Republic of Vanuatu
Department of Energy,
Ministry of Climate Change Adaptation,
Meteorology, Geo-Hazards, Energy, Environment
and National Disaster Management

DATA COLLECTION SURVEY ON POWER SECTOR IN ESPIRITU SANTO IN REPUBLIC OF VANUATU

FINAL REPORT

MAY, 2017

Japan International Cooperation Agency (JICA)

Tokyo Electric Power Services Co., Ltd.

(TEPSCO)

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Abbreviations

Abbreviations	Words
ADB	Asian Development Bank
ANRE	Agency for Natural Resources and Energy
CA	Catchment Area
CNO	Coconut Oil
CO_2	Carbon Dioxide
DEPC	Department of Environmental Protection and Conservation
DESPAC	Department of Strategic Policy Planning & Aid Coordination, Office of the Prime Minister
DGMWR	Department of Geology, Mines and Water Resources
DOE	Department of Energy
EIA	Environmental Impact Assessment
FIT	Feed-in Tariff
GDP	Gross Domestic Product
GGGI	Global Green Growth Institute
GNI per capita	Gross National Income per capita
GPOBA	Global Partnership on Output-Based Aid
IPP	Independent Power Producer
IUCN	the International Union for the Conservation of Nature
JICA	Japan International Cooperation Agency
JPY	Japanese Yen
LICs	Low Income Countries
MCCA	Ministry of Climate Change Adaptation, Meteorology, Geo-Hazards, Environment
MOU	Memorandum of Understanding
MSHGG	Middle and Small Hydropower Generation Guidebook
MW	Megawatt
MWh	Megawatt-hour
NAMA	Nationally Appropriate Mitigation Action
NEF	New Energy Foundation
NERM	National Energy Road Map
NSDP	National Sustainable Development Plan
OBA	Output Based Aid
PAA	Priorities & Action Agenda
PEA	Preliminary environmental assessment
PIGGAREP	the Pacific Islands Greenhouse Gas Abatement and Renewable Energy Project
PPA	Power Purchase Agreement
SDP	Strategic Development Plan
SHS	Solar home system
SST	Sea surface temperature
TBD	To be determined
UNDP	United Nations Development Programme
UNELCO	Union Electrique du Vanuatu Limited
URA	Utilities Regulatory Authority
US	United State
USD	US Dollar
VMGD	Vanuatu Meteorological and Geo-Hazards Department

VMS	Vanuatu Meteorology Service
VNSO	Vanuatu National Statics Office
VPMU	Vanuatu Project Management Unit
VREP	Vanuatu Rural Electrification Project
VUI	Vanuatu Utilities and Infrastructure Limited
VUV, VT	Vanuatu Vatu
WB	World Bank
WBG	World Bank Group
kVA	Kilo-volt-ampere
kW	kilowatt
kWh	kilowatt-hour

Chapter 1 Outline of the Survey

1-1 Background of the Survey

The Republic of Vanuatu (hereinafter referred to as "Vanuatu"), with a population of approximately 260,000 people and a total area of approximately 12,000 km^2, is located in the western part of the South Pacific and consists of about 80 islands spreading about 1,200 km north and south. The population of the capital city, Port Vila in Efate Island, and Luganville in Espiritu Santo Island (hereinafter referred to as "Santo") accounts for 20% of the total population in Vanuatu.

According to the Vanuatu National Energy Road Map 2013-2020 (hereinafter referred to as "NERM"), its overall vision is to energize Vanuatu's growth and development through the provision of secure, affordable, widely accessible, high quality, clean energy services for an Educated, Healthy, and Wealthy nation. NERM focuses on the five energy sector priorities: 1) Access - access to secure, reliable and affordable electricity for all citizens by 2030, 2) Petroleum Supply - reliable, secure and affordable petroleum supply throughout Vanuatu, 3) Affordability - a more affordable and low cost of energy services in Vanuatu, 4) Climate Change - an energy secures Vanuatu at all times, and 5) mitigation climate change through renewable energy and energy efficiency. One of concrete targets of “Climate Change” among the above-mentioned priorities is to achieve 40% of renewable energy generation by 2015, 65% by 2020 and 100% by 2030; in spite of the fact that the actual achievement by 2015 was 29% of the renewable energy generation.

Based on the energy plan of the Government of Vanuatu, the Government of Japan implemented a project to construct the Sarakata River Hydroelectric Power Station with two 300 kW turbine generators (combined generating capacity of 600 kW) in 1994 and also another project to install a 600 kW turbine generator at the same hydropower station in 2009 as grant aid projects, which have been main power resources in Espiritu Santo Island, and contributing to a stable power supply in the area. However, a part of power demand in the island is still covered by diesel power generation to meet the peak demand in the day time. Under such circumstances, the Government of Vanuatu has made a request to the Government of Japan for a grant aid project for enhancement of power supply by renewable energy in Espiritu Santo Island, in order to reduce electricity tariff through reducing reliance on imported fuel and to contribute to climate change countermeasures, based on NERM. The requests are diverse requests including introduction of renewable energy, enhancement of existing hydropower stations, improvement of energy efficiency, development of energy management system and so forth. In the subsequent discussions between the Government of Vanuatu and JICA, it has been confirmed that the Government of Vanuatu has strongly requested support especially for the enhancement of hydropower generation facilities. In addition, the promising potential of hydropower generation facilities were pointed out in "the data collection survey on measures to improve power sector security in the power sectors in the Pacific region" conducted in 2015.

Based on the above circumstances, there is a need to collect and analyze basic information related to the current situation and challenges for power sector in the Republic of Vanuatu, especially in Espiritu Santo, in order to confirm necessity, urgency, and relevancy for possible Japanese assistance to the power sector project.

1-2 Outline of the Survey

1-2-1 Purpose of the Survey

The purpose of the Data Collection Survey on Electric Power Sector in Espiritu Santo Island (hereinafter referred to as "the Survey") is to collect and analyze basic information related to the current situation and challenges for power sector in the Republic of Vanuatu, especially in Espiritu Santo, in order to confirm necessity, urgency, and relevancy for possible Japanese assistance to the power sector project based on the request from the Republic of Vanuatu.

1-2-2 Target Areas of the Survey

Espiritu Santo Island, Vanuatu (Regarding to the collection of basic information on the power sector, the whole of Vanuatu shall be covered.)

Figure 1-2-1 Location of Vanuatu

1-2-3 Main Interviewees

The main interviewees in Vanuatu are shown below.

Table 1-2-1 Main Interviewees

Organization	Interviewee
Ministry of Climate Change Adaptation, Meteorology, Geo-Hazards, Environment (MCCA)	Mr. Jesse Benjamin, Director General
Department of Energy (DOE), Ministry of Climate Change Adaption, Meteorology, Geo-Hazards, Environment (MCCA)	Mr. Antony Garae, Director Mr. Christopher Simelum, Principal Scientific Officer
Department of Strategic Policy Planning & Aid Coordination, Office of the Prime Minister	Mr. Charlie Namaka, Senior Policy Analyst Infrastructure & Energy
Ministry of Internal Affairs	Mr. Nebcevanhas Benjamin Shing, Acting Director General
Department of Industry	Mr. Noel Kalo, Acting Director
Utilities Regulatory Authority (URA)	Mr. Maureen Malas, Project Manager Ms. Nitya Nitesh Nand, Economic Specialist M. Didier Joel, Community Consultation
Department of Lands, Ministry of Lands and Natural Resources	Mr. Jimmy PIERRE, Acquiring Officer
Department of Environmental Protection and Conservation (DEPC), Ministry for Climate Change Adaptation, Meteorology, Geo-Hazards, Environment, Energy and Disaster Management (MCCA)	Ms Naomay Tor, EIA Officer Mr. Anaclet Philip, Sanma Environment and Extension Officer
Department of Geology, Mines and Water Resources(DGMWR), Ministry of Lands and Natural Resources	Mr. Morris Stephen, Water Technician Mr. Erie Sammy, Water Quality Officer
Vanuatu Meteorological and Geo-Hazards Department (VMGD), Ministry for Climate Change Adaptation, Meteorology, Geo-Hazards, Environment, Energy and Disaster Management (MCCA)	Ms. Melinda Natapei, Climatologist and the acting Principal Scientific Officer Mr. Peter Feke, Weather Observer
Vanuatu Project Management Unit(VPMU)	Mr. Arthur V. Faerua, National Resettlement Specialist
Joint ADB/WBG Vanuatu Liaison Office	Ms. Nancy Wells, Development Coordinator
Sanma Provincial Government Council	Mr. Prosper Buletare, Senior Planner Ms. Kehana Andrew, Product Development Officer, Sanma Provincial Government Council, Department of Tourism
Luganville Municipality	Mr. Clifton Rau, Town Clerk Luganville Town

Public Works Sanma Province Office, Ministry of Infrastructure and Utilities	Mr. McCarthney Aga, Principal Engineer – Water Supply (belongs to Public Works Department: PWD)
Sanma Branch Office of Department of Lands	Ms. Quen Wells, Enforcement officer
Santo Tourist Information Center	Ms. Samantha Moody, Marketing & Communications Officer
Vanuatu Utilities and Infrastructure Limited (VUI)	Mr. Peter J. Allen, General Manager Mr. Rodolfo R. Fernandez JR., Operations Supervisor Mr. Wallace Smith, Supervisor
JICA Fiji Office	Mr. Shunichiro Ikeda, Assistant Resident Representative, Mr. Katsuhiko Ohara, Project Formulation Advisor for Regional Infrastructure
JICA Vanuatu Office	Mr. Toyoaki Itsubo, Resident Representative Ms. Yoko Asano, Assistant Representative

1-3 Team and Schedule of the Survey

1-3-1 Team Member

The members of the JICA Survey Team are shown below.

No	Name	Position	Organization
1	Masahiko NAGAI	Team Leader/ Power Development Planning	TEPSCO
2	Takashi KOIZUMI	Hydropower Civil Engineering	TEPSCO
3	Hisanobu KUROKI	Hydropower Electrical Engineering	TEPSCO
4	Noriko MORIYA	Environmental & Social Consideration	TEPSCO

1-3-2 Schedule of the Survey

The Survey Team conducted the First Works in Vanuatu for 23 days from November 26th and the Second Works in Vanuatu for 22 days from January 29th as shown in Table 1-3-1 and 1-3-2 respectively.

Table 1-3-1 Actual Schedule for the First Works in Vanuatu

Date & Day 2016			Team Member: Team Leader/ Power Development Planning **Masahiko NAGAI**	Hydropower Civil Engineering **Takashi KOIZUMI**	Hydropower Electrical Engineering **Hisanobu KUROKI**	Environmental & Social Consideration **Noriko MORIYA**
1	26-Nov	Sat	Leave Japan for Vanuatu (QF26 Haneda 22:00 - Sydney 9:35)			
2	27-Nov	Sun	Leave Sydney for Port Vila (NF11 Sydney 11:55 - Port Vila 15:10)			
3	28-Nov	Mon	AM: Meeting with JICA Vanuatu Office and DSPPAC PM: Meeting with MCCA and URA			
4	29-Nov	Tue	Move to Luganville (NF210 Port Vila 9:40 - Luganville 10:30) AM: Site visit to Isolate diesel power plant in Port-Olry PM: Visit to health center in Port-Olry and Diesel power station in Luganville		Data collection in Port Vila and preparation for request for quotation for Social Environmental Survey	
5	30-Nov	Wed	AM: Meeting with VUI and visit to Sarakata River Hydropower Station PM: Reconnaissance to hydropower potential site area		Data collection in Port Vila and preparation for request for quotation for Social Environmental Survey	
6	1-Dec	Thu	Move to Port Vila (NF211 Luganville 11:10 - Port Vila 12:00) PM: Meeting with JICA Vanuatu Office	Reconnaissance to hydropower potential site area	PM: Meeting with JICA Vanuatu Office	
7	2-Dec	Fri	AM: Meeting with Ministry of Internal Affairs PM: Meeting with GM of VUI and Report to JICA Vanuatu	Data collection from VUI in Luganville	AM: Data collection in Port Vila PM: Report to JICA Vanuatu	
8	3-Dec	Sat	Move to Luganville (NF210 Port Vila 7:30 - Luganville 8:20)		Move to Luganville (NF210 Port Vila 7:30 - Luganville 8:20)	
			Visit to target area (Turtle bay - Hog Harbour - Port-Olry) for grid extension program			
9	4-Dec	Sun	Data arrangement			
10	5-Dec	Mon	AM: Meeting with VUI PM: Visit to Diesel power station / Sub-station in Luganville and observation of distribution line conditions Visit to Provincial office of Vanuatu National Statistics Office (VNSO)			
11	6-Dec	Tue	AM&PM: Visit to potential hydropower plant sites downstream of existing Sarakata hydropower plant			
12	7-Dec	Wed	AM: Visit to outside of Luganville concession area PM: Visit to Sanma Provincial Office			
13	8-Dec	Thu	AM: Visit to Sarakata Hydropower Plant PM: Visit to Nambel Village, where a rainfall gauge has been installed			Visit to Provincial office of Vanuatu National Statistics Office (VNSO)
14	9-Dec	Fri	Meeting with VUI			
15	10-Dec	Sat	Data arrangement			
16	11-Dec	Sun	Move to Port Vila (NF211 Luganville 8:55 - Port Vila 9:45)			
17	12-Dec	Mon	Visit to Department of Energy (DOE)			
18	13-Dec	Tue	Meeting with DOE			
19	14-Dec	Wed	AM: Data arrangement	Meeting with Department of Water		Preparation for sub-contract
			PM: Meeting with ADB coordinator in Joint ADB/WBG Vanuatu Liaison Office			
20	15-Dec	Thu	Am: Signing of sub-contract	Meeting with Department of Water		Signing of sub-contract
			PM: Meeting with Ministry of Industry and Report to JICA			
21	16-Dec	Fri	Meeting with DOE Report to JICA Vanuatu office			
22	17-Dec	Sat	Leave Port Vila for Sydney (NF10 Port Vila 15:20 - Sydney 19:15) Leave Sydney for Haneda (QF25 Sydney 21:35 - Haneda 05:00)			
23	18-Dec	Sun	Arrive at Haneda (05:00)			
Total Days			23	23	23	23

Table 1-3-2 Actual Schedule for the Second Works in Vanuatu

Date & Day 2017			Team Member			
			Team Leader/ Power Development Planning	Hydropower Civil Engineering	Hydropower Electrical Engineering	Environmental & Social Consideration
			Masahiko NAGAI	**Takashi KOIZUMI**	**Hisanobu KUROKI**	**Noriko MORIYA**
1	29-Jan	Sun	Leave Japan for Sydney (QF026 Haneda 22:00 - Sydney 9:35)			
2	30-Jan	Mon	Leave Sydney for Nadi (FJ910 Sydney 14:15 - Nadi 19:10)			
3	31-Jan	Tue	Leave Nadi for Suva (FJ007 Nadi 7:30 - Suva 8:00) 12:00 Meeting with JICA Fiji Office Leave Suva for Nadi (FJ018 Suva 17:30 - Nadi 18:00)			
4	1-Feb	Wed	Leave Nadi for Port Vila (FJ263 Nadi 7:30 - Port Vila 9:05) P.M.: Meeting with JICA Vanuatu Office and DOE			
5	2-Feb	Thu	Meeting coordination with DOE			
6	3-Feb	Fri	A.M.: Meeting with DEPC and Department of Water P.M.: Meeting with Local consultants on social environmental matter			
7	4-Feb	Sat	Move to Luganville (NF210 Port Vila 7:30 - Luganville 8:20)			
8	5-Feb	Sun	Visit to Wind Observing Tower in Port Olry and Turtle Bay Lodge Santo			
9	6-Feb	Mon	A.M.: Meeting with VUI, Sanma Branch Office of Department Lands, and Santo Travel Information Centre P.M.: Meeting with Sanma Provincial Government Council and visit existing solar power facilityin the office of Sanma Provincial Government Council			
10	7-Feb	Tue	A.M.: Visit to Sarakata Hydropower Station and potential hydropower plant sites downstream of existing Sarakata hydropower plant P.M.: Visit to Fanafo village			
11	8-Feb	Wed	A.M.: Visit to potential hydropower plant sites on the left bank of existing Sarakata hydropower plant P.M.: Meeting with Sanma DEPC Officer on natural environmental situation in and around the hydro potential sites.			
12	9-Feb	Thu	A.M.: Meeting with Luganville MunicipalityOffice, and a companyoperating factories in Santo, and visit existing solar power facilities in a college and a hospital. P.M.: Meeting with Department of Tourism, Sanma Provincial Government Council and Department of Public Works.			
13	10-Feb	Fri	A.M.: Meeting with Sanma Branch Office of Department Lands, and Visit to Diesel Power Station of VUI P.M.: Meeting with DOE			
14	11-Feb	Sat	Data arrangement			
15	12-Feb	Sun	Move to Port Vila (NF211 Luganville 9:00 - Port Vila 9:50)			
16	13-Feb	Mon	Meeting with DOE			
17	14-Feb	Tue	A.M.: Meeting with Local consultant, VPMU, and GGGI P.M.: Ministry of Lands, Meteorological Service and DOE			
18	15-Feb	Wed	A.M.: Meeting with URA P.M.: Meeting with Meteorological Service and DOE			
19	16-Feb	Thu	Meeting with Australia			
20	17-Feb	Fri	A.M.: Meeting with DOE P.M.: Meeting with JICA Vanuatu Office			
21	18-Feb	Sat	Leave Port Vila for Sydney(NF 10 Port Vila 15 :20 - Sydney 19 :15) Leave Sydney for Haneda (QF 25 Sydney 21:35 - Haneda 05 :00)			
22	19-Feb	Sun	Arrive at Haneda (05:00)			
Total Days			22	22	22	22

Chapter 2 Overview of Vanuatu

2-1 Social and Economic Situation

2-1-1 Politics

The Republic of Vanuatu is a parliamentary democracy with a written constitution, which declares that the "head of the Republic shall be known as the President and shall symbolize the unity of the nation." The powers of the President of Vanuatu, who is elected for a five-year term by a two-thirds majority of an electoral college, are primarily ceremonial. Baldwin Jacobson Lonsdale has served as the President of Vanuatu since 22nd September 2014

The Prime Minister, who is the head of government, is elected by a majority vote of a three-quarters quorum of the Parliament. The Prime Minister, in turn, appoints the Council of Ministers, whose numbers may not exceed a quarter of the numbers of parliamentary representatives. The Prime Minister and the Council of Ministers constitute the executive government. The current prime minister is Hon. Charlot SALWAI Tabimasmas, who was inaugurated in February 2016. So far ten people have served as the Prime Minister of Vanuatu, some on multiple occasions.

The Parliament of Vanuatu is unicameral and has 52 members, who are elected by popular vote every four years unless earlier dissolved by a majority vote of a three-quarters quorum or by a directive from the President on the advice of the Prime Minister. The national Council of Chiefs, called the Malvatu Mauri and elected by district councils of chiefs, advises the government on all matters concerning ni-Vanuatu culture and language.

Besides national authorities and figures, Vanuatu also has high-placed people at the village level. Chiefs continue to be the leading figures at the village level.

2-1-2 Economic Situation

The main industry of Vanuatu is service industry including tourism industry and agriculture. Approximately 75% of the population is engaged in agriculture. Besides cultivation of agricultural crops such as taro and yam, agricultural crops for export are also actively produced. As shown in Table 2-1-1, copra, coconut oil, kava, beef and cacao are the top export items in recent years.

Under the government's policy for national development, the tourism industry has been in good shape since 2003, and the number of tourists has been increasing year by year as the number of flights and cruise ships increases. There are many tourist attractions aimed at folk culture such as intangible World Heritage sand painting, scuba diving, volcano tour, etc. The tourist industry has been one of important sources for foreign exchange.

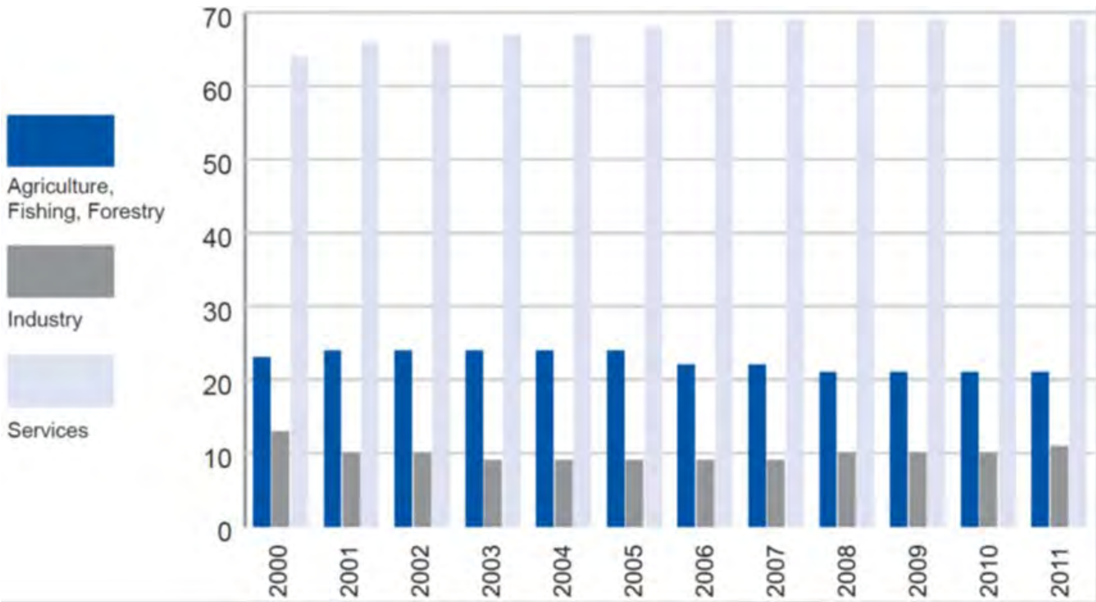
According to the Trade Policy Framework 2012 issued by the Government of Vanuatu, contributions by “Agriculture, Fishing and Forestry”, “Industry” and “Services” to national GDP (Gross Domestic Product) from 2000 to 2011 are 20%, 11% and 69% on average, respectively. Figure 2-1-1 shows the composition of GDP.

Table 2-1-1 Principal Domestic Exports, (FOB)

(Unit: million vatu)

Commodities	2010	2011	2012	2013	2014
Copra	579	1065	1088	367	1485
Coconut Oil	933	1592	1162	459	1081
Kava	508	762	661	834	807
Beef	494	516	518	326	441
Cocoa	384	247	258	294	454
Vanilla	5	5	11	7	4
Coffee	3	18	3	6	28

(Source : 2014 Statistics Pocket book, Vanuatu National Statistics Office)



(Source : Vanuatu Trade Policy Framework 2012)

Figure 2-1-1 Composition of GDP

Trends in GDP and GDP growth rate of Vanuatu in the last decade are as shown in Figure 2-1-2. Although a high growth rate exceeding 8% was recorded in 2006, the growth rates of the years from 2010 to 2014 had declined to about 2% due to the Global Financial Crisis (2007-2008). In 2015, Vanuatu was heavily damaged by the largest ever cyclone "Pam" landed in the country, and its economic growth slowed down with a negative growth of 0.8%.

Vanuatu is classified as a LDC (Least Developed Countries). Since the Gross National Income per capita (GNI per capita) in 2014 is USD 3,170 (World Bank Atlas base in 2014), Vanuatu is classified as a country of Lower Middle Income Countries (LMICs) in the World Bank classification.

(Source : The JICA Survey Team prepared based on World Bank web site data)

Figure 2-1-2 GDP and GDP Growth Rate

Vanuatu has experienced deficit in the balance on trade as shown in Table 2-1-2. The balances of trade in goods have been in deficit, while the balances of services have steadily been increasing with surplus.

