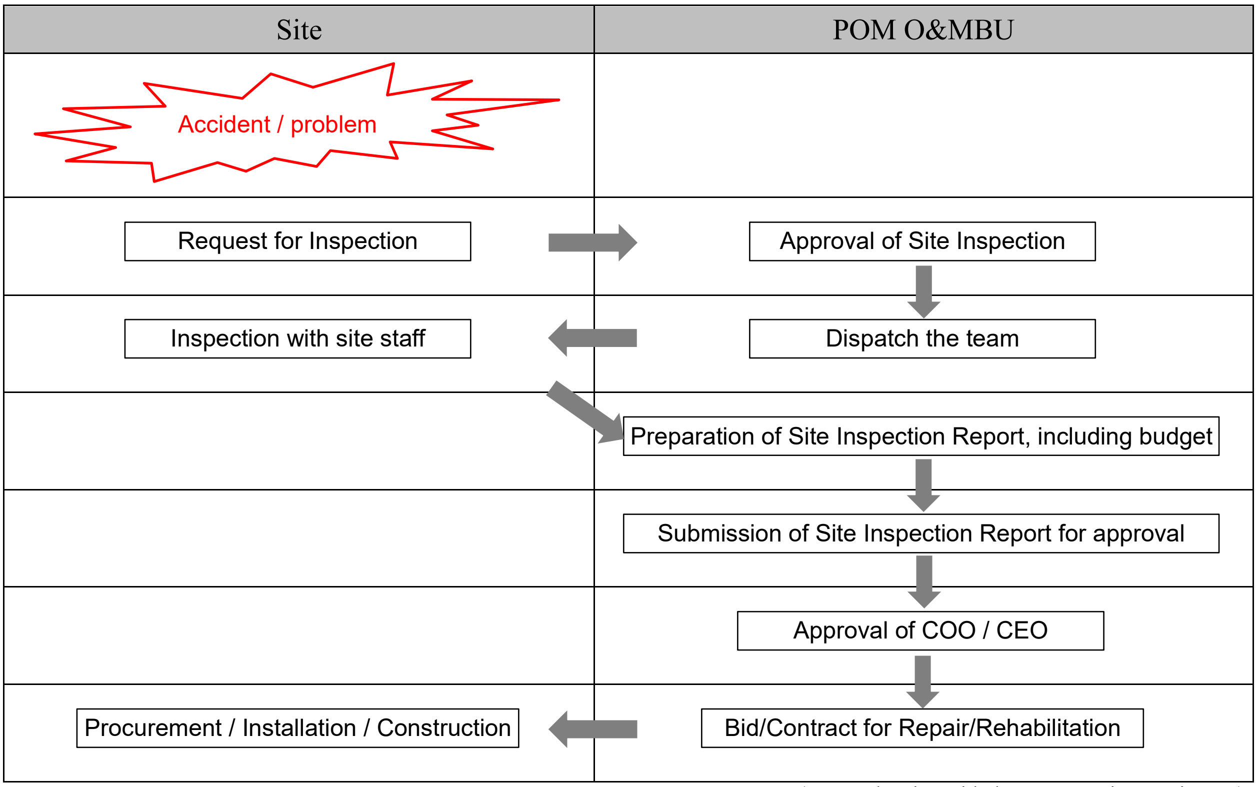


(Source: hearing with Pauanda hydropower plant, PPL)

Fig. 5.1-16 Organization Chart of Pauanda Hydropower Plant

(5) Maintenance of Hydropower Plants

The O&M Business unit in POM, PPL does not dispatch experts to conduct regular monitoring and checking of civil structures, E/M equipment, transmission, or distribution line facilities throughout all of PNG. The required procedures for maintenance, repair, and replacement are shown below.



(Source: hearing with the O&M Business unit, PPL)

Fig. 5.1-17 Flow Chart of Maintenance Procedures

The O & M Business unit makes a Monthly O&M Team Summary Report describing maintenance activities within the last 6 months. Every 12 months the report describes cost estimates, update status, etc. The table below summarizes the required maintenance for civil structures and power-generating operations of the HPPs of the Ramu system as of March 2015.

Table 5.1-14 PPL Proposed Maintenance Activities of Hydropower Plants of Ramu System as of March 2015

Issue/Activity	0-6 months	Cost estimate	Status	>12 months	Cost estimate	Status
Generation Hydro	Pauanda unit 1 restore-new bearings required	K120,000	Set for 30/04/15			
Civil Maintenance	Pauanda landslip to forebay reinforcement	K600,000				
	Pauanda landslip protection works to Power House	K700,000				
	Ramu Transmission Tower protection.	T3 - 603 line - K350,000	Work in progress 80% completed. Set for 30/04/15	Ramu machine hall False Roof maintenance to worst section	K150,000	Scoping and TOR for Tender. Set for 30/12/2015
Major Projects / Ramu Rehab.	1 U2 E&M upgrade 2 U1 E&M upgrade 3 Variation:4-CWS Pipe upgrade 4 Andritz Payments	1 K1.35 m 2 K1.35 m 3 K1.2 m 4 K2.5 m				

(Source: O&M Monthly Team Summary Month: March 2015, PPL)

The following is a summary of the major troubles and repairs of the E/M equipment, control systems, and civil structures of the HPPs of the Ramu system.

1) Ramu 1 Hydropower plant

Year	Unit No.	Trouble, etc.	Remarks
1976	Unit #1, #2, #3	Commission	15 MW × 3 units (turbine: Litostroj, Yugoslavia)
1990	Unit #4, #5	Commission The flow capacity of a tailrace tunnel (25~30 m^3/sec) was insufficient for full operation of all 5 units (47 m^3/sec).	16.2 MW × 2 units (turbine: Elin, UK)
1991	Unit #1, #2, #3	Heavy cavitation of runners occurred after operation of units #4 and #5. Damaged original runners were replaced with new ones. (Kvaerner Boving, UK) The accelerated corrosion due to cavitation was attributed to unacceptable low-load operation.	
	All units	The filters of the cooling water supply system for all units were blocked up by not only mud but also abundant vegetable debris. The generator coils were heated to high temperatures as a result.	
Sept., 2006	Unit #4	The runner was damaged due to excessive corrosion caused by cavitation, and operation was suspended.	

Year	Unit No.	Trouble, etc.	Remarks
2007	Unit #4	The runner was replaced with a new one.	
	Unit #5	The runner was damaged due to excessive corrosion caused by cavitation and the runner was replaced with the runner repaired in Thailand, which was the damaged #4 runner. After that damaged #5 runner was also repaired in Thailand.	
Mar, 2011	Unit #4	The runner was heavily damaged. Four of the blades were broken and the heavily damaged runner was repaired at Allied Industrial Engineering (AIE) in New Zealand.	
2011	Draft tube of Unit #4, #5	Steel liner plates for the draft tubes of Units #4 and #5 were heavily damaged. Operation was suspended.	
July, 2011	Draft tube of Unit #4, #5	PPL inspected the damaged portions of the draft tubes and runners. Repairs to the damaged parts in Unit #5 at the earliest possible time were recommended.	
2013 ~ 2014	Unit #1, #2, #3	Refurbishment works for the E/M equipment and control system were conducted by Andriz Hydro, Austria.	
2014	Unit #4, #5	Refurbishment works for the E/M equipment and control system by Andriz Hydro, Austria were postponed.	
Nov., 2014	Unit #3	Out of order, no operation	During the site visit

2) Pauanda Hydropower plant

Year	Unit No.	Trouble, etc.	Remarks
1983	Unit #1, #2	Commission	6 MW × 2 units, Turbine, Ebara, Japan
1999	Unit #1, #2	All guide vane bushes were replaced with spares because the guide vanes moved too slowly when fully opened. After the replacement, the guide vanes were well.	No spare parts were storage.
2008	Unit #1, #2	The automatic voltage regulator (AVR) was in poor condition, so the voltage was manually adjusted.	The AVR had used for more than 25 years
2011		The 6.6 kV switchgears on the main circuit were burned and the operation of power plant was stopped. The damaged panels were replaced with new panels.	
May, 2014	Unit #1	Out of order due to damage of the turbine bearings.	
Nov., 2014	Unit #1	Spare parts for the turbine bearings were ordered but had not yet been delivered. Operation has not yet been resumed.	

Year	Unit No.	Trouble, etc.	Remarks
Nov., 2014	Unit #2	The cooling water supply system functioned poorly. The max output therefore had to be limited to around 1 MW in order to maintain the specified temperature for the turbine bearings.	
at Present	Issues of E/M equipment	• Electrical components have reached the end of their lifetimes. • The control panel should be replaced due to difficulty in procuring spare parts. • An overhaul of all facilities, renewal of auxiliary equipment, and replacement of the governor system are required. • The cooling water supply system functions poorly, which restricts the maximum output.	
	Existing Issues of Civil Structures	• Countermeasures to stabilize the forebay are required since the forebay was found to have moved since construction. Sealing plates were installed in the gaps between the headrace and forebay to prevent leakage. • The displaced forebay pushed the steel penstock downward beyond the reserve allowance for the expansion joint. The steel pipe was damaged as a result. • Abundant sediment materials deposits in front of the intake, especially after large floods. Sediment deposits are regularly removed using heavy equipment.	

3) TOD Hydropower plant

Year	Unit No.	Troubles etc.	Remarks
2003	Unit #1, #2	Commission	9 MW × 2 units, (turbine: Harbin Electric Machinery, China)
2003	Unit #1, #2	A large impulse of water pressure occurred during shutdown due to the absence of a surge chamber. The maximum output was restricted to no more than 6 – 7 MW in order protect the equipment and structures.	
Nov., 2014	Unit #1, #2	The cooling water supply system functioned poorly, so maximum output could not be achieved.	

5.1.3 Rehabilitation / Refurbishment of Existing Hydropower Plants

(1) General

HPPs play an important role in the Ramu system and generate adequate profits because they have the cheapest generating costs among the various generating sources. The Ramu 1 HP, the most critical generating plant in the Ramu system, has supplied 72% of the total generated energy in the last 10 years. HPPs altogether have supplied 88%.

However, no sufficient or proper maintenance is performed for the aged E/M equipment, control equipment, auxiliary machines, etc., of the aged HPPs. Machine troubles and failures are therefore becoming more frequent.

For the short-term power development plan (PDP), the Rehabilitation / Refurbishment / Enhancement of existing HPPs is essential from economic, time, and environmental aspects.

(2) Ramu 1 Hydropower plant

1) Refurbishment of Electro-mechanical Equipment

The Ramu 1 HP was constructed in 1980, more than 35 years ago. Substantial refurbishment works to remove the current operational limitations and improve station reliability, unit availability, and safety are required. Refurbishment works are to be conducted for all 5 units.

Andritz Hydro, Austria contracted the design, supply, procurement manufacture, workshop testing, transportation, installation, and commissioning of the necessary equipment over a 27-month period. The project was funded by a consortium of local banks.

(Source: Hydro News No.23 / 06-2013, ANDRITZ Hydro)

The refurbishment works of units #3, #4 and #5 were begun in October 2013 and completed in October 2014. The following works were conducted by Andritz Hydro.

- Replacement with a new turbine governor in each unit
- Replacement of the cooling water supply system in each unit
- Shaft seal, servomotor (valves)
- Control panels, protection panel, 11 kV power cable
- SCADA control and monitoring system
- Heat exchangers, flat gate, and accumulator

Replacement of new runners for units #4 and #5 and refurbishment works for units #1 and #2 have been postponed due to delayed payment.

Refurbishment works of Ramu 1 Hydropower plant

Refurbishment works of Ramu 1 Hydropower plant

Source: PNG Advantage Investment Summit 2013

2) Enhancement of Maximum Power Output

The flow capacity of a tailrace tunnel of the Ramu 1 HP is assumed to be 25 to 30 m^3/sec, which is equivalent to a maximum power discharge of only 3 hydro turbines (10 m^3/sec per turbine). The available output therefore amounts to 45 to 50 MW.

When three units were installed in phase-1, the power discharge ran in a tailrace tunnel in a free flow condition. Next, when the additional two turbines were installed in phase-2, it was assumed that the power discharge would run in a tailrace tunnel in pressure flow condition in order to increase the tunnel flow capacity.

According to the original design Four units are fully operated with a power discharge of nearly 40 m^3/sec under a pressure flow condition and 1 unit is reserved as a stand-by unit, however the water pressure and flow velocity would both rise, and the flow condition would also be disturbed due to choking of the outlet section by increased power discharge during the wet season.

In order to solve the above issue and utilize all 5 turbine units effectively, the construction of a No.2 (additional) tailrace tunnel would be a good option for providing the required flow section. After completion of No. 2 tailrace tunnel to solve the limitation in power discharge capacity, the maximum total output would increase to 75 MW from the presently available maximum of 50 MW, and the total annual energy would increase to around 400 GWh/year from the presently available energy of 320 GWh/year.

This increased energy would cut down on the expensive cost of operating diesel power plants.

Reconnaissance of the pressure shaft and draft tubes was conducted during the refurbishment works for the E/M equipment. As a result, a large-scale concrete separation and remarkable leakage around an elbow portion of the pressure shaft and cavity were found around the draft tubes due to faulty construction of backfill concrete. These defective conditions will be investigated in detail during the design stage.

Because the Ramu 1 HP is a critical power plant that supplies most of the electricity consumed by the Ramu system, construction works will not interrupt the operation of the Ramu 1 HP.

It is estimated that it will take around 1.5 years to conduct the detailed investigation, design, and bidding. Construction will take around 2 to 3 years, depending on the work volume. The duration of the financing arrangement is unknown.

(3) YTOD hydropower plant

On one occasion after the commencement of operations, a large impulse struck during the shut-down of a turbine that had been operating at full output. It was then judged that the turbines and structures could be seriously damaged by large impulses in the future. Since then this power plant has operated at less than half of the maximum power discharge with a constant output of 6 to 7 MW, far lower than the maximum output of 18 MW (9 MW, 2 units).

Though the waterway length between an intake tower and turbine is around 700 m, there is no surge tank structure. Hence, the construction of a new surge chamber is recommended in order to protect the hydro machine and structures from a sudden load shutdown or emergency shutdown.

After completion of a surge chamber installation, no operational restriction will be necessary. The maximum output will then be recovered from 6 MW to 18 MW and the output for the base load will reach around 12 MW. The annual available generated energy of 50 GWh/year at present will be increased to 80 MWh/year.

Bidding and bid evaluation were completed in 2014 and the approvals of PPL and KCH are in progress. Once the above approvals are obtained, a contract will be concluded with the awarded Contractor. The estimated construction period is about 2 years. The construction of the surge chamber is not expected to interfere with the power generation operations of either the YTOD HP or the Ramu 1 HP.

(4) Pauanda hydropower plant

The Pauanda HP has operated since 1980, for more than 30 years. The E/M equipment requires an overhaul and the control system needs to be replaced, as no such overhaul or replacement has ever taken place.

As of April 2015, unit 1 is still out of order because of turbine bearing trouble (the trouble started in May 2014). Procurement of spare parts is pending, and unit 2 is operating to control the temperature of the hydro turbine bearings. The available output is therefore falling lower and lower.

No countermeasures against the sliding and settlement of the forebay foundation have yet been done, and generation has to stop whenever the sediment deposits in front of the intake gate reach abundant levels and need to be removed. Countermeasures against the above issues are required from the viewpoints of safety and reliable operation.

The generated energy of the Pauanda HP in 2013 and 2014 was 46.6 GWh/year and 30.3 GWh/year, respectively. These values are about 66% and 43% of the maximum energy in the last 10 years which is 70.1 GWh/year in 2012. Assuming an average output of 9 MW through the year and a CF of 0.9, energy of 71.0 GWh/year could be generated.

5.1.4 Current Hydropower Development Plan

(1) General

PNG has abundant, untapped hydropower resources and hydropower is the major energy produced in PNG. Hydropower energy is cheaper, and HPPs generally have lower annual O&M costs and lifetimes of over 50 years. Hydropower is also environmentally friendly: no greenhouse gas is emitted and environmental and social impacts are usually low. The impacts of hydropower are higher in large-scale reservoir dam type schemes, which cause resettlement and inundation issues.

Hydropower potential studies were conducted all over PNG in the 1980s. These were generally preliminary map studies using 1:100,000 scale topographic maps and available hydrological data (river flow and rainfall). After the 1980s, meteorological and hydrological stations were closed and all observations were discontinued. A few further studies on attractive hydropower potential sites have also been conducted (i.e., pre-feasibility studies, feasibility studies, and so on). Abundant hydropower potentials have not yet been developed at present.

In the Ramu system, the following hydropower projects are preceded from economical and practical aspects.

- Ramu 2 Hydropower project
- Mongi-Bulum Hydropower project
- Kaugel Hydropower project
- Gowar Hydropower project

The locations of the above attractive hydropower projects are shown in the following figure.

Fig. 5.1-18 Existing Hydropower Plants and Planned Hydropower Projects in the Ramu System

(2) Baime Hydropower Project (IPP)

The Baime hydropower project is a run-of-river type scheme located in Morobe province. The project is to be developed by IPP. The expected commissioning year is in 2018. Plans call for a maximum output of 9 MW (4.5 MW × 2 units) and capacity factor of around 80%. Firm capacity in the dry season will be around 7 MW.

Unit generated energy cost is assumed to be the same as that of the Bauine IPP HPP, which is 0.37 PGK/kWh as of 2015*
*: to adjust the purchase price by 50% of the PNG CPI every year

(3) Ramu 2 Hydropower Project

Details and basic parameters of the Ramu 2 hydropower project were obtained from the following reports. The Final Feasibility Study Report was submitted in December 2014. An environmental study and economic and financial analysis of the project are ongoing in 2015 and will be finalized at the end of the year.

- Interim Feasibility Report Ramu 2 Hydropower Scheme, Nov., 2006, PB Power with URS
- Pre-Feasibility Comparative Study Ramu 2 Hydropower Scheme, Sept., 2006, PB Power with URS

The Ramu 2 Hydro Power Plant (HPP) is located the downstream of the existing Ramu 1 HP. The intake of the Ramu 2 HPP is planned just downstream of the outlet of Ramu 1 HP as part of the cascade development scheme (YTOD HP – Ramu 1 HP – Ramu 2 HPP).

The Ramu 2 HPP utilizes the regulated flow released from the Yonki reservoir dam, which is already used in the YTOD HP and Ramu 1 HP.

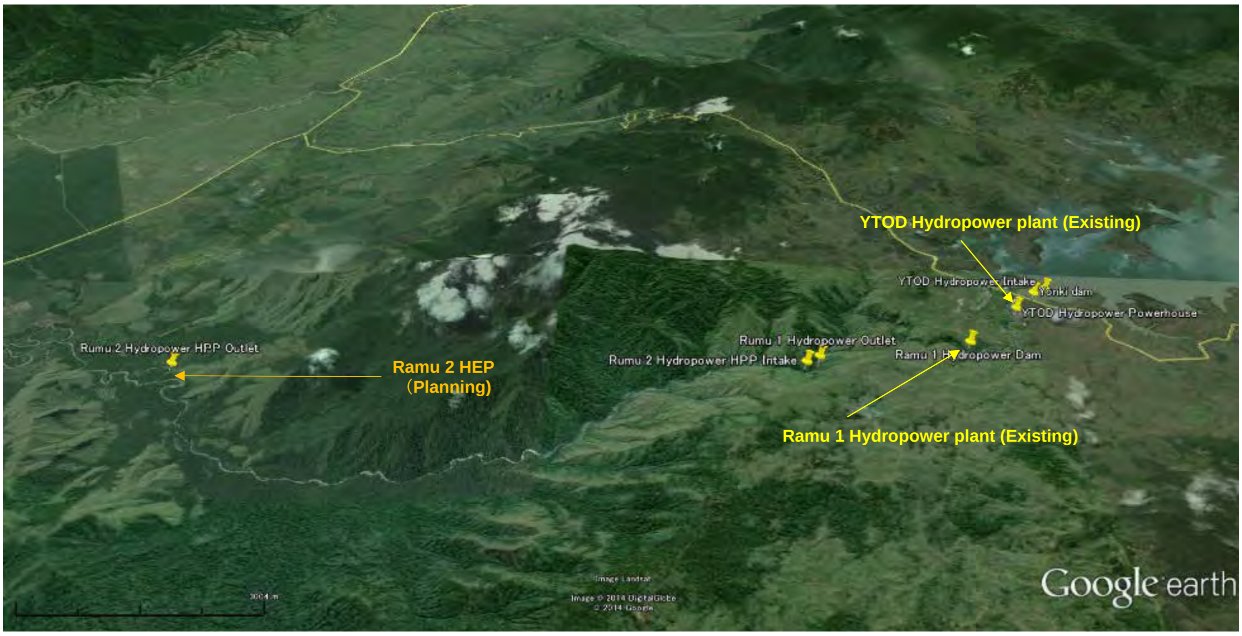


Fig. 5.1-19 Location of Existing and Planned Hydropower Cascade Projects in the Ramu River

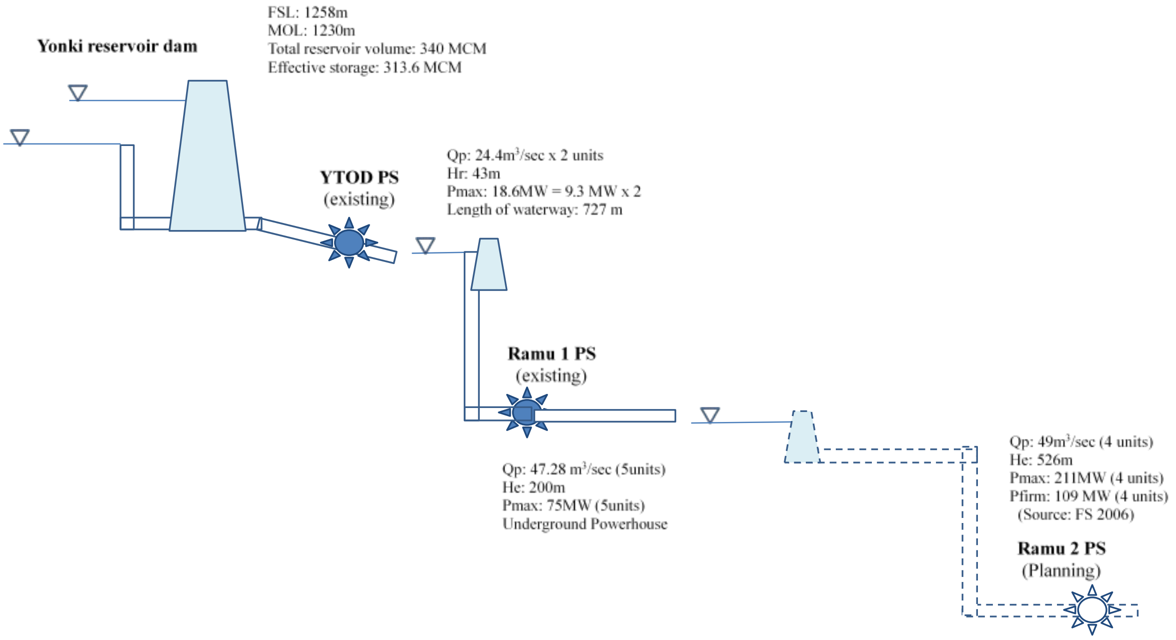


Fig. 5.1-20 Scheme of Hydropower Cascade Projects in the Ramu River

In the Pre-Feasibility study conducted in 2006, a 1-stage scheme with a long 10 km tunnel (200 MW) was compared with a 2-stage scheme consisting of an upstream plant (100 MW) and downstream plant (100 MW). Ultimately, a 1-stage plant with a maximum capacity of 200 MW was selected from technical and economical viewpoints. Based on the above result, a final feasibility study report covering geological investigations, environmental assessments, and economic / financial analyses will be submitted at the end of 2015.

The Ramu 2 HPP is the project furthest downstream in the cascade, just below the existing Ramu

1 HP. The power discharge of the three cascade plants will be regulated by the Yonki reservoir dam.

No reservoir operation rule to maximize the generated energy at the existing Ramu 1 HP and YTOD HP has been found. To minimize spilled water, the design power discharges for the three power plants shall be the same, because the Ramu 1 HP and Ramu 2 HPP have small poundages that are only capable of regulating the released water from the Yonki reservoir dam on a daily operation basis.

An optimization study by means of reservoir simulation shall be conducted to determine a reservoir operation rule for the Yonki reservoir dam.

KCH commissioned a full feasibility study of the Ramu 2 HPP, which is expected to be developed under a PPP/IPP scheme on an EPC or Turn-key contract basis. The major demands of the Ramu 2 HPP are expected to be mine demand from Ramu Nico, Wafi/Golpu, and the like.

The following is the preliminary evaluation of the Ramu 2 HPP.