Table 2-1-2 Vanuatu's Trade Performance

(unit: Milion VT)

	2002	2003	2004	2005	2006	2007	2008	2009	2010
Balance on Trade in Goods	**-8,117**	**-7,949**	**-8,398**	**-10,215**	**-11,459**	**-14,993**	**-22,641**	**-20,482**	**-18,583**
Exports	2,793	3,249	4,264	4,166	4,166	3,040	4,230	5,887	4,947
Imports	10,910	11,198	12,662	14,381	15,625	18,033	26,871	26,369	23,530
Balance on Trade in Services	**5,342**	**5,741**	**6,282**	**6,941**	**8,055**	**11,633**	**12,342**	**14,622**	**14,506**
Services credit	12,707	13,664	14,226	16,094	17,435	20,910	23,594	26,094	26,743
Service debit	7,365	7,923	7,944	9,152	9,380	9,277	11,252	11,472	12,237

(Source : Vanuatu Trade Policy Framework 2012)

Vanuatu's recent efforts for boosting tourism resulted in an increasing number of tourists to Vanuatu, which is about twice as much as the number 20 years ago, and the number of tourists in 2014 reached 109,000. Many of the tourists are from Australia, New Caledonia, and New Zealand. The tourism industry continues to contribute to the national economy. With the increase in the number of tourists, the tourism receipt also has increased two-fold in twenty years, and it recorded 207 million US dollars in 2013, which is actually 80% of the total export value and 36% of GDP. Figure 2-1-3 shows the trends in the number of tourist arrivals from foreign countries and Figure 2-1-4 shows the trends in tourism receipt.

(Source : JICA Survey Team prepared based on World bank web site data)

Figure 2-1-3 Number of Tourist Arrivals

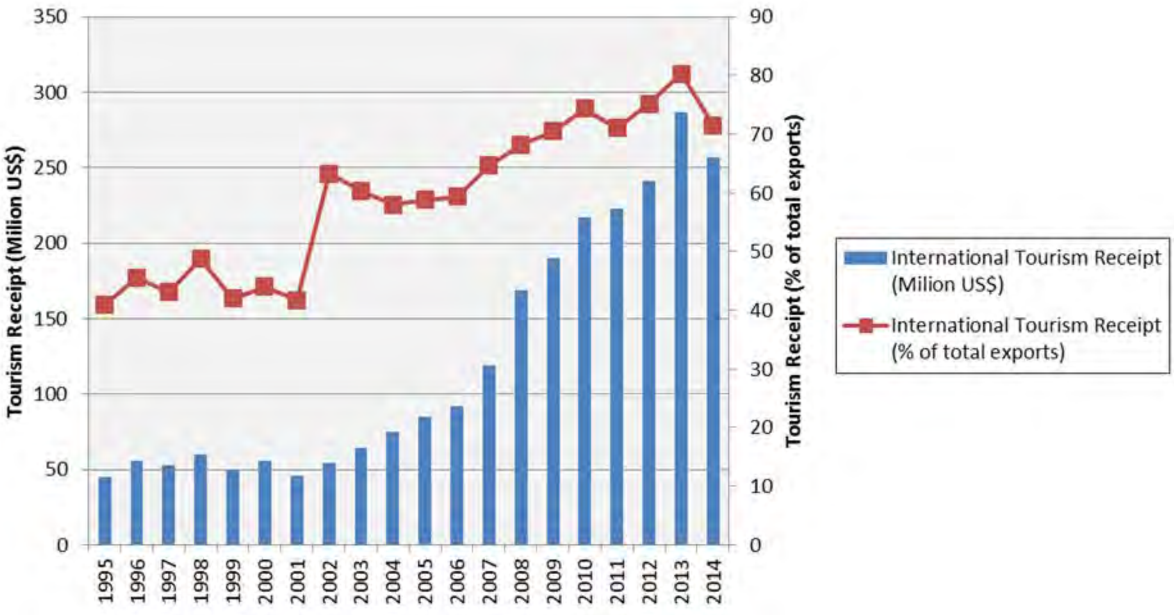


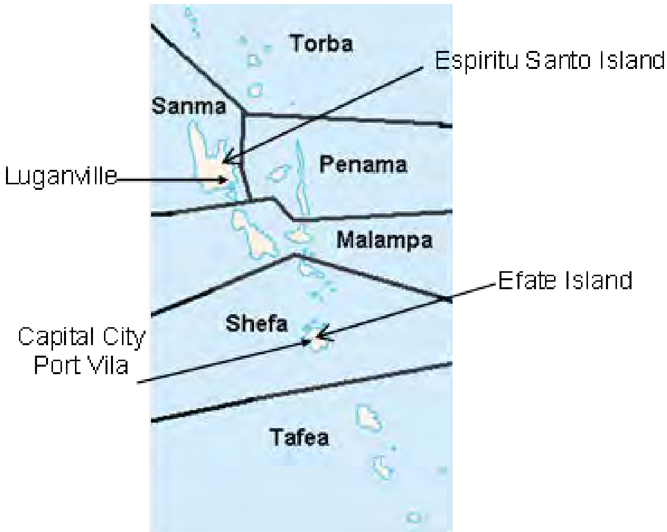
Figure 2-1-4 Tourism Receipt

2-1-3 Social Situation

Vanuatu has a population of about 260,000 people (World Bank data 2015). About 99% of the population is Melanesian, and the remaining 1% consists of immigrants such as European. Regarding the population distribution, although population inflows into urban areas are progressing gradually, about 74% of the total population lives in rural areas including remote islands. Approximately 75% of the population is engaged in agriculture, but the share of agricultural GDP is only about 20%, and revenues from service industry make up 70% of GDP.

Many people in the country continue living in accordance with traditional living standards. Since ceremonies, customs and social systems vary significantly from island to island or from region to region, more than 100 local languages are used even today. Bislama is used as the national language of Vanuatu to communicate among tribes. Since the colonial policy by co-governance between England and France continued before 1980's independence, Bislama, English and French have been the official languages of Vanuatu. In religion, Christianity accounts for about 90% of the population, while in remote islands there are many areas where traditional religion is practiced.

The administrative division of Vanuatu has been divided into six provinces since 1994 as shown in Figure 2-1-5. The provinces are divided into the Area Councils and the Municipality. Table 2-1-3 shows the population and land areas of each province.



(source：Wikipedia web site)

Figure 2-1-5 Provinces of Vanuatu

The latest census was implemented in 2009. According to the 2009 census, Santo, that is covered by the Survey and belongs to Sanma province, is the largest island in the nation of Vanuatu with a population of 39,601 which is 86.4% of that in Sanma Province and 16.9% of the total population of Vanuatu and a household number of 7,922 which is 85.4% of that in Sanma Province and 16.6% of the total number of households in the country. The population of Santo is the second largest after the Efate Island where the capital city, Port Vila, is located. (Source: 2009 Census Basic Tables Report, Vanuatu National Statistics Office: VNSO)

Table 2-1-3 Population and Land Area of Provinces (2009 Census)

Urban/Rural Province	Main Islands	Polulation			Land Area	
		number	% of total	growth rate (%)	km^2	%
Total	-	234,023	100.0	2.3	12,281.25	100.0
Urban	-	57,195	24.4	3.5	-	-
Rural	-	176,828	75.6	1.9	-	-
Torba	Torres Islands Banks Islands	9,359	4.0	1.9	867.33	7.1
Sanma	Espiritu Santo Malo	45,855	19.6	2.4	4,262.06	34.7
Penama	Pentecost Ambae Maewo	30,819	13.2	1.5	1,203.92	9.8
Malampa	Malakula Ambrym Paama	36,724	15.7	1.2	2,808.41	22.9
Shefa	Shepherd Islands Efate Epi	78,723	33.6	3.7	1,507.36	12.3
Tafea	Tanna Aniwa Futuna Erromango Anatom	32,540	13.9	1.1	1,632.17	13.3

(Source : The Survey Team prepared based on 2009 National Population and Housing Census, Basic Tables Report Volume 1, VNSO)

2-2 Geography and Climate

2-2-1 Geography

The archipelago of Vanuatu stretches over some 1,300 km lying between latitudes 13°S and 21°S and longitudes 165°E and 170°E. The 83 islands, of which 65 are inhabited, have a total land area of 12,281 km^2. Efate Island, the capital city of Port Vila, is located approximately in the center of the archipelago and has an area of 887 km^2.

Major islands consist of volcanic mountainous terrain, hilly parts with high elevation difference, low ground parts divided by eroded river, and narrow terrace-like flat lands along the coast. Volcanoes in Vanuatu are associated with the subduction zone where the Pacific plate moves under the Australian plate and form a part of the Pacific Rim Volcanic Belt. Strong earthquakes with over 7 magnitude have occurred frequently near the islands.

The largest island is Espiritu Santo with an area of 3,956 km^2, on which the highest mountain in Vanuatu at 1,879 m, Mount Tabwemasana, is located. The biggest town is Port Vila with a population of 44,039 in Efate; the second is Luganville with a population of 13,156 in Espiritu Santo Island. (Source of population: Vanuatu 2009 Census data (VNSO))

2-2-2 Climate

The whole area has a tropical rainforest climate and the characteristics of topical maritime climate. It is under the influence of the southeast trade wind, and the temperature falls from May to October. The highest temperature in the capital Port Vila reaches 25 ℃ in winter and 29 ℃ in summer.

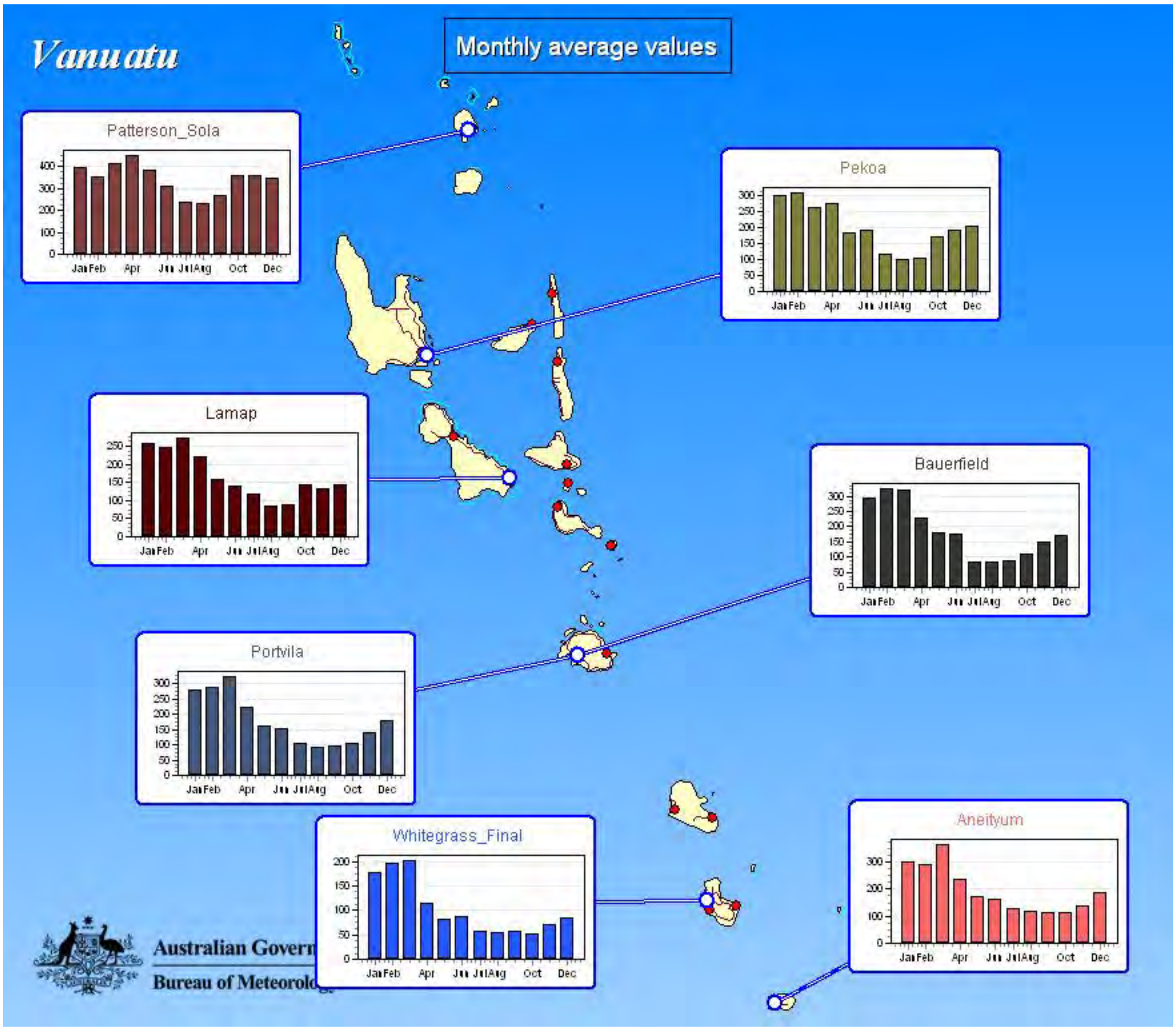
Rainfall is generally higher in summer (from November to April) than in winter (from May to October). Usually, the month with the most rain in Vanuatu is March, while the lowest is August. The average annual rainfall is around 2,300 mm. The average monthly rainfall in each region of Vanuatu is shown in Figure 2-2-1.

The trade wind blowing from the east to the southeast is weak during the summer from November to April, and it gets stronger in the winter from May to October. However, tropical cyclones and low atmospheric pressures with strong winds that bring significant harm to Vanuatu occur in the summer.

The summer season from November to April is also known as a cyclone season. The topographical position of Vanuatu located in the Southwest Pacific is on the passage route of the cyclones. In the past 10 years, Vanuatu has been hit by 20 to 30 cyclones, of which 2 to 3 cyclones caused catastrophic damage. Late on March 13, 2015, the severe tropical Cyclone Pam hit Vanuatu and caused a great deal of damage to the country.

Flooding often occurs with the coming of tropical cyclones. In the year of La Niña, also flooding often occurs in low altitude floodplains close to the rivers. The prolonged rainfall in the year of La Niña often has a great influence on agricultural crops.

Droughts in Vanuatu are linked to El Nino. In El Nino's years, rainfall is generally less than average. In recent years, El Nino got drought in 1982-83, 1990-95, 1997-98 and 2015-26 after Cyclone Pam. The worst drought in Vanuatu occurred in 1993.



(Source：Vanuatu Government, Meteorological Services web site)

Figure 2-2-1　Monthly Average Rainfall

Chapter 3 Power Sector in Vanuatu

3-1 Energy Policy and Overview of Energy Sector

3-1-1 National Sustainable Development Plan 2016 to 2030

National Sustainable Development Plan (NSDP) 2016 to 2030 was issued as the country's highest level policy framework, replacing the Priorities and Action Agenda 2006-2015 (PAA 2006-2015).

The 15 National Sustainable Development Goals provide a prioritized policy framework across the three pillars that are the social, environmental and economic pillars of sustainable development, as shown in Figure 3-1-1.

National Sustainable Development Goals

Society Pillar		Environment Pillar		Economy Pillar	
SOC 1	Vibrant Cultural Identity	ENV 1	Food and Nutrition Security	ECO 1	Stable and Equitable Growth
SOC 2	Quality Education	ENV 2	Blue-Green Economic Growth	ECO 2	Improve Infrastructure
SOC 3	Quality Health Care	ENV 3	Climate e and Disaster Resilience	ECO 3	Strengthen Rural Communities
SOC 4	Social Inclusion	ENV 4	Natural Resource Management	ECO 4	Create Jobs and Business Opportunities
SOC 5	Security, Peace and Justice	ENV 5	Ecosystems and Biodiversity		
SOC 6	Strong and Effective Institutions				

(Source：Vanuatu 2030 National Sustainable Development Plan 2016 to 2030)

Figure 3-1-1 National Sustainable Development Goals

There are two energy-related targets mentioned in the national sustainable development goals as follows. This policy framework clearly shows the goal to promote the use of renewable energy from the environmental and economic viewpoints.

1) EVN 2 Blue-Green Economic Growth:
   ENV 2.3: Promote renewable sources of energy and promote efficient energy use

2) ECO 2 Improve Infrastructure:
   ECO 2.1: Increase access to safe, reliable and affordable modern energy services for all that are increasingly generated from renewable sources and reduce reliance on imported fossil fuels

3-1-2 National Energy Road Map 2016 - 2030

National Energy Road Map (NERM) is the policy framework for developing the energy sector in Vanuatu. National Energy Road Map 2013-2020 (NERM 2013-2020) with goals and action plans targeted for the period until year 2020 was issued in 2013, but it was updated by reflecting recent developments. Updated National Energy Road Map 2016-2030 (Updated NERM 2016-2030) covering the period until year 2030 was issued in 2016. The NERM's overall vision is to energize Vanuatu's growth and development through the provision of secure, affordable, widely accessible, high quality, clean energy services for an educated, healthy, and wealthy nation.

To achieve the NERM's vision, the updated NERM 2016-2030 focuses on five priorities as shown below.

- Accessible energy
- Affordable energy
- Secure and reliable energy
- Sustainable energy, and
- Green growth

Vanuatu is highly dependent on expensive fuel imports, which is a heavy burden on the national economy. For this reason, the use of renewable energy aiming to break away from imported fossil fuel dependence has become one of the major pillars.

In NERM 2013-2020, target values for 2015 and 2020 were set. Updated NERM 2016-203 shows the actual progresses made in 2015 and projected progresses (target values) for 2030 as well as projected progresses (target values) for 2020 as shown in Table 3-1-1. As a specific target of the priority item of "Sustainable energy", the share of renewable energy generation should reach 40% by 2015, which is more than the actual progress of 29%. (See yellow colored portion in Table 3-1-1) However, the target value of 65% for 2020 was not revised down and the ambitious target value of 100% for 2030 was newly set. Even for targets other than the target of the share of renewable energy generation, many of the actual progress values as of 2015 are below the targets. In particular, in Table 3-1-1, as for "Increase electricity access by households in off-grid areas" the target for 2015 is 55%, while the actual progress is only 9%. This very low actual progress value on electricity access reminds of the serious delay of electrification in Vanuatu.

The updated NERM 2016-2030 proposes 68 actions as a concrete action plan to achieve the NERM's objectives. Of these, 22 actions are indicated as the highest priority actions, among which the six (6) actions shown in Table 3-1-2 are projects related to electric power facilities, and the following two projects are located in Santo, which are the target areas of the Survey. (See yellow colored portion in Table 3-1-2)

- Grid Extension, East Coast Santo
- Sarakata Hydro Power Extension Project (600 kW)

Overall, it is estimated that it will cost at least US$250 million between 2016 and 2030 to implement all the actions in the Implementation Plan. These costs will be funded through a mix of Government, donor, private sector, and other funding.

Table 3-1-1 Updated NERM Targets

Priority	Target	Indicator	Current	2020 Target	2030 Target
Accessible energy	Increase electricity access by households in and near concession areas	% of households with access	62% (69%)	75%	100%
	Increase electricity access by households in off-grid areas	% of households with access	9% (55%)	60%	100%
	Increase electricity access by public institutions (on- and off-grid)	% with access	54% (90%)	80%	100%
Affordable energy	Improve the efficiency of diesel generation	Grams of diesel fuel per kWh of electricity	2% improvement from 2010 (248.33 g/kWh) (10%)	20% improvement from 2010 (202.41g/kWh)	20% improvement from 2010 (202.41g/kWh)
	Reduce the cost of distributing petroleum products in Vanuatu	Vatu per litre	No data	10% reduction from 2012	15% reduction from 2012
Sustainable energy	Increase the proportion of electricity generated from renewable sources	% of grid-based electricity from renewable sources	29% (40%)	65%	100%
	Improve electricity sector end-use efficiency	% saving on BAU projection31	n/a	5%	13.50%
	Improve transport (land and marine) energy efficiency	% saving on BAU projection	n/a	2%	10%
	Improve biomass end-use (cooking and drying) efficiency	% saving on BAU projection	n/a	5%	14%
	Ensure all energy infrastructure projects comply with Government and donor environmental and social safeguard requirements32	% of projects complying	n/a	100%	100%
Green growth	Increase the proportion of electricity generated from biofuels	% of electricity generated from biofuels33	5%	10%	14%
	Increase renewable electricity use by rural tourism bungalows	% of bungalows using renewable energy sources for electricity supply	TBD	25%	65%

Note: (%): target set in the NERM 2013-2020)

(Source : Updated Vanuatu National Energy Road Map 2016-2030)

Table 3-1-2 Ongoing and Highest Priority Actions

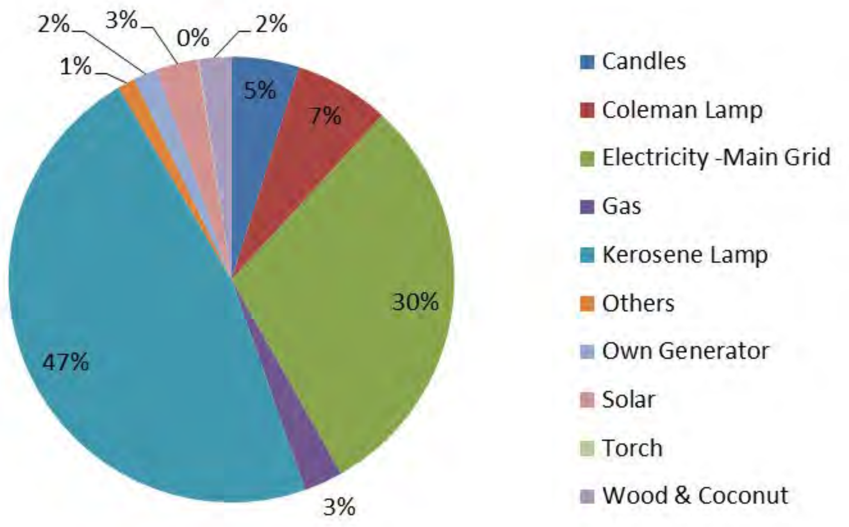
Investment/action	Main outcome(s) it contributes to	Energy subsector(s)	Priority	Status	Funding source
Whitesands Solar PV Micro-grid, Tanna	Access, sustainability, green growth	Electricity	Highest	Proposed	
Efate Grid Connected Solar PV Project (1MW)	Sustainability	Electricity	Highest	Proposed	
Vanuatu Rural Electricity Project (VREP) Phase 2	Access, sustainability, green growth	Electricity	Highest	Proposed	
Grid Extension, East Cost Santo (Matelevu to Shark Bay, Port Olry, Stone Hill and Palekula)	Access	Electricity	Highest	Proposed	
Sarakata Hydro Power Extension Project (600KW), Santo	Access, sustainability, green growth	Electricity	Highest	Proposed	
Brenwe Hydro Power Project (< 1.2MW), Malekula	Access, sustainability, green growth	Electricity	Highest	Proposed	

(Source : Updated Vanuatu National Energy Road Map 2016-2030)

3-1-3 Basic Information on Energy

(1) Primary Energy Sources

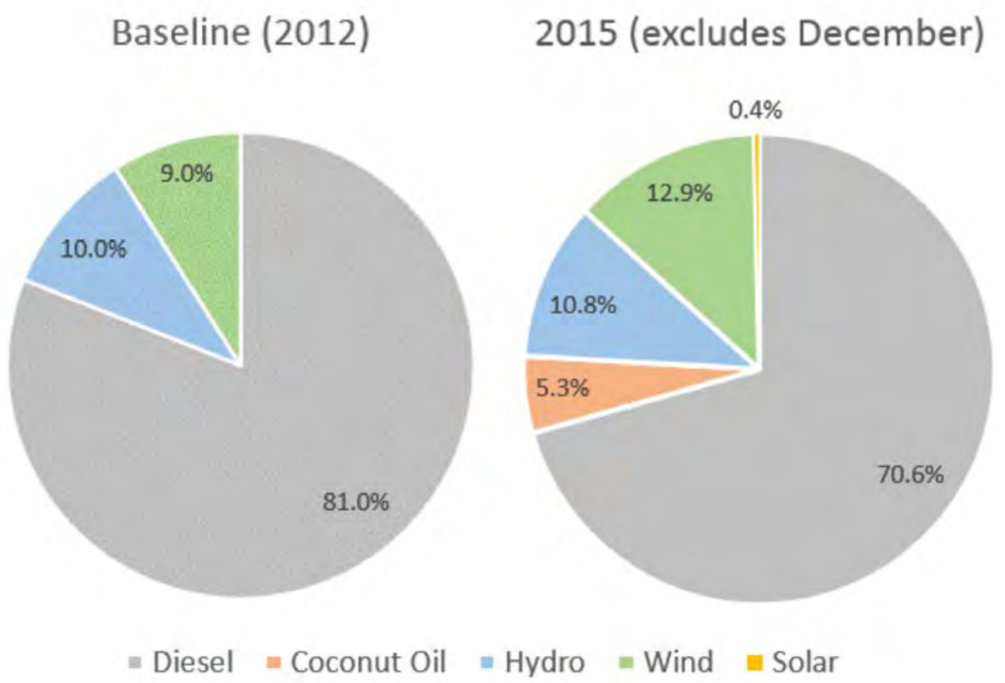
According to the 2009 Census, as shown in Figure 3-1-2, kerosene is most used for lighting in Vanuatu and electricity from main grid is the second. This means that the electrification ratio by electric power grid is relatively low.



(Source : the JICA Survey Team prepared based on Census of Population and Housing 2009, Vanuatu National Statistics Office (VNSO))

Figure 3-1-2 Main Source of Lighting in Vanuatu

Figure 3-1-3 compares the mix of electricity generation in 2012 and 2015. In 2012, 19% of electricity was generated from renewable energy sources, and this proportion increased to approximately 30% in 2015.

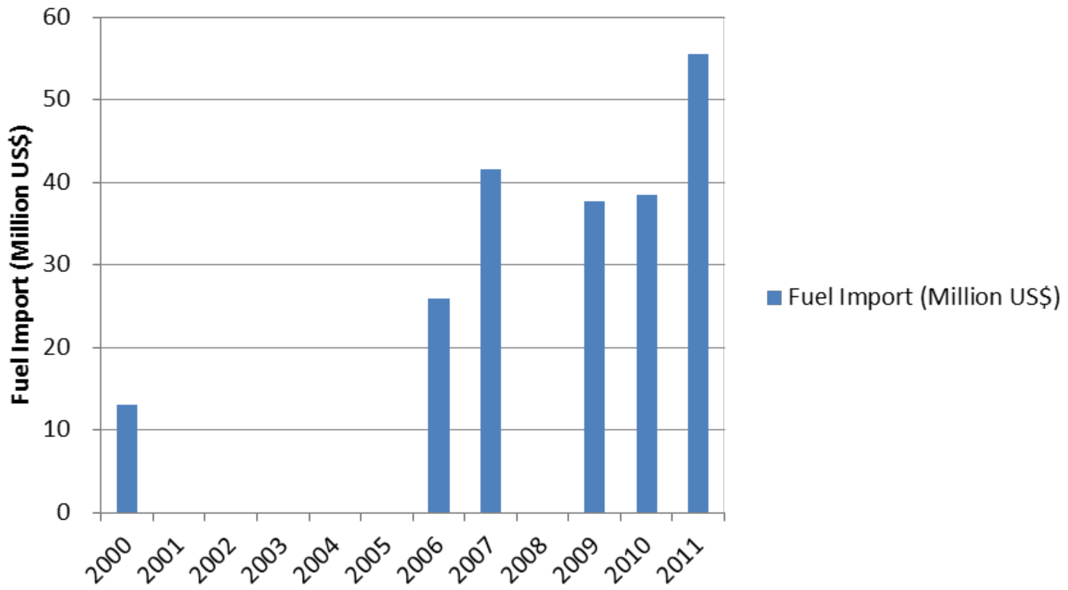


(source : Updated Vanuatu National Energy Road Map 2016-2030)

Figure 3-1-3 Comparison of Electricity Generation Sources in Whole Vanuatu

(2) Imports of Fossil Fuels

Fossil fuels including diesel fuel are dependent on 100% imports. The amount of their imports is steadily increasing year by year as shown in Figure 3-1-4. Such increasing imports of fossil fuels have been leading to a greater burden on Vanuatu's national economy. Therefore, it has been urgent to promote a shift of fossil fuels to renewable energies in terms of a national economy.



(Source : The JICA Survey Team prepared based on World bank data)

Figure 3-1-4 Amounts of Fuel Imports

3-2 Laws and Regulations related to Power Sector

In Vanuatu, there are no state-run/managed organizations supplying electricity, and utilities manage and operate assets that are belongs to the Government. They produce electricity to supply distribution network of their assigned concession. They also maintain the poles and the connections to the homes. There are currently two operators in four concessions, which are Port Vila, Luganville and the other two areas (Malekula Island, Tanna Island). Since the power supply businesses in Vanuatu are implemented in such concession system, the laws and regulations related to power sector have been designed with power supply business in concession system.

- Electricity Supply Act No.13 of 2010
  The basic law of Vanuatu's electricity supply business which is regulating the matters of the generation and supply of electricity in Port Vila, Luganville and other areas in the concession system.

- Utilities Regulatory Authority Act No .11 of 2007
  Since 2007, there has been a Utility Regulatory Authority Act in place, which established a regulatory authority under the Ministry of Finance and Economic Management that is responsible for managing the concession contracts for electricity and water. The Utilities Regulatory Authority (URA) commenced operations on the 11th of February 2008.

- Government Contracts and Tenders Act 1998
  "Government Contracts and Tenders Act 1998" is the law concerning bids by the government and contracts between the government and private operators (concessionaires), which are applied to bids and contracts for concessions.

Electricity supply businesses in Vanuatu are conducted by a concession system, and then the concession contracts between the government and the private power utilities (concessionaires) also include provisions on electricity pricing. Therefore, such concession contracts are one of the important regulations for the electric power sector. The contracts between the government and power utilities for the four concessions are shown in Table 3-2-1.

Table 3-2-1 Concession Contracts/MOU

No.	Name of Concession	Concessionaire	Name of Contract
1	Port Vila	UNELCO	Convention Relating to the Concession for the Generation and Public Supply of Electric Power in Port Vila (15 August 1986)
2	Malekula	UNELCO	Concession Contract for the Generation and Public Supply of Electric Power in Malekula Island (dated 14 July 2000)
3	Tanna	UNELCO	Concession Contract for the Generation and Public Supply of Electric Power in Tanna Island (dated 14 July 2000)
4	Luganville	VUI	Memorandum of Understanding (MOU) between VUI and the Government (signed on18 November 2010)

(source：URA web site)

3-3 Power Sector Structure

3-3-1 Power Supply in Concession System

In Vanuatu, utilities manage and operate assets that belong to the Government. They produce electricity to supply distribution network of their assigned concession. They also maintain the poles and the connections to the homes. There are currently two operators in four concessions: Port Vila, Luganville, Malekula, and Tanna.

Union Electrique du Vanuatu Limited (UNELCO) is a private company and a subsidiary of French GDF Suez. UNELCO has been producing and supplying electricity and water in Vanuatu since 1939. It has concessions on Efate, Malekula and Tanna islands.

In Luganville concession area in Santo, initially UNELCO also had been doing business as the concessionaire, but as a result of bidding for the selection of new concessionaire after 2011, which was implemented in 2010, Vanuatu Utilities and Infrastructure Limited (VUI), that is a subsidiary of US's Pernix Group, Inc., was selected as a new power operator (concessionaire). VUI started operating a concession in Santo on 1 January 2011after signing an O&M agreement with the Government of Vanuatu for the Luganville electricity concession. UNECO, who lost the bid for the concession starting in 2011, filed a lawsuit against the government claiming that the selection process was not transparent. On the back of such matter, the government had not been able to conclude a long-term contract with VUI; the contracted services are performed on the basis of a Memorandum of Understanding (MOU). However, UNELCO's law suit have already been concluded with the court declaring that the previous O&M contract awarded to VUI was NULL and VOID, hence an instruction to go through a re-tender. Based on this court' declaration, the government commenced the re-tender process for the Luganville concession in December 2016, and according to DOE, the new concessionaire is expected to be selected after July 2017.

Table 3-3-1 shows the main technical features of the four concessions and Figure 3-3-1 shows maps of the concessions.

Table 3-3-1 Main Technical Features of Four Concessions

Concession	Port Vila	Luganville	Malekula	Tanna
Customers	11,080		558	875
Peak Demand (kW)	11,162		127	173
Installed Capacity				
Number of Installed Diesel Generation Sets	10	8	4	4
Diesel Capacity (diesel fuel + CNO*) (MW)	26.50		0.50	
Diesel Capacity without CNO* (MW)		2.90		0.50
Hydropower (MW)		1.20		
Wind (MW)	3.02			
On-grid Solar Installed by the Utility (MW)	0.07			0.04
Grid-connected Solar**(MW)		0.04	0.02	
Total Capacity (MW)	29.59	4.14	0.52	0.54
Total (MW)	34.79			
Energy Generation				
Energy Generation (MWh)	59,529	9,044	725	721
Diesel %	72.60	20.36	65.78	95.88
CNO* %	17.73	0.09	29.93	0.00
Hydropower (%)	0.00	79.56	0.00	0.00
Wind (%)	9.51	0.00	0.00	0.00
Solar (%)	0.18	0.09	4.30	4.12

* Coconut oil
** Government of Vanuatu Project

(Source : Vanuatu Renewables Readiness Assessment, International Renewable Energy Agency (IRENA), June 2015)

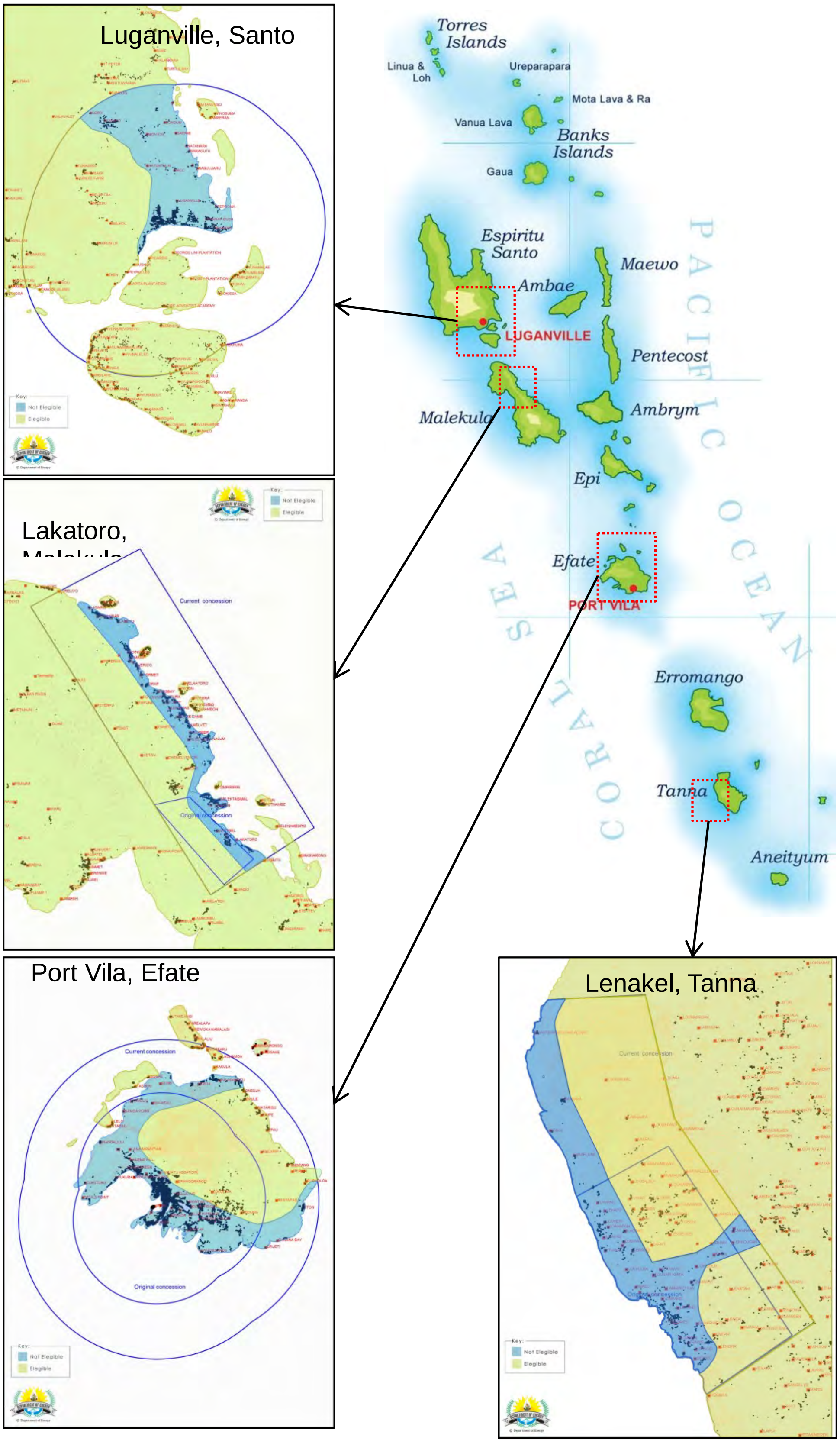
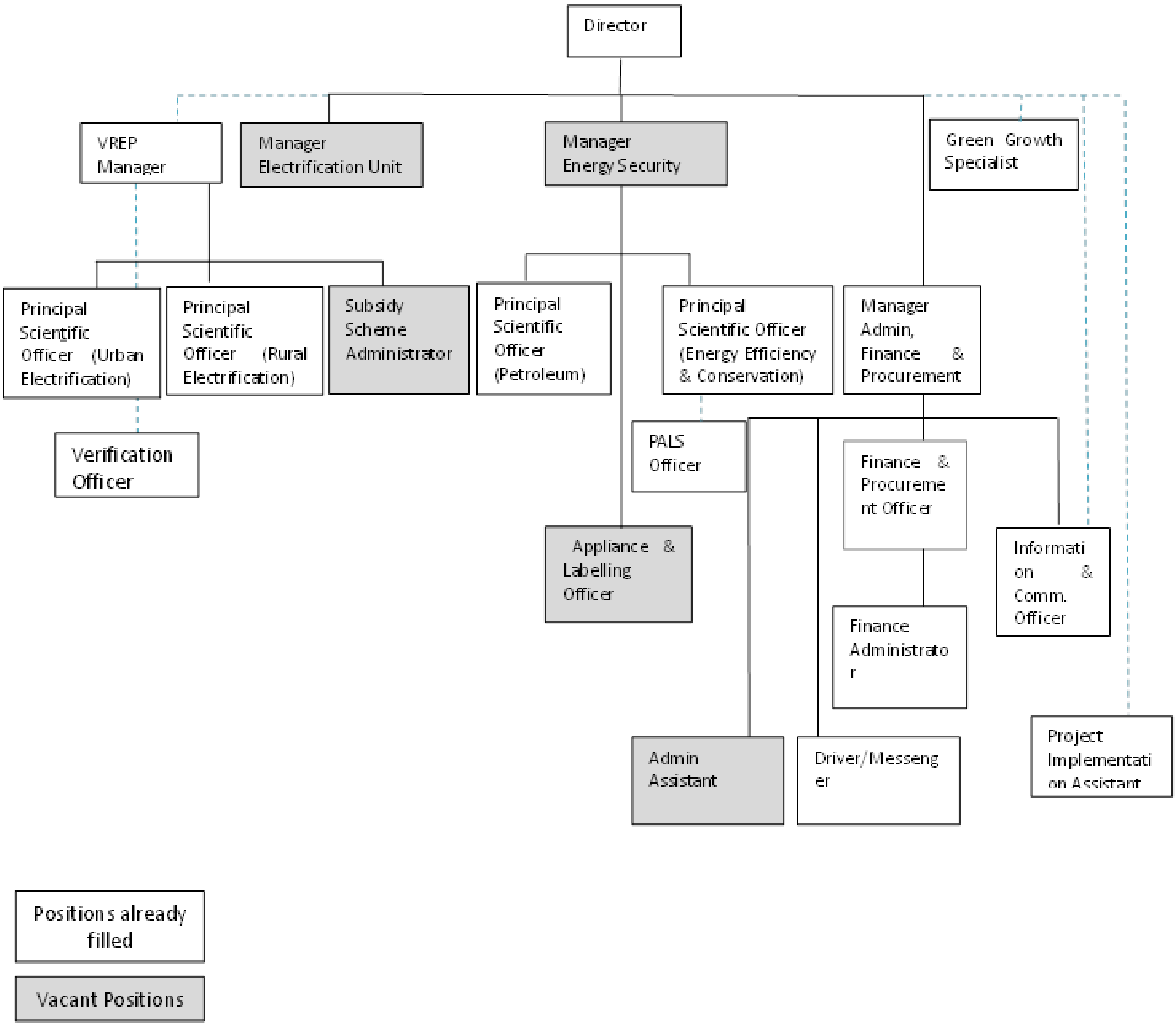


Figure 3-3-1 Maps of Four Concession Areas

3-3-2 Department of Energy

The Department of Energy (DOE) is within the Ministry of Climate Change Adaptation, Meteorology, Geo-hazards, Energy, Environment and National Disaster Management Office. The DOE is responsible for the development of energy policies, legislations and regulations to guide the development of energy services in Vanuatu and improve service delivery. The Department is also responsible for the identification, implementation, management and evaluation of energy projects, monitoring and facilitating energy activities as well as providing awareness and training activities.

The Department consists of 14 permanent staff members as of December 2016 as shown in 3-3-2.



(Source：DOE)

Figure 3-3-2 Organization Chart of Department of Energy (as of December 2016)

3-3-3 Utilities Regulatory Authority (URA)

The Utilities Regulatory Authority (URA) of Vanuatu was established on 11 February 2008 as an independent body as a mediator between the Government and the private utilities under the Utilities Regulatory Act No. 11 of 2007. URA approves tariffs for electricity and water services for private providers under Concessions Contracts and the State-Owned water enterprise. URA also assists in resolving consumer complaints and advises the Government on policy and legislative matters related to electricity and water. URA was created in part to promote the consumers long-term interest and to increase access to safe, reliable and affordable electricity and water services throughout Vanuatu.

In the electricity sector, URA monitors the concessions operated by private utilities in Luganville, Port Vila, Malekula and Tanna islands. URA may also regulate the small utilities operating outside the concession areas.

3-3-4 Independent Power Producers (IPP) and Feed-in Tariff (FIT)

(1) Independent Power Producers (IPP)

As mentioned in section 3-3-1, the electricity market in Vanuatu currently consists of two vertically integrated companies (UNELCO and VUI), which in their respective concession areas carry out all electricity generation, transmission, distribution, supply, and customer services, under the concession contracts with the Government.

In 2010, the Electricity Supply Act was amended to enable any person to generate electricity and sell wholesale electricity to the concessionaires. In June 2014, URA issued preliminary guidelines for Independent Power Producers (IPPs) and Power Purchase Agreements (PPAs), opened them up for public consultation, but there has been no final decision on these guidelines up to now.

(2) Feed-in Tariff (FIT)

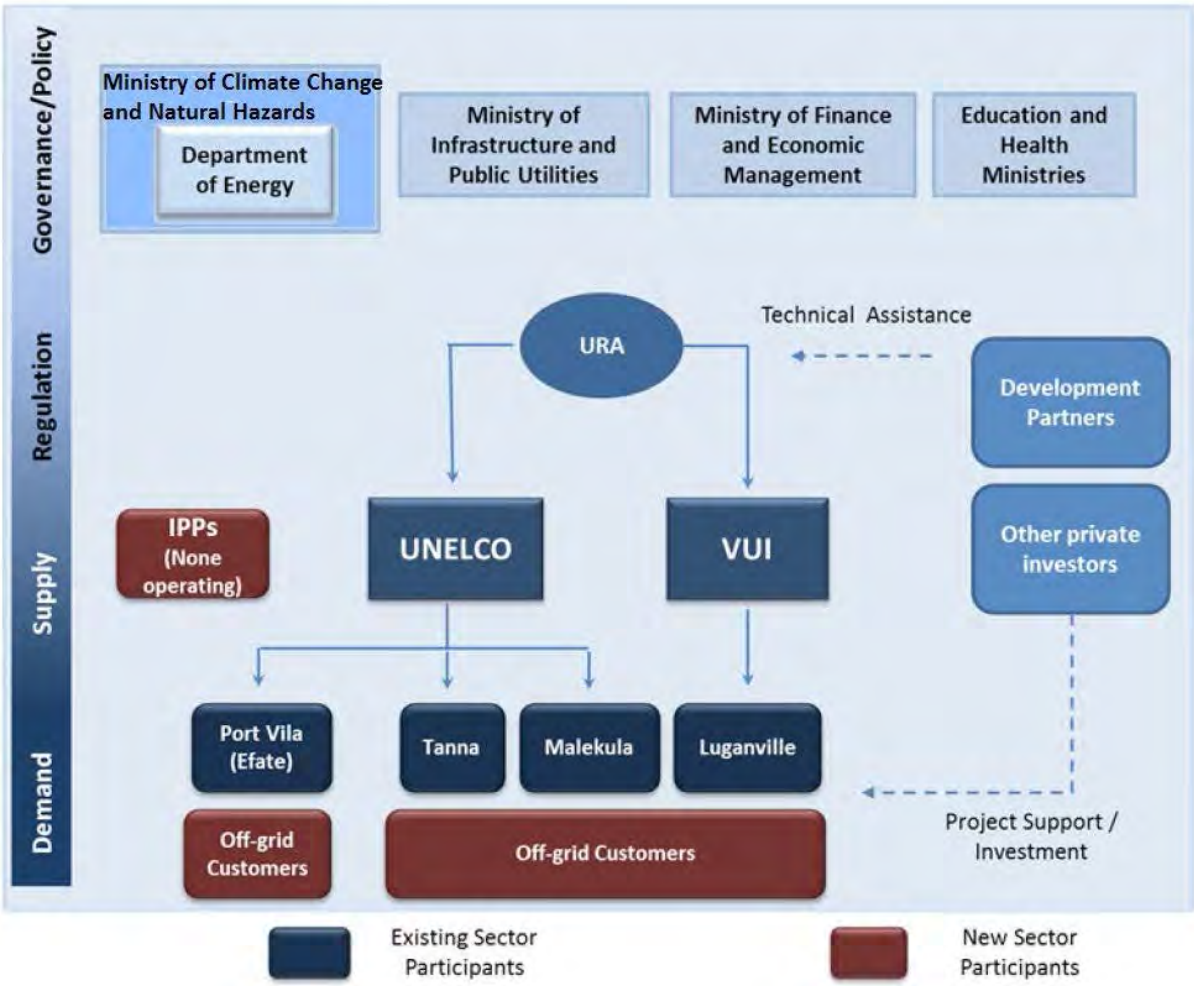
In July 2014, the Utilities Regulatory Authority (URA) Commission issued the Final Decision and Order implementing feed-in and net-metering tariffs for small-scale solar renewable energy for electric customers of UNELCO. (Final Decision and Commission Order, Case U-0002-14, In the matter of investigating and implementing feed-in tariffs and net-metering program for renewable energy in Port Vila, July 2014）

According to URA, this program allows customers to install solar panels to reduce their electricity expenses without constraining their total usage. The benefits of the low cost solar excess energy sent to the network will be shared with all customers, and reduce the dependence on imported diesel fuel.
The program contains limits on the size of individual installations, and also the total installed capacity. A customer may install solar panels equivalent to the subscribed kVA of their current connection, up to 20kWp. The total program is limited to 500kWp, with approximately 50-70 domestic customers, 10 commercial customers, and 3 High voltage customers. No negative bills will be possible so any energy delivered to the grid in excess of usage will result in a zero meter reading and no energy bill, but the excess will be provided to UNELCO without credit or payment.

Unlike feed-in tariff systems adopted in other countries, the feed-in tariff system in Vanuatu is very limited in terms of areas, quantity and amount of money as mentioned above, and does not seem to effectively promote renewable power in the country.

3-3-5 Overview of Energy Sector Stakeholders

The whole structure of Vanuatu's energy sector including stakeholders of the energy sector is expressed in NERM as shown in Figure 3-3-3.



(Source : Vanuatu National Energy Road Map 2013-2020)

Figure 3-3-3 Overview of Energy Sector Stakeholders

3-4 Electricity Tariff System

The electricity pricing structure, including reference price, price adjustment formula, price adjustment timing and tariff structure are set out in concession agreements between the Government and concessionaires. The adjustment formula enables prices to be amended in the period between fundamental tariff reviews, to incorporate changes in input prices, such as for fuel, labor and materials. Conditions for undertaking a full review of tariffs are also set out in the concession agreements, and include factors such as more than five years have passed since the last revision, significant changes in parameters or taxes, or agreement between the parties to modify aspects of the tariff formula or customer classes. UNELCO has three concessions, and the same tariffs are adopted in their concessions.