- Long-term reliable river flow data is available, so accurate power and energy estimates are possible using long-term data. A 40-year record and good estimates of the expected inflows to the Yonki dam are utilized for the study.
- Many investigations and studies have been conducted, and it was concluded that the project is technically feasible. Reservoir simulation to optimize the project is required.
- The project is economical (4 cost USD/kWh, assuming that annual expense calculated by multiplying estimated construction cost by annual equalization discount rate of 12% with return period of 50 years, unit construction cost of 1,700 USD/kW).
- The foreseeable environmental impact seems to be small because the dam is low in height and has a regulated poundage and long tunnel. The land near the intake of Ramu 2 HPP is the property of PPL.
- The environmental impacts are likely to be small in terms of resettlement, land, etc.
- Access is not so difficult and the access road is short.
- An appropriate water management strategy is required for the overall Ramu scheme (Yonki reservoir, YTOD, Ramu 1 and 2)
- The general accuracy is to be within +/- 10%

Geology

- Detailed subsurface investigations are recommended because of the limited geological data.
- No significant geological factors likely to adversely affect the technical validity of the Project have been identified.
- The published 1:100,000 topographic Maps are used. Topographic survey maps will be required for the final F/S.
- The sedimentation of the Yonki reservoir from upstream mines is to be studied.

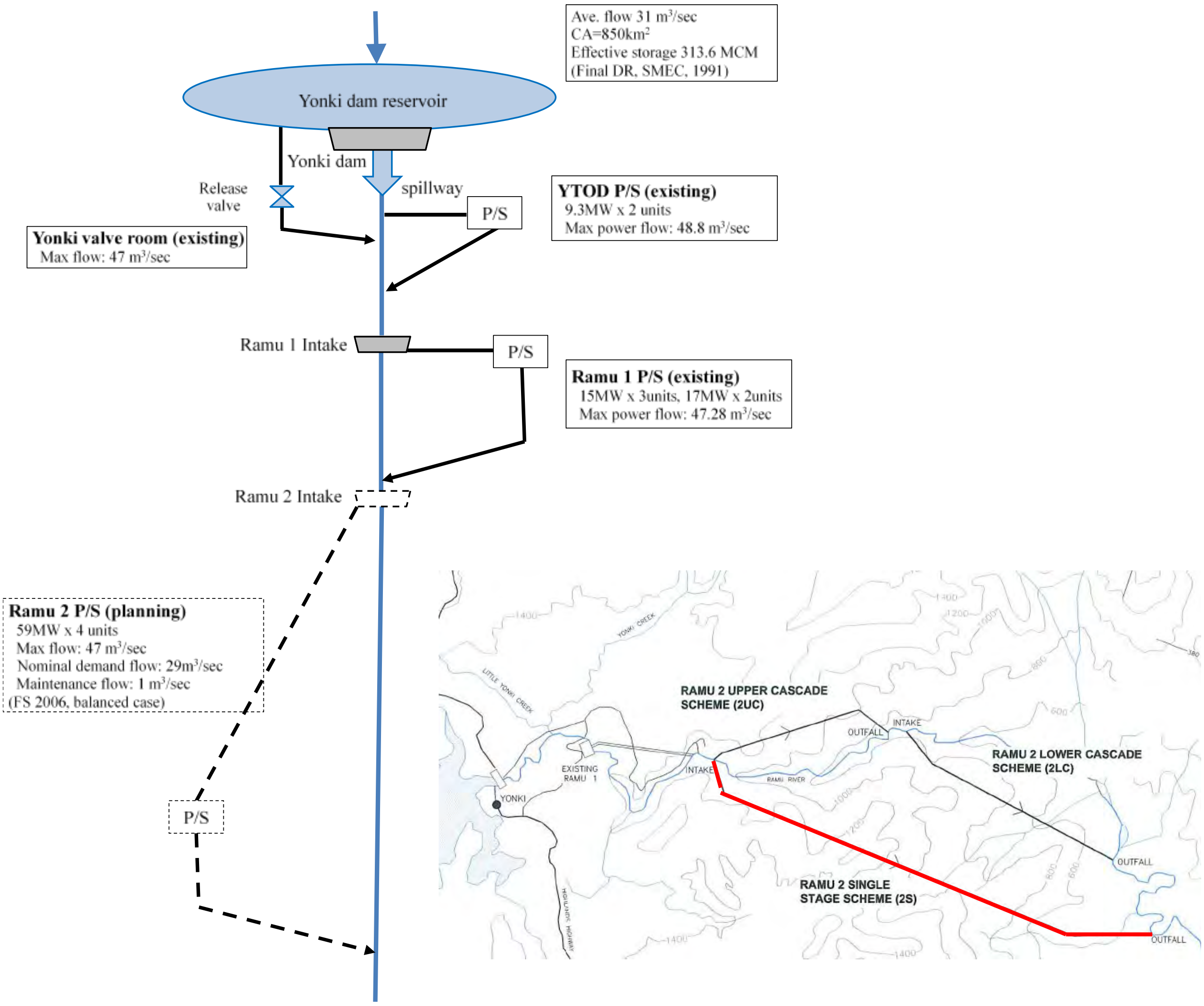


Fig. 5.1-21 Water Utilization of Hydropower Cascade Projects in the Ramu River

Full Feasibility Study being conducted financed by KCH and the Feasibility Study report was submitted in December 2014, but environmental and social study and economic/financial analysis are being conducted in 2015, in order to proceed the next stage, i.e., land acquisition, PPA finance arrangement, project scheme (PPP/IPP), etc.

Major project features (180MW case) are as follows;

Max. installed output	180 MW (60 MW × 3 units)
Power discharge	39.7 m³/sec
Net head	516 m
Annual generation excluding transmission line loses	10% exceedance probability flow 1,340 GWh/year 95% exceedance probability flow 850 GWH/year

Table 5.1-15 Major Features of the Ramu 2 Hydropower Project (1-stage scheme, 2006 F/S)

Item	Description
Study stage	F/S
Study year	Dec. 2006
Target demand (MW)	Ramu Nickel: 15.5 MW, Processing plant: 44.0 MW
Type	Head pond and upstream Yonki reservoir (316 MCM).
Max. power discharge (m^3/sec)	49 (47 from YTOD + 2 from sub-catchment area)
Effective head (m)	526
Average river flow (m^3/sec)	long-term average: 30.9
Environmental flow (m^3/sec)	1.0
Number of units	4 units (4 × 60 MW)
Max. output / Firm output (MW)	211 (Balanced case) / 129
Annual Generated energy (GWh/y)	1,190
Primary energy / Secondary energy (GWh/y)	1,060 / 130
Capacity factor (%)	64
Preliminary Project cost	PGK 847M (USD 293M), 1 PNG Kina =0.346 USD (excl. T/L, incl. 27 % of margin on Contractor's ID cost)
Construction period	43 months
Cost/Length of T/L	PGK 180M (USD 64M) (base cost PGK 740M)
Unit KW cost (USD/kW)	1,690 (incl. T/L) / 1,390 (excl. T/L)
Dam / Weir	34 m high dam and intake
Waterway	- Headrace tunnel: ID= 5 m, L= 7.4 km - Surge shaft: D= 14 m - Surface type: 2 penstock ID= 2.75 - 1.6 m L= 1.4 km - Surface powerhouse: 10 × 32 m - Tailrace channel: B= 2 – 5 m, L= 2 km (unlined)

Table 5.1-16 Major Features of the Ramu 2 Hydropower Project (1-stage &2-stage schemes, 2006 Pre-F/S)

item	Single scheme	Upper scheme 2-stage cascade type	Lower scheme 2-stage cascade type
Study stage	Pre-F/S Comparative Study	Pre-F/S Comparative Study	Pre-F/S Comparative Study
Study year	Sept. 2006	Sept. 2006	Sept. 2006
Max. power discharge (m^3/sec)	49 = 47 (from YTOD) + 2 (from sub-catchment area)		
Effective head (m)	538 (at 49 m^3/s)	274 (at 49 m^3/s)	275 (at 49 m^3/s)
Average river flow (m^3/sec)	long-term average: 30.9, median flow: 18.8		
Environmental flow (m^3/sec)	1	1	1
Number of units	4 units (4 × 60 MW)	4 units (4 × 32 MW)	4 units (4 × 32 MW)
Max. output/Firm output (MW)	218(Balanced case)/137	113/72	113/72
Annual Generated energy (GWh/y)	1,230	641	646
Primary/Secondary energy (GWh/y)	1,114 / 116	560 / 61	586 / 60
Capacity factor (%)	58	57	58
Preliminary Project cost (excl. T/L, incl. 27 % of margin cost)	PGK 676M (USD 210M) 1 PNG K=0.31 USD	PGK 563M (USD 175M)	PGK 599 M (USD 186M)
Construction period	30 months	30 months	30 months
Unit KW cost (USD/kW)	920	1,550	1,640
Dam / Weir	22 m high dam & intake	22 m high dam & intake	
Waterway	- Headrace tunnel: ID= 5 m, L=7.6 km - Surge shaft: ID= 14 m - Surface penstock: 2 lines, ID=2.75 - 1.6 m, L= 1.4 km - Surface powerhouse: 10 × 32 m - Tailrace channel: B= 2 – 5 m, L= 2 km (unlined)	- Headrace tunnel: ID= 5 m, L= 4.4 km - Pressure shaft: L= 215 m - Surge shaft: ID= 13 m, H=15 m - Surface penstock: 2 lines, ID=2.75 - 1.6 m L= 1.4 km - Surface powerhouse: 10 × 32 m - Tailrace channel: B= 2 – 5 m, L= 2 km (unlined)	- Headrace tunnel: ID= 5 m, L= 4,4 km - Surge shaft: ID= 14 m - Surface penstock: 2 lines, ID=2.75 - 1.6 m, L= 0.3 km - Surface powerhouse: 10 × 32 m - Tailrace channel: B= 2 – 5 m, L= 2 km (unlined)

(4) Mongi-Bulum Hydropower Project

The details and basic parameters of the Mongi-Bulum HPPwere obtained from the following reports. The pre-feasibility study Phase-1 was completed in October 2013 and Phase-2 was completed in April 2014.

- Mongi-Bulum, Project - Pre-Feasibility Study Phase-1 Report, October 15, 2013, Entura, Hydro Tasmania
- Mongi-Bulum Hydropower Project - Pre-Feasibility Study Phase-2 Report, April 2014, Entura, Hydro Tasmania

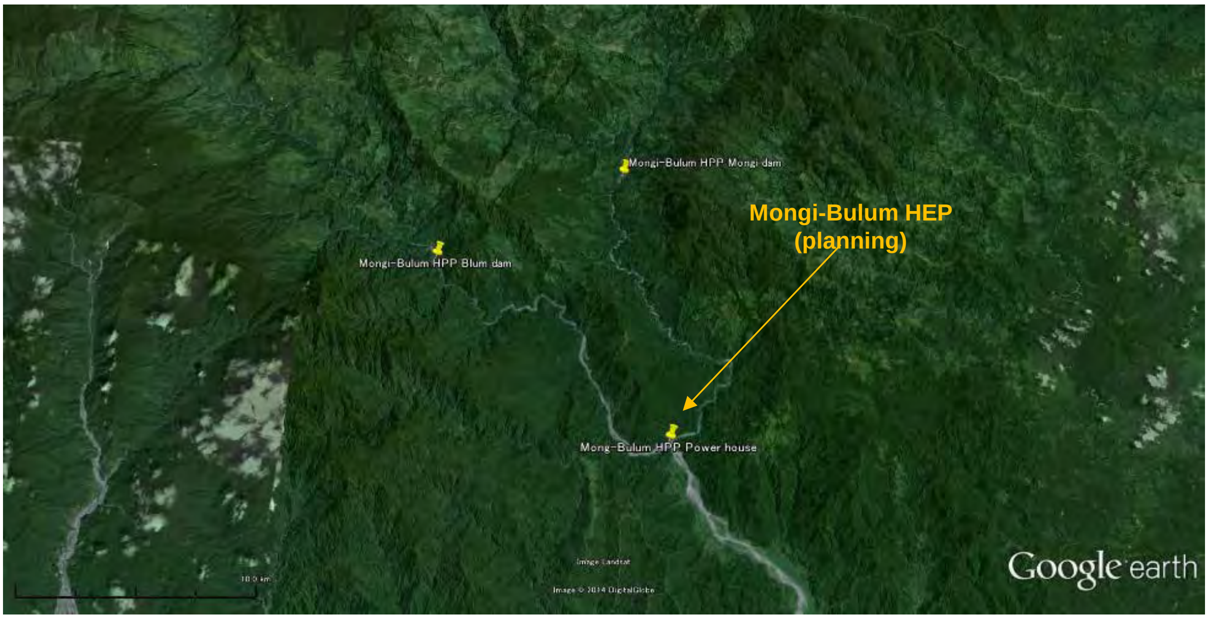


Fig. 5.1-22 Location Map of Hydropower Projects in the Mongi and Bulum Rivers

Dams are constructed in the Mongi River and the Bulum River, and a powerhouse is constructed near the confluence of two rivers. As an option, stage-1 construction of the Mongi hydropower project (max. output of 77 MW) will go ahead. Later, in stage-2, the Bulum hydropower project will follow. Ultimately, the maximum output of the Mongi-Bulum HPP will reach around 116 MW.

Prior to the commencement of the Feasibility study, hydrological observations are to be carried out.

The following summarizes the preliminary evaluation of the Mongi-Bulum HPP.

- River flow data are poor and large portions are missing (replaced by daily average values). Flow measurements are to be conducted to confirm the reliability of the river flow data, and the estimated power output and generated energy are to be reviewed.
- No major geological impediments likely to prevent the hydropower project have been found.
- The estimated construction cost is very expensive. A 60 km access road, 77 km road upgrade, and 95 km T/L will all be required. Physical access to the project site is very difficult.
- EIRR and FIRR were calculated by using benefit of diesel generation cost of USD 0.268/kWh and return period of 50 years. Conditions for calculation of levelized tariff are 10-year loan with interest rate of 7%, discount rate of 10% and operational period of 50 years.
  Therefore, it seems to be feasible based on the above conditions although the project cost is relatively high.

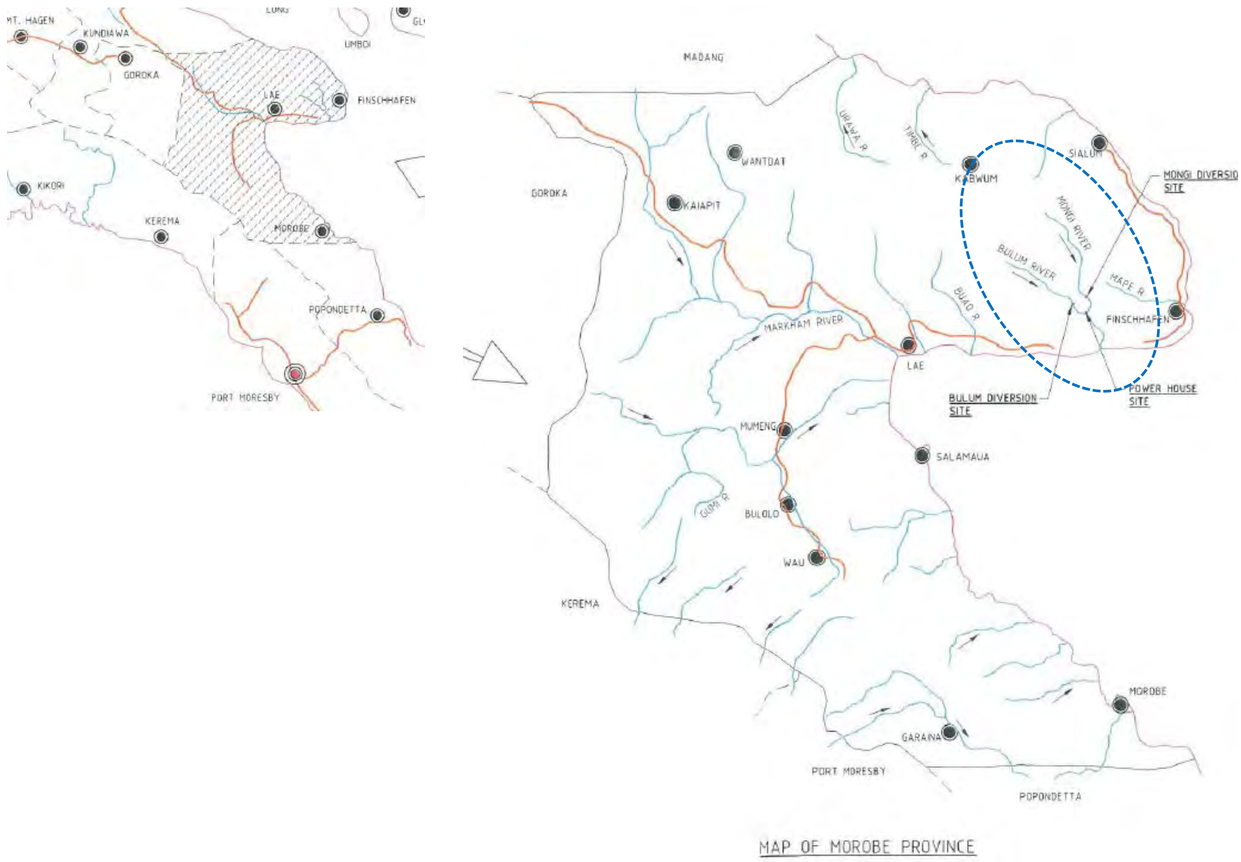


Fig. 5.1-23 Locations and Accessibility of the Projects in the Mongi -Bulum Projects

Table 5.1-17 Major Features of the Mongi-Bulum Hydropower Project

item	Mongi-Bulum (Combined stage)	Mongi (stage-1)	Bulum (stage-2)
Study stage	Pre-F/S	Pre-F/S	Pre-F/S
Study year	2014	2014	2014
Type	Run-of-River	Run-of-River	Run-of-River
Max. power discharge (m^3/sec)	54.3	33.1	21.3
Effective head (m)	248	248	248
Average river flow (m^3/sec)	Mongi: 55.5 Bulum: 27.5	55.5 (Pindu GS, 908 km^2, daily flow: 1984-1994)	29.5 (neighboring catchments are used)
Environmental flow (m^3/sec)	10% of average flow		
Catchment area (km^2)	Mongi-Bulum: 1,415	908	507
Unit flow ($m^3/s/km^2$)		0.045	0.050
Number of units	3 units (38.8 MW)	2 units (38.8 MW)	1 unit (38.8 MW)
Max. output / Firm output (MW)	116 / 75 80% exceed. proba. Flow	77 / 41 80% exceed. proba. Flow	
Annual Generated energy (GWh/y)	876 (avg. year)	566 (avg. year)	
Capacity factor (%)	86	84	
Preliminary Project cost	USD 820 M (incl. access road, T/L) (FC Civil: 25%, E/M: 15%)	USD 670 M (incl. access road, T/L) FC Civil: 25%, E/M: 15%)	USD 150 M (incl. access road, T/L) (FC Civil:25%, E/M:15%)
Construction period	4 years	4 years	
Cost/Length of Access road	USD 150M New: 60 km, Upgrade: 77 km	USD 140M New: 46 km, Upgrade: 77 km	USD 9.10M New: 46 km
Cost/Length of T/L	USD 28.5M 95 km, 132 kV (to Taraka SS)	USD 28.5M 95 km, 132 kV (to Taraka SS)	-
Unit KW cost (USD/kW)	7,050 5,520 (excl. A/R & T/L)	8,650 6,480 (excl. A/R & T/L)	
Dam / Weir	Concrete Gravity type H=27 m, L=115 m (Mongi) H=27 m L=69 m (Bulum)	Concrete Gravity type H=27 m, L=115 m	Concrete Gravity type H=27 m, L=69 m
Waterway	<u>Mongi branch tunnel</u> Concrete lined tunnel D-shaped 3.8 m, L=6.8 km <u>Bulum branch tunnel</u> D-shaped 4.9 m, L=6.9 km <u>Headrace tunnel</u> D-shaped 3.1 m, L=7.7 km <u>Pressure shaft</u> Circular 3.7 m dia, L=1.6 km <u>Powerhouse</u> Semi-underground	<u>Mongi branch tunnel</u> Concrete lined tunnel D-shaped 3.8 m, L=6.8 km <u>Headrace tunnel</u> D-shaped 4.9 m, L=6.9 km <u>Pressure shaft</u> Circular ID=3.7 m, L=1.6 km <u>Powerhouse</u> Semi-underground	<u>Bulum branch tunnel</u> Concrete lined tunnel D-shaped 3.1 m, L=7.7 km

(5) Kaugel Hydropower Project

The details and basic parameters of the Kaugel hydropower project were obtained from the following report.

- Feasibility Study Kaugel Hydropower electric Scheme, Feb., 1979,

The project is a run-of-river type scheme located in the Highland area. No further studies of the project have been done since the Feasibility study conducted in 1979. The maximum output is around 90 MW.

Fig. 5.1-24 Existing Pauanda Hydropower Plant and Kaugel Hydropower Project

The following summarizes the preliminary evaluation of the Kaugel HPP.

- No further study has been conducted since 1979, so an updated study is required.
- Long-term flow data have not been found. River flow observation is essentially required.
- The project site is near the national highway (around 11 km), so accessibility is fair.

Table 5.1-18 Major Features of Kaugel Hydropower Plant

Item	Description
Study stage	F/S
Study year	1979
Type	Run-of-River
Max. power discharge (m^3/sec)	28.95 (Firm 80% flow: 18.7)
Effective head (m)	345 (3 units)
Catchment area (km^2) / Unit flow (m^3/s/km^2)	
Number of units	3 units (3 x 28 MW)
Max. output / Firm output (MW)	84 / 56
Annual Generated energy (GWh/y)	346 (total)
Primary energy /Secondary energy (GWh/y)	275 (normal) /71 (off-peak)
Capacity factor (%)	47
Preliminary Project cost	USD 82 M (K 56M) 1 PNG Kina =1.46 USD (excl. 22 kV T/L, land, administration cost)
Construction period	68 months
Length of T/L	30 km to Mt Hagen
Dam / Weir	Weir and intake
Waterway	- Headrace tunnel: ID= 2.41 m L= 3.1 km (unlined) - Incline pressure shaft: Steel lining, ID= 2.5 m, L= 371 m. - Surge shaft: conventional type - Penstock: ID= 2.44m, L= 120m - Underground power house - Tailrace tunnel: ID= 4.5 m (unlined)

(6) Gowar Hydropower Project

The details and basic parameters of the Gowar hydropower project were obtained from the following report.

- Hydropower Development Study of Papua New Guinea, SHAWININGAN November 1980

The project is located in Madang Province, around 50 km from Madang city. The project is a 2-stage development scheme. Stage-1 is developed as a run-of-river type, and a reservoir is to be constructed in stage-2. The maximum output will be around 44 MW in total.

Table 5.1-19 Major Features of the Gowar Hydropower Project

Item	Description
Study stage	Potential study (map study)
Study year	1980
Type	Stage-1: Run-of-River Stage-2: reservoir with run-of-river
Max. power discharge (m^3/sec)	Stage-1: 5 m^3/sec Stage-2: 10m^3/sec in total
Gross head (m)	520 m
Catchment area (km^2) / Unit flow ($m^3/s/km^2$)	260 km^2
Number of units	Stage-1: 9 MW × 4 units Stage-2: 9 MW × 2 units
Output (MW)	Stage-1: 20 MW Stage-2: total 37 MW/ Max. 44 MW/ Min. 26 MW
Annual Generated energy (GWh/y)	Stage-1: 106 (LF=60%) Stage-2: 192 (LF=60%)
Capacity factor (%)	60%
Preliminary Project cost	Stage-1: USD 31 M (K 20M) 1 PNG Kina =1.57 USD Stage-2: USD 39 M (K 25M) in total
Construction period	
Dam / Weir	Stage-1: Weir: H=5 m Stage-2: Rock-fill dam: H=30 m, L=150 m
Waterway	- Reservoir (stage-2): live storage V=16 Mm^3 - Headrace tunnel - Pressure shaft: Steel lining, ID= 1.8 m, L= 520m. - Penstock: ID= 2.44m, L= 120m - Underground powerhouse - Tailrace tunnel: ID= 3.4m, L=8 km (unlined)

The following summarizes the preliminary evaluation of the Gowar HP project.

- No further study has been conducted since the hydropower potential study was done in 1980, so a pre-feasibility study shall be conducted in due course before the feasibility study.
- There is no gauging station in the Gowar River, so the flow duration curve is synthesized from rainfall and evaporation data and the daily/annual flow duration coefficient used in the previous study. It has been proposed that river discharge measurements be started in order to check the previous duration curve.
- Careful geological investigation around the reservoir area is required because limestone is prevalent in the topography around the site.

(7) Other Hydropower Projects

In the 1980s, hydropower potential studies were conducted all over PNG using 1:100,000-scale topographic maps with 40-m-interval counter lines, along with rainfall and river discharge data observed from the 1960s to 1980s. The following hydropower potential study reports were produced.

- Hydropower Development Study of Papua New Guinea, November 1980, SHAWININGAN
- Hydropower Resource Inventory, August 1986, Snowy Mountains

Hydropower potential sites in these studies were selected based on map studies without site investigations and discharge measurements at the sites. The selected sites therefore seem to be less reliable, given the scantly site information available.

1) Hydropower Development Study of PNG

The gross head of each site was obtained from 1:100,000-scale topographic maps with 40-m-interval contours. Flow was estimated using rainfall, evaporation, and run-off coefficients. The cost estimate has a margin of error of ±20%. The study area does not include the Highland area.

The Mongi-Bulum HPP and Gowar HPP were identified in this study as attractive hydropower projects to be developed by dint of their economical aspects.