Tariffs are adjusted as costs change through a factor (P), which is essentially the price per kWh plus a charge based on the power demand subscribed by the user. The factor P represents the tariff cost factor, which provides for varying costs. This factor is updated as costs change.

(1) Tariff Structure for UNELCO

Table 3-4-1 shows tariff structure for UNELO operating three concessions of Port Vila, Malekula and Tanna. The tariff in the UNELCO grid for low usage residential customers is tiered. Up to consumption of 60 kWh per month, consumers pay only one third of P. Households that is consuming more than 120 kWh, pay triple P for each kWh above 120 kWh. This tiered tariff supports low-income families as a cross subsidy system. No fixed charges are applied to small domestic customers.

Table 3-4-1 UNELCO Electricity Tariff Structure

Customer Group	Price per kWh (Vatu)	Monthly Fixed Charge
Small Domestic Customers	Up to 60 kWh=0.34 x P	None
	61 to 120 kWh=1.21 X P	
	Over 120 kWh=3.00 X P	
Other Low Voltage customers	1.21 X P	5 X P per subscribed kVA
Business Licence Holders¾Low Voltage	0.87 X P	20 X P per subscribed kVA
Sports Fields	1.00 X P	None
Public Lighting	0.54 X P	None
High Voltage Users	0.70 X P	25 X P per subscribed kVA

(Source : A NAMA on Rural Electrification in Vanuatu, UNDP)

The base rate P of UNELCO is adjusted every month reflecting fluctuations in oil prices etc. UNELCO's electricity tariffs in January 2017 are shown in Table 3-4-2. Table 3-4-3 shows UNELCO's electricity tariff changes (annual average price for each year) from 2000 to 2014.

Table 3-4-2 UNELCO Electricity Tariffs (January 2017)

ELECTRICITY TARIFFS

Month of January 2017

BASE RATE P= 45,46 Vatu/kWh

A - (B*) - "SMALL DOMESTIC CONSUMERS" TARIFF (PCD)

Low voltage consumers 5 or 10 amps single phase for a maximum consumption of 120kWh per month

a) Electricity consumed	1st block	up to 60 kWh	0,34 x P =	**15,46 Vatu/kWh**
	2nd block	from 61 to 120 kWh	1,21 x P =	**55,01 Vatu/kWh**
	3rd block	over 120 kWh	3 x P =	**136,38 Vatu/kWh**
b) Fixed charge				**NONE**
c) Security deposit		flat rate : 70 x P =		**3182 VATU**

B - (D*) - "BUSINESS LICENCE HOLDERS - LOW VOLTAGE" TARIFF (TUP)

a) Electricity consumed	Flat rate	0,87 x P =	**39,55 Vatu/kWh**
b) Fixed charge	20xP per subscribed kVA		**909,20 x kVA**
c) Security deposit	150xP per subscribed kVA		**6819 x kVA**

C -(T*) - "SPORTS FIELDS" TARIFF (T)

a) Electricity consumed	Flat rate	1,00 x P =	**45,46 Vatu/kWh**
b) Fixed charge			**NONE**
c) Security deposit			**NONE**

D (E*) - "PUBLIC LIGHTING" TARIFF (EP)

a) Electricity consumed	Flat rate	0,54 x P =	**24,55 Vatu/kWh**
b) Fixed charge			**NONE**
c) Security deposit			**NONE**

E (A*) - "OTHER LOW VOLTAGE USERS" TARIFF (TU)

a) Electricity consumed	Flat rate	1,21 x P =	**55,01 Vatu/kWh**
b) Fixed charge	5xP per subscribed kVA		**227,30 x kVA**
c) Security deposit	150xP per subscribed kVA		**6819 x kVA**

F (F*) - "HIGH VOLTAGE" TARIFF (MT)

a) Electricity consumed	Flat rate	0,70 x P =	**31,82 Vatu/kWh**
b) Fixed charge	25xP per subscribed kVA		**1136,50 x kVA**
c) Security deposit	150xP per subscribed kVA		**6819 x kVA**

(Source：UNELCO website)

Table 3-4-3 Changes of UNELCO Electricity Tariffs

		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Base rate		33.64	37.62	34.80	34.52	34.99	40.15	45.39	47.84	56.87	45.16	51.09	54.54	55.44	55.51	55.45
"Small Domestic Consumers"																
1st Block	0 - 60 kWh	20.86	23.32	21.58	21.40	21.69	24.89	28.14	29.66	35.26	28.00	25.17	17.40	18.85	18.87	18.85
2nd Block	61 - 120 kWh	31.29	34.99	32.36	32.10	32.54	37.34	42.21	44.49	52.89	42.00	47.51	56.76	67.08	67.17	67.09
Penalty	> 120 kWh	57.19	63.95	59.16	58.68	59.48	68.26	77.16	81.33	96.68	76.77	86.84	129.73	166.33	166.53	166.34
Fixed Charge		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Security Deposit		2354.80	2633.40	2436.00	2416.40	2449.30	2810.50	3177.30	3348.80	3980.90	3161.20	3575.95	3499.65	3880.92	3885.70	3881.33
"Business Licence Holder "																
Electricity Consumed	flat rate	29.27	32.73	30.28	30.03	30.44	34.93	39.49	41.62	49.48	39.29	44.44	43.50	48.23	48.29	48.24
Fixed Charge		672.80	752.40	696.00	690.40	699.80	803.00	907.80	956.80	1137.40	903.20	1021.70	999.90	1108.83	1110.20	1108.95
Security Deposit		5046.00	5643.00	5220.00	5178.00	5248.50	6022.50	6808.50	7176.00	8530.50	6774.00	7662.75	7499.25	8316.25	8326.50	8317.13
Sports Fields																
Electricity Consumed	flat rate	33.64	37.62	34.80	34.52	34.99	40.15	45.39	47.84	56.87	45.16	51.09	50.00	55.44	55.51	55.45
Fixed Charge		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Security Deposit		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Public lighting																
Electricity Consumed	flat rate	18.17	20.31	18.79	18.64	18.89	21.68	24.51	25.83	30.71	24.39	27.59	27.00	29.94	29.98	29.94
Fixed Charge		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Security Deposit		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other Low Voltage users																
Electricity Consumed	flat rate	32.29	36.12	33.41	33.14	33.59	38.54	43.57	45.93	54.60	43.35	49.04	57.16	67.08	67.17	67.09
Fixed Charge		639.16	714.78	661.20	655.88	664.81	762.85	862.41	908.96	1080.53	858.04	970.62	436.44	277.21	277.55	277.24
Security Deposit		5046.00	5643.00	5220.00	5178.00	5248.50	6022.50	6808.50	7176.00	8530.50	6774.00	7662.75	7499.25	8316.25	8326.50	8317.13
High Voltage Users																
Electricity Consumed	flat rate	23.55	26.33	24.36	24.16	24.49	28.11	31.77	33.49	39.81	31.61	35.76	35.00	38.81	38.86	38.81
Fixed Charge		841.00	940.50	870.00	863.00	874.75	1003.75	1134.75	1196.00	1421.75	1129.00	1277.13	1249.88	1386.04	1387.75	1386.19
Security Deposit		5046.00	5643.00	5220.00	5178.00	5248.50	6022.50	6808.50	7176.00	8530.50	6774.00	7662.75	7499.25	8316.25	8326.50	8317.13

(Source：URA)

(2) Tariff Structure for VUI

The electricity tariffs for Luganville concession are different from those of UNELCO's concessions because VUI has been operating the Luganville concession since 2011 as a private utility (concessionaire) in place of UNELCO. Although it adopts almost the same structure as the UNELCO electricity tariff structure shown in Table 3-4-1, the base rate P and the coefficients to multiply for category tariff are different from those of UNELCO. In the Luganville concession area, the base rate is set at 36.29 VUV / kWh, which is cheaper by 20% compared to the base rate of UNELCO 45.46 VUV / kWh, because of a very high performance rate for hydropower generation with a cheap generation costs.

Electricity tariffs of UNELCO are updated monthly, but the electricity tariffs of VUI have been revised by URA only three times since VUI started operation in 2011, until now. Table 3-4-4 shows the changes of base rate (P) of VUI from the beginning to the latest revision.

Table 3-4-4 Changes of VUI Electricity Tariffs

Revision	Period	Base Rate (p)	Change Rate (%)
Initially	2011～	54.76 VUV/kWh	－
After 1st revision	March 2014～	47.07 VUV/kWh	－14.06%
After 2nd revision	June 2016～	40.52 VUV/kWh	－13.92%
After 3rd revision	February 2017～	36.29 VUV/kWh	－10.44%

(Source : The JICA Survey Team prepared based on data provided by URA)

Table 3-4-5 shows the latest VUI electricity tariff structure revised in February 2017.

Table 3-4-5 VUI Electricity Tariffs (effect from February 2017)

Base electricity price currently effective: **P = 36.29 Vatu/kWh**

Customer category	Charge	Vatu/kWh
Low Voltage (including small domestic, business license holders, and other low voltage customers)	**Unit charge per kWh**	
	Up to 60 kWh	15.78 VT per kWh
	61-120 kWh	36.14 VT per kWh
	Over 120 kWh	52.44 VT per kWh
Sports Fields	**Unit charge per kWh**	36.29 VT per kWh
High Voltage	**Unit charge per kWh**	29.00 VT per kWh

(Source：URA website)

According to URA, although El Niño during the period from the September 2015 to 2016 led to a large decrease in VUI's hydro contribution rate (from more than 80% to below 50%), these climate factors have normalized and for the month of December 2016, the hydro's contribution rate has already increased to 68.86%. Taking into consideration this recovery of hydro's contribution rate, the above VUI's tariffs were calculated.

The mini-grid at Port Olry has been operating independently with a separate base rate of 150 VUV/kWh charged to the Port Olry customers. In consideration of such unaffordable tariff for the customers and financially unfeasible operation of the mini-grid for VUI, the URA Commission has approved to amalgamate the Port Olry operations with the overall operations of VUI in Luganville. This initiative allows the Port Olry customers to be subsidized by the Luganville customers and enables the Utility to recover its cost of operations at Port Olry.

The base rate of 36.29 VUV/kWh includes continuation of the Santo customer fund contribution of 1.00 VUV/kWh and a 2.00 VUV/kWh payment to the Government by VUI. These funds are explained below:

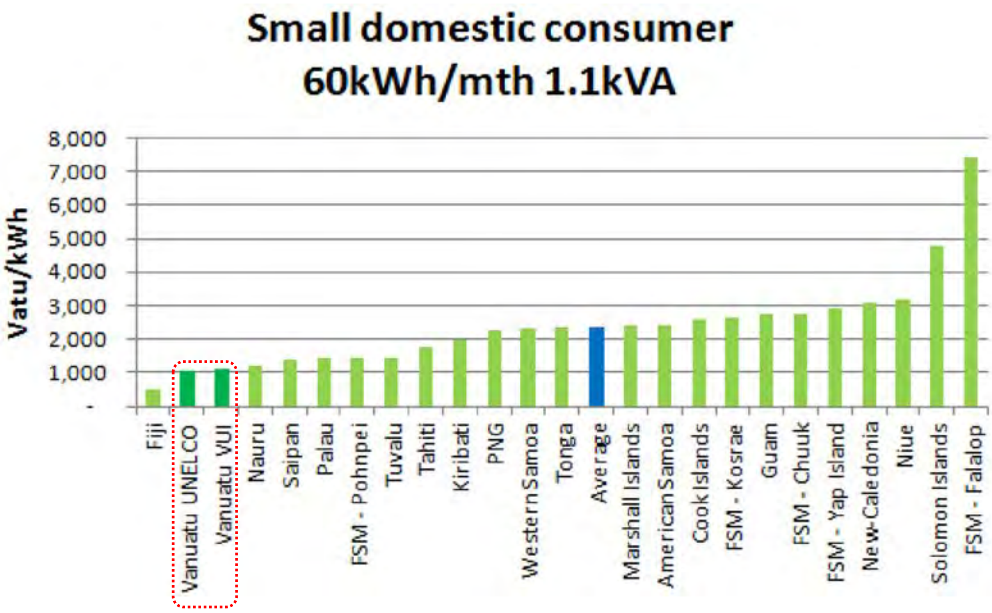
"Santo Fund and Governmental asset contribution fee"

Operation of the low-cost hydropower plant at Sarakata River, which was constructed as a Japanese grant aid project in 1994 and 1995, generated extra income through the savings in cost of imported diesel fuel. Accordingly, the governments of Japan and Vanuatu agreed with the then concessionaire UNELCO to create the Sarakata Renewal Fund and Sarakata Special Reserve Fund in which the savings in the cost of imported diesel fuel were to be pooled. The Sarakata Special Reserve Fund (SSRF) was to finance rural electrification projects and the Sarakata Renewal Fund was to finance the purchase of equipment and materials required for the maintenance of the facilities. The Sarakata Special Reserve Fund was instrumental in financing many electrification projects not only in the Luganville region, but also other parts of Santo Island and other islands. However, the operations of these funds stopped at the time VUI took over the operation and maintenance in 2011.

After VUI took over the operation and maintenance of Luganville concession in 2011, two funds similarly to the Sarakata Renewal Fund and Sarakata Special Reserve Fund, called "Santo fund" and "Government asset contribution fee" respectively, have been established. The Santo Fund was created in 2013 to promote electricity access in rural and outlying areas of Santo. Money for the Fund is collected from all Santo electricity consumers through 1.00 VUV/kWh charge in their monthly bills, and the annual amount of funds is VUV 7 to 8 million (USD 60,000-70,000). The Governmental asset contribution fee of 2 VUV/kWh billed, has been established. The fee is to be collected by VUI and paid to the Government on an annual basis as described in the Order. This fee is applicable until the re-tendering of Luganville concession, which began in December 2016, is completed and awarded to the winning bidder.

(3) Comparison of Electricity Tariffs with Other Countries across the Pacific Island Region.

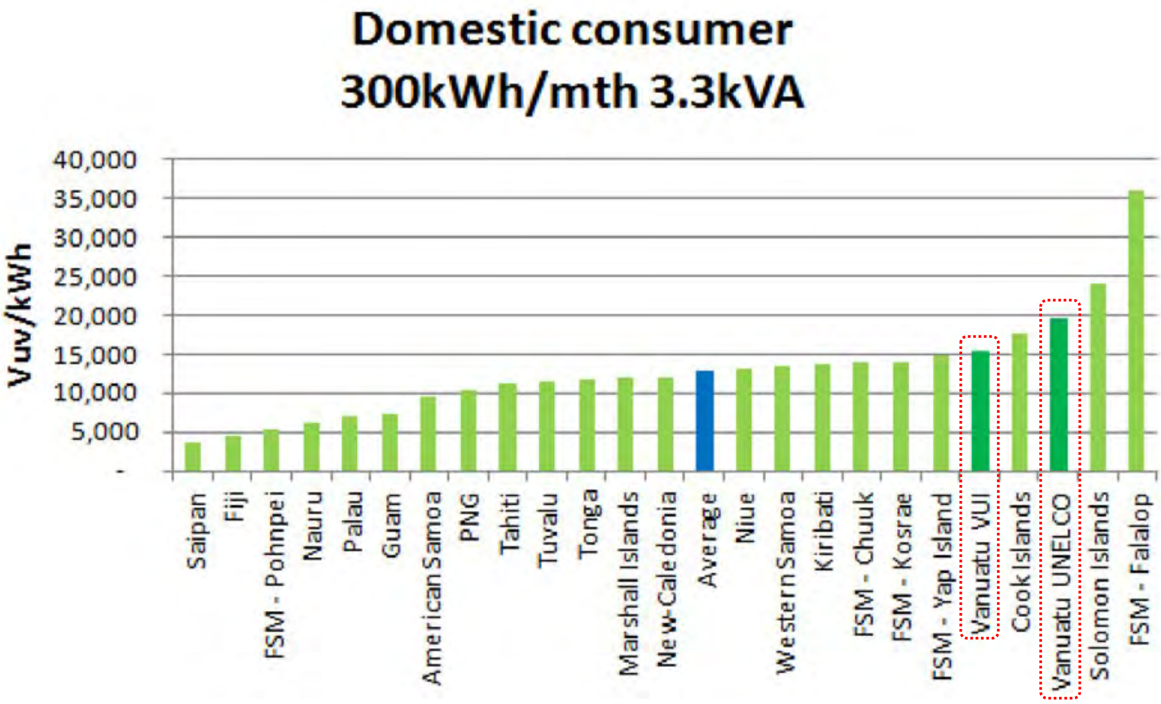
URA provides a comparison of electricity prices paid by customers in Vanuatu with different countries across the Pacific island region. Figure 3-4-1 shows the total bill for monthly consumption of 60kWh on a 5A connection for the sample of 24 electricity companies across the Pacific region. The electricity costs for the "small domestic consumers" category in Vanuatu are among the cheapest in the Pacific region, with UNELCO and VUI ranking respectively 2nd and 3rd cheapest out of the 24 utilities in the sample.



(Source : Utilities Regulatory Authority –Pacific Region Electricity Bills Comparison Report, June 2016)

Figure 3-4-1 Comparison of Bills Paid by "Small Domestic Consumers" Across the Pacific Region in VUV/kWh

Figure 3-4-2 shows the total bill for monthly consumption of 300 kWh on a 15A connection for the sample of 24 electricity companies across the Pacific region. The electricity costs for the "Domestic consumer" category in Vanuatu are among the most expensive in the Pacific region, with UNELCO and VUI ranking respectively 3rd and 5th most expensive out of the 24 utilities in the sample. The typical bill paid for these customers in Vanuatu is VUV 19,604 for UNELCO customers, and VUV 15,316 for VUI customers, based on January 2016 prices. This compares to an average bill of VUV 12,818 for the Pacific area. UNELCO is 53% above the Pacific average, and VUI is 19% above the Pacific average.

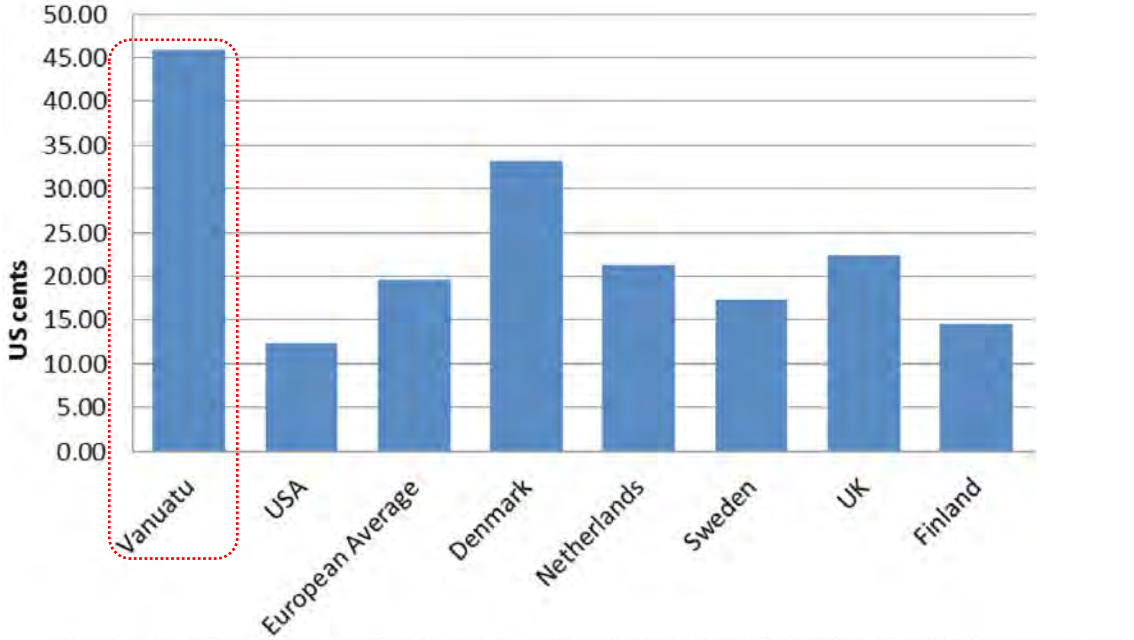


(Source : Utilities Regulatory Authority -Pacific Region Electricity Bills Comparison Report, June 2016)

Figure 3-4-2 Comparison of Bills Paid by "Domestic Consumer" Across the Pacific Region in VUV/kWh

(4) Comparison of Electricity Tariffs with Other Countries across the Pacific Island Region.

Figure 3-4-3 shows a comparison of Vanuatu basic electricity tariff and electricity tariffs in Western countries is shown in Figure 3-4-3. The Vanuatu's electricity tariff is more than twice the tariff of the average in the US and Europe.



[a] Prices are as of April 2015 except for Vanuatu, for which the base tariff for May 2015 is given. Exchange rates used to derive the prices in US dollars are US$1 = VT104.05, €1 = US$1.08.11

(Source : A NAMA on Rural Electrification in Vanuatu, UNDP)

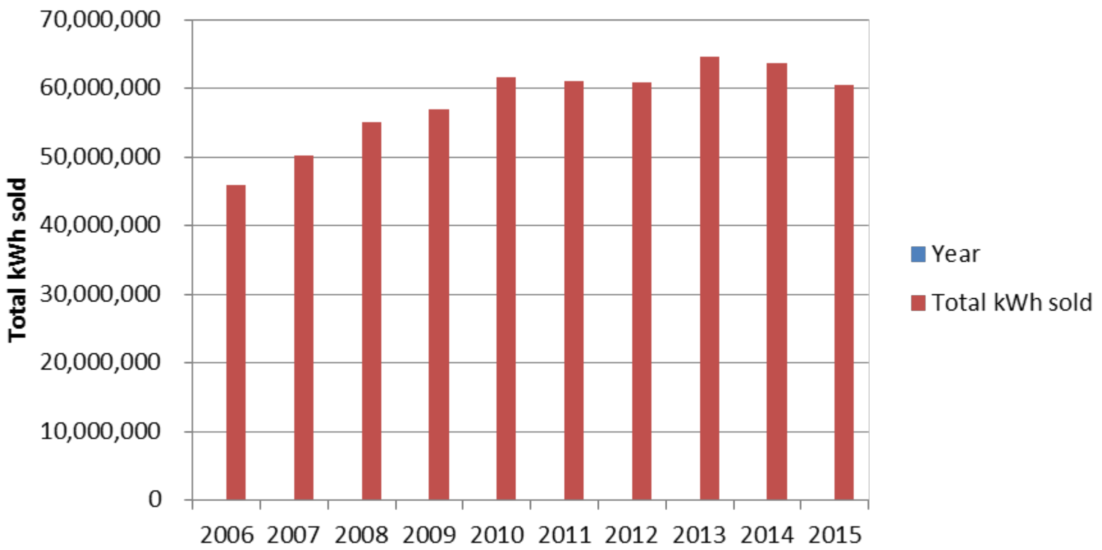
Figure 3-4-3 Electricity Tariff Comparison with Western Countries

3-5 Power Development Plan

3-5-1 Power Supply and Demand

(1) Demand for Electricity

The total electricity sold of the four concession areas from 2006 to 2015 is shown in Figure 3-5-1, and the annual average rate of increase from 2006 to 2015 is 3.5%.



(source : URA)

Figure 3-5-1 Annual Electricity Energy Sold throughout Vanuatu

The number of customers, the annual electricity energies sold and the composition ratios of these to the whole as of December 2015 are shown in Table 3-5-1, and the electricity consumptions in Port Vila and Luganville account for 84% and 14% respectively of all electricity consumption in whole Vanuatu.

Table 3-5-1 Number of Customers and Annual Electricity Energy Sold in Each Concession as of December 2015

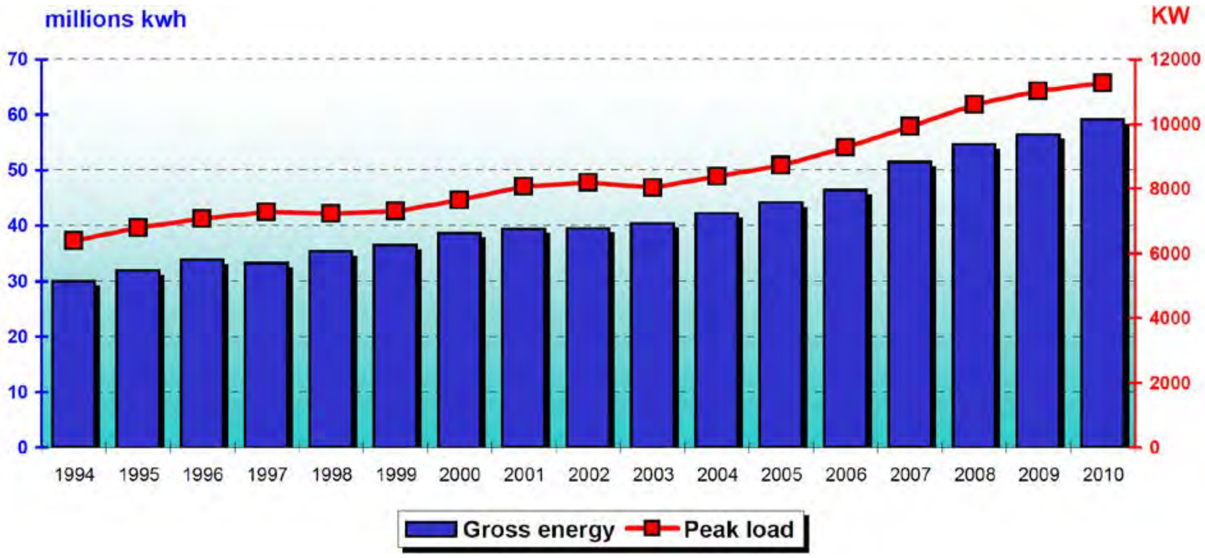
	Customer Numbers		kWh sold (kWh)	
	No.	%	(kWh)	%
Port Vila	12,563	73	4,697,246	84
Malekula	585	3	44,063	1
Tanna	1,187	7	37,061	1
Luganville	2,758	16	799,704	14
Total	17,093	100	5,578,074	100

(Source : The JICA Survey Team prepared based on data provided by URA)

(2) Peak Load

① Port Vila Concession

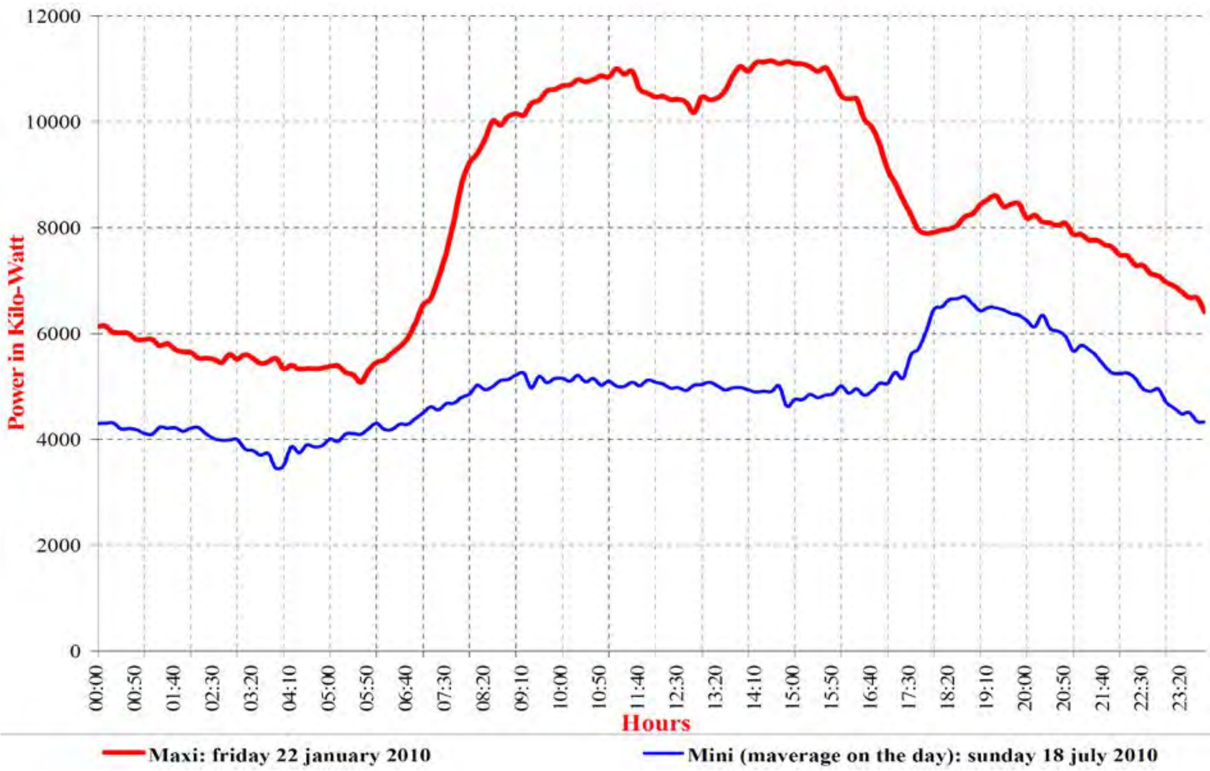
Peak load in the Port Vila concession area for the period from 1994 to 2010 are shown in Figure 3-5-2 along with the annual generated energies.



(Source : UNELCO Annual Technical Report year 2010)

Figure 3-5-2 Peak Load and Annual Generated Energy in Port Vila Concession

On the other hand, the daily load curve for Port-vila, as shown in Figure 3-5-3, is similar to a common daily load curve in developed countries where the peak of demand appears during the daytime on weekdays, mainly due to cooling demand.



(Source : UNELCO Annual Technical Report year 2010)

Figure 3-5-3 Daily Load Curves in Port Vila Concession

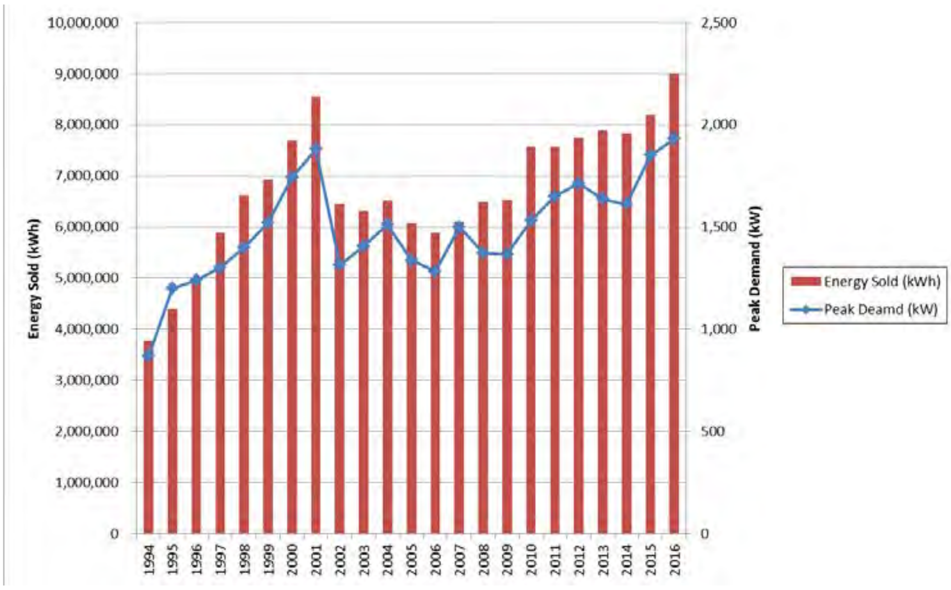
② Luganville Concession

Peak demands and annual electricity energies sold in the Luganville concession area for the period from 1994 to 2016 are shown in Table 3-5-2 and Figure 3-5-4.

Table 3-5-2 Peak Demand and Annual Electricity Sold in Luganville Concession

Year	Peak Deamd (kW)	Energy Sold (kWh)
1994	870	3,784,836
1995	1,200	4,396,966
1996	1,240	5,012,572
1997	1,300	5,881,620
1998	1,400	6,612,372
1999	1,520	6,927,533
2000	1,740	7,687,967
2001	1,880	8,544,537
2002	1,314	6,451,910
2003	1,408	6,302,979
2004	1,512	6,511,733
2005	1,338	6,069,839
2006	1,283	5,887,789
2007	1,499	6,106,038
2008	1,373	6,481,999
2009	1,366	6,529,069
2010	1,530	7,555,377
2011	1,650	7,557,895
2012	1,713	7,741,646
2013	1,637	7,882,870
2014	1,611	7,828,173
2015	1,850	8,196,169
2016	1,932	8,983,224

(Source：UNELCO Annual Technical Report year 2010, VUI Performance Report for 2014, VUI Report in URA format for 2016)



(Source：UNELCO Annual Technical Report year 2010, VUI Performance Report for 2014, VUI Report in URA format for 2016)

Figure 3-5-4 Peak Demand and Annual Generated Energy in Port Vila Concession

3-5-2 Existing Power Facilities

Table 3-5-2 shows the generation mix and installed capacity in each concession as of December 2015.

Table 3-5-3 Installed Capacities by Concession (as of December 2015)

		Port Villa	Malekula	Tanna	Luganville	Total	%
Operator		UNELCO	UNELCO	UNELCO	VUI	-	-
Energy sources (MW)	Diesel	21.83	0.39	0.39	2.85	25.46	84
	Hydro	-	-	-	1.20	1.20	4
	Wind	3.58	-	-	-	3.58	12
	Solar	0.08	0.02	0.03	0.04	0.17	1
Total Installed Capcity		25.49	0.41	0.42	4.09	30.41	100

(Source : The JICA Survey Team prepared based on data provided by URA)

Overall, diesel accounts for more than 80% of the total installed capacity. However, as renewable energy power sources, in Port Vila concession, 13 wind turbines, which started operation from 2007 to 2014 at the Devil's Point of Efate Island, produce 3.58 MW of total power; while in Luganville concession, the Sarakata hydropower plant with an installed capacity of 1.2 MW (300 kW x 2, 600 kW x 1) is under operation. Solar power generation facilities have also been introduced in every concession, but a total installed capacity is still less than 1 MW.

The peak load in Port Vila concession in 2010 was 11 MW, which was only around 50% of the diesel's total installed capacity of 21.83 MW. The peak load in Luganville concession reached a record high of 1.93 MW in 2016, which is also only around 70% of the diesel’s total installed capacity of 2.85 MW there. In both the concession areas, the installed capacities of existing diesel power generation units are sufficiently large for the current demand scale, and it is possible for the existing diesel power generation units to meet the peak demand without relying on any renewable energy generation units.

3-5-3 Existing Power Development Plan

(1) Demand Forecast

The National Energy Road Map (NERM) 2013-2020 shows demand forecast for each concession area at the end of the volume. Main assumptions for demand forecasting are as follows.

- 2010 demand is taken from the 2010 UNELCO annual technical report
- Demand from commercial customers, public administration, and households that are already connected grow at 4 percent per annum.
- New household connections are based on successfully achieving the actions set out in this Road Map.

The portions of households connected to each grid for concession area in 2010 are as low as 31% - 78%. It is assumed that unconnected households will be sequentially connected to the grid in the future. The peak loads are not projected in NERM.

Table 3-5-3 shows the demand forecast for generated energy in each concession in NERM 2013-2020. The annual generated energy throughout Vanuatu in 2025 is forecasted at 124,084 MWh, which is about twice annual generated energy of 62,435 MWh recorded in 2010.

Table 3-5-4 Forecasted Annual Generated Electricity for Each Concession Area

Concession Area	Units	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Port vila	MWh	53,934	56,092	58,335	61,264	64,151	67,171	70,293	73,569	76,994	80,448	84,033	87,730	91,613	95,665	99,895	104,309
Malekura	MWh	579	604	634	714	780	850	933	1,017	1,107	1,201	1,277	1,331	1,401	1,472	1,546	1,622
Tanna	MWh	418	435	452	555	632	714	802	863	941	1,024	1,112	1,205	1,304	1,409	1,520	1,638
Luganville	MWh	7,504	7,804	8,116	8,734	9,292	9,881	10,469	11,099	11,649	12,267	12,915	13,595	14,309	15,058	15,844	16,515
Total Annual Demand	MWh	62,435	64,935	67,537	71,267	74,855	78,616	82,497	86,548	90,691	94,940	99,337	103,861	108,627	113,604	118,805	124,084
Totale demand growth rate	%	-	4%	4%	6%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	4%

(Source : NERM 2013-2020)

(2) Power Development Plan

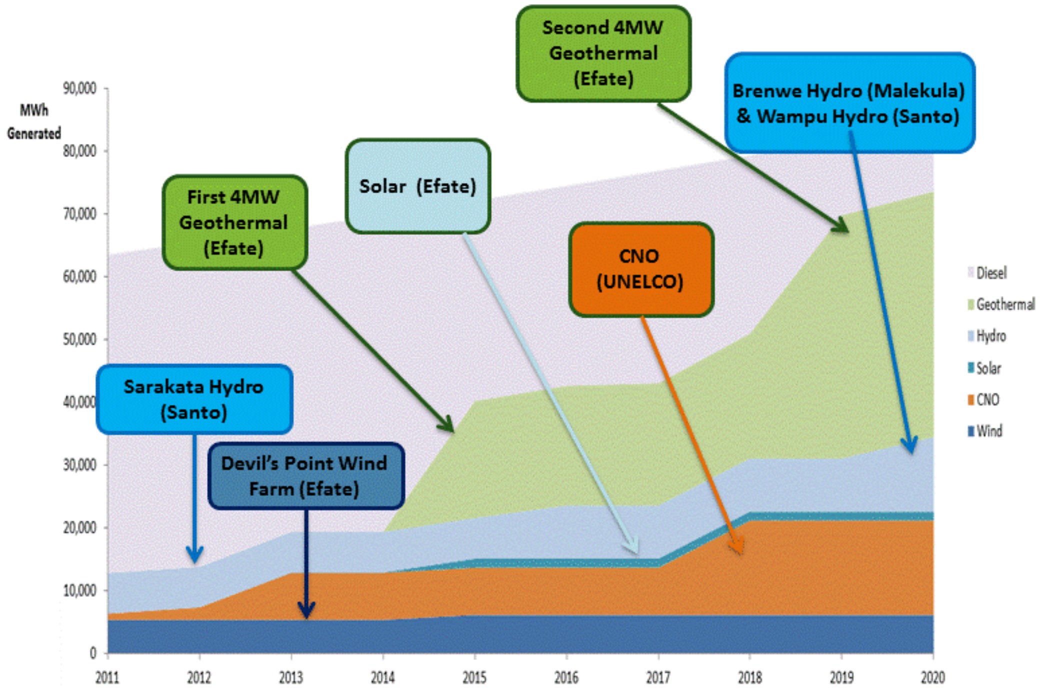
In Vanuatu, there is no power development plan clearly showing required installed capacities (kW) in the future years and development plan for new power facilities to meet the required installed capacities.

However, through NERM 2013-2020, the Government is actively supporting the next tranche of investment in new renewable generation as follows:—a proposed geothermal power development on Efate, and hydro developments in Malekula and Espiritu Santo.

- A proposed geothermal power development on Efate
  A pre-feasibility study has been undertaken for an 8 MW geothermal plant at Takara on Efate. Once further feasibility studies and exploration drilling are completed, and the resource is confirmed, the proposed plant could provide power to the island by 2019 in two stages: 4MW by the end of 2015, and another 4MW by 2019.

- Hydro developments in Malekula and Espiritu Santo
  Malekula: the Brenwe Hydro Power Project (< 1.2MW) was planned to be completed by 2021.
  Espiritu Santo: the Wambu River Mini Hydro Project with an installed capacity of 2.2 MW was planned to be developed for the period from 2013 to 2021.

NERM 2013-2020 expresses the image of the increase in renewable energy power generation mix including the above renewable power development plans by 2020 as shown in Figure 3-5-4.



(Source：NERM 2013-2020)

Figure 3-5-5 Projected Share of Cost Competitive Renewable Energy Generation

As mentioned in 3-1-2 section, the updated NERM 2016-2030 proposes 68 actions to achieve the NERM's objectives. Of these actions, the four actions shown in Table 3-5-5 are power development projects, of which two solar power projects and two hydropower projects are shown as the highest priorities. The Wambu hydropower plant project with an installed capacity of 2.2 MW located in Santo described in NERM 2013-2020 was taken off the updated NERM 2016-2030 (NERM Implementation Plan 2016-2030), due to the fact that the system cannot absorb the additional 2.2 MW of generation capacity within a 20 year time frame.

Table 3-5-5 Power Development Plans Shown in NERM Implementation Plan 2016－2030

Area	Investment/action	Priority	Timing
Efate	Grid Connected Solar PV Project (1MW)	Highest	2016-2018
	Takara Geothermal Power Plant (4+4MW) preparatory study & investment	Medium	TBD
Espiritu Santo	Sarakata Hydro Power Extension Project (600kW),	Highest	2018-2021
Malekula	Brenwe Hydro Power Project(< 1.2MW),	Highest	2018-2021
Tanna	Whitesands Solar PV Micro-grid	Highest	

(Source：Updated NERM 2016-2030)

3-5-4 Existing Power System Facilities

Table 3-5-5 shows lengths of transmission lines in each concession area.

Table 3-5-6 Lengths of Transmission and Distribution Lines in Each Concession Area

Concession	Port Vila	Malekula	Tanna	Luganville	Total
High Voltage lines length in km	222.6	11.4	18.6	69.4	321.9
Low Voltage lines length in km	267.1	14.2	20.6	68.7	370.6

(Source : Annual technical data - UNELCO - VUI 2012-2013)

The NERM Implementation Plan 2016-2030 in the updated NERM 2016-2030, which is mentioned in section 3-1-2, includes the grid extension projects as shown in Table 3-5-7.

Table 3-5-7 Grid Extension Projects Listed in NERM Implementation Plan 2016-2030

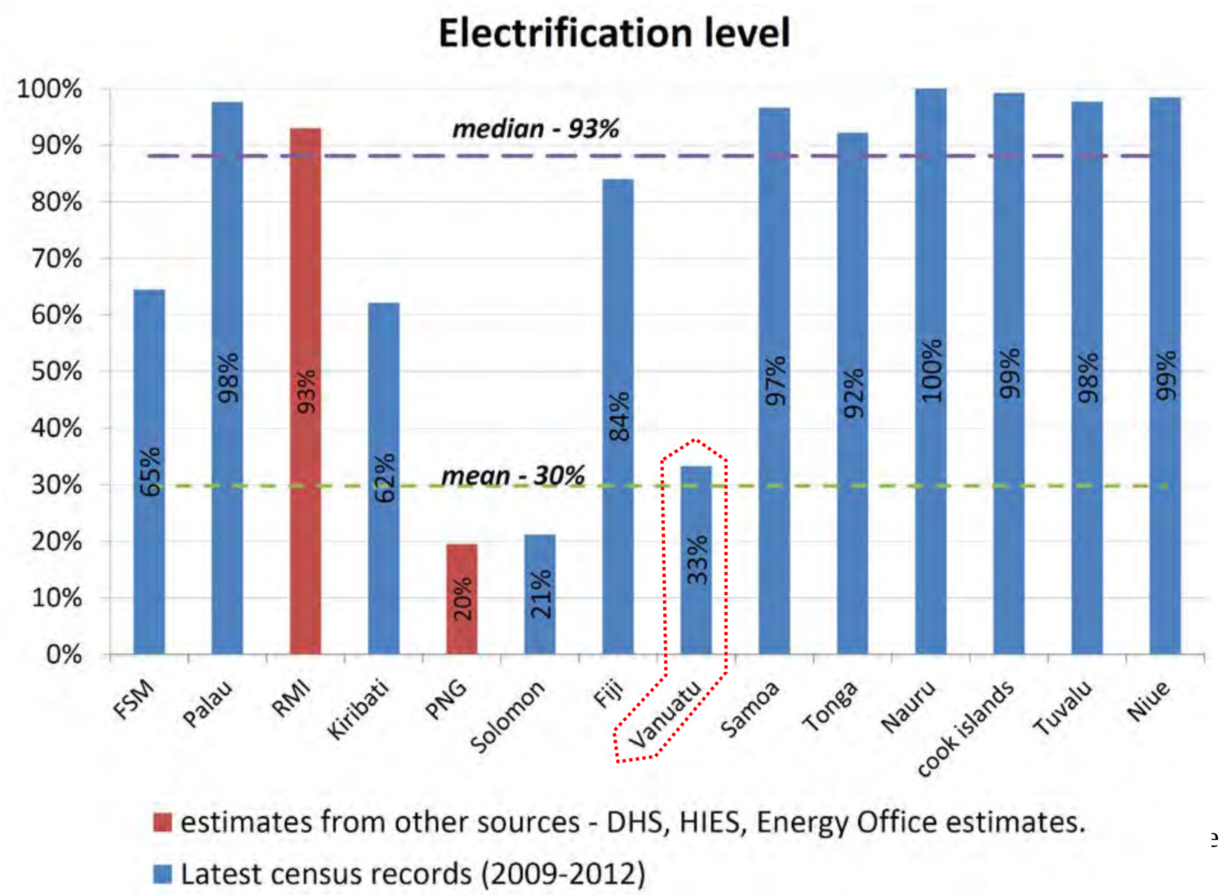
Area	Investment/action	Priority	Timing
Espiritu Santo	Grid Extension, East Coast Santo (Matelevu to Shark Bay, Port Olry, Stone Hill and Palekula)	Highest	2017-2018
Port Vila, Espiritu Santo, Malekula	Low Voltage and Medium Voltage Extensions (Vila, Santo, Malekula)	High	2020-2023

(Source : Updated NERM 2016-2030)

3-6 Actual Progress and Future Plan on Electricity Access

3-6-1 Actual Progress on Electricity Access

Vanuatu is an archipelago in the South Pacific, spread over more than 80 islands, of which 65 are inhabited. About 75% of the population lives in rural areas. These structural factors have led to many technical issues and low cost efficiency in using energy services in Vanuatu. These situations have resulted in lower levels of electricity access and higher generation and supply costs compared to other countries. Figure 3-6-1 shows the comparison of electrification rates with the Pacific countries, Vanuatu's electrification rate is only 33%, which is considerably lower than the average.



(Source : Regional Overview of Energy Situation in the Pacific island Countries (PICs),

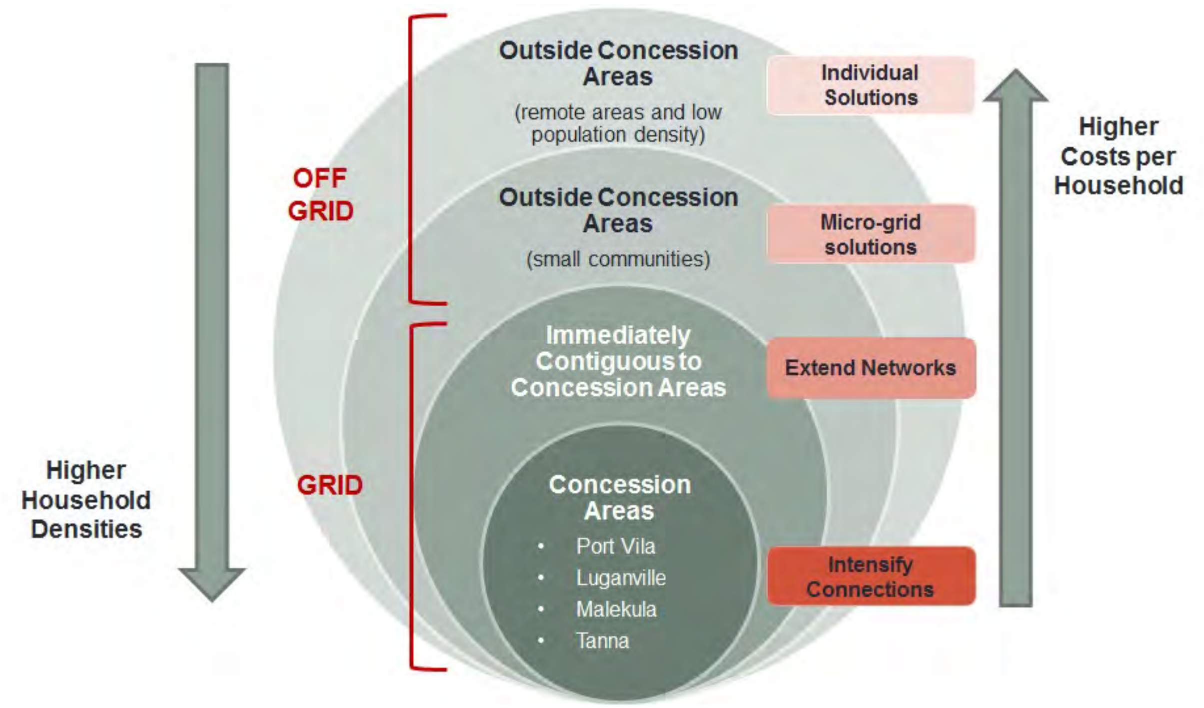
Figure 3-6-1 Electrification Ratios in the Pacific Island Countries

In Vanuatu, there are now power grid systems only in the four concession areas including the urban areas of Port Vila and Luganville. Electrification by connecting to these power grid systems accounts for the majority of electrification in Vanuatu. However, a connection rate for households in and near to concession areas by grid extensions is still 62% even in 2015. On the other hand, electrification rate in the off-grid areas outside the power grid systems is only 9%. (Source: Updated 2015-2030)

3-6-2 Plans and Targets for Increasing Electricity Access

The updated NERM published in 2016 shows the actual progresses of electricity access made in 2015, which have not achieved the targets for 2015, while electricity access targets for 2030 are set at 100% in and near concession areas and in off-grid areas.