2) Hydropower Resource Inventory

Stream flow records in major river watersheds were analyzed. Heads were obtained from 1:100,000-scale topographic maps. The projects, mainly run-of-river schemes, were ranked by unit cost indicator based on the ratio of the head to waterway length.

The Kaugel HPP was identified in this study as an attractive hydropower project from economical aspects.

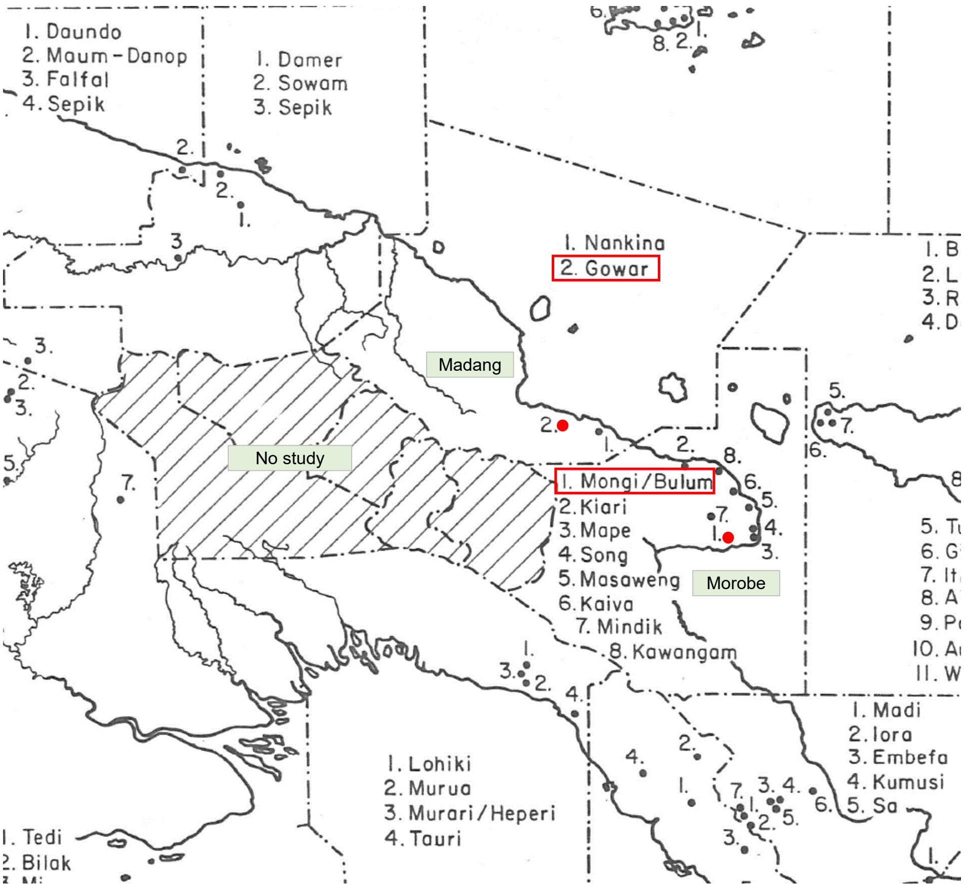
Hydropower Potential sites identified in Madang, Morobe, and Gulf Provinces in or near the Ramu grid are listed in the following table (reference: Hydropower Development Study of PNG).

Table 5.1-20 Hydropower Potential sites identified in Madang, Morobe and Gulf Provinces

Rank	site	type	capacity MW	Max MW	Ave. MW	Min MW	unit nun. n	Energy GWh	LF	Capital cost MK	Unit cost K/kW	Energy cost t/kWh	LF	Unit cost USD/kW	Energy cost UScent/kWh
Gulf															
1	Tauri - Alternative 3	RES	50.00	41.30	36.20	29.00	5	317.10	100%	38.200	764	1.55	100%	1,199	2.43
2	Tauri - Alternative 2	RES	35.00	31.60	28.90	21.80	5	253.10	100%	31.200	891	1.58	100%	1,399	2.48
3	Tauri - Alternative 1	RES	20.00	14.20	12.60	9.00	4	110.30	100%	19.000	950	-		1,492	
4	Tauri - Alternative 1	RES	10.00	9.30	8.40	6.70	2	73.50	100%	12.100	1,210	1.96	100%	1,900	3.08
5	Lahiki	RES	18.00	17.50	16.60	15.10	3	132.20	100%	25.500	1,417	2.26	100%	2,225	3.55
6	Murua	ROR	3.00	2.25	2.11	1.27	3	9.24	50%	4.900	1,632	6.08	100%	2,562	9.55
7	Murari/Heperi	ROR	0.60	0.48	0.41	0.30	3	1.43	40%	2.000	2,667	15.58	40%	4,187	24.46
Madang															
1	Gowar														
	stage 1	ROR	36.00	21.30	20.10	7.30	4	105.80	60%	19.600	545	2.55	60%	856	4.00
	stage 2	RES	54.00	43.50	36.60	25.80	6	192.30	60%	5.400	300	1.02	60%	471	1.60
	total		54.00	43.50	36.60	25.80	6	192.30	60%	25.000	462	3.57	60%	725	5.60
2	Nankina														
	stage 1	ROR	1.50	1.12	1.11	0.64	3	3.88	40%	1.950	1,301	5.98	40%	2,043	9.39
	stage 2	ROR	2.25	2.89	2.55	0.64	3	7.56	60%	2.000	891	3.30	60%	1,399	5.18
3	Zedzed 2	ROR	0.45	0.41	0.40	0.25	3	1.41	40%	0.800	1,780	6.67	40%	2,795	10.47
Morobe															
1	Mongi/Bulum	ROR	90.00	69.70	60.30	15.90	5	316.90	60%	71.900	799	2.88	60%	1,254	4.52
2	Mongi/Bulum	ROR	60.00	43.50	41.80	15.80	4	219.70	60%	50.900	848	2.91	60%	1,331	4.57
3	Kaiva - 1	ROR	0.45	0.27	0.27	0.15	3	0.94	40%	0.442	983	5.80	40%	1,543	9.11
4	Kaiva - 2	ROR	0.50	0.24	0.24	0.18	2	0.83	40%	0.545	1,090	7.78	40%	1,711	12.21
5	Kawangan	ROR	0.30							0.455	1,517	7.70		2,382	12.09
6	Song	ROR	0.80							1.226	1,517	7.70		2,382	12.09
7	Masaweng	ROR	1.05							1.770	1,686	8.50		2,647	13.35
8	Kiari	ROR	0.15							0.282	1,880	9.23		2,952	14.49
9	Mape	ROR	1.40							2.648	1,891	9.75		2,969	15.31
10	Mindik	ROR	0.15							0.284	1,893	11.61		2,972	18.23

Notes: PGK is converted using 1 PGK=1.57 USD as of 1980,

(Source: Hydropower Development Study of Papua New Guinea, SHAWININGAN November 1980)



(8) River flow and Rainfall Data

Hydrological observations (rainfall, river flow) were done by the Bureau of Water Resources (BWR) until the early 1990's. The data collection efforts of BWR were initially very well funded. But many of the gauging stations were remote and very distant from road access, so considerable cost was necessary to operate and maintain the stations. Ultimately, the financial support to the BWR was reduced. Hence, little data has been collected from the mid 1990's.

Area	River flow station	Rainfall station
Division 1 (Sepik)	24	4
Division 2 (Madang)	16	7
Division 3 (Morobe)	20	10
Division 4 (Oro)	25	5
Division 5	5	0
Division 6 (Central & Gulf)	51	29
Division 7 (Highland-West)	50	12
Division 8 (Highland-East)	27	3
Division 9 (Island)	38	8
total	256	78

Under the current Environment Act of 2000, the Department of Environment and Conservation (DEC) is charged with the responsibility of managing the nation's water resources. However, due to limited finance conditions, no hydrological observations (rainfall, river flow) have been conducted.

There is currently little to no hydrological data collection in PNG. This makes it impossible to quantify the yield from a catchment.

A minimum of 10 years of consistent and continuous data is needed to prepare the hydrological statistics necessary for planning hydropower development. Hydrological data for many of the catchments has been either lacking or not updated for almost 40 years.

The (DEC) took over and keeps the hydrological data that had been collected up to the 1990's. There are presently no operational gauging stations in PNG, except at certain sites like mines. Rainfall and river flow data is currently collected by 256 river flow gauging stations and 78 rainfall gauging stations.

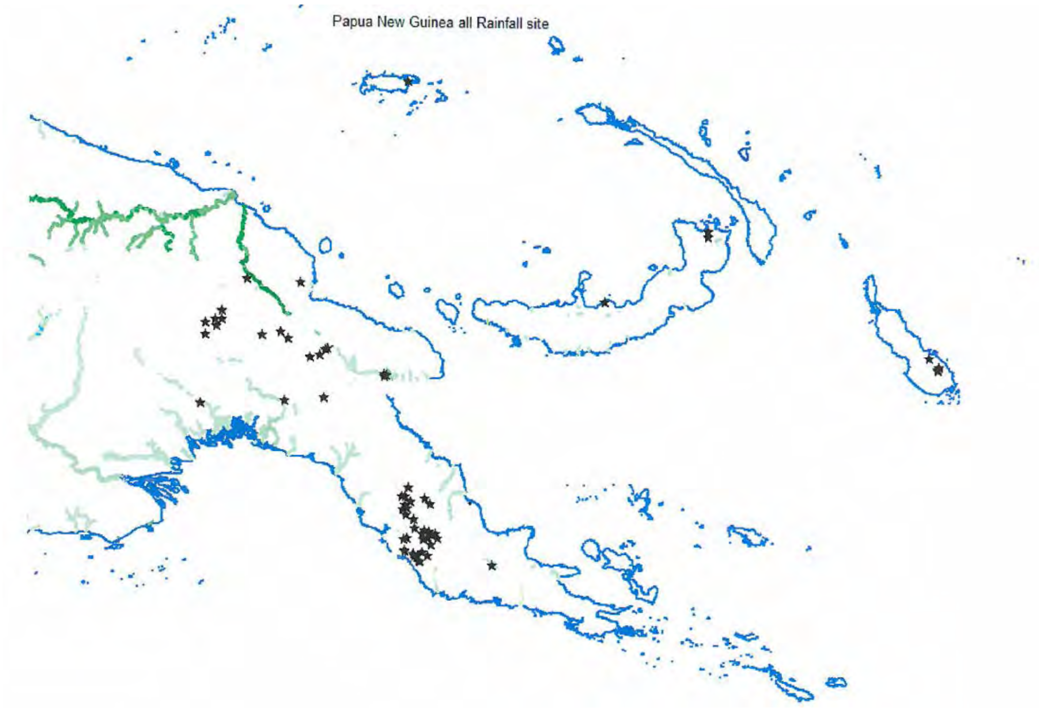


Fig. 5.1-25 Location Map of Rainfall Gauging Stations in PNG

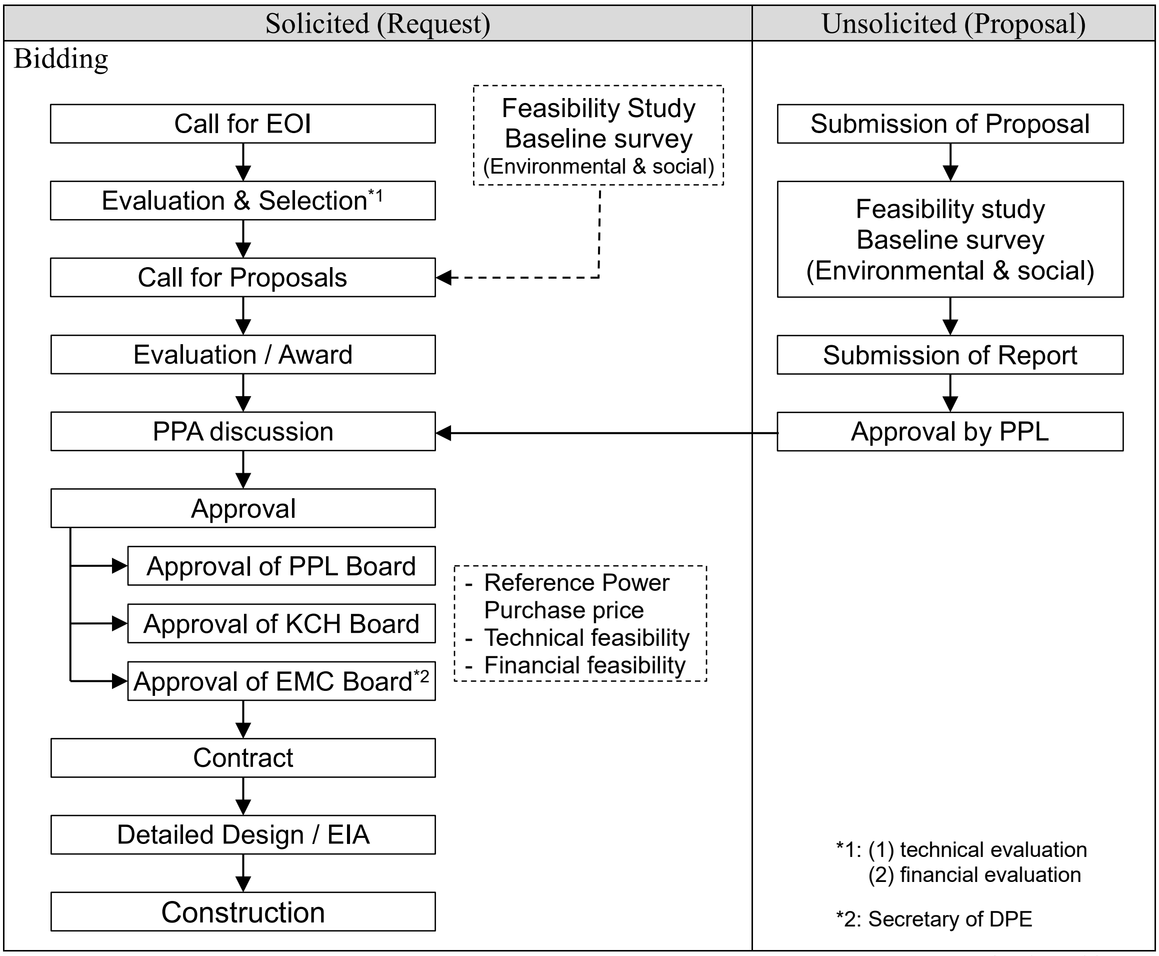
Fig. 5.1-26 Location Map of Flow Gauging Stations in PNG

(Source: Department of Environment and Conservation (DEC))

5.1.5 Candidate Hydro Power Plans for the Future

(1) Procedures of IPP Projects

A Third Party Access Code was officially issued by ICCC in PNG in January 2014 to promote private investments into the power generation sector. PPL has monopolized the power generation business so far, but projects by means of IPP/PPP schemes are expected to increase because of financial difficulties faced by PPL.



(Source: hearing with PPL)

Fig. 5.1-27 Procedure for an IPP Project by PPL

It can generally take around a year from bidding to approval when a PPA is contracted with PPL for small-scale power projects with capacities of less than several tens of MW. If PPL requests a required capacity without specifying generation sources for bidding, a feasibility study and EIA may be necessary. It will take more time to conduct the necessary studies in such cases.

The Third Party Access Code stipulates that the Regulator (ICCC) is to approve the Power Purchase Reference Price (PPRP) submitted by the Regulated Retailer (PPL). The PPRP for hydropower has not yet been approved by ICCC but is expected to be around 20 – 35 PGK/kWh.

(2) Lead time of Hydropower Projects

The lead times necessary for hydropower projects are generally longer than those for diesel/gas thermal, solar, and biomass power projects because of the longer periods required for study and construction.

It is quite difficult to predict the lead times for large hydropower projects developed by IPPs, particularly when PPAs are concluded with Third Party Retailers.

The periods for the feasibility study, EIA study, and construction all depend on the site conditions and scale of the project, especially for the high dam with a reservoir. The roughly estimated periods are as follows.

	Feasibility study	EIA	Construction	total
Several 10 MW (run-of-river type)	1 year	-	2 years	3 years
Several 100 MW (reservoir type)	2 year	1-2 year	4 years	7-8 years

However, it is very difficult to estimate the period required for finance arrangements for a project and PPA conclusion.

(3) Available Input of Hydropower Projects into GDP

The actual capacity of the existing HPPs is restricted due to poor maintenance and design flaws. In the short-term plan, a rehabilitation/upgrade of existing HPPs is practical and economical. For a mid-long term plan, new hydropower projects are to be developed from economic and environmental viewpoints. However, projects evaluated as feasible in their feasibility studies are limited. It will be necessary to review the previous study and find new attractive projects to take advantage of the abundant hydropower potential in PNG.

1) Rehabilitation / Refurbishment plan for existing hydropower plants

The following schedule is assumed based on the information and assumptions. Completion of rehabilitation / refurbishment depends on the commencement of the required investigation and study and budget allocation by PPL.

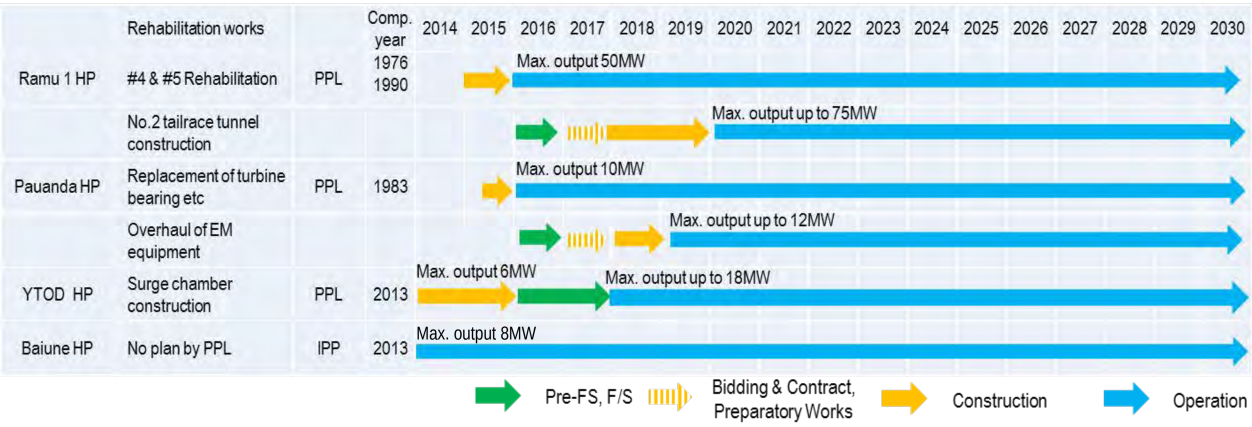


Fig. 5.1-28 Schedule for Rehabilitation / Refurbishment Plan of Existing Hydropower Plants

2) Development plan for new Hydropower projects

The following schedule is assumed based on the relevant reports and assumptions. The completion years of the projects depend largely on the commencement of the required study, PPA conclusion, and finance arrangement, for the projects.

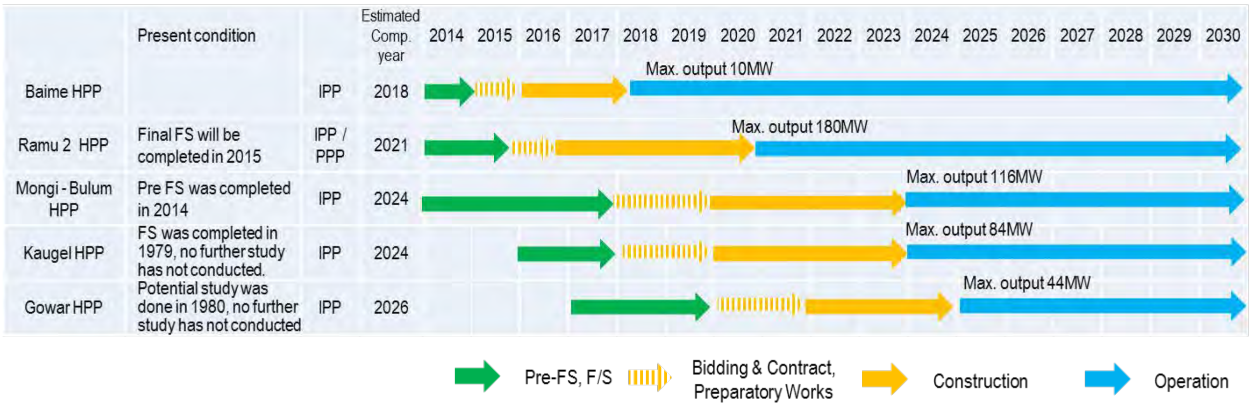


Fig. 5.1-29 Schedule for the Development of New Hydropower Projects

5.1.6 Findings and Recommendations

The following summarizes the findings and recommendations regarding hydropower generation.

(1) Effective Operation of existing hydropower plants

The generation costs (PNG Kina/kWh) of the existing HPPs are the cheapest among various power plants in the Ramu system. Run-of-river type HPPs supply base load. Reservoir-type HPPs supply base and middle loads, and also can supply peak load. Therefore, The Ramu 1 HP can supply more energy within available maximum output (45 – 50 MW) and increase energy production by conducting effective reservoir operation and utilizing release water efficiently.

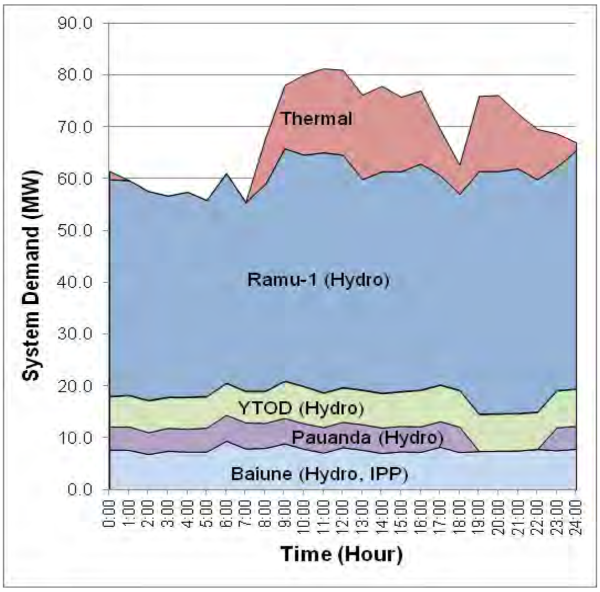


Fig. 5.1-30 Typical Daily Load Curve of the Ramu System

Maximizing hydropower generation results in reduction of diesel / thermal generation and saving fuel costs. The CF of Ramu1 HP is around 60% on average for an available maximum output of 48 MW. It will be possible to raise the CF up to around 80 %, resulting in an increase of additional energy of to about 60 GWh/year on average. Diesel generation cost for 60 GWh is around 21 mil USD.

(2) Proper Maintenance of existing hydropower plants

Periodical and proper maintenance of power plants is essential to keep the plants operating in good condition, maximize the generated energy, and prolong the plant lifetimes. Once serious troubles occur without regular maintenance and replacement of aged spare parts, repair and replacement cost quickly rise to prohibitive levels. It is recommended that PPL allocate sufficient budget for regular maintenance and spare parts.

The CF of the Pauanda HP has been around 60% on average for the last 10 years, with an available maximum output of 10 MW in the wet season (run-of-river type) and a decrease of energy generated in the dry season to around 8 MW, 80% of that generated in the wet season. In 2014 the generated energy decreased by up to 30 GWh/year, reaching a CF equivalent to only 35%, due to serious troubles with the turbines. Around 20 GWh/year, the difference between the energy generated in 2014 and the average for the Pauanda HP over last 10 years, was generated by a diesel power plant. The diesel generation cost for 20 GWh is around 7 mil USD.

(3) Immediate Rehabilitation / Refurbishment of existing hydropower plants under the short-term generation plan

Longer lead times are necessary for hydropower projects, even though the HPPs are on a scale of several tens of MW and the capital costs are higher than for power plants of various other types. Therefore, Rehabilitation / Refurbishment of existing HPPs is the most economical and feasible short-term measures for addressing the power shortages anticipated over the next several years.

The benefits obtained by Rehabilitation / Refurbishment of existing HPPs are estimated as follows (calculated based on the diesel generation costs saved). However, energy generated by thermal plants was 25 GWh/year in 2013 and 47 GWh/year in 2014, so increased energy obtained by Rehabilitation / Refurbishment will be utilized up to the amount of thermal energy at the time the works are completed.