NERM 2013-2020 represents a strategic frame work for increasing electricity access as shown in Figure 3-6-1. This shows the various area types and the possible solutions for electrification under consideration. As distance from towns and concession areas increases, household density decreases. This increases costs per household of electricity provision. Taking into consideration these topographical conditions, the basic approaches to increase electricity access are shown based on the concept of least cost as follows.



(Source : NERM 2013-2020)

Figure 3-6-2 Strategic Framework for Increasing Electricity Access

According to this framework, suitable solutions for each area type are shown below:

1) Increasing electricity access in and near concession areas (grid areas)
   ① to intensify grid connections for the concession areas in the four towns (Port Vila, Luganville, Malekula and Tanna)
   ② to extend the network to neighboring areas for the near concession areas
2) Increasing electricity access outside the concession areas (off-grid areas)
   ① to be given through micro grid solutions for the areas with small communities
   ② to be given individual (household) solutions for remote areas and low population density

As mentioned above, possible solutions to increase electricity access in and near concession areas are roughly divided into two types. One way is to increase sustainable access to formal grid-based electricity services within Vanuatu's electricity concession service areas for low income customers through targeted subsidies, which are now implemented under the program "Global Partnership on Output-Based Aid" (GPOBA). The other is to increase new connections by grid extension. UNELCO has plans to extend the distribution lines in their three concession areas. Article 6 Fund is a fund based on income from UNELCO's customers and is used for extension of their concession areas.

Santo Fund was established in 2013 and the funds collected by the VUI's electricity charge with 1 VUV / kWh billed are used for not only grid extension but also off-grid electrification including micro-grid. Both the funds are owned by the Government and used is at the discretion of the government. In addition to grid extensions by the concessionaires with utilizing the above mentioned Article 6 Fund or Santo Fund, there are grid extension projects that are planned and implemented by donors' supports as described in Section 3-7.

Possible solutions to increase electricity access outside the concession areas (off-grid areas) also are roughly divided into two types. The first is to electrify small communities by establishing micro grids using renewable energy sources. Under the support of donors, DOE plays as the executing agency. The project called "Intervention 1" of "Nationally Appropriate Mitigation Action (NAMA) on Rural Electrification in Vanuatu", which is described later in Section 3-7, will establish five micro grids using renewable energy sources (solar, wind, hydro) providing electricity for lighting, radio and phone charging for households, and for service and production activities in Rural Productivity Zones (RPZs). The other is to promote electrification in off grid areas by giving individual (household) solutions for remote areas and low population density. Solar home systems (SHSs) are commonly used as a main power source. Currently, the Vanuatu Rural Electrification Project (VREP) Phase 1 seeks to provide access of basic electricity services to consumers for whom grid system is unlikely to be economical using a subsidy mechanism of 'plug and play' solar systems and utilizing the local electricity retailers in country. Products approved are subsidized at 50% of the retail prices in 2016 with the subsidy planned to decrease in the years thereafter.

These funds for increasing electricity access and the main electrification projects are summarized in Table 3-6-1.

Table 3-6-1 Funds and Projects for Increasing Electricity Access

Fund/Program	Purpose	Location	Source of Funding	Households to be connected	
				Total	2015-2020
GPOBA (Global Partnership on Output-Based Aid)	Targeted subsidies that provide 80% of connection and wiring cost	Vanuatu's four concession areas	World Bank	4,375	4,218
Article 6 Fund	Investment support fund to expand electricity access	Port Vila grid concession	Customer contributions	953	320
Santo Fund	Funds projects to extend electricity access through a charge collected from Santo electricity consumers	Rural and outlying of Santo	Customer contributions	568	190
NAMA Intervention 1 and Intervention 2	The NAMA is to provide electricity access to all households. Intervention 1 to establish micro grids, while Intervention 2 extend existing electricity grids	Outside of 4 concession areas (Off-grid areas)	TBD*	around 1,000	-
Vanuatu Rural Electrification Project (VREP) phase 1	Scaling up access to electricity services for rural households, aid posts and not-for-profit community halls located in dispersed off-grid areas	All off-grid areas	New Zealand Aid & World Bank	17,500 households, 2,000 not-for-profit community halls and 230 aid posts. .	

* to be determined

(Source : The JICA Survey Team prepared based on NERM 2013-2020 and Rural Electrification in Vanuatu, UNDP)

3-7 Other Donors' Activities

The following projects supported by the donors are being implemented as major projects for Vanuatu's electric power sector.

(1) Asian Development Bank (ADB)

ADB has been supporting "Energy Access Project - 1" in Vanuatu, which will increase energy access and renewable energy generation in the two islands of Espiritu Santo and Malekula, being second and third largest population centers after Efate. The project will assist Vanuatu install hydropower generation to replace diesel generation in Malekula and will extend the distribution grid in both Malekula and Espiritu Santo. Project preparatory technical assistance was used in project preparation.

The sub-projects of "Energy Access Project - 1" as shown in Table 3-7-1 are currently being prepared for implementation.

Table 3-7-1 Sub-Projects of Energy Access Project-1 (2013)

	Project	Outline
1	Brenwe River Hydropower Project	A 400 kW run-of-river hydropower plant, including (a) 2 km of access roads, (b) 21 km transmission line (20 kilovolts), (c) intake structure, (d) 1.0 km headrace canal, (e) 190-meter steel penstock, and (f) powerhouse
2	Port Olry Grid Extension Project	The grid will be extended to an estimated additional 1,050 households in Malekula and Espiritu Santo. This will increase the grid access rate from 8% to 14% in Malekula and from 22% to 29% in Espiritu Santo. The project will finance 79 km distribution lines, step-down transformers and poles.
3	Capacity building	Newly connected households will be trained on options for electricity-based income generation, electricity safety, and budget management.

(Source : ADB AIDE MEMOIRE ENERGY ACCESS PROJECT, signed on June 17, 2016 in Port Vila)

(2) World Bank (WB)

In 2008, with assistance from the Australian Government and the World Bank, the Government of Vanuatu established the Utilities Regulatory Authority to protect consumers and provide the legal framework for the pricing and service standards that are now being delivered. WB has been supporting institutional setup forming the foundation of Vanuatu's power sector. Currently, WB is supporting projects to improve electricity access in the on-grid areas and in the off-grid areas as follows:

For the concession areas in the four towns (Port Vila, Luganville, Malekula and Tanna) the aim is to intensify grid connections and extend the network to neighboring areas. Outside the concession areas, electricity access will be given through micro grid solutions and individual (household) solutions.

① Global Partnership on Output Based Aid (GPOBA), Improved Electricity Access Project
According to World Bank web site, the objective of the Global Partnership on Output Based Aid (GPOBA) Improved Electricity Access Project for Vanuatu is to increase sustainable access to formal grid-based electricity services within Vanuatu's electricity concession service areas for low income customers through targeted subsidies. The project has four components. (1) Output Based Aid (OBA) subsidies for new electricity connections for low-income households' component will provide one-off OBA subsidy to cover up to 80 percent of the cost of connecting low-income households to grid-based

electricity services in Vanuatu. The subsidy will be available for both post-paid electricity meters and pre-paid meters. (2) OBA subsidies for household wiring for low-income households accessing electricity services under the project component will provide one-off OBA subsidies to cover the cost of household wiring for low-income households accessing grid-based electricity services under the project, where wiring is not up to standard or not in place. The households will be wired according to a standard design for the project in accordance with Australian and New Zealand standards. Household wiring will include cabling and backfilling from the utility meter box to a ready board in the consumer's premises. (3) Implementation support for project management, communications and outreach, and training component will oversee implementation and develop longer-term institutional capacity for managing energy-related subsidies. (4) Independent verification component will fund a suitably qualified consultant or firm as an Independent Verification Agent to undertake the verification of outputs under the project.

The project is conducted with the budget amount of USD 4.85 million for the period from May 2014 to June 2018. DOE is the project implementing agency.

② Vanuatu Rural Electrification Project: VREP

According to DOE's web site, the objective of the Vanuatu Rural Electrification Project (VREP) is to scale up access to electricity services for rural households, aid posts and not-for-profit community halls located in dispersed off-grid areas that are unlikely to have grid connection within the next four years as per UNELCO and VUI's grid extension plans. The Phase 1 of VREP is aimed at increasing access to basic lighting and phone charging capabilities using subsidized 5-30 watts 'Plug and Play' solar systems. Approved products are subsidized at 50% of the retail prices in 2016 with the subsidy planned to decrease in the years thereafter. VREP 1 is funded through a grant of USD 4.7 million from the New Zealand Government. Management of the Project is through DOE with implementation support from the World Bank.

(3) Other Donors' Activities

Table 3-7-2 shows donors' supported projects for power sector which DOE is involved in.

Table 3-7-2 Projects for Power Sector which DOE is Involved in (2013-2015)

No.	Project	Donor	Amount (Vatu)
1	Access Power Project	AusAid	63.6 million
2	Global Partnership on Output Based Aid (GPOBA)	World Bank	400 millinon
3	Energy Sector Management Assistance Program (ESMAP)	SID fnnd through the World Bank	100 million
4	Talise Micro Hydro Project Phase II	Italian Fund through IUCN	20 million
5	Pacific Appliances & Labeling Standards (PALS)	Secretariat of the Pacific Community (SPC)	8 million
6	Vanuatu Rural Electrification Project (VREP)	New Zealand	470 million
7	Biofuel Projects for Malampa, Penama & Torba	European Union GoV	191m illion 218 million
8	Melanesia's Millions Miracle Project (M3P)	Ausaid-through SPC	7 million
9	Global Green Growth Institute (GGGI)	GGGI	–
10	ACP-EU Energy Facility II	European Union UNELCO GoV	306.37 million 122.55 million 88.2 million
11	Intended National Determined Contribution (INDC)	UNDP-Fiji	15 milion

(Source : DEPARTMENT OF ENERGY IMPLEMENTING PROJECTS (2013-2015))

3-8 Issues of Power Sector in Vanuatu

The power sector in Vanuatu is strongly influenced by two factors, the high dependency on fuel imports and the geographical setting.

As with other Pacific Island countries, Vanuatu is forced to import all fossil fuels because it has no fossil fuel resources in its territory. Diesel oil accounts for the largest share of fuel imports with a volume of 33 million liters during 2012. Half of the fuel demand comes from the transport sector, but diesel oil is also the main fuel for electricity generation in Vanuatu. Although the Government of Vanuatu is trying to increase the amount of clean renewable energy to replace fossil fuels, only around 30% of all electricity generated is from renewable energy, and the majority of generated electricity still relies on diesel fuel. For these reasons, high power generation cost continues, and electricity tariffs in Vanuatu are higher than those of other Pacific countries. These situations have led a decrease in the competitiveness of Vanuatu’s domestic industry and increasing in environmental load by increasing CO2 emissions.

On the other hand, from the geographical setting such as the population widely dispersed to 65 islands, it is difficult to put electric power grids all over the country. The electric power grids are limited to only four areas. Power supply to each household scattered in other areas should be very costly. As a result, these conditions have resulted in a remarkably low electrification rate compared to other Pacific countries of 33%.

High electricity tariffs and low electrification rates are the main issues in the power sector in Vanuatu, and it is required to promote the development and to increase use of affordable renewable energy to reduce the amount of imported fossil fuels.

Chapter 4 Power Sector in Espiritu Santo

4-1 Overview of Espiritu Santo

According to the 2009 census, Espiritu Santo is the largest island in Vanuatu, with an area of 3,955.5 km^2 and a population of around 40,000 (17% of total population of Vanuatu), which is the second largest population, following the capital, Port Vila in Vanuatu. It is in the Sanma Province of Vanuatu, and its area and population account for 93% and 87% of those of the Province, respectively. Its western area is hilly and mountainous, while flat terrains spread in the eastern and southern part of the island. Also, the settlements and plantations are distributed in the east coast part from the southeast to the northeast and the southern part along the southern coast.

Luganville City (population: approximately 13,000), the second largest city in Vanuatu is located in the southeastern coastal area of Santo island. Santo Pekoa International Airport (Pekoa airport), which has international flights, is located 6 km east of the city, and the city has a port with the function of a trade port. Luganville, therefore, functions not only as the center city of Sanma Province but also as the center of commercial activities in the northern four provinces in Vanuatu. In addition, Luganville has Northern Provincial Hospital, which is the second largest hospital in Vanuatu.

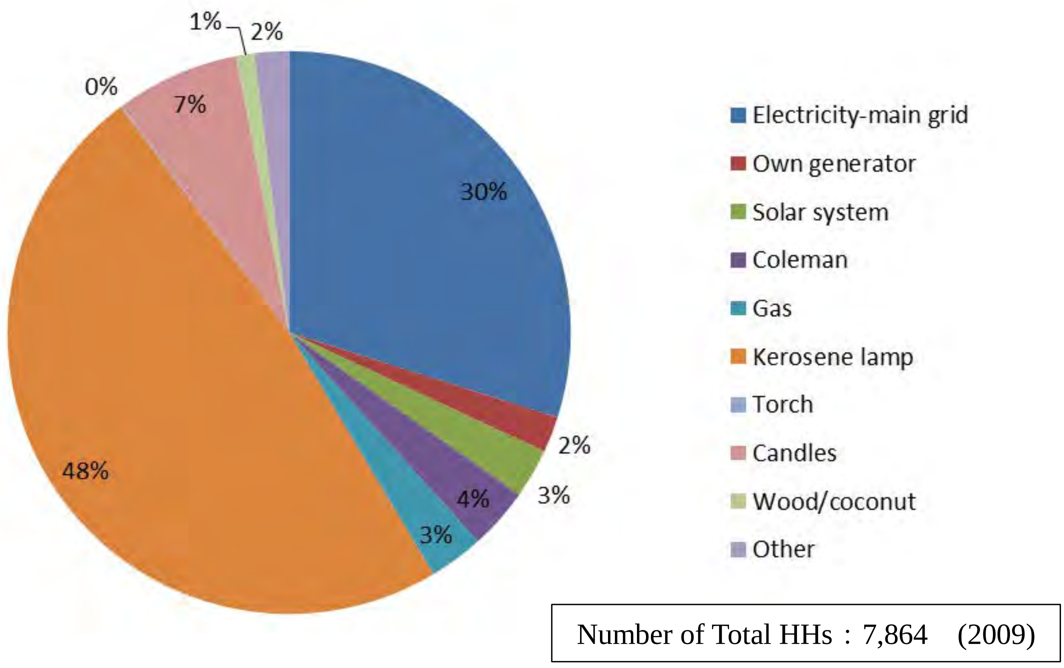
As shown in Figure 4-1-1, the east coast road between Luganville and Port Olry, which is the second largest town located in the northeast of the island, has been sealed. Relatively large villages including Port Olry are scattered in the east coast area, and a lot of large scale plantations and resort facilities have been developed.

As shown in Fig. 4-1-1, the electrification by the electric power grid is limited to the range of about 15 km north from Luganville, with a width of 7 to 8 km in the east-west direction from the east coast.

Figure 4-1-1 Map of Espiritu Santo

4-2 Primary Energy Sources in Santo

According to DOE, as shown in Figure 4-2-1, kerosene lamp is used most for lighting in Santo (48%), followed by the electric power grid (30%). This means that the proportion of households that are electrified by the electric power grid throughout Santo is only about 30%.



(Source : The JICA Survey Team prepared based on data provided by DOE)

Figure 4-2-1 Main Sources of Lighting in Espiritu Santo

4-3 Operator for Luganville Concession

UNELCO, which currently operates three concession areas that are Port Vila, Malekula and Tanna, had operated the concession area of Luganville until 2010 under the concession contract with the Government for 20 years from 1990. As a result of bidding for the selection of utility company from 2011, which was implemented following the end of the contract period in 2010, Vanuatu Utilities and Infrastructure Limited (VUI), a subsidiary of Pernix Group, Inc., (Concessionaire), was selected as a new concessionaire and has been operating Luganville concession area since January 2011 in the form of vertical integration from power generation to distribution and collection of electricity bills. However, UNELCO, who lost the bid for the concession starting in 2011, filed a lawsuit against the government claiming that the selection process was not transparent. Accordingly, the government has not been able to conclude a long-term concession contract with VUI; the contracted services are performed on the basis of a Memorandum of Understanding (MOU). UNELCO's law suit has already been concluded with the court declaring the previous O&M contract awarded to VUI was NULL and VOID, hence an instruction to go through a re-tender. Based on this court's declaration, the Government commenced the re-tender process for the Luganville concession in December 2016, and according to DOE, the new concessionaire is expected to be selected after July 2017.

The organization and personnel of VUI are as follows.

Table 4-3-1 The Organization and Personnel of VUI (as of December 2016)

Section	Number of Staff member
Corporate	8
Diesel Power Plant	12
Hydropower Plant	11
Transmission & Distribution lines	11
Port Olry (Diesel Power Mini Grid)	4

(Source : The JICA Survey Team prepared based on material provided by VUI)

VUI has experienced operating the Luganville concession for only 6 years since 2011. According to VUI, many of the staff members working at a diesel power plant and a hydropower plant are staff members who continue to work since UNELCO was in operation. In spite of the change of operating company, no major problems concerning the operation and maintenance of facilities have occurred.

4-4 Overview of Existing Power Facilities

4-4-1 Power Generation Facilities

Lists of the existing power facilities are shown in Table 4-4-1. The total capacity of Santo island is 4,290 kW excluding Port Orly diesel power plant which is not connected to the grid, and the peak load up to the end of 2016 is less than 2,000 kW, so there is sufficient spare power at present.

Table 4-4-1 Rated Capacity and Supply Output of Existing Power Plant

Power Plant Location	Unit Name	Source and Type	Commisioning Year	Rated Capacity (kW)	Actual Capacity (kW)
Luganville	DG1	Diesel	2001	1,000	800
	DG2	Diesel	1999	1,000	800
	DG3	Diesel	2013	750	750
	DG4	Diesel	2006	264	200
	DG5	Diesel	2013	520	500
Port Orly	–	Diesel	2008	45	45
Sarakata River	T1	Hydropower	1995	300	300
	T2	Hydropower	1995	300	300
	T3	Hydropower	2009	300	600
Hospital	–	PV	2013	20	20
Collage	–	PV	2013	10	10
Samma Office	–	PV	2013	10	10
Total				4,519	4,335

The monthly power generation (kWh) by power source for past three years is shown in Figure 4-4-1.

From November to April which is hatched with light blue color is generally the rainy season, and until 2015, the power supply by diesel power generation in the dry season trend to be increasing. However in 2016, the amount of rainfall was small, and the supply of diesel power generation was large in the whole year.

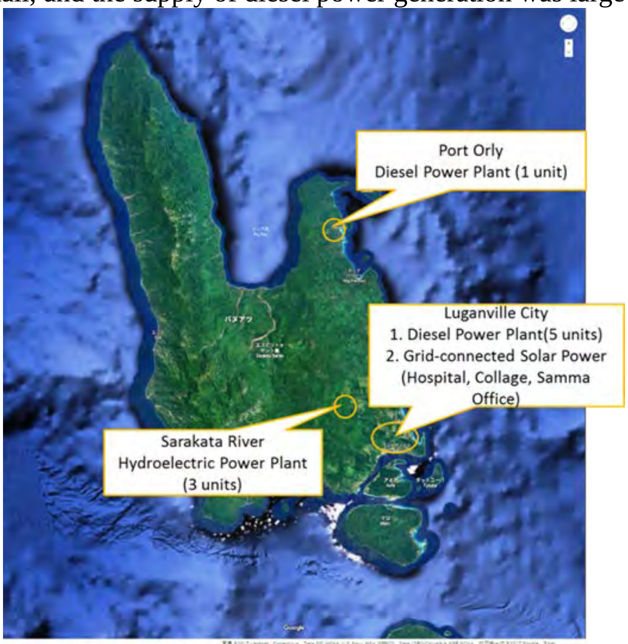


Figure 4-4-1 Locations on Each Power Generation Facilities

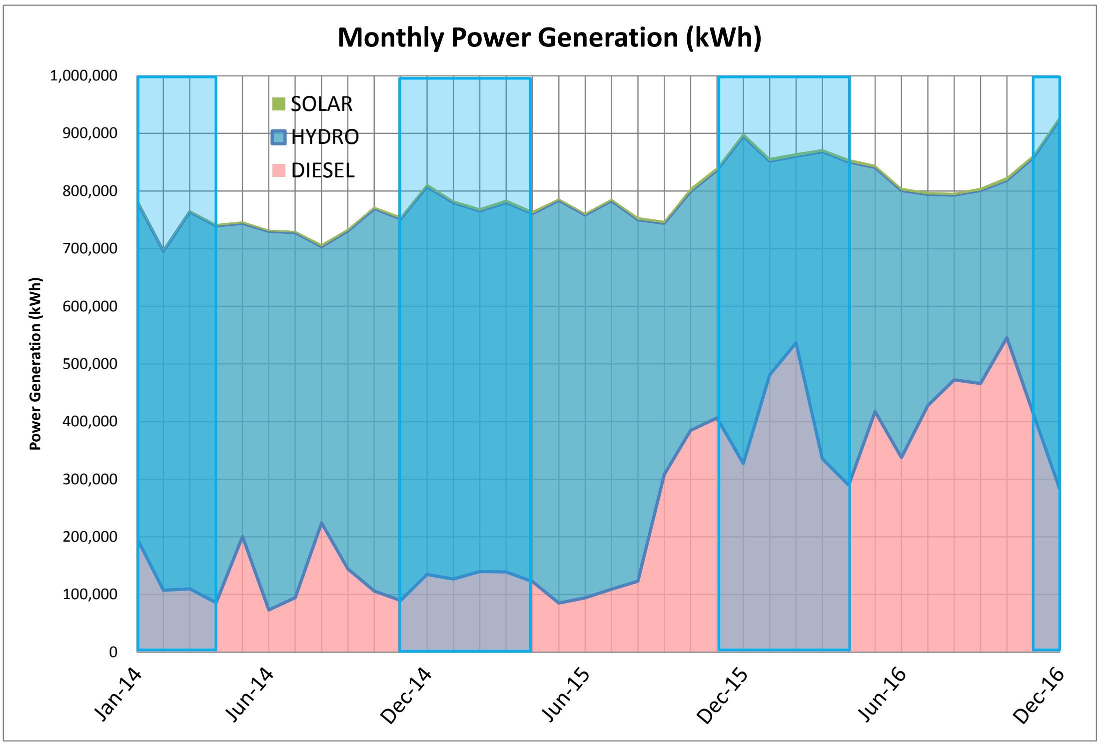


Figure 4-4-2 Transition of Monthly Power Generation Amount (2014 - 2016)

4-4-2 Transmission and Distribution Facilities

The list of existing transmission and distribution facilities is shown in Table 4-4-2. Total extension growth by new extension line is small in 2013 and 2014. Transmission failure time, especially unplanned power failure time is short, and it is less than 1 minute per customer in 2014. The power loss rate due to distribution is about 9%.