Rehabilitation / Refurbishment	Increase of annual energy	Annual saving cost of diesel generation
Ramu 1 HP Enhancement of Maximum Power Output (No.2 Tailrace tunnel)	Before Reh.: 320 GWh/year After Reh.: 400 GWh/year Increased energy: +80 GWh/year	80 GWh × 10^6 × 0.36 USD/kWh = 28.8 mil USD
	Before Reh.: 45-50 MW After Reh.: 75 MW Increased output: +25-30 MW	Increased peak output will help to minimize peak load generation facilities such as diesel power plants.
YOTD HP Surge chamber construction	Before Reh.: 50 GWh/year After Reh.: 80 GWh/year Increased energy: +30 GWh/year	30 GWh × 10^6 × 0.36 USD/kWh = 10.8 mil USD
Pauanda HP Overhaul of E/M equipment	Before: 38 GWh/year*1 After: 70 GWh/year*2 Increased energy: +32 GWh/year *1: mean energy in 2013 and 2014 *2: max. energy in 2012	32 GWh × 10^6 × 0.36 USD/kWh = 11.5 mil USD

Reference: Generation cost of a diesel power plant
6,000 liters / hour x PGK 3.50 / liter / 23,000 kWh = PGK 0.91 / kWh = 36 centUSD/kWh
Where, Fuel: HDS (High-Speed Diesel) PGK 3.50 / liter
6,000 liters/hour of a 23 MW diesel plant
1 US$ = 0.40 PGK Kina

(4) Update of Hydropower Potential Study

Hydropower potential studies were conducted all over PNG in the 1980's. Yet further studies have been carried out on only a few of the potential sites initially identified in the 30 years since. Even worse, no hydrological observations (rainfall and river flow) have been conducted since the 1990's. We therefore recommend that an up-to-date study of potential be conducted and hydrological observations be resumed in the selected basins where promising potential sites have been identified.

The hydropower projects for which Pre-F/S and F/S have been completed are medium-scale (several hundred MW) and suitable for large-demand consumers such as mines. The implementation schedule for those medium-scale projects depends on the demand, and the projects will invariably be delayed or canceled. Therefore, suitable scale hydropower projects for definite demands will be required from practical and economical aspects, in order to save expensive diesel generation costs.

(5) Promotion of Hydropower Development Projects

The development of mines is important for PNG's economic growth and government benefits. Yet the mining business depends on global economy, market prices, financial situation, and so on. It would therefore be difficult to confirm details such as commencement dates for operation, required maximum outputs, energy consumption, operating duration, and so on. IPPs therefore bear risks when they invest in power generation facilities.

Considering the above situation, the PPP scheme mitigates risk for IPPs in several ways through government participation. PPL can also purchase cheaper energy from IPPs. An assumed PPP/IPP scheme for hydropower projects is shown in the following figure.

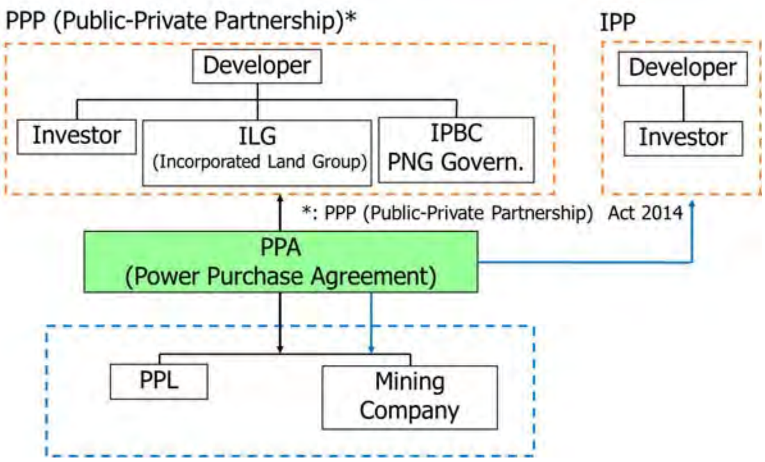


Fig. 5.1-31 Assumed Scheme for PPP/IPP Hydropower Project

5.2 THERMAL POWER STATION

5.2.1 Current Status of Thermal Power Station

In the first field survey, JICA Study Team obtained and collected operation, maintenance data, etc., from PPL Head Office and Lae Area Power Stations, partly in the form of hard copies and some soft copies (digital information). Subsequently, making use of the opportunity of the 3rd field survey, the team visited the PPL Head Office and power stations again to collect and analyze complementary data.

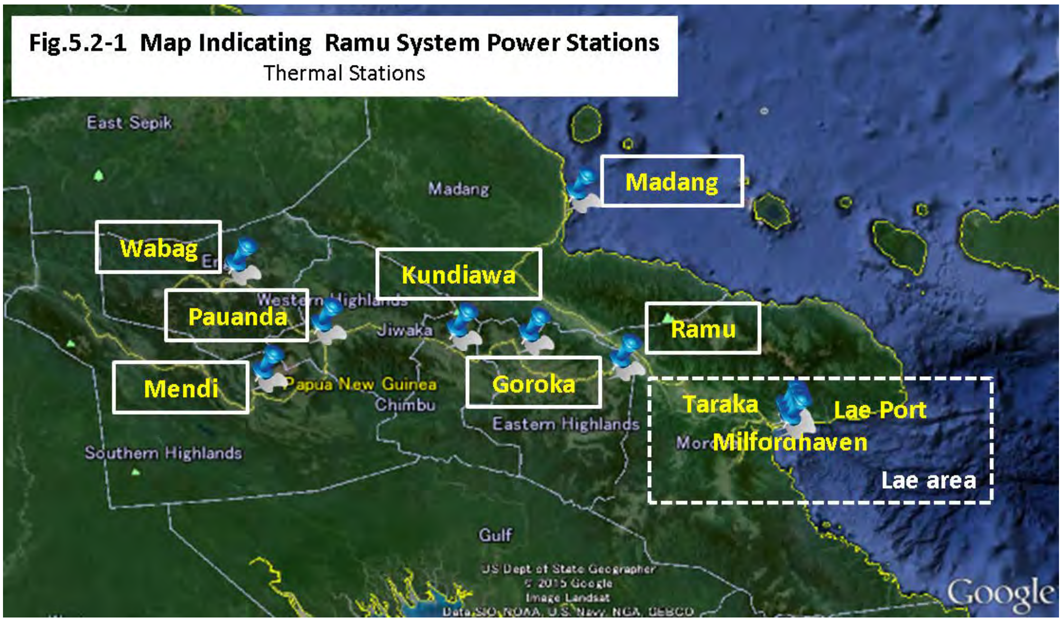
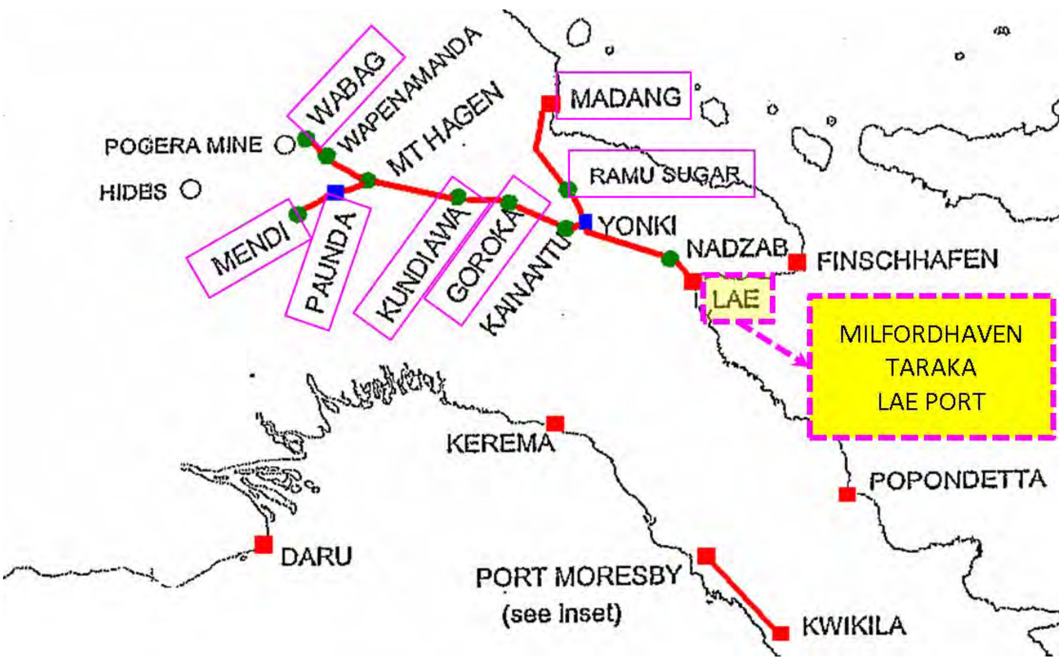


Fig. 5.2-1 Simplified Transmission System Diagram of the Ramu System

(Source：PPL)



(1) The following figure shows the Engineering Workshop Organization Structure associated with the Operating and Maintenance of the Head Office of PPL;

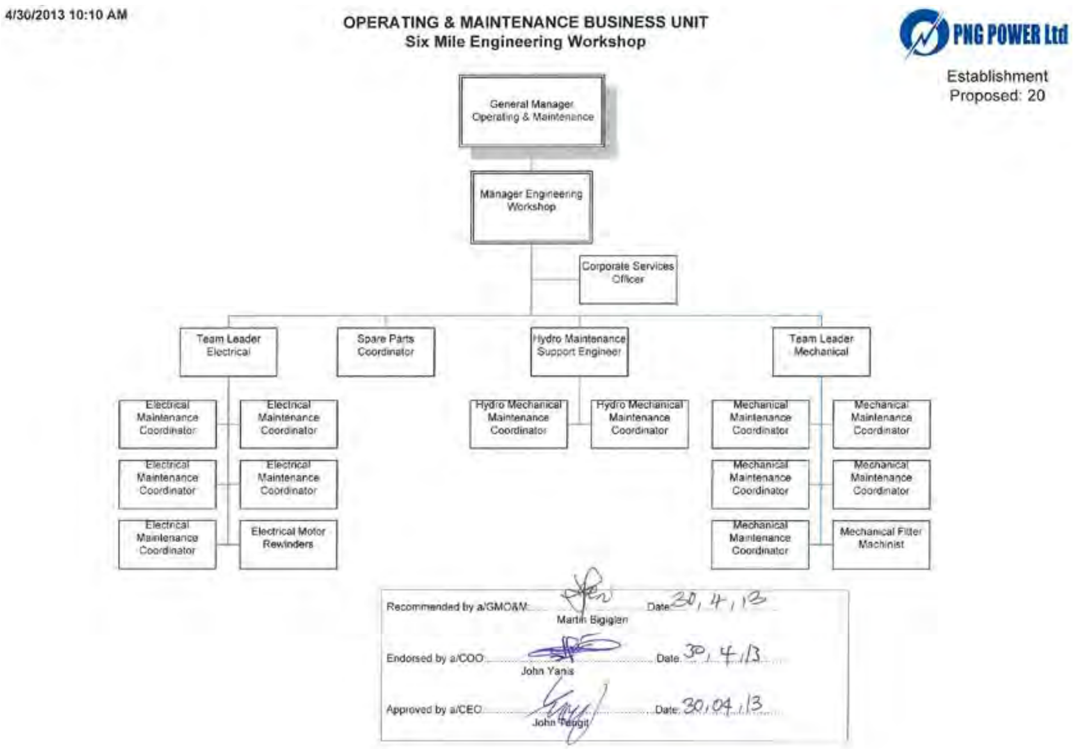


Fig. 5.2-2 Engineering Workshop Organization Structure

The following tasks for the Diesel Engine & Generator / Gas Turbine & generator, etc., for thermal power generation are performed at the Engineering Workshop.

- Estimation of maintenance costs and evaluation of alternatives
- Assessing the need for equipment replacement and establishing replacement programs when due
- Application of scheduling and project management principles to replacement programs
- Assessing required maintenance tools and skills required for the efficient maintenance of equipment
- Assessing and reporting safety hazards associated with the maintenance of equipment

(2) The numbers of thermal Power stations (P/Ss) and units owned by PPL in the Ramu system, diesel engine and generator specifications, and operating status.

The Lae area and Ramu system have nine existing Diesel Engine & Generator P/Ss, as well as Lae Port.
There are ten PPL P/Ss in total and there are a cluster of three thermal P/Ss (Milford, Taraka and Lae Port) in the Lae area.

In the meantime, the Gas Turbine & Generator of Lae Port Power Station (light-diesel-oil-fired / natural-gas-fired) started commercial operation in March 2015.
In the Ramu system as of November 2014, the specifications of the thermal power generator equipment owned by PPL are as follows.

1) Diesel Engine Specifications:

The following table lists up the number of units and specifications for the existing Thermal-Diesel Engine in the Ramu system.

Table 5.2-1 Schedule of Existing Thermal-Diesel Engine

No.	Station	Unite No.	Engine Manufacturer	Number. of Cylinders	Speed (rpm)	Date of Commission	Age (years since installation)
1	Milford	3	Ruston	12	600	1969	45
		4	Ruston	12	600	1969	45
		5	Ruston	16	600	1969	45
		6	M/Blackstone	6	600	1988	26
		7	M/Blackstone	6	600	1988	26
		8	M/Blackstone	6	600	1988	26
		9	M/Blackstone	6	600	1988	26
		10	M/Blackstone	6	600	1988	26
		11	M/Blackstone	6	600	1988	26
		12	Foxtel Caterpillar	16	1,500	2008	6
2	Taraka (PPL)	1	Caterpillar	16	1,500	2009	5
		2	Caterpillar	16	1,500	2009	5
		3	Caterpillar	16	1,500	2009	5
		4	Caterpillar	16	1,500	2009	5
		5	Caterpillar	16	1,500	2009	5
		7	Caterpillar	16	1,500	2009	5
		8	Caterpillar	16	1,500	2009	5
	Taraka (Aggreko)	1	Cummins	12	1,500	2014	0.8
		2	Cummins	12	1,500	2014	0.8
		3	Cummins	12	1,500	2014	0.8
		4	Cummins	12	1,500	2014	0.8
		5	Cummins	12	1,500	2014	0.8
		6	Cummins	12	1,500	2014	0.8
		7	Cummins	12	1,500	2014	0.8
		8	Cummins	12	1,500	2014	0.8
		9	Cummins	12	1,500	2014	0.8
		10	Cummins	12	1,500	2014	0.8
		11	Cummins	12	1,500	2014	0.8
		12	Cummins	12	1,500	2014	0.8
3	Madang	2	Niigata	6	375	1972	42
		3	English Electric	16	600	1965	49
		5	Niigata	16	600	1980	34
		7	Caterpillar	12	1,500	2007	7
		8	Caterpillar	16	1,500	2007	7
		9	Caterpillar	16	1,500	2007	7
		10	Caterpillar	16	1,500	2008	6
		11	Caterpillar	16	1,500	2008	6
		12	Caterpillar	16	1,500	2008	6
4	Mendi	4	Caterpillar	16	1,500	1999	15
5	Wabag	1	Caterpillar	12	1,500	1979	15
		2	Caterpillar	8	1,500	1980	14
		3	Detroit	-	1,500	2004	14
		4	Cummins	16	1,500	2012	2
6	Ramu Aux.	1	Cummins	6	1,500	1990	24
7	Pauanda Aux.	2	Deutz	8	1,500	-	
8	Goroka	1	Caterpillar	16	1,500	2008	16
		2	Caterpillar	16	1,500	2009	15
9	Kundiawa	1	Caterpillar	16	1,500	2009	15

(Source : PPL)

2) Generator (AC Alternator) Specifications:

The following table lists up the number of units and main specifications of the existing generators (AC alternators) in the Ramu system:

Table 5.2-2 Existing Generator (AC Alternator) Specifications

No.	Station	Unit No.	Manufacturer	Volts (V)	N'Plate Rating (kVA)	N'Plate Rating (kW)	Site Rating (kW)	Date of Commission
1	Milford	3	Eng/ Electric	11,000	3,000	2,400	1,500	1969
		4	Eng/ Electric	11,000	3,000	2,400	1,500	1969
		5	Eng/ Electric	11,000	3,750	3,000	1,500	1969
		6	Hawker Siddely	6,600	3,869	3,095.2	2,000	1988
		7	Hawker Siddely	6,600	3,869	3,095.2	2,000	1988
		8	Hawker Siddely	6,600	3,869	3,095.2	2,000	1988
		9	Hawker Siddely	6,600	3,869	3,095.2	2,000	1988
		10	Hawker Siddely	6,600	3,869	3,095.2	2,000	1988
		11	Hawker Siddely	6,600	3,869	3,095.2	2,000	1988
		12	Caterpillar	6,600	2,137.5	1,710	1,400	2008
			Sub-Total Site Capacity (kW)				17,900	
2	Taraka (PPL)	1	Caterpillar	415	1,800	1,440	1,000	2009
		2	Caterpillar	415	1,800	1,440	1,000	2009
		3	Caterpillar	415	1,800	1,440	1,000	2009
		4	Caterpillar	415	1,800	1,440	1,000	2009
		5	Caterpillar	415	1,800	1,440	1,000	2009
		7	Caterpillar	415	1,800	1,440	1,000	2009
		8	Caterpillar	415	1,800	1,440	1,000	2009
			Sub-Total Site Capacity (kW)				7,000	
	Taraka (Aggreko)	1	Cummins	415	1,250	1,100	800	2014
		2	Cummins	415	1,250	1,100	800	2014
		3	Cummins	415	1,250	1,100	800	2014
		4	Cummins	415	1,250	1,100	800	2014
		5	Cummins	415	1,250	1,100	800	2014
		6	Cummins	415	1,250	1,100	800	2014
		7	Cummins	415	1,250	1,100	800	2014
		8	Cummins	415	1,250	1,100	800	2014
		9	Cummins	415	1,250	1,100	800	2014
		10	Cummins	415	1,250	1,100	800	2014
		11	Cummins	415	1,250	1,100	800	2014
		12	Cummins	415	1,250	1,100	800	2014
			Sub-Total Site Capacity (kW)				9600	
3	Madang	2	Toshiba	415	1,875	1,340	1,000	1972
		3	Eng/ Electric	415	1,675	1,500	1,000	1965
		5	Toshiba	415	4,125	3,300	2,000	1980
		7	Caterpillar	415	1,020	816	800	2007
		8	Caterpillar	415	1,400	1,120	1,000	2007
		9	Caterpillar	415	1,400	1,120	1,000	2007
		10	Caterpillar	415	2,275	1,820	1,600	2008
		11	Caterpillar	415	2,275	1,820	1,600	2008
		12	Caterpillar	415	2,275	1,820	1,600	2008
			Sub-Total Site Capacity (kW)				11,600	
4	Mendi	4	Caterpillar	415	1,700	1,360	1,000	1999
			Sub-Total Site Capacity (kW)				1,000	

No.	Station	Unit No.	Manufacturer	Volts (V)	N'Plate Rating (kVA)	N'Plate Rating (kW)	Site Rating (kW)	Date of Commission
5	Wabag	1	Caterpillar	415	431	345	250	1979
		2	Caterpillar	415	345	230	200	1980
		3	Virtus	415	288	624	500	2004
		4	Caterpillar	415		1,140	1,000	2012
			Sub-Total Site Capacity (kW)				1,950	
6	Ramu Aux.	1	Cummins	415	1,000	800	600	1990
			Sub-Total Site Capacity (kW)				600	
7	Paunda Aux.	2	Caterpillar	415	-	50	50	-
			Sub-Total Site Capacity (kW)				50	
8	Goroka	1	Caterpillar	415	-	1,440	1,350	2008
		2	Caterpillar	415	-	1,440	1,350	2009
			Sub-Total Site Capacity (kW)				2,700	
9	Kundiawa	1	Caterpillar	415	-	1440	1200	2009
			Sub-Total Site Capacity (kW)				1,200	
	Total Site Capacity (kW)						**53,600**	

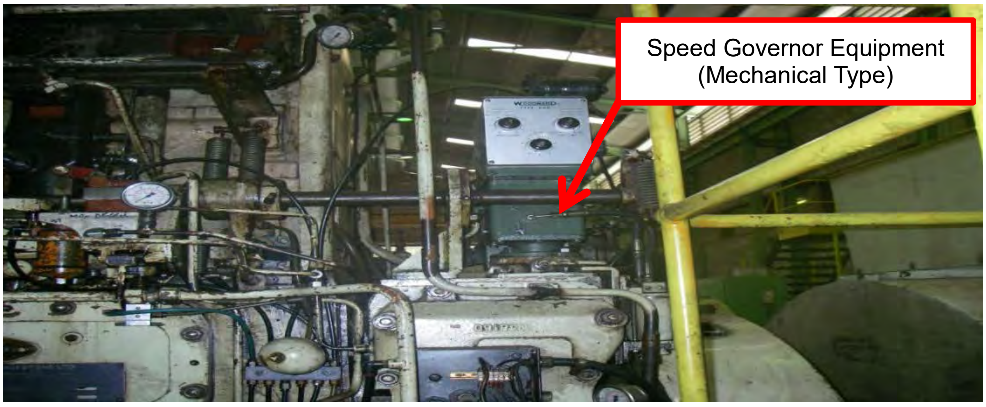
(Source: PNG POWER LTD)

The followings are the summary of the current situation (the gist) of the Diesel Engine & Generator units in the Ramu System:

(a) Milford Power Station

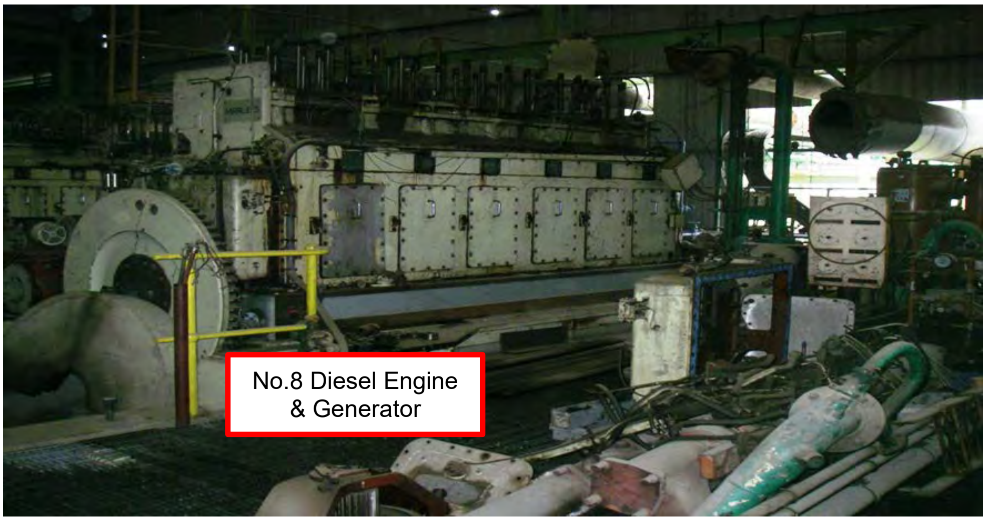
i) Three of the Diesel Engine & Generator units were manufactured in 1969 and six were manufactured in 1988.

ii) The Speed Governor Equipment for the Ruston & M/Blackstone-made Diesel Engine & Generator is the mechanical type and the Speed Governor Equipment for the Caterpillar-made Diesel Engine & Generator installed for emergencies is the electric type.
Meanwhile, the Speed Governor Equipment for the Caterpillar-made Diesel Engine & Generators installed in the other power stations is the electric type.



iii) As of 2014, Unit Nos. 3, 4, 5, 6 and 12 were in operation and the remaining five units (Unit Nos. 7, 8, 9, 10 and 11) were in forced outage condition and waiting for supply of spare parts from the manufacturer.

The Diesel Engine & Generator of Unit No.8 was too heavily damaged to be put back into service and was accordingly scrapped. Some parts available for use from No.8 Diesel Engine & Generator were already used as spare parts for the other Diesel Engine & Generators.



iv) At the time of the overhaul of the Engine made by No.7 M/Blackstone, a malfunction of the ceiling crane (16 tons) disallowed lifting and lowering works with the crane. The lifting and lower works therefore had to be conducted manually.

b) Taraka Power Station (PPL)

i) The No.6 Diesel Engine & Generator has been removed because the turbo charger cooling oil inlet hose was ruptured and broken.

ii) The No.3 Diesel Engine & Generator was put into forced outage on June 23, 2014 when the exhaust side was partly burnt in a fire accident.

iii) General Electrics (GEE) is currently dispatching a supervisor to perform a major overhaul of the Diesel Engine & Generator manufactured by Caterpillar (in ROK).

(c) Taraka Power Station (Leased Machines):

PPL has Leased 12 Diesel Engine & Generator units whose operation is subcontracted to the Australian firm Aggreko.

(d) Madang Power Station

Diesel Engine & Generator Unit No.2 was installed in 1972 and Diesel Engine & Generator Unit No. 3 was installed in 1965.

Diesel Engine & Generator Unit No.5 was installed in 1980.→ More than 40 years have already passed since the former were installed. All of them are aging.

In the meantime, these three units have suffered economic losses because they could not be put into full load operation.

(e) In the event that the Ramu System Power goes off, stand-by power is supplied to each center (Mendi, Goroka, Kundiawa).

(f) Wabag Power Station (Leased Machine)

PPL has leased 1 Diesel Engine & Generator unit of which operation is subcontracted to the Australian firm Aggreko.

(g) The following table summarizes details of the Diesel Engine & Generator operated for emergency use and specific details about emergencies.

Station	Unit No.	Engine Manufacturer	Site Rating (kW)	Operating Purpose
Milford	12	Foxtel Caterpillar	1,400	Operated only for emergency use in the power station.
Ramu Aux. Unit	1	Cummins	800	Ramu Aux. Unit & Paunda Aux. Unit are only for auxiliary supply to start the Hydro Power station. Not for transmission.
Paunda Aux. Unit	1	Deutz	50	

(3) Operating status and maintenance status of the existing Diesel Engine & Generator units:

1) Operations are conducted under the following four categories:

- Nameplate Rating (kW) : Manufacturer's Standard
- Site Rating (MW) : Lowering of power output due to deteriorated performance of the Diesel Engine & Generator
- Safe Rating (MW) : Lowering of power output in order to protect transmission systems
- Available (MW) : Power output available for supply

The operating status of the thermal power plants shown in the table below as of February 23, 2015 is reported to be as follows;

The total available power capacity of the Diesel Engine & Generator units is 45,830 kW. Four of the Diesel Engine & Generators units are operated under load adjustment with generated power of 3,800 kW.

The number of units kept on stand-by for daily load adjustments is 26. The number of units shut down due to equipment trouble (forced outage) and periodical maintenance is 18.

Table 5.2-3 Generation Status (February 23, 2015)

No.	Station	Unit No.	Engine Manufacturer	N' Plate Rating (kW)	kW Available 23/02/15	Contents
1	Milford	1	English Electric	U/S	0	Decommissioned *U/Sact:. Unserviceable
		2	English Electric	U/S	0	Decommissioned
		3	Ruston	2,400	0	Forced Outage (FO)-needs major overhaul; awaiting spare parts
		4	Ruston	2,400	1,500	Stand-by
		5	Ruston	3,000	0	Major Overhaul (MOH) - Under service since 01/03/14; awaiting parts from overseas; fuel and oil lining leaking
		6	M/Blackstone	3,095.2	2,000	Stand-by
		7	M/Blackstone	3,095.2	0	FO-Parts transferred to M/C; damaged fuel pump cam #6
		8	M/Blackstone	3,095.2	0	FO- Has no alternator; failed big end bearing #2
		9	M/Blackstone	3,095.2	0	FO-Big end bearing damaged
		10	M/Blackstone	3,095.2	0	FO-Fuel injector faulty
		11	M/Blackstone	3,095.2	0	FO-Bearing shell for cylinder #3 is totally smashed
		12	Foxtel Caterpillar	1,710	500	Stand-by
			Subtotal	28,081.2	4,000	
2	Lae Port GT	1	GEE	26,000	21,800	Stand-by
			Subtotal	26,000	21,800	
3	Taraka (PPL)	1	Caterpillar	1,440	1,000	Stand-by
		2	Caterpillar	1,440	1,100	Stand-by
		3	Caterpillar	1,440	0	FO-caught fire on 23/06/14, exhaust side partly burnt; needs new roof ceiling and welding silencer
		4	Caterpillar	1,440	0	Stand-by
		5	Caterpillar	1440	800	Stand-by
		6	Caterpillar	U/S	0	Decommissioned: completely burnt
		7	Caterpillar	1,440	0	Stand-by
		8	Caterpillar	1,440	1,000	Stand-by
			Subtotal	10,080	3,900	
3	Taraka (Aggreko)	1	Cummins	1100	800	Stand-by
		2	Cummins	1100	800	Stand-by
		3	Cummins	1100	800	Stand-by
		4	Cummins	1100	800	Stand-by

No.	Station	Unit No.	Engine Manufacturer	N' Plate Rating (kW)	kW Available 23/02/15	Contents
		5	Cummins	1100	800	Stand-by
		6	Cummins	1100	800	Stand-by
		7	Cummins	1100	800	Stand-by
		8	Cummins	1100	800	Stand-by
		9	Cummins	1100	800	Stand-by
		10	Cummins	1100	800	Stand-by
		11	Cummins	1100	800	Stand-by
		12	Cummins	1100	800	Stand-by
			Subtotal	13,200	9,600	
4	Madang	1	Caterpillar	Empty	0	Empty bay; decommissioned and sent to Buka
		2	Niigata	1,340	0	FO-engine ok, but alternator faulty; G4 alternator to be moved G2 engine
		3	English Electric	1,500	0	Under repair; oil leakage from the oil cooler inlet elbow. We anticipate a test run during the week.
		4	Niigata	U/S	0	Decommissioned- alternator ok, engine faulty [defective crank and defects in other major components]
		5	Niigata	3.300	0	FO-engine head crack
		6	Niigata	U/S	0	Decommissioned
		7	Caterpillar	816	500	Running
		8	Caterpillar	1,120	0	FO
		9	Caterpillar	1,120	0	FO-Alternator problem
		10	Caterpillar	1,820	1,100	Running
		11	Caterpillar	1,820	0	FO
		12	Caterpillar	1,820	1,100	Running
			Subtotal	14,656	2,700	
5	Mendi	1	Rolls Royce	U/S	0	BOS (Board of Survey: removed), old Rolls Royce machines
		2	Rolls Royce	U/S	0	BOS, Old Rolls Royce machines
		3	Rolls Royce	U/S	0	BOS, Old Rolls Royce machines
		4	Caterpillar	1,500	900	Available on stand-by
			Subtotal	1,500	900	
6	Wabag	1	Caterpillar	300	0	FO
		2	Caterpillar	230	180	Available on stand-by
		3	Detroit	630	0	Fuel transfer pump problem; alarm on speed detector
	(Lease)	4	Cummins	1,140	1,000	Available on stand-by
			Subtotal	2,300	1,180	
7	Ramu Aux. Unit	1	Cummins	800	600	Stand-by
			Subtotal	800	600	
8	Paunda Aux. Unit	1	Deutz	50	50	Stand-by
			Subtotal	50	50	
9	Goroka	1	Caterpillar	1,440	1,100	Running
		2	Caterpillar	1,440	0	FO- Alternator winding burnt, but sent for rewinding; Circuit Breaker (CB) fault
			Subtotal	2,880	1,100	
10	Kundiawa	1	Caterpillar	1440	0	FO- Alternator winding burnt, but sent for rewinding; CB fault
			Subtotal	1,440	0	
Total				**100,987.2**	**45,830**	

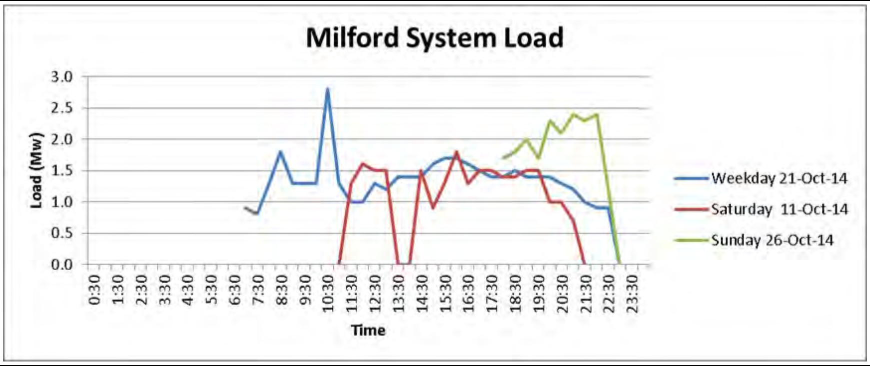
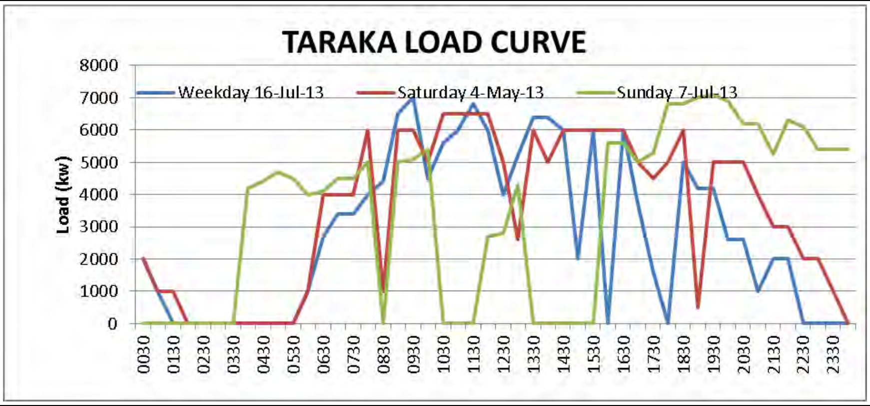
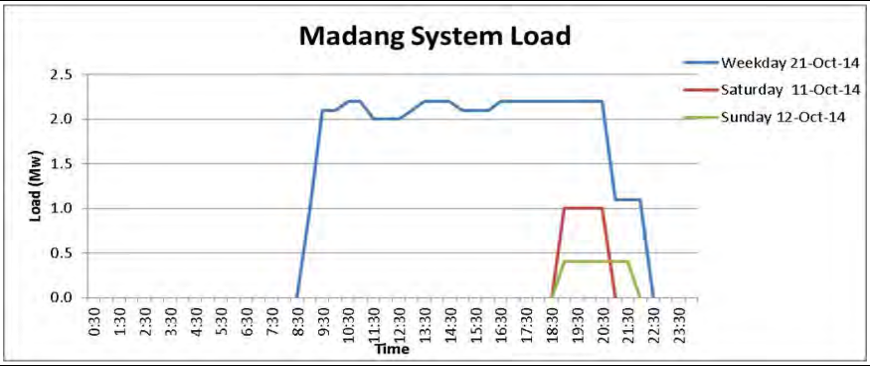
(Source: PPL)

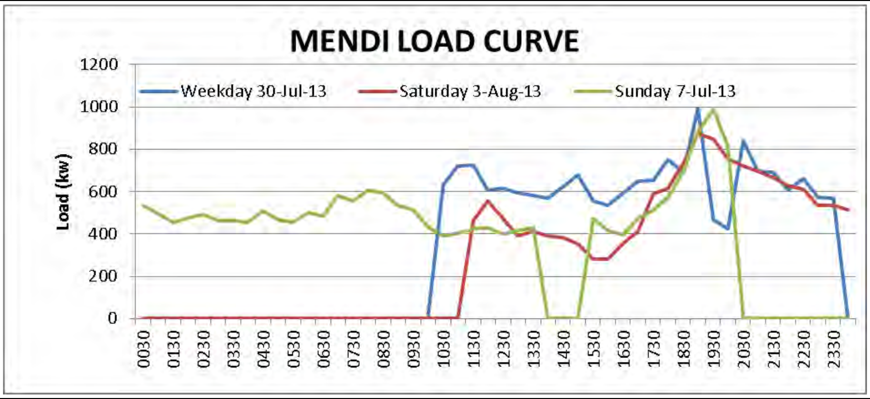
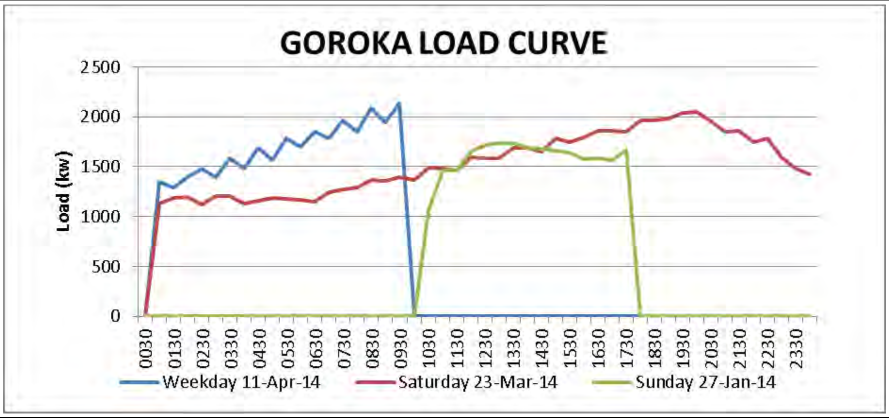
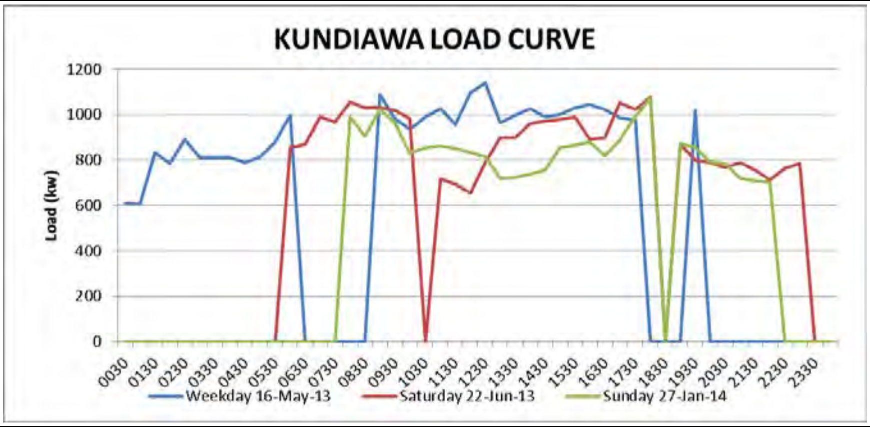
2) Thermal power stations that correspond to peak load hours on Weekdays, Saturdays and Sundays along with standard daily load times;

Table 5.2-4 Standard Daily Load Times on Weekdays/Saturdays/Sundays (Milford, Taraka (PPL), Madang, Mendi, Goroka, Kundiawa)

<table>
<tr><th>Name of Power Station</th><th>Site Rating (kW)</th><th>Number of Units</th><th>Weekday</th><th>Saturday</th><th>Sunday</th></tr>
<tr><td rowspan="4">Milford:
①Number of Start-ups
- Weekday: -
- Saturday: 2
- Sunday: -
②Number of Shut-downs
- Weekday: 1
- Saturday: 2
- Sunday: 1</td><td>1,500</td><td>3</td><td rowspan="3">Operating hours:
Running~23:45

Max. load: 2.8 MW</td><td rowspan="3">Operating hours:
10:45~13:15
13:45~21:15
Max. load: 1.8 MW</td><td rowspan="3">Operating hours:
Running~23:00

Max. load: 2.4 MW</td></tr>
<tr><td>2,000</td><td>6</td></tr>
<tr><td>1,400</td><td>1</td></tr>
<tr><td colspan="5">
</td></tr>
<tr><td rowspan="2">Taraka (PPL):
①Number of Start-ups
- Weekday: 3
- Saturday: 1
- Sunday: 4
②Number of Shut-downs
- Weekday: 4
- Saturday: 2
- Sunday: 3</td><td>Site Rating (kW): 1,000</td><td>Number of Units: 7</td><td>Weekday:
Operating hours:
Running~01:15
05:15~15:45
15:45~17:45
17:45~22:15
Max. load: 7,000 kW</td><td>Saturday:
Operating hours:
running~02:15
05:15~23:45
Max. load: 6,500 kW</td><td>Sunday:
Operating hours:
03:15~08::15
08:15~10:15
11:15~13:15
15.15~Running
Max. load: 7,000 kW</td></tr>
<tr><td colspan="5">
</td></tr>
<tr><td rowspan="6">Madang:
①Number of Start-ups
- Weekday: 1
- Saturday: 1
- Sunday: 1
②Number of Shut-downs
- Weekday: 1
- Saturday: 1
- Sunday: 1</td><td>1,000</td><td>3</td><td rowspan="5">Weekday:
Operating hours:
8:15~22:15
Max. load: 2.2 MW</td><td rowspan="5">Saturday:
Operating hours:
18:15~20:45
Max. load: 1.0 MW</td><td rowspan="5">Sunday:
Operating hours:
18:15~21:45
Max. load: 0.4 MW</td></tr>
<tr><td>2,000</td><td>1</td></tr>
<tr><td>300</td><td>1</td></tr>
<tr><td>800</td><td>1</td></tr>
<tr><td>1,600</td><td>3</td></tr>
<tr><td colspan="5">
</td></tr>
</table>

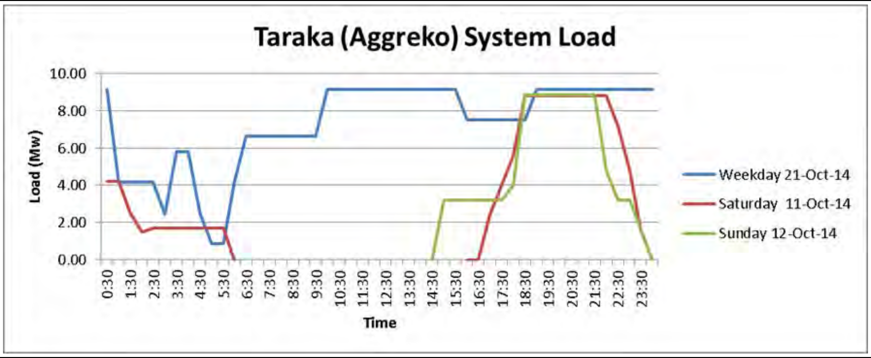
<table>
<tr><th>Name of Power Station</th><th>Site Rating (kW)</th><th>Number of Units</th><th>Weekday</th><th>Saturday</th><th>Sunday</th></tr>
<tr><td rowspan="2">Mendi:
①Number of Start-ups
・Weekday: 1
・Saturday: 1
・Sunday: 1
②Number of Shut-downs
・Weekday: 1
・Saturday: 0
・Sunday: 2</td><td>Site Rating (kW):
1,000</td><td>Number of
Units: 1</td><td>Weekday:
Operating hours:
9:45~23:45
Max. load: 1,000 kW</td><td>Saturday:
Operating hours:
10:45~Running
Max. load: 900 kW</td><td>Sunday:
Operating hours:
Running~13:45
14:45~20:15
Max. Load: 1,000 kW</td></tr>
<tr><td colspan="5">
</td></tr>
<tr><td rowspan="2">Goroka:
①Number of Start-ups
- Weekday: 1
- Saturday: 1
- Sunday: 1
②Number of Shut-downs
- Weekday: 1
- Saturday: 0
- Sunday: 1</td><td>Site Rating (kW)
1,350</td><td>Number of
Units: 2</td><td>Weekday:
Operating hours:
00:15~09:45
Max. load: 2,200 kW</td><td>Saturday:
Operating hours:
00:15~Running
Max. load: 2,050 kW</td><td>Sunday:
Operating hours:
09:45~17:45
Max. load: 1,750 kW</td></tr>
<tr><td colspan="5">
</td></tr>
<tr><td rowspan="2">Kundiawa:
①Number of Start-ups
- Weekday: 2
- Saturday: 2
- Sunday: 2
②Number of Shut-downs
- Weekday: 3
- Saturday: 2
- Sunday: 2</td><td>Site Rating (kW):
1,200</td><td>Number of
Units: 1</td><td>Weekday:
Operating hours:
Running~06:15
08:15~18:15
19:15~20:15
Max. load: 1,140 kW</td><td>Saturday:
Operating hours:
05:45~10:45
10:45~23:15
Max. load: 1,080 kW</td><td>Sunday:
Operating hours:
07:45~18:15
18:15~21:45
Max. load: 1,080 kW</td></tr>
<tr><td colspan="5">
</td></tr>
</table>

3) Leased Diesel Engine & Generator at Taraka & Wabag Power Station:

Operation of the leased Diesel Engine & Generator installed at Taraka Power Substation is subcontracted to the Australian firm Aggreko.

- Leasing cost: Australian$ 439,803.45/month
- Leasing Period: 6 months
- Terms and Conditions of O&M:
  The power station is operated and maintained by Aggreko and included in the lease.
  As additional information, the Leased Diesel Engine & Generator Fuel Cost is borne by PPL.
- Standard daily load times are as follows;

Table 5.2-5 Standard Daily Loads Times on Weekdays/Saturdays/Sundays (Taraka Leased Machine)

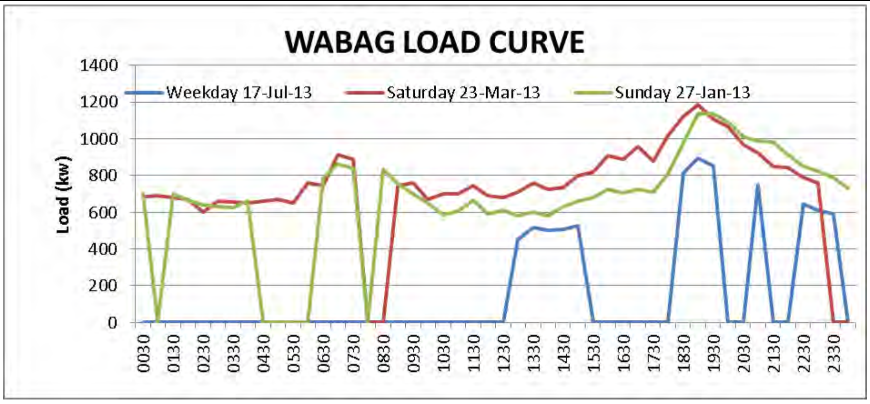
Site Rating (kW)	Number of Units	Weekday	Saturday	Sunday
800	12	Operating hours: Running~Running Max. load: 9.2 MW	Operating hours: Running~5:45 15:45~23:45 Max. load: 9.0 MW	Operating hours: 14:15~23:45 Max .load: 9.0 MW
① Number of Start-ups Weekday: 0, Saturday: 1, Sunday: 1 ② Number of Shut-downs Weekday: 0, Saturday: 2, Sunday: 1				
				

(a) Diesel Engine & Generators in Aggreko (Australia) are operated in a two-shift two-group system.
(Number of operators: 3 persons)
1st shift: 06:00~18:00 hours by 2 operators
2nd shift: 18:00~06:00 hours by 1 operator

Operation of the Leased Diesel Engine & Generator installed at Wabag Power Station is subcontracted to the Australian firm Aggreko. The standard daily load times are as follows;

Table 5.2-6 Standard Daily Load Times on Weekdays/Saturdays/Sundays (Wabag Leased Machine)

Site Rating (kW)	Number of Units	Weekday	Saturday	Sunday
1000	1	Operating hours: 12:15~15:15 17:45~19:45 20:15~21:15 21:45~23:45 Max. load: 9,000 kW	Operating hours: Running~07:45 08:15~23:15 Max. load: 1,200 kW	Operating hours: Running~00:45 00:45~04:15 05:45~07:45 07:45~Running Max. load: 1,140kW
①Number of Start-ups Weekday: 4, Saturday: 1, Sunday: 3 ②Number of Shut Shut-downs Weekday: 4, Saturday: 2, Sunday: 3				



4) The following table shows operation and maintenance status of the thermal power stations in the Ramu System as of March 2015.

Table 5.2-7 Operation and Maintenance Status of the Thermal Power Stations in the Ramu System as of March 2015

Station	0~ 6 months	Cost Estimate	Status	>12 months	Cost Estimate	Status
Milford				D12: TOH	K250,000	2015 budget
Taraka	D1: 6000 hrs service D4: 6000 hrs service	K150,000 K150,000	Set for 30/06/15 Set for 30/06/15	D2: TOH D3: TOH D7: TOH D8: TOH	K250,000 K250,000 K250,000 K250,000	2015 budget 2015 budget 2015 budget 2015 budget
Madang				D5: MOH D7: MOH D8: TOH D9: TOH D10: TOH D11: MOH D12: TOH	K2.5 m K360,000 K250,000 K250,000 K300,000 K550,000 K280,000	2015 budget 2015 budget 2015 budget 2015 budget 2015 budget 2015 budget 2015 budget
Mendi	D4: TOH	K250,000	Set for 30/06/15			
Wabag	D4: 6000 hrs service D1: Correct elect fault D2: Correct elect fault D3: Elect fault to be by Detroit-Aus	K15,000 K15,000	Set for 30/06/15 D1&D2 to be replaced in 2015 with a new unit Set for 30/06/15	D1: MOH [s/exch] D3: MOH (replace G1&G2)	K300,000 K550,000	2015 budget 2015 budget
Goroka	D upgrade AVR D2 upgrade AVR	K25,000 K25,000	Completed Completed	D1 tune up D2 tune up	K50,000 K50,000	2015 budget 2015 budget
Kundiawa	D1 upgrade AVR	K25,000	Set for 30/04/15	D1 tune up	K50,000	2015 budget

* TOH: Top Cylinder Heads Overhaul
MOH: Major Overhaul

(Source: PPL)

5) The following table shows the status of the Forced Outage of the Diesel Engine Generators in 2014. In view of the continuing accidents of similar equipment, it is essential that efforts be made to identify the causes of the accidents and take appropriate countermeasures for other Diesel Engine Generators of the same type.

Table 5.2-8 2014-Forced Outage of the Diesel Engine & Generators

Power Station	Unit No.	Status	Remarks
Milford	3	FO	Leaking from A-Bank Cylinder #5 and B-Bank Cylinder #4. Needs major overhaul; awaiting spare parts.
	4	FO	
	5	FO	
	6	SB	
	7	FO	Damaged fuel pump cam #6. Parts transferred to D6.
	8	FO	Fail big end bearing #2.
	9	FO	Fail big end bearing #1.
	10	FO	Fail big end bearing #3
	11	FO	Bearing cell for cylinder #3 is smashed.
	12	SB	
Taraka	1	SB	
	2	SB	
	3	FO	Gen. Circuit Breaker trip coil burnt.
	4	SB	
	5	SB	
	6	FO	Generator completely burnt out.
	7	SB	
	8	SB	
Madang	2	FO	
	3	FO	
	4	FO	Major internal problems. Needs Management decision for funding to purchase parts and carry out A major overhaul.
	5	FO	
	6	FO	Needs Management decision for funding to purchase parts and restore the unit or purchase replacement
	7	FO	
	8	SB	
	9	FO	Damaged / burnt alternator as of Monday 02.06.2014
	10	FO	
	11	FO	Under Investigation. MR&M advised that a new engine block has been identified. A quote will be issued by Hastings.
	12	SB	
Mendi	4	SB	
Wabag	1	SB	
	2	FO	
	3	FO	Alarm on speed detector
Goroka	1	SB	
	2	SB	
Kundiawa	1	FO	

FO : Forced Outage
SB ： Stand-By

6) Implementation status of digitalization of electric and control systems at each power station

The implementation status of digitalization of electric and control systems at each power station is as follows;

As shown in the following table, PPL has been working on the renewal of electric/control system instruments such as Protection Relay from analog instruments to digital ones.