Table 4-4-2 The Outline of Facilities and Distribution Record of the Existing Transmission and Distribution Line

Year	Units	Year		Variation
		2013	2014	%
High Voltage Lines Length	km	69,373	71,373	2.9
Low Voltage Lines Length	km	68,707	71,167	3.6
Distribution Losses	kWh	828728	809431	−2.3
Total Planned Distribution Disruption	Time/ Customer	5:53	4:12	−28.6
Total Unplanned Distribution Disruption	Time/ Customer	2:47	0:41	−75.4
Distribution Efficiency Rate	%	90.6	90.7	0.1

(Source: VUI Technical Report 2014)

There is one substation facility in Luganville city. The transformer is 1.5 MVA, 22 kV/5.5 kW and it connects from the 20 kV transmission line of the existing Sarakata hydroelectric power plant to the 5.5 kV distribution line of the diesel power plant in Luganville city.

The Single Line Diagram of the Concession Area on Santo Island is shown on the next page. The western end of the grid area extends at St. Michel heading west along the coast from Luganville city center the south-east end extends at Million Dollar Point ahead of Pekoa International Airport. The northeast direction extends to the Turtle Bay northward along the east coast.

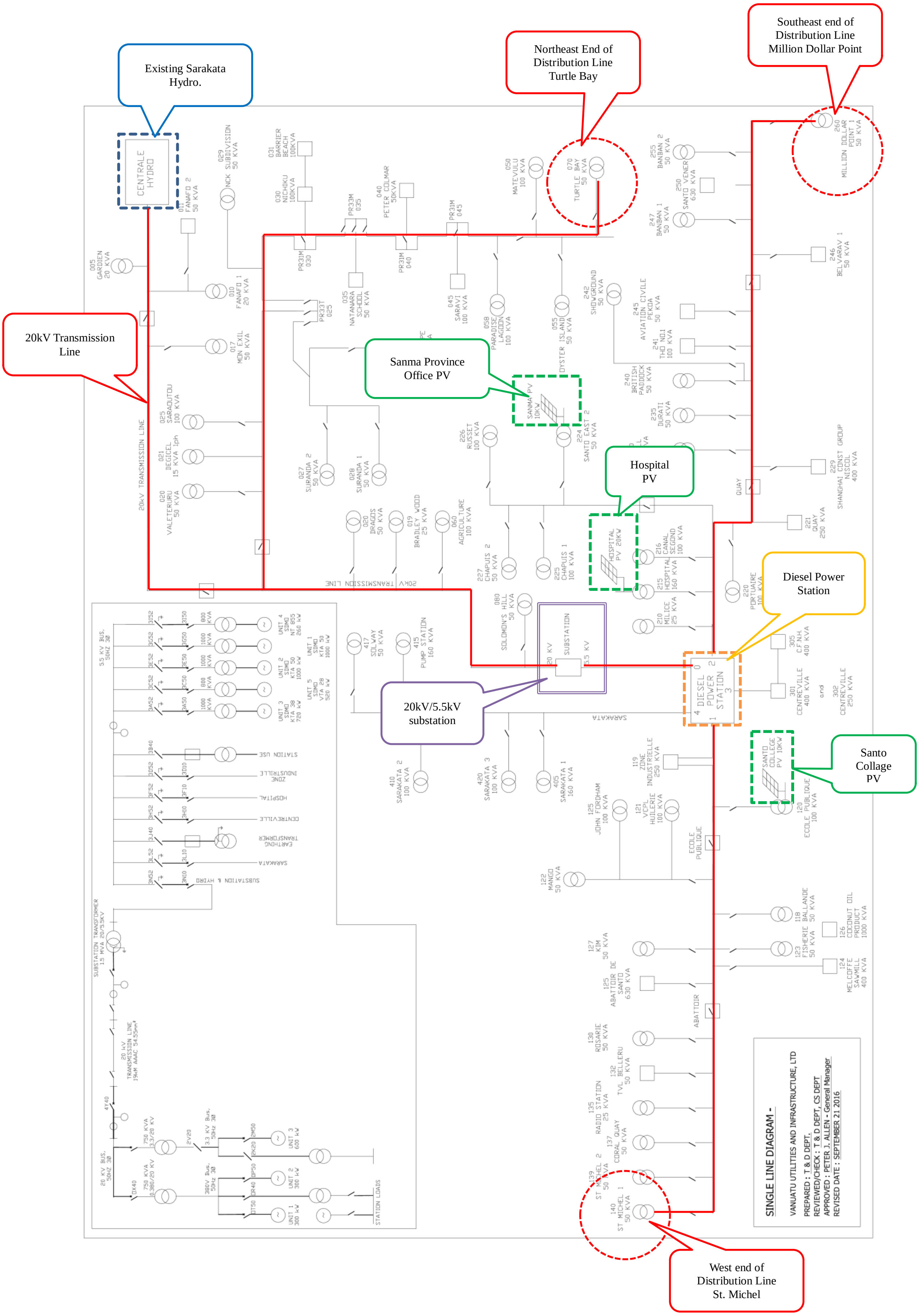


Figure 4-4-3 The Single Line Diagram of the Concession Area on Santo Island

4-5 Previous Power Development Plan

4-5-1 Power supply and demand

The transition of maximum peak Load and power generation in Santo Island is shown in Table 4-5-1 and Figure 4-5-1 and 4-5-2. The data is from 2012, when VUI started the electricity business in Santo Island. The growth rate of the maximum electricity demand has been recorded an average of 3.5% from 8,824 MW in 2012 to 10,122 MW in 2016.

The proportion of each electricity source of power generation to about 80% by 2015, but in 2016 the percentage of diesel power generation increased and the ratio of diesel and hydropower became half for each. This is because the amount of electricity generated by hydroelectric power was small due to the drought in 2016.

Table 4-5-1 Maximum Peak Load and Power Generation (2012 - 2016)

Year	Peak Load	Grouth Rate	Power Generation	Grouth Rate
	(kW)	(%)	(MWh)	(%)
2012	1,710	-	8,824	-
2013	1,637	-4.3%	9,056	2.6%
2014	1,620	-1.0%	8,990	-0.7%
2015	1,850	14.2%	9,492	5.6%
2016	1,932	4.4%	10,122	6.6%
Average	-	3.3%	-	3.5%

(Source: VUI monthly Report)

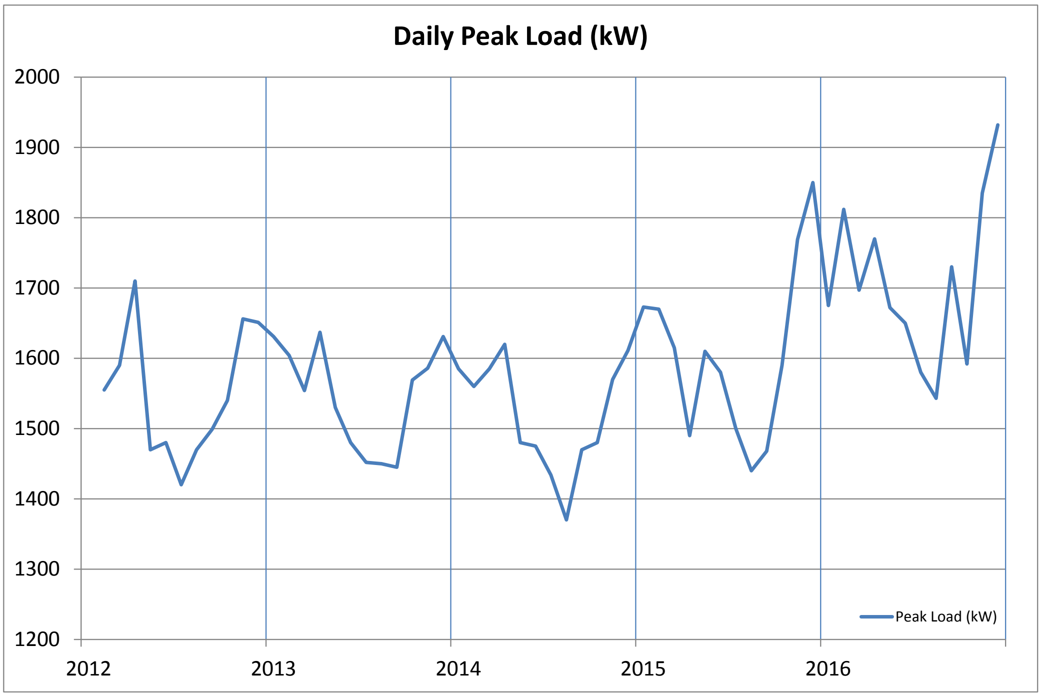


Figure 4-5-1 Transition of Daily Peak Load (2012 - 2016)

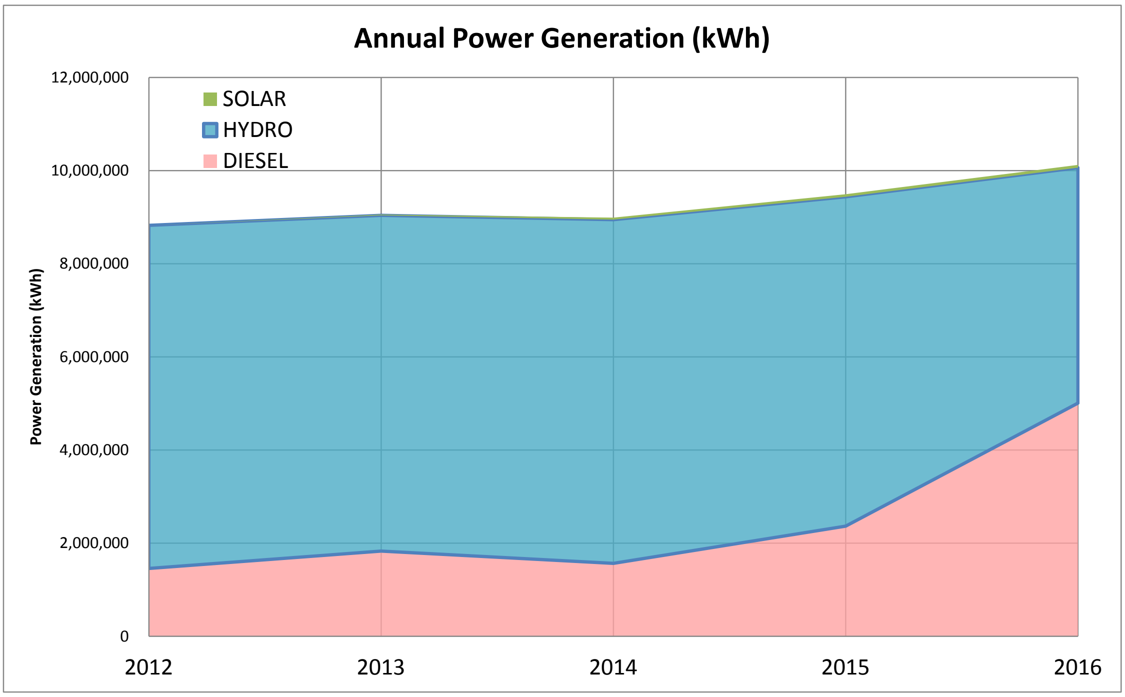


Figure 4-5-2 Transition of Annual Power Generation (2012 - 2016)

4-5-2 Power Supply Development Plan, including Development Plan for Renewable Energy

The power development plan at Santo Island is mainly development of Sarakata hydroelectric power plant, and others are only implementing small scale solar power generation and investigation of potential of wind power generation.

(1) Sarakata Hydroelectric Power Plant

① Japan’s Grant Aid Project

Since Santo Island used to depend on diesel power generation, importation of expensive fuel was a heavy burden for Vanuatu's economy. Therefore, the Sarakata River hydroelectric power station (inflow type, Francis turbine, 300 kilowatts × 2 units) was installed in 1994-1995 and the fuel cost of Santo Island was reduced by switching from diesel power generation to hydroelectric power generation. Also, by utilizing the funds obtained by fuel cost reduction, government had been also promoting electrification across Santo and on remote islands. Since then, the electricity demand on Santo island increased and the rated capacity of the existing Sarakata hydroelectric power plant could not cover the electricity demand, so the dependence on the diesel power plant, which increased from 32% in 1996 to 61%, heavy burden from importation for the Vanuatu's economy. The Government of Vanuatu aims to contribute to stable electricity supply; therefore, the government requested the government of Japan to expand this power plant as a grant aid project.

Due to the existing Sarakata Hydropower Improvement Plan in 2007-2009, the total installed capacity reached 1200 kW and it was possible to cover up to 64% against Santo's peak load of 1884 kW. This contributed to the reduction of about 850,000 liters of diesel fuel. Also, since the supply reserve increases as Unit 3 increased to 600 kW, stable power supply became possible even if the generator stops for periodic inspection or due to mechanical failure.

② ADB Extension Plan

According to the ADB report "Draft Final Report –R0, Volume3 Feasibility Study of Sarakata-1 Extension Project" prepared in August 2014, a plan was considered for the Sarakata Hydropower Extension Project of additional 600 kW power plant at the existing Sarakata hydroelectric power plant (1,200 kW). In the future, plans were also considered for construction of a 1,200 kW hydropower station downstream of the Sarakata hydroelectric power plant.

With an increase of 600 kW power generation output, the Extension Project is planned to build civil engineering structures such as raising existing civil engineering structures (e.g. raising the water intake dam by 0.4 m), headrace channels, head tanks, power plants, transmission lines, etc.

(2) Solar Power Project by ADB

The power generation plan by ADB's Grant Financing Trial Project introduced in May 2013. It is a grid connected by solar power generation facilities installed in three places in Luganville city. The installation location is three places (total 40 kW): College de Luganville (10 kW), Sanma Province Office (10 kW), Hospital (20 kW).

(3) Port Olry Wind Farm Potential Survey

The Vanuatu government conducted six surveys on wind potential sites through 2012-2014 by the Pacific Islands Greenhouse Gas Abatement and Renewable Energy Project (PIGGAREP) and the International Union for the Conservation of Nature (IUCN). One of the six places is Port Olry in Santo Island.

Data is basic information collection of wind direction, wind speed; however, a concrete power generation plan is not currently planned.

4-5-3 Transmission and Distribution Line Development Plan

(1) East Coast Grid Extension

Along the eastern coast of the power system's concession area, it extends only to Turtle Bay, Port Olry (about 2,000 villagers) in the northern part of Santo island with many villagers is using independent diesel generation. Since about 40 km from Turtle Bay to Port Olry there are many tourism resources and the increase in the future demand for electricity is expected, ADB's power distribution line extension plan "Grid Extension, East Cost Santo (Matelevu to Shark Bay, Port Olry, Stone Hill and Palekula)"is scheduled for 2017 - 2018. Construction cost is about 2.4 million USD.

(2) Medium-Low Voltage Distribution Lines Extension

Development plan aimed at the power system area of Vanuatu. In Santo Island, VUI will develop medium-low voltage distribution network from 2020 to 2023. The cost of the overall plan is 18 million USD.

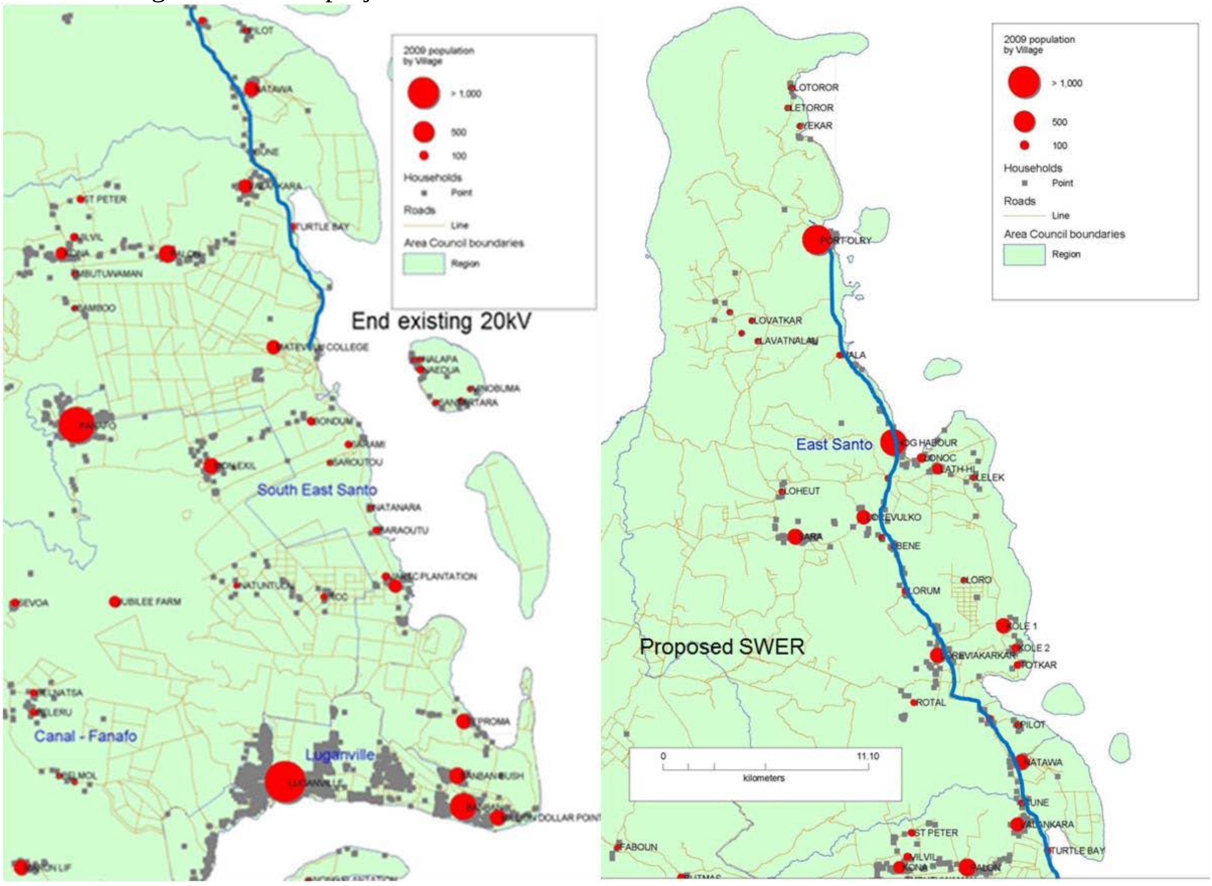
4-6 Survey on Electricity Demand

4-6-1 Projects that Affect Electricity Demand

As shown in Figure 4-1-1 of Section 4-1, the electrified area by the electric power grid is merely a part of Santo Island and the number of VUI customers who is connected to the electric power grid is 2,758 households (URA data as of December 2015), which is only about 35% of the total number of households in Santo (7,864 households, the 2009 Census). Projects, which include the extension plans of Luganville power grid that will influence the future electricity demand, are discussed as follows:

(1) East Coast Grid Extension Project

As mentioned in the previous Section 4-5-3, ADB has studied the project of grid extension from Turtle Bay, which is located at the northeast end of current Luganville power grid to Port Olry, which is located in the northeast of the Sand Island and the second most populous town following Luganville, along the Santo East Coast Road in the east coast of the Santo Island. This grid extension, with a distance of around 40 km, is expected to be constructed in 2017 and 2018. Figure 4-6-1 outlines the route of this grid extension project.



(Source : TA No8285-VAN:Energy Access Project-1, Draft Final Repot Appendix C-Feasibility Study for Transmission Lines and Grid Extensions, ADB)

Figure 4-6-1 East Santo Map – Port Olry Extension

The feasibility study[1] for this grid extension project conducted by ADB assumed that the number of households, which will be connected to the extended grid, is 600 households and the electricity consumption per household per month is 47 kWh / month / customer. The newly increased electricity

[1] TA N°8285-VAN:Energy Access Project-1, Draft Final Repot Appendix C-Feasibility Study for Transmission Lines and Grid Extensions

demand per year from this extension is 338,400 kWh, which is equivalent to about 4% of the annual energy sold of 8,983,224 kWh in the Luganville concession in 2016.

End of Existing 20 kV（Turtle bay）

Port Olry

(2) Medium and Low Voltage Distribution Line Extension

As stated in the previous Section 4-5-3, there is the development plan aiming at expanding the power grids in Vanuatu, under which, in Santo, extension of low voltage distribution network are expected to be conducted in 2020-2023 by VUI as the concessionaire for the Luganville concession area.

4-6-2 Industrial Development Plan and Others in Santo

Development plans that affect future electricity demand in Santo are described as follows:

(1) Sanma Province/ Luganville Municipality, Strategic Development Plan 2016-2027

In January 2017, the Sanma Provincial Government Council and Luganville Municipality launched their Strategic Development Plan (SDP) 2017-2026.

This strategic plan is arranged according to three thematic areas: Economy, Social and Environment. The objective frameworks are set out by each thematic area. However, specific numerical targets such as electrification ratio and number of electrified households are not shown in this plan.

Along with the development of various industries, the promotion of rural electrification mainly with utilizing renewable energy is clearly stated as a goal in the area of Environment. "Establish hydropower and windmill plants" and "Establish and extend rural electrification projects in Sanma and Luganville" are set as a Strategy Framework for the objective of "Promote renewable energy initiative".

Along with agriculture, tourism is also a significant sector. The visitors explore the remains of World War II. The Strategic Development Plan’s strategy framework to promote Sanma Province and Luganville Municipality as principal tourist destinations includes 1) Upgrading of Pekoa International Airport to meet international standards, 2) Establishment of World War II Museum, etc. According to the Elwood J Euart Association, the World War II Museum will be constructed in the land adjacent to the Town Hall in Luganville city and the association already made a land loan agreement with the country in 2016. The total floor space of the museum is 3,286 m^2, of which the interior floor area is 2,437 m^2, and the electricity capacity for this museum is assumed to be around 120 kW.

Luganville is experiencing rapid growth as people from rural areas migrate to the town. There is a growing need for immediate development and expansion of infrastructure for more densely populated districts in and around the city. Under these situations, the Luganville municipality has proposed to expand the municipal boundary of Luganville. The extension of the Luganville municipality area needs increasing and/or upgrading infrastructure facilities such as street lights, which are expected to lead to increase in electricity demand.

(2) Other Development Plans that might affect New Electricity Demand

According to an entrepreneur (Wong Sze Sing Store) who operates meat-processing plants, supermarkets, etc. in Santo, due to the recent rise in copra prices, they have a plan to establish a coconut oil factory, a shopping mall and a casino. These new facilities will require some hundreds kW in electricity demand.

As shown in Figure 2-1-3 and Figure 2-1-4 in Section 2-12 of Chapter 1, the number of tourists from abroad to Vanuatu has been increasing. According to the tourism department of the Sanma Provincial Government Council and others, an airline company is considering a launch of new international flights to Pekoa International Airport, which is expected to increase much the number of tourists visiting Santo. In expectation of such an increase in tourists to Santo, one resort hotel has already been under construction, and accommodation facilities in Santo are likely to increase year by year.

4-6-3 Forecasting of Electricity Demand

NERM 2013-2020 basically assumes a 4% annual growth rate for electricity consumption.

On the other hand, the annual growth rate of actual electricity consumption in the Luganville concession area for the period from 1996 to 2016 is 4.4% on average, which is roughly the same rate assumed by NERM 2013-2020. In NERM, no peak loads were forecasted, but the actual peak loads have increased by an average of 4.5% per year. Table 4-6-1 shows actual values of peak load and energy sold in the Luganville concession area.

Table 4-6-1 Actual Peak Load and Energy Sold in Luganville Concession

Year	Peak Deamd (kW)	Energy Sold (kWh)
1994	870	3,784,836
1995	1,200	4,396,966
1996	1,240	5,012,572
1997	1,300	5,881,620
1998	1,400	6,612,372
1999	1,520	6,927,533
2000	1,740	7,687,967
2001	1,880	8,544,537
2002	1,314	6,451,910
2003	1,408	6,302,979
2004	1,512	6,511,733
2005	1,338	6,069,839
2006	1,283	5,887,789
2007	1,499	6,106,038
2008	1,373	6,481,999
2009	1,366	6,529,069
2010	1,530	7,555,377
2011	1,650	7,557,895
2012	1,713	7,741,646
2013	1,637	7,882,870
2014	1,611	7,828,173
2015	1,850	8,196,169
2016	1,932	8,983,224
average growth rate	4.5%	4.4%

(Source：The JICA Survey Team prepared based on UNELCO Annual Technical Report year 2010, VUI Performance Report for 2014, VUI Report in URA format for 2016)

Regarding future electricity demand forecasts, since the current electrification rate in whole of Santo

Island is still 30% that is much lower. Therefore, it is expected that the power grid will be expanded over the medium to long term, while the electricity demand on commercial and industrial basis is also expected to steadily increase by the increase of industrial, commercial and tourism facilities newly-developed in line with the development plans described in Section 4-6-2. In consideration of these situations, the electricity demand growth is expected to continue basically at the same level with the previous level (or actual growth rate) over the medium to long term. The JICA Survey Team forecasted electricity demands up to 2030, assuming an annual electricity energy growth rate of 4.4% and an annual peak load growth rate of 4.5% based on the actual growth rates of the past peak demands and energy sold. The forecasted electricity demands are shown in Table 4-6-2.