Table 5.2-9 Implementation Status of Digitalization of Electric and Control Systems at Each P/S

Station	Protection Relay	Monitoring Instrument	Distributed Control System	Sequencer
Milford	Analog	Analog & Digital	Analog & Digital	Analog & Digital
Taraka (PPL)	Analog & Digital	Digital	Analog & Digital	Digital
Madang	Analog & Digital	Digital	Analog & Digital	Digital
Mendi	Analog & Digital	Digital	Analog & Digital	Digital
Wabag	Analog & Digital	Digital	Analog & Digital	Digital
Ramu Aux.	Analog & Digital	Digital	Analog & Digital	Digital
Paunda Aux.	Analog & Digital	Digital	Analog & Digital	Digital
Goroka	Analog & Digital	Digital	Analog & Digital	Digital
Kundiawa	Analog & Digital	Digital	Analog & Digital	Digital
Lae Port	Digital	Digital	Digital	Digital

(4) The organization structure of Milford & Taraka (PPL) Power Stations and design specifications of the power stations are as follows;

1) Organization & Structure of Milford & Taraka (PPL) P/Ss:

At Milford & Taraka (PPL) Diesel Engine & Generator P/Ss, consolidated operation based in Milford P/S is performed.

The organization consists of Operator Department and Maintenance Department and is operated under a 22-man system.

Under the structure shown in the following table, the operators are stationed at both Milford & Taraka (PPL) P/Ss and the maintenance staff are all stationed at Milford P/S on a routine basis.

Table 5.2-10 Organization Structure of Milford & Taraka (PPL) P/Ss

(Unit: Number of People)

No.	Organization & Structure	Milford	Taraka (PPL)	Remarks
1.	Thermal Specialist (Milford & Taraka)	1		Manager of Milford, Taraka and Lae Port P/Ss
	Subtotal	*1*		
2.	Operator Department			
2-1	Supervisor	1	1	Capacity of operators at both power stations: four
2-2	Shift Foreman	1	1	
2-3	Shift Operators	4	4	
	Subtotal	*6*	*6*	
3.	Maintenance Department			
3-1	Mechanical			
3-1-1	Supervisor	1		Office usually in Milford Power Station
3-1-2	Technician	1		
3-1-3	Diesel Mechanic	3		
	Subtotal	5		
3-2	Electrical			Office usually in Milford Power Station
3-2-1	Supervisor	1		
3-2-2	Electrician	2		
	Subtotal	*3*		
4.	Plant & Tools, Equipment Officer	1		Office usually in Milford Power Station
	Subtotal	*1*		
	Total	**22**		

(a) The following table shows the work hours of the Operator Shifts for a 10-day period with the operators working in three shifts in four groups.

Table 5.2-11 Operator Shift Roster (PPL)

<table>
<tr><th>Date</th><th>00:00~08:00</th><th>08:00~16:00</th><th>16:00~24:00</th><th>Off Duty</th><th>Remarks</th></tr>
<tr><td>1</td><td>A</td><td>C</td><td>D</td><td>B</td><td rowspan="10">Operated in a 3-shift, 4-group system.
<table><tr><th></th><th>Milford</th><th>Taraka</th></tr><tr><td>A- group</td><td>1 Person</td><td>1 Person</td></tr><tr><td>B- group</td><td>1 Person</td><td>1 Person</td></tr><tr><td>C- group</td><td>1 Person</td><td>2 Persons</td></tr><tr><td>D- group</td><td>1 Person</td><td>1 Person</td></tr><tr><td>Total</td><td>4 Persons</td><td>5 Persons</td></tr></table>* There is an increase of one Shift Foreman in the C-group at Taraka P/S.</td></tr>
<tr><td>2</td><td>A</td><td>C</td><td>D</td><td>B</td></tr>
<tr><td>3</td><td>C</td><td>D</td><td>B</td><td>A</td></tr>
<tr><td>4</td><td>C</td><td>D</td><td>B</td><td>A</td></tr>
<tr><td>5</td><td>D</td><td>B</td><td>A</td><td>C</td></tr>
<tr><td>6</td><td>D</td><td>B</td><td>A</td><td>C</td></tr>
<tr><td>7</td><td>B</td><td>A</td><td>C</td><td>D</td></tr>
<tr><td>8</td><td>B</td><td>A</td><td>C</td><td>D</td></tr>
<tr><td>9</td><td>A</td><td>C</td><td>D</td><td>B</td></tr>
<tr><td>10</td><td>A</td><td>C</td><td>D</td><td>D</td></tr>
</table>

(b) As shown in the following table, the Scheduled Maintenance System is based in Milford P/S and the whole staff of the Maintenance Department is engaged in scheduled maintenance of Milford & Taraka P/Ss.

Table 5.2-12 Scheduled Maintenance System of Milford &Taraka P/Ss

Maintenance Department

Mechanical:	5 persons	Electrical:	2 persons
Supervisor :	1 person	Supervisor:	1 person
Technician :	1 person	Electrician:	1 person
Diesel Mechanic:	3 persons		

↓

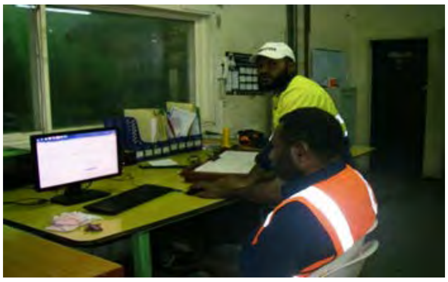
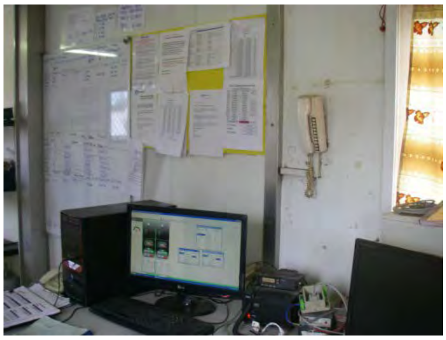
Supervisor

Milford Power P/S	Taraka Power P/S
Industrial Marin Power Service (IMPS: England): 1 person	GEE (Republic of Korea: ROK): 4 persons * Hyundai has no Middle Contractor staff. Four Supervisors from GEE (Republic of Korea: ROK) are actually conducting technical assistance.

2) The existing conditions of the design specifications of Milford & Taraka P/Ss are as follows.

Table 5.2-13 Survey of the Existing Conditions of the Design Specifications of Milford & Taraka P/Ss

No.	Item	Milford P/S	Taraka P/S
1	Access road	Accessible from the national road Milford Haven in front of the P/S.	Accessible from the national road Regulus in front of the P/S.
2	Method of carrying in Equipment & Materials	Equipment & Materials are carried in by truck from the No.1 and No.2 Gates.  * No.3 Gate, which is exclusively used by pedestrians, is installed near the No.2 Gate.	Equipment & Materials are carried in by truck from Main Gate.  * The gates are located in one location.
3	Green Belt Area	The premises of the power station are not designed to take account of the Green Belt Areas.	The premises of the power station are not designed to take account of the Green Belt Areas.
4	Equipment & Material Yard	The open space on the transformer side is used as an Equipment & Material Yard.	The space between the Main Gate and Control Room and other open space are used as Equipment & Material Yards.

No.	Item	Milford P/S	Taraka P/S
			
5	Security Facilities (Gates, Guardhouse, and Fences)	① There is a guardhouse (shed) at the entrance of the No.1 Gate and another at the entrance of the No.2 Gate. Each gate is manned by one security officer. The No.3 Gate is served concurrently by the security officer of the No.2 Gate. ② In order to protect the P/S, fences are installed around the boundary and switchyard.	① There is a guardhouse (shed) at the entrance of the gate manned by two security officers. ② In order to protect the P/S, fences are installed around the boundary and switchyard.
6	Road and parking areas	Road width: About 8 meters. There is a designated place where several vehicles can be parked around the open hatch.	Road width: About 8 meters. There is space where several vehicles can park in front of the Static Verse Generator.
7	Main Facilities		
1)	Office	① 2nd Floor of the main building: - Manager Room - Operator Supervisor Room ②1st Floor of the Main Building: - Mechanic Staff Room. - Electrical Staff Room, and Network Room on the 2nd floor.	The Operator Supervisor Room is located in a makeshift house opposite from the unit side.
2)	Control Room 	The Diesel Generator Operation and Control Room are on the 1st floor of the main building. The Operation Room and Relay Room for auxiliary machinery are on the 2nd floor. 	Operators are manned in the makeshift house on each Engine unit side. 
3)	Diesel Engine & Generator Room	① 11 units of Diesel Engine & Generators are installed in the main building. The No.1 & No.2 Diesel Engine & Generators have been demolished and available parts are spare parts. ② An Air Compressor is installed on each Diesel Engine & Generator. ③ Engine fuel pumps (2 units) and an Engine oil pump (1 unit) are installed in each Diesel Engine & Generator unit. ④ Ceiling crane: - On the Ruston Engine side: 20 tons × 1 unit & 5 tons × 1 unit are installed. - M/Blackstone Engine side: 16 tons × 1 unit is installed. 2 small-size Cooling Water Pumps (Output: unknown) are installed. 1 unit for Emergency use (product of Caterpillar: USA) is installed inside a container outdoors.	① Currently, 7 Diesel Engine & Generator units (Product of Caterpillar: Korean) are installed inside a container outdoors. The No.6 Diesel Engine & Generator has been cleared, leaving open space. *) 12 container type Leased Diesel Engine & Generator units are installed.

No.	Item	Milford P/S	Taraka P/S
4)	Machinery Repair Room	A ceiling crane (5tons) is installed in an electric room on the 1st floor of the main building. Space is provided there for the inspection and repair of the electric equipment.	None, in particular.
5)	Warehouse	A warehouse for storing spare parts and tools is located on the 1st floor of the main building is.	Spare parts and tools are stored in a building outdoors.
8	Method of receiving water for power generation	Water is received from the city water piping of Water PNG Ltd. (water supplier) via an interfacing valve near the No.1 Gate. Water is sent to the cooling water storage tank on the premises via buried piping and then pumped to each unit.	Water is received from the city water piping of Water PNG Ltd. (water supplier) via an interfacing valve near the fuel tank. Water is sent to the cooling storage tank on the premises via buried piping and pumped to two water hose stations via buried piping.
	Capacity and number of Cooling water storage tanks	2 units of Cooling water storage tanks (Capacity: unknown) are installed.	2,000Kl×2 units * 2 units of Cooling water pumps (output: unknown) are installed near the Cooling water storage tank.
9	Cooling System (Radiator Fan)	Radiator Fans are installed opposite to the Fuel Tank. 	None
10	Used Fuel	Light Diesel Oil * Currently, heavy fuel oil is not used.	Light Diesel Oil
	Method of receiving Fuel	Tanker lorry	Tanker lorry
	Capacity and number of Fuel Tanks	Operation is conducted with 4 tanks. 2 fuel tanks: No.3 Tank-250Kl, No.4 Tank-494KL, 2 service tanks: No.5 Tank-58.5KL No.7 -60KL. 	Operation is conducted with 4 tanks. No.1-73KL, No.2-57KL, No.3-46KL and No.4-30KL. 
11	Environmental Standard Values for drainage, warm drainage, noise, etc.	None	None
12	Drainage disposal measures: Drainage containing Oil	Carried out by drum	Carried out by drum

No.	Item	Milford P/S	Taraka P/S
			
	Other drainage	Other drainage is discharged to Didiman Creek via buried piping.	Other drainage is discharged out of the P/S through ditches. Eventually it is discharged into Bunbu River flowing nearby.
13	Disaster prevention measures	The following equipment is installed as a fire prevention measure. ①Fire Detector ②Fire Alarm System ③Portable CO_2 cylinder	The following equipment is installed for fire prevention. ①Fire Detector ②Fire Alarm System ③Portable CO_2 cylinder
14	Measures against noise	① An Exhaust Silencer is installed on each Engine. ② Earplugs are distributed to all operators and maintenance staff.	① An Exhaust Silencer is installed on each Engine. ② Earplugs are distributed to all operators and maintenance staff.
15	Landscape	Factory warehouses, private houses, etc., are located around and next to the P/S.	Factory warehouses are located on both sides of the P/S. The area behind the P/S is forestland.

Comments: It is necessary to enrich the fire-fighting equipment to achieve stable supply of electric power for the following reasons:

With the current fire-fighting equipment, a fire similar to the past fire accident of Unit No.6 Diesel Engine at Taraka P/S would threaten the stable supply of power. Therefore, JICA Study Team recommends that fire-fighting pumps, fire-fighting water piping, fire hydrants, etc., be promptly put in place at all of the power stations owned by PPL to protect them against fire.

3) Layout of Milford Power Station & Outline of Layout of Taraka (PPL & Aggreko) P/Ss:

Fig. 5.2-3 shows Outline of the Layout of Milford Power Station and Fig. 5.2-4 shows Outlines of the Layout of Taraka Power Station (PPL & Aggreko).

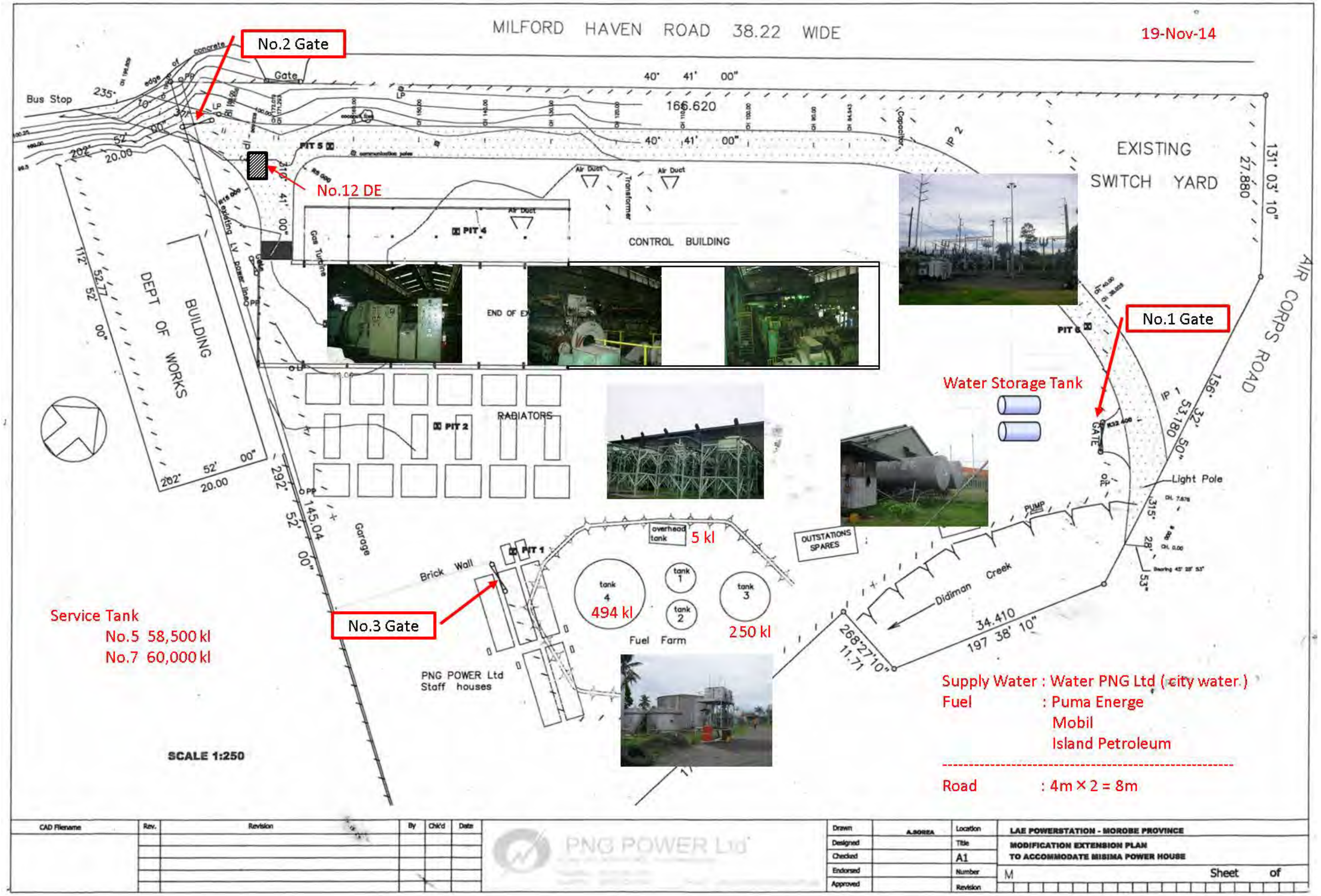


Fig. 5.2-3 Outline of the Layout of Milford Power Station

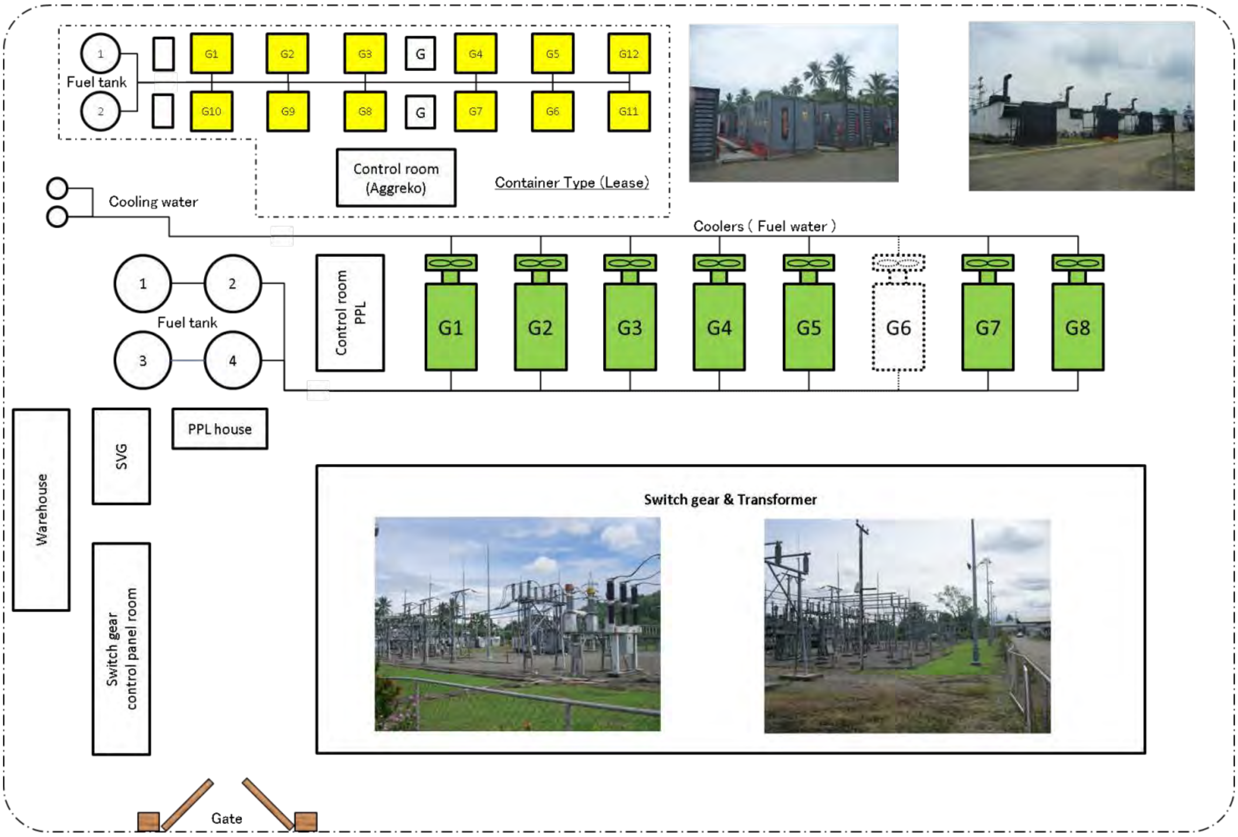


Fig. 5.2-4 Outlines of the Layout of Taraka Power Station (PPL & Aggreko)

4) The running operation and monitoring parameter of the Diesel Engine & Generators at Milford & Taraka P/Ss

Normal running operation of the Diesel Engine & Generator Generators at Milford & Taraka P/Ss are conducted based on the Standard Operating Procedures prepared by Diesel Engine & Generator Manufacturers shown in the table below.

Table 5.2-14 Milford & Taraka P/Ss: Standard Operating Procedures

Milford Power Station		Taraka (PPL) Power Station
Rustin Engine	M/Blackstone Engine	Caterpillar Engine
1. Standard operating procedures for starting a Ruston Engine 2. Standard operating procedures for Synchronizing a Ruston Engine 3. Standard operating procedures for Off lining a Ruston Engine	1. Standard operating procedures for Preparing an M/Blackstone Engine before starting. 2. Standard operating procedures for Starting an M/Blackstone Engine 3. Standard operating procedures for Synchronizing an M/Blackstone Engine	1. Standard operating procedures for 8×1.440 MW Caterpillar Diesel Engine & Generators 2. Engine Isolation Procedure

(a) Time required from start-up till synchronism of Diesel Engine & Generators:

JICA Study Team confirmed the time required from start-up till synchronism of Diesel Engine & Generators at Milford and Taraka (PPL) P/Ss, as follows;

- Start-up and shutdown of Milford P/S are manually conducted by one operator. The time required from startup to synchronism of a Diesel Engine & Generator does not exceed 10 minutes (confirmed by interviews).
- At Taraka P/S, startup and shutdown are automatically operated by one o perator. The time required from start-up to synchronism of a Diesel Engine & Generator is 2 or 3 minutes (confirmed by demonstration tests).

(b) Single-line Diagram in Taraka P/S:

Because there is a concentration of consumers in the Lae area, the trunk line system is centrally controlled at Taraka substation inside Taraka P/S.

Fig. 5.2-5 shows Taraka Power Station - Transmission System.

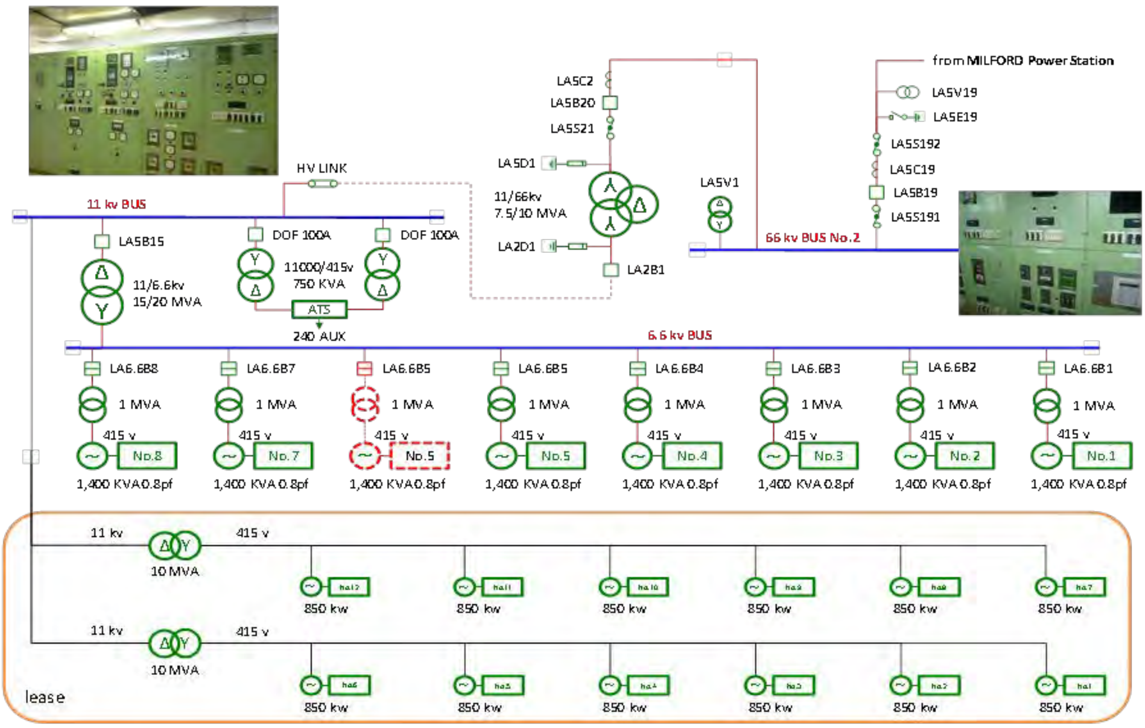


Fig. 5.2-5 Taraka Power Station-Transmission System

(c) Monitoring Parameter:

The following table shows highly important monitoring parameter items for the Low-Speed Engine & High-Speed Engine.

Table 5.2-15 Monitoring Parameters

No.	Low-Speed Engine: 500 rpm below
1	Temperature
1)	Lubricating Oil
	at engine outlet
	at engine inlet (cooler outlet)
	piston return
2)	Jacket water
	at engine outlet (cooling or radiator inlet)
	at engine inlet (cooling or radiator outlet)
3)	Valve cage cooling water
	at engine outlet
	at engine inlet
4)	Air manifold inlet temperature
2	Pressure
1)	Lubricating Oil
	at the main gallery supply to the exhaust-valve stems
2)	Jacket water at engine inlet
3)	Valve cage water at pump outlet
4)	Charge air cooler, air side, pressure losses water side
5)	Exhaust system back pressure downstream of the turbocharger

No.	High-Speed Engine: 1000 rpm above
1	Engine
1)	Speed
2	Generator
1)	Load/Volt & Amp.
2)	Power Factor
3	Lubricating Oil
1)	Oil pressure
2)	Oil temperature
4	Jacket water
1)	Pressure
5	Fuel
1)	Pressure
2)	Consumption
6	Exhaust
1)	Temperature (R/L)

*1) Medium-Speed Engine: 500~1000 rpm
*2) Efficiency of Diesel Engine; - Low-Speed Engine : 37~51%
- Medium-Speed Engine : 30~48%
- High -Speed Engine : 29~42%

5) Manufacturer's standards for maintenance intervals and inspection patrol of the facilities at the Milford & Taraka (PPL) P/Ss:

(a) As for the frequency of the Preventive Maintenance (Scheduled Maintenance) of the Diesel Engine & Generators at Milford & Taraka P/Ss, the Manufacturer's standards for Maintenance Intervals are employed in principle.

Table 5.2-16 Maintenance Intervals for the Diesel Engine & Generator made by Ruston

Item	Interval
Group '**A**' →Routine Maintenance	① Daily Check before starting / at shutdown: -Turbo Charge / Pedestal Bearing / Lub. Oil Centrifuges/Oil Mist Detector
Group 'B' →Routine Maintenance	① Every 50 inspection hours : -Drain air receiver & pipeline / Lubricate the fuel pump operating gear ② Every 250 inspection hours : -Fuel filter & air intake filters ③ Every 500 inspection hours : -Drain and refill the sumps / Drain and refill the camshaft lubricating oil filter ④ Every 1,000 inspection hours : -Drain and refill the lubricating oil sump / all bearing nuts / fuel filters ⑤ Every 2,000 inspection hours : -Air valves / lubricate oil filter body & oil relief by-pass valves / crankshaft aliment
TOP Overhaul(TOH) →TOP Cylinder heads Overhaul *TOP: TOP end of Cylinder Heads	① Every 4,000 inspection hours: -Overhaul pressure chargers. ② Every 5,000 inspection hours: -Remove cylinder heads, grind in valves, and clean out water spaces. -Clean camshaft / Examine bearing & fuel pump / clean out all exhaust pipes and silence. ③ Every 8,000 inspection hours : -Renew pressure charger turbine and compressor end ball bearing
MOH →Complete Engine Overhaul	• Every 40,000 inspection hours: Renew connecting rod and slave rod bolts

Table 5.2-17 Maintenance Intervals for the Diesel Engine & Generator made by Caterpillar

Item	Interval
Group ‘**A**’ →Routine Maintenance	① Daily Check: Air starting motor lubricator oil level / Air tank moisture and sediment / Bearing temperature / Cooling system coolant level / Engine air pressure・Engine oil level / Generator load / Jacket water heater / Power factor / Voltage and Frequency ② Every Week Check: Air inlet filter / Battery charge / Electrical Connections Generator / Space heater / Stator winding temperature
Group ‘B’ →Routine Maintenance	① Every 50 inspection hours: Zinc rods ② Every 250 inspection hours: Engine valve lash / Fuel injector ③ Every 500 inspection hours: Air shutoff / Engine oil and Filter ④ Every 1,000 inspection hours: Cooling system coolant sample / Engine protective device / Fuel system filter / Insulation ⑤ Every 2,000 inspection hours : Air staring motor lubricator bowl / Crankshaft vibration damper / Engine mount / Generator set vibration / Stator Lead / Turbocharger ⑥ Every 3,000 inspection hours: Cooling system coolant (DEAC) ⑦ Every 4,000 inspection hours: Engine valve lash / Fuel injector ⑧ Every 6,000 inspection hours: Cooling system water temperature regulator / Prelub. Pump / Speed sensor starting motor / Water pump ⑨ Every 7,500 inspection hours: Rotating rectifier ⑩ Every 12,000 inspection hours: Cooling system coolant (ELC)
TOP Overhaul(TOH) →TOP Cylinder Heads Overhaul *TOP:TOP end of Cylinder Heads	① Every 9,000 inspection hours: After cooler core / Generator bearing / Maintenance recommendations ② Every 18,000 inspection hours: After cooler core / Generator bearing / Maintenance recommendations
Major Overhaul(MOH) →Complete Engine Overhaul	①Every 27,000 inspection hours: After cooler core Generator bearing / Maintenance recommendations

(b) Inspection Patrol of the Facilities

Inspection patrols of the facilities at Milford & Taraka (PPL) P/Ss are conducted daily and weekly.

Table 5.2-18 Inspection Patrol of the Facilities at Milford & Taraka (PPL) P/Ss

Item	Milford Power Station	Taraka (PPL) Power Station
Daily	- Operators: They do not conduct inspection patrols of the facilities. - Maintenance staff: They conduct inspection patrols of the facilities based on a Daily Check List. If they find any defect in the facilities they report it to the shift operator.	- Operators: Shift operators conduct inspection patrols of the facilities every hour. - Maintenance staff: They conduct inspection patrols of the facilities based on a Daily Check List. If they find any defect in the facilities they report it to the shift operator.
Weekly	Maintenance staff prepares a Weekly Plan and conducts inspections based on the contents of the Weekly Check List.	Maintenance staff prepares a Weekly Plan and conducts inspections based on the contents of the Weekly Check List.

6) Following are the plans and past records for the Top Cylinder Heads Overhaul (TOP) & MOH;

<Milford Power Station>

Unit No.	2009~2013	2014~2015
3	——————	2015-MOH
4	2009/6~2012/6-MOH	2014-TOH (waiting for parts)
5	2009/6~2012/6-MOH	2014/3~2015-TOH
6	———————	2015-MOH
7	———————	2015-MOH
8~11	——————(Out of Service)	
12	——————(Operational)	

<Taraka Power Station>

Unit No.	2009~2013	2014~2015
1	2014/1~2014/2-TOH	(Operational)
2~5	(Operational)	2015-TOH
7~8	(Operational)	2015-TOH

7) Details of the recent troubles and countermeasures (as of Mid-November, 2014) are as follows:

<Milford Power Station>

Unit No.	Manufacturer	Site Rating (MW)	Operating Status	Recent Trouble and Countermeasures
3	Ruston	1.5	Out of Service	Require major overhaul and replacement of cooling system radiators i.e.: Oil / Water / charge Air
4		1.5	Available	Replacement of cooling system radiators i.e.: Air, Oil, water, Fan Motors
5		1.5	Out of Service	Replacement of cooling system radiators i.e.: Air, Oil, water, Fan Motors, water leaking through liner register
6	M/Blackstone	2.0	Out of Service	Require major overhaul and replacement of cooling system radiators i.e.: Oil / Water/charge Air, Cooling, Engine C / Breaker Fan / Motors, Engine controls and monitoring and protections, replacement of AVR,
7		2.0	Out of Service	Require major overhaul and replacement of cooling system radiators i.e.: Oil / Water / charge Air, Cooling Fan / Motors, Engine controls and monitoring and protections ,replacement of AVR, Engine C/Breaker
8		2.0	Out of Service	Require major overhaul, replacement of crankshaft, replacement of cooling system radiators i.e.: Oil / Water /charge Air / Engine controls and monitoring and protections, replacement of AVR
9		2.0	Big end bearing	Require major overhaul and replacement of cooling system radiators i.e.: Oil / Water / charge Air, Cooling Fan / Motor, Engine controls and monitoring and protections, replacement of AVR, Engine C / Breaker
10		2.0	Big end bearing	Require major overhaul, replacement of crankshaft, replacement of cooling system radiators i.e.: Oil / Water / charge Air / Engine controls and monitoring and protections, replacement of AVR
11		2.0	Big end bearing	Require major overhaul and replacement of cooling system radiators i.e.: Oil / Water / charge Air, Cooling Fan / Motor, Engine controls and monitoring and protections, replacement of AVR, Engine C / Breaker
12	Caterpillar	1.4	Available	-
	Total	**17.9**		

<Taraka (PPL) Power Station>

Unit No.	Manufacturer	Site Rating (MW)	Operating Status	Recent Trouble and Countermeasures
1	Caterpillar	1.4	Forced Outage	- Jacket water leakage - Broken seal jacket water leaking down to sump
2		1.4	Available	
3		1.4	Forced Outage	- Exciter rotor needs rewinding - Broken exhaust silencer result in heat from exhaust burning all wiring and roof ceiling
4		1.4	Available	- Exciter rotor needs rewinding
5		1.4	Available	
7		1.4	Forced Outage	- Faulty radiator fan motor
8		1.4	Forced Outage	- Exhaust needs repair
	Total	**9.8**		

8) Maintenance records and retention periods:

PPL keeps records of the Daily & Weekly checks. However, PPL does not keep records of most the maintenance and control of the equipment, including overhaul records and records of the regular inspections of the Diesel Engine & Generator units.

9) Training plans for maintenance staff:

① Training of the maintenance staff is conducted mainly by means of On the Job Training (OJT).

② Training plans for the operators: The main courses are as follows.
The current training programs for the operators of Milford & Taraka P/Ss were started on July 18, 2013 for the purpose of further improving the knowledge, techniques and capability to gain. Subsequently, the programs are implemented for 2 hours every Thursday.

Table 5.2-19 Training Plans for the Operators: Main Courses

<Power Station Course>	**<System･Operation Course>**
1. Power Station Safety	1. Operational Fault Reports
2. Diesel Engine & Generators	2. Switching Schedules
3. Alternators	3. Operational Priorities
4. Communication system and Procedures	4. Operating Procedures
5. D.C Supply for Power Station Restoration	Comment: It is recommended that disaster drills in the following items be carried out as part of OJT education. 1. Education and evacuation drills in preparation for “Tsunami” 2. Fire prevention drills
6. Auxiliary Supplies and Systems	
7. Power System Operation	
8. Black Start Procedures	
9. Synchronizing of Alternators	
10. System Loading Procedures	
11. System Loading Procedures	
12. Power System Restoration	

10) Preparation of the Standards and Manuals for Operations and Maintenance

JICA Study Team has confirmed by interviews that the main standards were described in one A4 size sheet.

Table 5.2-20 Standards and Manuals for Operations and Maintenance

No.	Standards for Operations	Manuals for Maintenance
1	Education of operators	Daily & Weekly patrols
2	Operation jobs	Handling of works on the switchboards
3	Operation, maneuvering and control by maker (at time of start-up, parallel operation, etc.)	* Maintenance standards and inspection works are implemented in accordance with the Manuals provided by the makers.
4	Key monitoring parameters * Manuals for measures to be taken when any alarm is issued are not in place.	

11) Recording of operating data and storage period

<Milford P/S>

Shift operators do not conduct inspection patrols of the equipment, but they manually fill out log sheets every hour with data from the monitoring equipment related to power generation on the switchboard in the control room. Later, they input the data on computers.

The log sheets of the operating Diesel Engine & Generator are locally prepared. The product of Ruston keeps records every 30 minutes and the product of M/Blackstone records data on the engine pressure and temperature every hour.

The retention period for the aforesaid data is one year, except for the main data (data such as the time of power generation).

<Taraka P/S>

Shift operators manually record data based on the Engine Log sheets and also conduct equipment inspections every two hours during the period from 08:00 to 20:00 hours. The hourly data is also recorded in the computers equipped in the Control Room and retained for one year.

Additionally, JICA Study Team confirmed that the job handover is conducted by way of handover daybooks at both of the P/Ss.

12) Rotation of Maintenance staff and Operators

The maintenance staff and operators are not rotated. The operators are, however, rotated between Milford & Taraka P/Ss on a case-by-case basis.

(5) The Organization Structure of Lae Port Power Station and design specifications for the power station are as follows.

PNG Government purchased two GT2500 type Gas Turbine units from GEE in order to increase reliability and improve capacity and has decided to install one of the units at Lae Port Power Station (with one unit of 26 MW; peak load operation: 4 hours/ day) in the Lae area.

Trial operation was completed on February 28, 2015 and the P/S was put into operation on March 1, 2015.

*1) PNG Government was handed over two GT2500 type Gas Turbine units to PPL.

*2) PPL's reason for installing the GT in Lae Port:
Under the original plan, the GT was to be installed at Taraka P/S. However, it became evident that the bridge located between Lae Port and Taraka P/Ss was unable to bear the weight of a vehicle carrying the GT generator. PPL therefore decided to install the GT in Lae Port as a temporary unit for convenience sake.

1) Contract Form: Full Turn-Key Contract between PPL and LR Group Limited (Israel)

2) For design, procurement, delivery, installation and commissioning of 1 × 26 MW mounted GEE TM2500 + gas turbine at Lae Port

3) Construction Work System: LR Group Limited (Israel)

↓

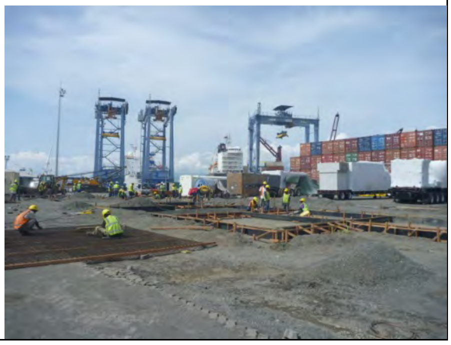
Israel Electric Corp. (Joint Venture)

4) Survey of the existing conditions on the design specifications of the Lae Port Power Station: Please refer to the following table.

Table 5.2-21 Survey of the Existing Conditions on the Design Specifications of the Lae Port Power Station

No.	Item	Contents
1	Site for Power Station	A site for the P/S was secured at a land section inside the Lae Port Container Terminal by a Memorandum of Agreement with PNG Power, Teikom, PNG Ports, etc.
2	Access road	The distance from Milford P/S to the GT plant can be covered by car in about 5 to 6 minutes via the national road Milford Haven.
3	Method of bringing in Equipment & Material	① The large equipment of the GT generator will be shipped by a transport vessel and unloaded at Lae Port. ② The other smaller equipment and materials will be shipped by a transport vessel and unloaded at Lae Port.
4	Equipment & Material Yard	Currently, GT generators and so on are installed near the place where GT was scheduled to be installed. The installation site is paved with concrete and used as an Equipment & Material Yard. 

No.	Item	Contents
5	Installation method for the GT	The GT is installed on the carriage of a vehicle. 
6	PPL Office and Control Room	At present, at the site office is an office of the Supervisor's LR Group (Israel). The future plan is to use this office both as a PPL office and Control Room.
7	Security facilities (gates, guardhouse and fences)	- A guardhouse (shed) manned by a security staff is located at the gate entrance. - Fences are installed along the boundary with PNG-Pacific Cement Factory in order to protect the P/S. 
8	Method for receiving water for P/S	The P/S is scheduled to receive water from Water PNG Ltd. (Water supplier) through its city water pipeline via the interfacing valve located near the water tanks.
	Capacity and number of water storage tanks	6,000 Liters × 2 Tanks 
9	Used fuel	Light Diesel oil (Including NG)
10	Method for receiving fuel	Tanker lorry
	Capacity and number of Diesel oil Tanks	Operation is conducted with two tanks: No.1 (80,200 liters) and No.2 (64,600 liters) 
11	Transformation installation	Presently, one transformer (Product of the Peoples Republic of China, rated voltage 11.5 kV, cycle 50 Hz), one VT (Product of Australia, 66 kV 3 3-tiered), and one transformer (made by Siemens, rated voltage 72.5 kV, rated current 2,000 A) are installed in the P/S. 

No.	Item	Contents
11	Landscape	PNG-Pacific Cement factories, warehouses, and containers are located near the entrance gate. Container carriers enter the port and dock at unloading facilities on the sea side.
12	Others	- Time required from Start-up till Synchronism of GT: 15 min. - Time required Shutdown: 30 min. 

5) Operation & Maintenance Organization Structure for the Lae Port Power Station

Manager Generation Lae

(Unit: Person)

Team Leader	1
Mechanical	1
Electrical	1
Operators	6

*) Operation & Maintenance system of the Lae Port Power Station: established with the manager of Milford concurrently working for the Lae Port Power Station

The table below shows work hour shifts of the operators over a period of 7 days. The operation is performed by six operators in four groups working in three shifts.

Table 5.2-22 Operator Shift Roster (PPL)

Date /March	00:00~08:00	08:00~16:00	16:00~24:00	Day off	Remarks
1	A	B	C	D	Operated in 3-shifts
2	B	C	D	A	4-group system.
3	B	C	D	A	A: 1 Person
4	C	D	A	B	B: 2 Persons
5	C	D	A	B	C: 2 Persons
6	D	A	B	C	D: 1 Persons
7	D	A	B	C	Total 6 Operators

6) Generator Specifications

Generator Specifications	
Manufacturer	Brush
Terminal Voltage (kV)	11.50
Frequency (Hz)	50
Speed (rev /min)	3,000
Power factor	0.9
Rated air in let temperature (°C)	15.0
Rated output (MW)	26,300
Rated output (MVA)	29,222

(6) 5-Year (2015-2019) - Rehabilitation Works and Replacement Plans of the P/Ss

Fundraising for PPL is in a considerably severe situation. In order to achieve stable power supply, the following 5-Year (2015 through 2019) Rehabilitation Works and Replacement plans of the P/Ss are now under consideration.

Table 5.2-23 5-Year (2015-2019) - Rehabilitation Works and Replacement Plans (Draft)

<table>
<tr><th>No.</th><th>Station</th><th>Contents</th><th>Remarks</th></tr>
<tr><td>1</td><td>Milford</td><td>-MOH Unit Nos.3, 4, 5, 6, 7, 9, 11, 12
-Radiators Fan Replacement-Unit Nos.4, 5
-Electrical & Control Protection Replacement (Digital)</td><td rowspan="9">The estimate cost for MOH at each P/S is as follows:
(K million)
<table><tr><th>Station</th><th>Cost Estimate</th></tr><tr><td>Milford</td><td>10</td></tr><tr><td>Taraka (PPL)</td><td>3</td></tr><tr><td>Madang</td><td>6</td></tr><tr><td>Mendi</td><td>0.5</td></tr><tr><td>Wabag</td><td>0.5</td></tr><tr><td>Goroka</td><td>0.5</td></tr><tr><td>Kundiawa</td><td>0.3</td></tr><tr><td>Paunda Aug.</td><td>0.3</td></tr><tr><td>Ramu Aug.</td><td>0.3</td></tr><tr><td>Total</td><td>21.4</td></tr></table>(Source: PPL)</td></tr>
<tr><td>2</td><td>Taraka (PPL)</td><td>-MOH Unit Nos.1, 2, 3, 4, 5, 7, 8
-Electrical & Control Protection Replacement (Digital)</td></tr>
<tr><td>3</td><td>Madang</td><td>-MOH Unit Nos.2, 3, 5, 7, 8, 9, 10, 11, 12
-Electrical & Control Protection Replacement (Digital) Replacement</td></tr>
<tr><td>4</td><td>Mendi</td><td>-MOH Unit Nos.4
-Electrical & Control Protection Replacement (Digital)</td></tr>
<tr><td>5</td><td>Wabag</td><td>-MOH Unit Nos.1, 2, 3
-Electrical & Control Protection Replacement (Digital)</td></tr>
<tr><td>6</td><td>Goroka</td><td>-MOH Unit Nos.1, 2
-Electrical & Control Protection Replacement (Digital)</td></tr>
<tr><td>7</td><td>Kundiawa</td><td>MOH Unit No.1
-Electrical & Control Protection Replacement (Digital)</td></tr>
<tr><td>8</td><td>Paunda Aug.</td><td>-MOH Unit No.1
-Electrical & Control Protection Replacement (Digital)</td></tr>
<tr><td>9</td><td>Ramu Aug.</td><td>-MOH Unit No.1
-Electrical & Control Protection Replacement (Digital)</td></tr>
</table>

(7) Abolition plans

1) The following table shows the number of units where diesel engines and generators were abolished (nine in total).

Table 5.2-24 List of Diesel Engine & Generators Abolition

No.	Station	Unit No.	Engine Manufacturer	N'Plate Rating (kW)	Site Rating (kW)	Speed (rpm)	Date of Commission
1	Milford	1	English Electric	840	500	428	1969
		2	English Electric	840	500	428	1969
		8	B/Blackstone	3,095.2	2,000	600	1988
2	Taraka (PPL)	6	Caterpillar	1,440	1,000	1500	2009
3	Madang	1	Caterpillar	600	0	1500	2005
		4	Niigata	1,500	1,000	375	1972
		6	Niigata	3,300	2,000	600	1980
4	Mendi	1	Rolls Royce	300	0	1500	1980
		2	Rolls Royce	250	0	1500	1979
		3	Rolls Royce	300	0	1500	1979

2) Future abolition plans of the existing Diesel Engine & Generators

With respect to power supply for the next 5 years (from 2015 until 2019), operation of the thermal power stations faces a very severe situation.

Therefore, the Diesel Engine & Generators owned by PPL in the following table cannot be abolished, regardless of their rapidly deteriorating condition with age.

It is therefore recommend that studies on abolition and actual abolition of the existing Diesel Engine & Generators be implemented between 2020 and 2024, when there are not expected to be any problems with power supply from the thermal power stations.

Table 5.2-25 Aging Diesel Engine & Generators

No.	Station	Unit No.	Engine Manufacturer	N'Plate Rating (kW)	Site Rating (kW)	Speed (rpm)	Date of Commission
1	Milford	3	Ruston	2,400	1,500	428	1969
		4	Ruston	2,400	1,500	428	1969
		5	Ruston	3,000	1,500	600	1969
		6	M/Blackstone	3,095.2	2,000	600	1988
		7	M/Blackstone	3,095.2	2,000	600	1988
		9	M/Blackstone	3,095.2	2,000	600	1988
		10	M/Blackstone	3,095.2	2,000	600	1988
		11	M/Blackstone	3,095.2	2,000	600	1988
		2	Niigata	1,340	1,000	375	1972
2	Madang	3	English Electric	1,500	1,000	600	1965
		5	Niigata	3,300	2,000	600	1980
		5	Niigata	3,300	2,000	600	1980
	Total			**29,426**	**18,500**		

(Source: PPL)

(8) Collection of information on Operation and Maintenance Expenses, etc.

1) Operation and Maintenance Expenses in 2014

Following is the 2014 Operation & Maintenance expense data for the Lae (Milford & Taraka), Madang, Mendi, Wabag, Goroka, and Kundiawa P/Ss:

The expenses related to O&M for Lae (Milford & Taraka) are mainly spent on the Taraka Power Station.

Table 5.2-26 Operation and Maintenance Expenses in 2014

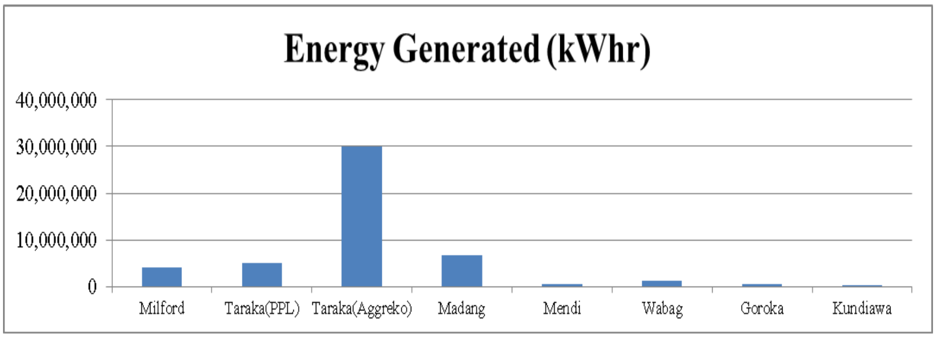
(Unit: Kina)

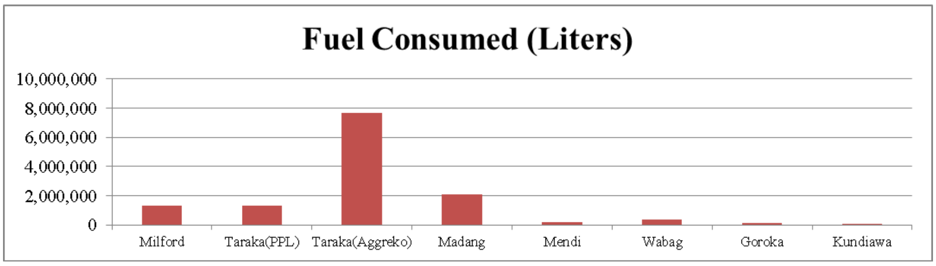
Station	General Expenses		Personnel Expenses	Store Issues		Directly Purchased Consumables	Total
	Operating	Repairs & Maintenance		Store Issues	Fuel Cost		
Lae	14,156,373.96	994,838.57	6,545,018.11	1,432,758.62	30,857,253.16	3,167,160.79	57,153,403.21
Madang	2,034,103.56	259,598.38	2,795,826.55	405,758.62	5,282,961.37	701,643.89	11,479,892.37
Mendi	1,126,223.08	118,201.03	1,087,922.84	348,062.54	820,373.37	125,203.71	3,625,986.57
Wabag	1,413,217.87	22,588.53	1,059,775.18	244,747.08	1,318,056.24	-218,985.20	3,839,399.70
Goroka	1,572,932.28	16,987.97	2,131,627.27	547,187.57	651,529.09	303,712.49	5,223,976.67
Kundiawa	949,598.13	0.00	995,783.82	316,329.88	49,773.50	142,536.27	2,454,021.6

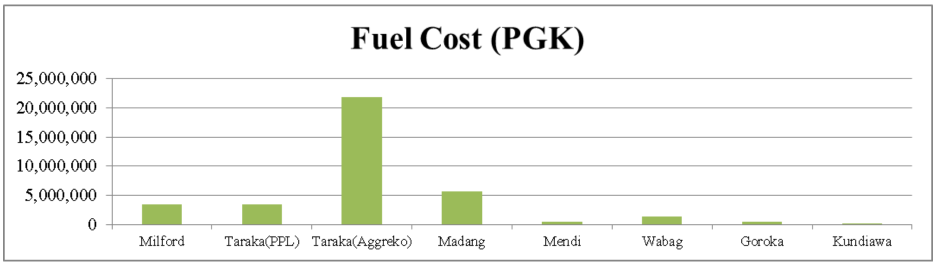
*1) Lae Station; Milford Station + Taraka (PPL) Station
*2) Personnel Expenses: Total Direct Personnel Expenses + Total Other Personnel Expenses
*3) Store Issues: Total Materials / Stationery / Uniforms + Total Fuel Expenses
*4) Because material supplies-consumable expenses in Dec.2014 for Wabag was -245,629.92 Kina, so total direct purchases-consumables expenses was -218,985.20 Kina.

2) The Annual Energy Fuel Data in 2014

(a) The Annual Energy Fuel Data in 2014 for each thermal power station in the Ramu System is shown in Fig. 5.2-6.







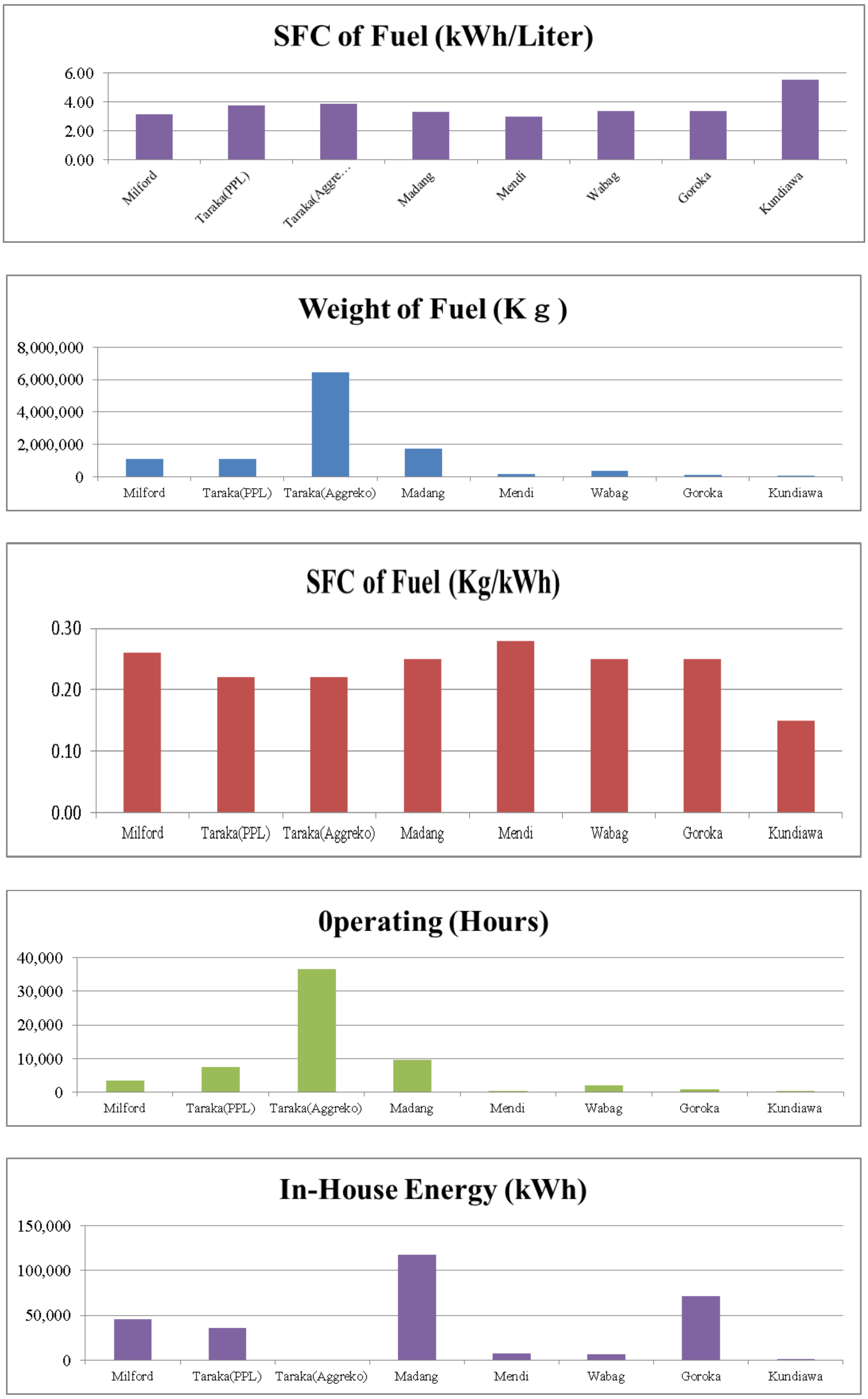


Fig. 5.2-6 2014- Annual Energy Fuel Data for Each Thermal Power Station in the Ramu System

(b) The Annual Energy Fuel Data in 2014 for each unit of the thermal power station in the Ramu System is shown in the following table.

Table 5.2-27 2014- Annual Energy Fuel Data (1/2)

Station	Unit No.	Site Plate Rating (kW)	Energy Generated (kWhr)	Fuel Consumed (Liters)	Fuel Cost (PGK)	SFC of Fuel (kWh/Liter)
Milford	3	2,400	35,000.00	12,392.00	32,838.80	2.8244
	4	2,400	1,465,065.00	417,366.00	1,081,868.76	3.5103
	5	3,000	646,700.00	220,543.00	584,438.95	2.9323
	6	3,095	2,052,590.00	668,140.52	1,754,344.39	3.0721
	7	3,095	0.00	0.00	0.00	0.0000
	8	3,095	0.00	0.00	0.00	0.0000
	9	3,095	0.00	0.00	0.00	0.0000
	10	3,095	0.00	0.00	0.00	0.0000
	11	3,095	0.00	0.00	0.00	0.0000
	12	1,710	19,145.00	6,733.33	17,270.46	2.8433
Total			4,218,500.00	1,325,174.85	3,470,761.36	3.18
Taraka (PPL)	1	1,440	398,970.00	106,246.00	277,302.06	3.7552
	2	1,440	1,092,617.00	261,561.00	677,398.95	4.1773
	3	1,440	71,014.00	18,844.00	49,182.84	3.7685
	4	1,440	890,099.00	214,566.00	560,992.98	4.1484
	5	1,440	612,822.00	224,637.00	584,906.87	2.7281
	7	1,440	886,734.00	224,472.00	586,350.85	3.9503
	8	1,440	1,040,179.00	279,249.00	725,926.09	3.7249
Total			4,992,435.00	1,329,575.00	3,462,060.64	3.75
Taraka (Aggreko)	1	1,100	2,570,215.00	650,675.69	1,861,447.73	3.9501
	2	1,100	2,769,521.00	683,064.56	1,939,452.31	4.0546
	3	1,100	2,732,550.00	694,835.65	1,974,928.82	3.9327
	4	1,100	1,996,833.00	505,733.84	1,447,348.72	3.9484
	5	1,100	2,364,105.00	609,036.89	1,721,868.45	3.8817
	6	1,100	2,676,355.00	692,478.52	1,970,255.76	3.8649
	7	1,100	2,870,744.00	731,614.29	2,088,615.38	3.9238
	8	1,100	2,927,910.00	754,780.74	2,154,921.45	3.8792
	9	1,100	1,828,016.00	431,144.61	1,206,275.14	4.2399
	10	1,100	2,728,733.00	701,148.64	1,980,942.76	3.8918
	11	1,100	2,393,918.00	660,162.39	1,857,878.26	3.6263
	12	1,100	2,182,597.00	582,590.75	1,652,960.44	3.7464
Total			30,041,497.00	7,697,266.55	21,856,895.21	3.90
Madang	2	1,340	0.00	0.00	0.00	0.0000
	3	1,500	0.00	0.00	0.00	0.0000
	5	3,300	1,697,240.00	545,499.00	1,495,421.45	3.1114
	7	616	313,826.25	120,808.65	329,461.08	2.5977
	8	1,120	848,500.00	283,518.40	777,170.29	2.9928
	9	1,120	426,372.92	130,334.70	347,138.39	7.1672
	10	1,820	931,719.00	290,211.00	832,805.42	3.2105
	11	1,820	0.00	0.00	0.00	0.0000
	12	1,820	2,124,959.40	708,295.60	1,980,053.59	3.0001
Total			6,342,617.57	2,078,667.35	5,762,050.22	3.30
Mendi	4	1,360	519,794.40	173,264.80	572,982.84	3.0000
Total			519,794,40	173,264.80	572,982.84	3.00
Wabag	1	345	0.00	0.00	0.00	0.0000
	2	230	0.00	0.00	0.00	0.0000
	3	624	0.00	0.00	0.00	0.0000
	Leased	1,000	1,377,825.00	404,986.90	1,345,169.55	3.4021
Total			1,377,825.00	404,986.90	1,345,169.55	3.40
Goroka	1	1,440	275,646.00	82,994.00	266,118.15	3.3213
	2	1,440	229,643.00	65,720.00	219,952.24	3.4943
Total			505,289.00	148,714.00	486,070.39	3.40
Kundiawa	1	1,440	14,071.00	2,542.00	8,897.00	5.5354
Total			14,071.00	2,542.00	8,897.00	5.54

Table 5.2-27 2014- Annual Energy Fuel Data (2/2)

Station	Unit No.	Site Plate Rating (kW)	Weight of Fuel (Kg)	SFC of Fuel (Kg/kWh)	Operating (Hours)	In-House Energy (kWh)
Milford	3	2,400	10,409.2800	0.2974	94.00	
	4	2,400	350,587.4400	0.2393	1,361.20	
	5	3,000	185,256.1200	0.2865	443.02	
	6	3,095	561,238.0368	0.2734	1,490.54	
	7	3,095	0.0000	0.0000	0.00	
	8	3,095	0.0000	0.0000	0.00	
	9	3,095	0.0000	0.0000	0.00	
	10	3,095	0.0000	0.0000	0.00	
	11	3,095	0.0000	0.0000	0.00	
	12	1,710	5,656.0000	0.2954	67.00	
Total			1,113,146.88	0.26	3,455.76	46,000.00
Taraka (PPL)	1	1,440	89,246.6400	0.2237	610.00	
	2	1,440	219,711.2400	0.2011	1,697.20	
	3	1,440	15,828.9600	0.2229	122.00	
	4	1,440	180,235.4400	0.2025	1,661.70	
	5	1,440	188,695.0800	0.3079	1,021.70	
	7	1,440	188,556.4800	0.2126	1,090.10	
	8	1,440	234,569.1600	0.2255	1,306.50	
Total			1,116,843.00	0.22	7,509.20	36,000.00
Taraka (Aggreko)	1	1,100	546,567.5796	0.2127	3,041.30	
	2	1,100	573,774.2304	0.2072	3,119.00	
	3	1,100	583,661.9460	0.2136	3,346.80	
	4	1,100	424,816.4239	0.2127	2,441.40	
	5	1,100	511,590.9884	0.2164	2,960.80	
	6	1,100	581,681.9576	0.2173	3,292.30	
	7	1,100	614,556.0036	0.2141	3,536.10	
	8	1,100	634,015.8174	0.2165	3,594.30	
	9	1,100	362,161.4682	0.1981	2,187.60	
	10	1,100	588,964.8542	0.2158	3,265.80	
	11	1,100	554,536.4042	0.2316	3,073.20	
	12	1,100	489,376.2292	0.2242	2,735.10	
Total			6,465,703.90	0.22	36,593.70	
Madang	2	1,340	0.0000	0.0000	0.00	
	3	1,500	0.0000	0.0000	0.00	
	5	3,300	458,219.1600	0.2700	1,458.60	
	7	616	101,479.2660	0.3234	1,136.60	
	8	1,120	238,155.4560	0.2807	2,052.00	
	9	1,120	109,481.1480	0.2568	913.50	
	10	1,820	243,777.2400	0.2616	1,300.40	
	11	1,820	0.0000	0.0000	0.00	
	12	1,820	594,968.3040	0.2800	2,690.00	
Total			1,746,080.57	0.28	9,551.10	117,648.00
Mendi	4	1,360	145,542.4320	0.2800	249.60	
Total			145,542.43	0.28	249.60	7,271.00
Wabag	1	345	0.0000	0.0000	0.00	
	2	230	0.0000	0.0000	0.00	
	3	624	0.0000	0.0000	0.00	
	Leased	1,000	340,188.9960	0.2469	1,953.60	
Total			340,189.00	0.25	1,953.60	6,162.00
Goroka	1	1,440	69,714.9600	0.2529	442.00	
	2	1,440	55,204.8000	0.2404	354.00	
Total			124,919.76	0.25	796.00	71,296.00
Kundiawa	1	1,440	2,135.2800	0.1518	11.50	
Total			2,135.28	0.15	11.50	92.00

* Specification of fuel (Diesel Oil) used for Diesel Engine & Generator:

JICA Study Team obtained the results of the analysis on Diesel Oil in Table 5.2-28 from Intertek and confirmed the low heating value estimate of 45.56 MJ/kg (10,800 kcal/kg). The fuel cost of diesel oil by a Kina basis is estimated to be 2.62/liter.

Table 5.2-28 Test Analysis of Diesel Oil

Intertek

CERTIFICATE OF QUALITY
LNS01289

Client's Name:	**InterOil Products Ltd**	Sample No.:	**NS13/03172**
Vessel's Name:	**GUNES K**	Client Reference No.:	**GUN 031**
Terminal:	**InterOil Refinery**	Job No.:	**IPNG-13-212**
Product:	**DIESEL**	Date Sampled:	**14/11/2013-1110H**
Source:	**T723** Batch No.: **B# 66**	Date Received:	**14/11/2013-1130H**
Type of Sample:	**UML Composite**	Date Tested:	**14-15/11/2013**
Container:	**3 x 1L Glass Bottle**	Date Reported:	**15/11/2013**
Remarks:	**Before Loading**		

Page 1 of 1

The above sample was tested and the following results were obtained:

Test	Test Method	Unit	Min	Max	Result
Appearance	Visual/ASTM D4176 (P1)	-	C&B		C&B
Colour, ASTM	ASTM D1500	Scale		2	L2.0
Acid Number, Strong	ASTM D664	mg KOH/g		Nil	Nil
Acid Number, Total	ASTM D664	mg KOH/g		0.25	0.02
Ash	ASTM D482	mass %		0.01	<0.001
Carbon Residue	ASTM D4530	mass %		0.20	<0.01
Cetane Index, Calculated	ASTM D4737		45		45.7
Cloud Point	ASTM D5773_ ASTM D2500 Equivalent	°C		+14	+6
Pour Point	ASTM D97 Note 4	°C		+12	0
Copper Corrosion, 3 Hrs @ 100 Deg C	ASTM D130	Grade		1	1a
Density @ 15 Deg C	ASTM D4052	kg/L	0.8200	0.8700	0.8665
Distillation:	ASTM D86				
90% Recovered	ASTM D86	°C		370.0	356.6
Flash Point, PMCC	ASTM D93	°C	61.5		63.5
Oxidation Stability	ASTM D2274 Note 2	mg/L		25	-
Sulphur	ASTM D4294	mass %		0.05	0.0311
Water by Distillation	ASTM D95	vol %		0.05	<0.1
Sediment by Extraction	ASTM D473	Wt %		0.01	<0.01
Aromatics	IP 391 Note 2	mass %		35	-
Kinematic Viscosity @ 40 Deg C	ASTM D445	mm²/s	1.900	5.000	2.818
Lubricity, (WS 1,4) @ 60°C	IP 450 Note 1	microns		460	366
Electrical Conductivity at Ambient Temp.	ASTM D2624	pS/m	50		560
Hydrogen Sulphide	IP 570 Note 3	mg/kg		2.00	<0.60

Notes:
[1] Not included in the scope of NATA Accreditation
[2] Tested every tenth batch of tank preparation only
[3] Frequency test from **Report No**: 2013-MIS-033368-001 **Date**:28 June 2013 **Lab**: Singapore Universal Lab

***For:* ITS PNG Ltd.**

FAITH ORILLAZA
Laboratory Supervisor

NATA ACCREDITATION

This document is issued in accordance with NATA's accreditation requirements. Accredited for compliance with ISO/IEC 17025. NATA accredited laboratory 532. This report must not be reproduced except in full.

This report relates specifically to the sample tested as received. All tests have been performed using the latest revision of the methods indicated, unless specifically noted otherwise on the report. Precision parameters apply in the determination of the above results. Users of the data shown on this report should refer to the latest published revisions of ASTM D-3244; IP 367; ISO 4259 and Appendix E of IP Standard Methods for Analysis and Testing for when utilising the test data to determine conformance with any specification, legislative or process requirement.

5.2.2 Diesel Engine Generation Facilities Plan

The following table lists subjects and countermeasures (recommendations) for thermal power generation facilities in the Short Term (2015~2019), Middle Term (2020~2024) and Long Term (2025~2030).

Table 5.2-29 16-Year (2015~2030) Subjects and Countermeasures

Period	Subjects	Countermeasures (Recommendations)
Short-term 2015~2019	If demand from the Mine increases, there will be a shortage of power supply capacity to meet the demand.	Since this is a problem to be faced in a year or two, measures should be taken promptly. - 5-Year (2015-2019) - Rehabilitation works and Replacement of the existing Diesel Engine & Generator - Renewal of the contract for the existing leased Diesel Engine & Generator. - Installation of a Small-Scale GT facility - Installation (or Lease) of a New Diesel Engine & Generator facility - Construction of full-fledged power generation facilities (replacement or additional installation) will be considered in parallel with the above. - Study on relocation and actual relocation of the Temporary Lae Port GT.
Middle-term 2020~2024	If the hydraulic power station Ramu-2 (180 MW) is not put into operation as scheduled, it will create room in for additional diesel power supply.	- Study on the abolition and actual abolition of the Diesel Engine & Generator and the existing leased Diesel Engine & Generator, both of which are deteriorating with age. - Installation (or Lease) of a New Diesel Engine & Generator facility to replace the Leased Machines.
Long-Term 2025~2030	There will be a shortage of power supply capacity due to further demand increase.	Details on demand and supply facilities should be studied. - Installation of a large-scale GT facility - Reconsideration of a New Diesel Engine & Generator facility

* In 2014 a decision was made at the PPL Directors' Board Meeting to cancel Munum heavy-oil-fired power station project (Daewoo-ROK, Power output: 30 MW, Commissioning: 2015) .

(1) Diesel Engine Generation Facilities Plan:

1) The required capacity of the thermal power generation facilities should be determined when clear data is available on power demand by region, the T/L system capacity, and the amount of thermal power supply. Current plans are as follows in accordance with the installation of New Diesel Engine·Generator (or Lease Machine) for load adjustment operation envisaged in the Short-Term (2015~2019).

● Diesel Engine Generator:

No.	Power Station	Key Objective(s)	Total Out Put	Commissioning
1	Munum (IPP: Daewoo-KOR)	Reliability improvement, Increasing amount of power generation	34MW (8,500kW × 4 Units)	2017
2	Madang (PPL)	Reliability improvement, Stand-By power generation increase	5MW (2,500 × 2 Units)	2016

● Lease Machine;

Lease period of the lease Diesel Engine·Generator (Leaser: Aggreko, Contractor: Aggreko) installed in Taraka Power Station has expired on 30 June. However, PPL has continued to carry out in the process of updating the contract in July 2016.

- Generator Specifications:

Manufacturer	Number of Units	Capacity (MW)	No.of Transformers	Commissioning
Cummins	12	10,20	2 × 6 MW	2014

● Lease machine installation plan at the time in Nov. 2015 in the Ramu System

No.	Power Station	Leaser	Contractor	Generator Manufact.	Capacity (MW)	No.of Transformers	Leasing Cost (PGK)
1	Madang	Aggreko	Lcs	Cummins	5.10	1×6MW	124,443.50

*Leasing Cost: Generator set+ Cables

2) For the Middle Term (2020~2024), there will be a room for additional thermal supply capacity because Ramu 2 P/S will still not be in operation. If the peak power capacity increases significantly, it will be necessary to install New Diesel Engine & Generator (or Leased Machine) for load adjustments.
   ♦ 2020 ~ 2021: 10 MW (IPP), 2022 ~ 2023: 25 ~ 30(IPP)

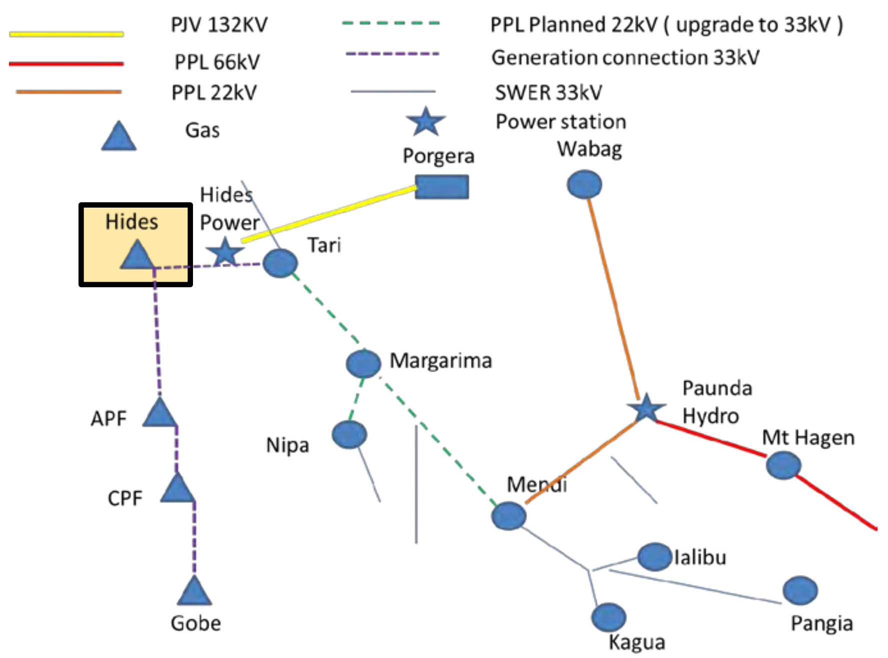
3) For the Long Term (2025~2030), it will be necessary to reconsider Diesel Engine & Generators, for instance, by devising a hydraulic development enhancing program, etc., after the Ramu 2 plan.
   ♦ 2025 ~ 2030: 40 ~ 50 MW (IPP)

* IPP company name and site location to be determined.

5.2.3 Gas Turbine Generation Facilities Plan

(1) GT Project Site:

The Project Site for the GT is located in Hela Province next to the existing Hides Power Plant.
* Location : Hides Gas Field Southern Highland Province (Mend)



(Source: PPL POWER LTD)

Fig. 5.2-7 Highlands Power Project Map

(2) GT Project Overview:

1) Small-Scale Gus Turbine Plant

At Hides, there is a plan in 2015 to install a power plant (IPP: Oil Search) with a capacity of 4 MW (1 MW ×4Units). A year later, in 2016, there is a plan to install a power station with a capacity of 2 MW (1 MW × 2 Units).

As interim for 2017 to 2019 power generation capacity is expected to increase up to 25 MW.

2) Large-Scale Gus Turbine Plant

At Hides, there is a plan to install a power plant (IPP: Oil Search) with a capacity of 65 MW over the period between 2025 and 2030.

3) In the meantime, Temporary Lae Port GT Power Station (26 MW GT Generator) had to be transferred to the Tidal Basin Area, which is located near the main wharf of Lae in two year's time after 2015.

*) The trial operation on February 28, 2015 and the P/S has been put into operation on March 1, 2015.