Table 4-6-2 Forecasted Peak Load and Energy Sold in Luganville Concession

Year	Peak Deamd (kW)	Energy Sold (kWh)
2016	1,932	8,983,224
2017	2,019	9,382,389
2018	2,109	9,799,290
2019	2,203	10,234,716
2020	2,302	10,689,490
2021	2,405	11,164,471
2022	2,513	11,660,558
2023	2,625	12,178,689
2024	2,743	12,719,842
2025	2,866	13,285,041
2026	2,994	13,875,355
2027	3,128	14,491,899
2028	3,268	15,135,838
2029	3,415	15,808,391
2030	3,568	16,510,828

(Note : figures in 2016 are actual)

4-7 Challenges on Power Supply and Demand in Santo

The electricity demand in Santo is expected to steadily increase at around 4% in the future as mentioned in the previous sections. On the other hand, no specific power development projects are planned besides the project to expand the existing Sarakata Hydropower Plant. Unless the extension project of the existing Sarakata hydropower or new power generation projects by other renewable energy are carried out, the portion of electricity generated from renewable energy (currently 60 to 70%) in the Luganville concessions area will decrease year by year. This is against the national target to achieve the higher portion of electricity generated by renewable energy. In addition, the use of expensive imported fossil fuels increases, resulting in higher power generation costs and finally higher electricity prices.

Chapter 5 Data Collection and Analysis on Existing Power Facilities in Espiritu Santo

5-1 Investigation Summary

5-1-1 Overview

The field survey of power facilities of Espiritu Santo (Santo Island) was carried out to confirm the current conditions and problems. The field survey was carried out as the first survey (from 26th November, 2016 to 18th December, 2016) and the second survey (from 29th January. 2017 to 19th February, 2017).

The subjects of this survey are as follows:

- Sarakata River Hydroelectric Power Plant
- Luganville Diesel Power Plant
- Port Olry Diesel Power Plant
- Luganville Grid-connected Solar Power
- Transmission and Substation Facility

Based on the field survey results and interview results from VUI staff, etc., overview of facilities, equipment, operation system, etc. of each facility will be described in chapters 5-2 to 5-6. Also, at the end of this chapter, each issue of the existing power equipment is described.

5-1-2 Locations

Locations of each power facilities are shown below.

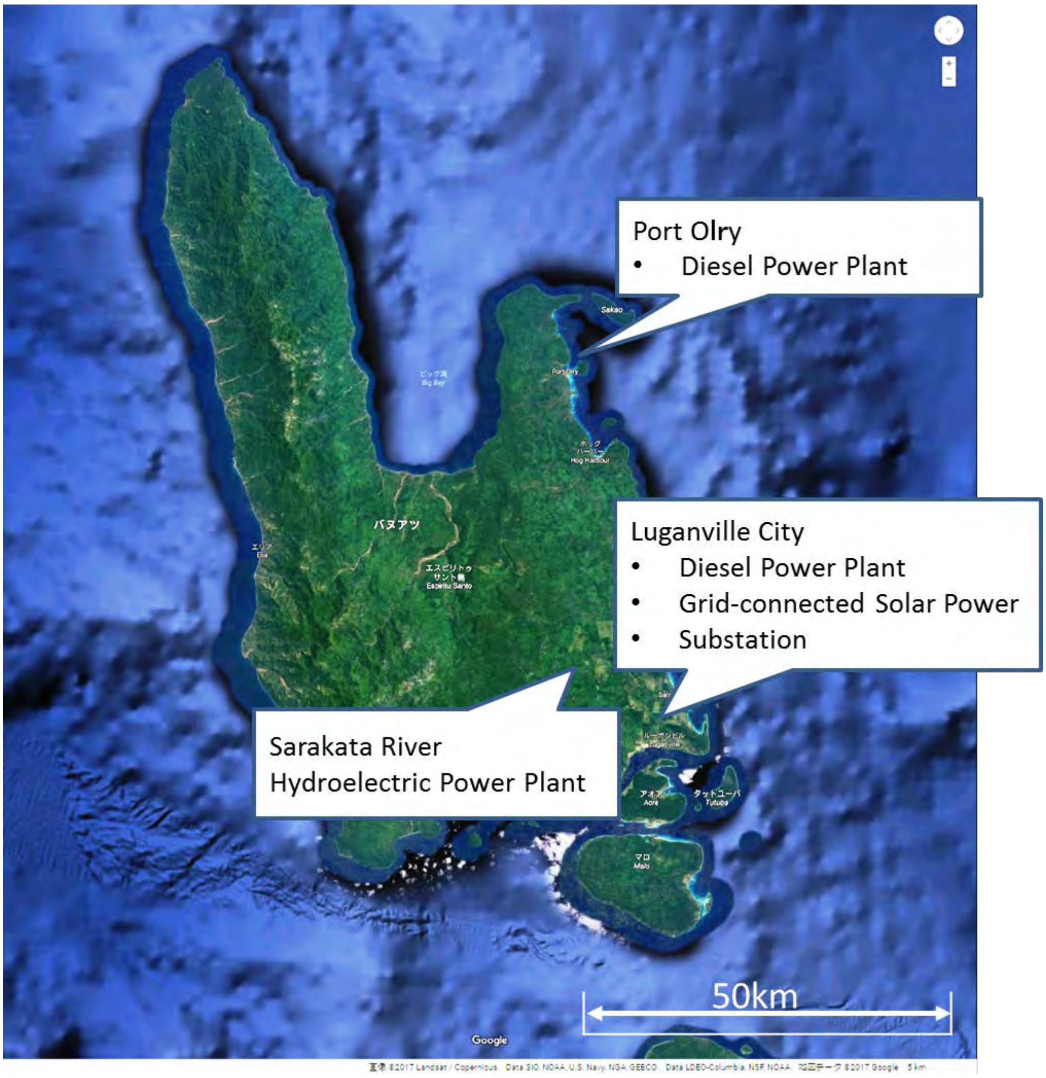


Figure 5-1-1　Locations of Power Facilities

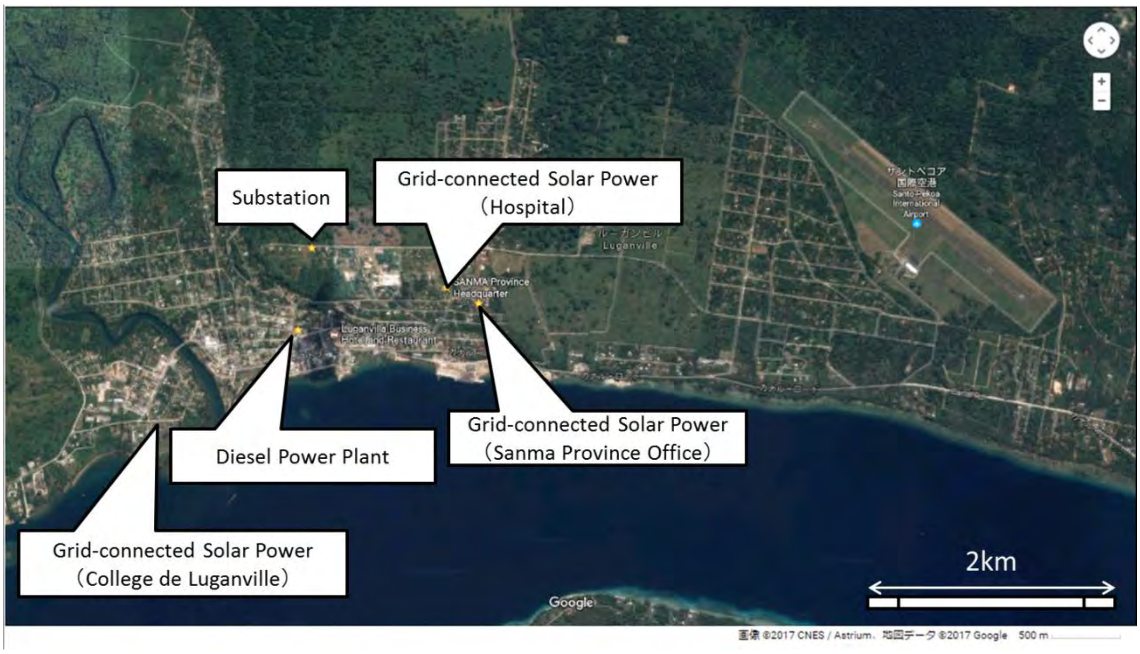


Figure 5-1-2　Facility Locations at Luganville City

5-2 Sarakata River Hydroelectric Power Plant

5-2-1 Overview of Facility

The Inflow Hydroelectric Power Plant was constructed by Japan grant aid t from 1994 to 1995. Due to the increase in electricity demand on Santo Island, the power plant can not fully cover the demand with the rated capacity (300 kW for Unit 1&2, 600 kW in total), Unit 3 for 600 kW was expanded by Japan grant aid from 2007 to2009. As present, the total capacity of the facility has been expanded to 1,200 kW.

5-2-2 Equipment

The overview of equipment is summarized in the table below.

Table 5-2-1 The Overview of Sakrakata River Hydroelectric Power Plant Equipments

Item		Sarakata Hydropower		
		Unit1	Unit2	Unit3
Turbine	(Type)	Horizontal Francis Turbine		
Discharge for Maximum Power	(m3/s)	1.45	1.45	2.90
Effective Head	(m)	27.8	27.8	27.8
Output	(kW)	300	300	674
Generator	(Type)	HS-TKB	HS-TKB	KSG
Output	(kWA)	375	375	750
Frequency	(Hz)	50	50	50
Rotation Speed	(r/m)	750	750	500
Operation Start	Year	1994. September		2009. February

5-2-3 Operation Systems

- Power generation operation is carried out in conjunction with Luganville Diesel Power Plant.
- The numbers of power generation operator groups are 5 groups per day (every 8 hours). One group for operating power plant and the other group for cleaning and logging, while one group is off. The total numbers of groups are 5 groups, and 10 staff, plus one security guard; hence the total is 11 people.
- The number of power generation operators is two pairs of three shifts per day (every 8 hours). One group for operating power plant and the other group for cleaning and logging, while one group is off. The total numbers are 5 groups, and 10 staff, in addition a security guard; hence the total is 11 people.
- The cleaning of the plant is carried out once a year while the power generation is shut down with the sand flush gate is open. The gate opens manually, and the cleaning takes about 2 hours to finish.

5-2-4 Other Information

(1) Intake Weir, Intake Gate and Settling Basin

- There is no serious damage to the equipment visually.
- Although sediment is somewhat confirmed on the upstream side of the left bank side of intake canal opposite the intake port, the sediment level in front of the intake gate is 2-3 m lower than the lower end of the intake gate (visual observation), and overall, there is few sedimentation.
- There are water gauges and automatic water level gauges on the side of the water intake gate. The water gauge reading of 2.73m is same as the level of the overflow weir crest height. The observation data from automatic water level gauging station has not been collected.
- In order to secure the amount of water required for power generation with full power output, VUI raised the wall height of settling basin with cement mortar. That's because the friction of the headrace channel is larger than expected, and the settling basin water level got higher than the design in order to pass the required amount of water.
- When the river flow amout below the maximum generation used water amount (5.8 m^3 / s) of the power plant, there is no discharge from the intake while sttling basin and the water does not flow ro rhw river between intake weir and power plant. It differs from the hearing information from VUI that sustaining flow has not been discharged from settling basin gate.
- The sand flush gate is a steel gate with four-side watertight. However, leakage was confirmed from a part of the rubber seal.

Picture 5-2-1 Intake Weir, Upstream Side

Picture 5-2-2 Intake Weir with Settling Basin, Downstream Side

Picture 5-2-3 Water Gauge, Beside Intake Weir.

Picture 5-2-4 Automatic Water Level Gauge Recorder

Picture 5-2-5 Settling Basin and Water Channel

Picture 5-2-6 Settling Basin Spillway Section Bulk-up Condition

Picture 5-2-7 River Condition, Downstream of the Weir (Overspill=0)

Picture 5-2-8 Sand Flush Gate

Picture 5-2-9 Sand Flush Gate Winch

(2) Headrace channel, Head Tank, Penstock

- Various kinds of ground countermeasure construction work against ground sliding, ground surface erosion etc., were done around the headrace channel, and most of the surface parts of construction site, except the surface drainage seat part, were already covered with vegetation and seemed to be stable.
- Also, there is no major change in the surface drainage sheet construction site after construction, so the effect of the ground countermeasure construction is considered to be stable.
- The water level of the waterway tends to be higher on the intake side and decrease as going to the head tank side.
- PCV sheet was introduced for the purpose of improving the water channel roughness coefficient,

but it was confirmed that substances which was considered to be calcium carbonate adhered to this PCV sheet.

- There is a high possibility that the roughness is increased and the water flow capacity is reduced.
- It was confirmed that water constantly overflowed from the spillway of the head tank. According to VUI's supervisor, this is because it manually responds to load fluctuations.
- There are no abnormalities on the penstock such as cracks in the fixing base and leakage from iron pipe.

Picture 5-2-10 Water Channel, Surface Drainage Sheet

Picture 5-2-11 Roughness Coefficient Inprovement Sheet and Surface Adhered Substances

Picture 5-2-12 Headtank

Picture 5-2-13 Headtank Spillway Overspill Condition

Picture 5-2-14 Penstock (View from Headtank)

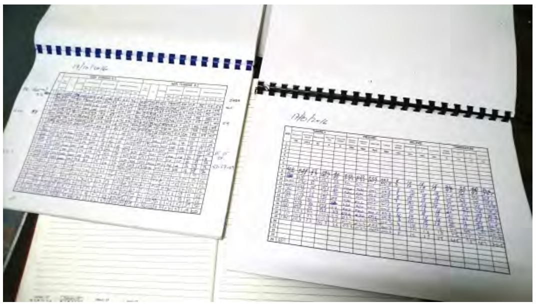
Picture 5-2-15 Penstock (View from Power House）

(3) Power House, Turbines and Generators, Tailrace

- The power house is the rectangle shape and it is long in the river direction and high in the vertical direction to keep the width as small as possible due to the constraints on the topography.
- There is no abnormal sound and vibration in the running turbine / generator, it is cleaned on the appearance and well maintained.
- The power generation operation record is written in the book and the data is sent to the Luganville diesel power plant.
- Spillway condition can be observed by a monitor at the operating room.

Picture 5-2-16 Power Houser Building

Picture 5-2-17 Hydroelectric Power Equipments



Picture 5-2-18 Operating Records

Picture 5-2-19 Spillway Monitor

Picture 5-2-20 Powerhouse Tailrace

Picture 5-2-21 Tailrace

5-3 Luganville Diesel Power Plant

5-3-1 Overview of Facility

In the Luganville City power sector, Luganville Diesel Power Plant is the largest, most historical and the only diesel power station. It is the main power plant with the Sarakata River hydropower station in Santo Island. The total installed capacity of all the Units are 3,520 kW.

5-3-2 Equipment

The basic information of Diesel Generator is as follows;

Table 5-3-1 The Basic Information on Diesel Generators

	Diesel Generator				
	#1	#2	#3	#4	#5
Fuel	Diesel	Diesel	Diesel	Diesel	Diesel
Rotation Speed (rpm)	1500	1500	1500	1500	1500
Apparent Power (kWA)	1600	1600	NO DATA	800	800
Maximum Output (kW)	1000	1000	750	250	520
Actual Output(kW)	800	800	700	180	400
Manufactured year	1995	1995	NO DATA	1995	1998
Manufactured Company	SDMO	SDMO	LSA 50 M4A	STANFORD	SDMO

5-3-3 Operation Systems

- The power generation is operating while maintaining regular communications with the Sarakata hydroelectric power station by transceiver or telephone.
- Power generation operation is carried out from 10 o'clock in the morning to 12 o'clock in the evening, and after that, it corresponds only to hydraulic power.

Picture 5-3-1 Diesel Generator Power House

Picture 5-3-2 Diesel Generator

5-4 Port Olry Diesel Power Plant

5-4-1 Overview of Facility

The Port Olry diesel power plant is an off grid power plant. The operation started in May 2008 to supply power to Port Olry village which is one of the biggest villages in Santo Island, as a biofuel pilot project fueled with coconut oil, but now, VUI operates and manages with diesel oil.

5-4-2 Equipment

- High-speed Diesel Generator Output：45kW x 1 unit
- Operation start year：May 2008
- Manufactured by Germany

5-4-3 Operation System

- After operated by UNELCO for the first three years, it was driven by a small community but it did not work well and soon, it stopped. After that, VUI resumed operating it on 15th December 2015.
- Hours Operation is from 6:00 to 10:00 (4 hours) in the morning, 5:00 to 10:00 (5 hours) in the afternoon.
- Four VUI staffs are affiliated. Two of them are operating power plant, and one is clerk, and one is distribution-line electrician.
- Regular maintenance of the generator is done by the operator.

Picture 5-4-1 Overview of Power Plant

Picture 5-4-2 Diesel Generator

Picture 5-4-3 Operation Records

Picture 5-4-4 Port Olry Village

5-5 Luganville Grid-Connected Solar Power

5-5-1 Overview of Facility

Grid-connected solar power generation facilities are installed at three places inside the Luganville City. They were introduced by the grant financing trial project of Asian Development Bank (ADB) on May 2013, and the installed locations are ①College de Luganville (10 kW), ②Sanma Province Office (10 kW), ③Hospital (20 kW). Locations are shown in Fig. 5-1-2 “Luganville city map”.

5-5-2 Equipment

Table 5-5-1 Basic Information on Luganville Grid-Connected Solar Power

Item	College de Luganville	Sanma Province Office	Hospital
Output (kW)	10	10	20
Operation Start	2013. May		

5-5-3 Operation System

- Once a month, local operating staff confirms the monthly generation by meter.
- Maintenance and repairing are carried out by operating staff, and the cost of repairing will be charged by the government.
- The equipment is connected to grid system, generated power is sold to VUI, and the amount of generated power is reduced from monthly usage.

Picture 5-5-1 Solar Equipment of Hospital (20kW)

Picture 5-5-2 Sanma Province Office(10kW)

Picture 5-5-3 College de Luganville(10kW)

5-6 Transmission and Substation Facilities

5-6-1 Overview of Equipment (Transmission and Distribution Line)

- High voltage distribution line: Extension 71,373 km (end of 2014)
- Low voltage distribution line: Extension 71,167 km (end of 2014)

5-6-2 Check Items

- 20 kV transmission line is only installed between Sarakata hydroelectric power plant and substation in Luganville city. The utility pillar is a cylinder of concrete (made in Japan.)
- Medium-voltage distribution line of 5.5 KV is used for power distribution.
- The low voltage power generation line is transformed from 5.5 kV to 230 V by a pole transformer.
- There is no leaning utility pole and no obstructing trees that were close and disturbing under the tilted electric poles and transmission and distribution lines.
- Periodic monitoring of transmission and distribution cable facilities is conducted and necessary maintenance such as logging of obstacles is properly carried out.
- Also, the new distribution line extension was checked. The construction cost is supported by the government.
- Even though it is relatively close to the Luganville city, some areas are still not connected to the power distribution line.
- Extension, maintenance and inspection of distribution lines are carried out by members of VUI, but if manpower is needed at the time of installation of equipment, local residents will also help. Materials are mainly imported from Australia and China.

Picture 5-6-1 20kV Transmission Line (Sarakata Hydro.～Luganville)

Picture 5-6-2 20KV/5.5kV Luganville Substation

Picture 5-6-3 5.5kV Distribution Line
（Low Voltage Distribution Line Coexistence Section）

Picture 5-6-4 Luganville City Domestic Low Voltage Distribution Line

Picture 5-6-5 Newy Extended Low Voltage Distribution Line
(Near Million dollar point)

Picture 5-6-6 Undistributed Settlement, Located Several Kilometers from the Left Low-Volatage Distribution Point

5-7 Issues of Existing Power Equipment

(1) Sarakata River Hydroelectric Power Plant

- Calcareous substances contained in the Sarakata River adhere to facilities over the years. Calcareous substances are adhering to the rubber packing part of the gate, and it takes time to clean up for the VUI staff. Calcareous substances are adhering to the water channel, and it creates friction, therefore reducing flow rate.
- There is an automatic mechanical water level measuring instrument installed at the intake dam at the time of investigation of ADB but it is not used.
- The staff manually controls the flow rate flowing from the headtank to the water turbine. Even if the power plant is not generating maximum output of 1,200 kW, water is flowing from spillway of the headtank to the river. Equipment that keeps the water level constant should have been introduced, but the reason why they are not using it is not clear.

(2) Luganville Diesel Power Station

- Because there is no power supply directive organization, the operator predicts and adjusts the amount of electricity that changes day by day by using telephone or radio with the operator of the Sarakata hydroelectric power station.
- Because the monitoring system is not installed, even if the power generation situation of the Sarakata hydroelectric power or the demand situation within the Grid suddenly changes, the diesel power plant cannot follow promptly, there is a possibility that stable and economical operation could not be achieved.

(3) Port Olry Diesel Power Plant

- The operation time is limited from 6 AM to 10 AM (4 hours), and from 5 PM to 10 PM (5 hours). If you need electricity during the off peak period, you only have to use the self-generated power solar panel. If the ADB project proceeds the transmission line extension plan, the problem of power supply at Port Olry will be solved.

(4) Luganville Grid-Connected Solar Power

- Since the equipment scale is small and the amount of electricity generation is small, it does not contribute to reduction of firing of diesel power generation, improvement of renewable energy generation rate, etc.

(5) Transmission and Substation Facilities

- Distribution wire extension line can not keep up with expansion in the city of Luganville. It seems that one of the reasons that the establishment of street light in the city does not proceed as expected is because the inadequate of the electricity distribution network.
- As a story from the VUI staff, mischief (distribution of wood chips etc) was observed at the distribution line, which might have caused power failure. From such a case, there is a concern of stone throwing and damage to the panel when mega solar is introduced.

Chapter 6 Climate, Hydrological, Topographic and Geological Study

6-1 Information Sources

6-1-1 Climate Data

(1) Weather Data Collected by Vanuatu Meteorology & Geo-Hazards Department

Vanuatu Meteorology & Geo-Hazards Department (VMGD) collects weather information on Espiritu Santo Island (Santo Island), and this study will examine the data they provided. The VMGD is the Climate Division belonging to Ministry of Climate Change Adaptation, Meteorology and Geo - Hazards, Environment, Energy and Disaster Management, and is responsible for collecting and analyzing weather information of Vanuatu.

(2) Collected Data

The Weather of Santo Island is analyzed with the collected data from VMGD in this study in addition to those described in the past reports.

- Regarding to the rainfall data, although there are 16 weather stations in Santo Island currently installed by the VMGD, the only long term observation point was installed in 1971 at the Pekoa airport. The other stations were installed after 2012, and are continuously observed and accumulated.
- Please refer to Photo 6-1-1 for all locations of rainfall observation stations on Santo Island.
- In this survey, the study team obtained the following rainfall data:
- The daily rainfall data of Pekoa Airport (1989 to 2003, 2010 to 2015) and the monthly rainfall data (2010 to 2016)
- The daily rainfall data of Fanafo Village as a rainfall observation point in the Sarakata River basin (March 2012 - January 2017)

(Picture in VMGD Climate Division)

Picture 6-1-1 Rainfall Observation Points at Santo Island

6-1-2 River Flow Data

(1) Existing Study Report Data

Flow rate data on Santo Island is only available from the Sarakata River flow data from 1982 to 1985, which was included in the report of ILES D'EFATE ET DE SANTO EVALUATION DES RESSOURCES EN EAU (ORSTOM, 1985). The observation position as stated in this report is the downstream point of the Sarakata River hydroelectric power plant (Catchment Area = 97.1 km^2). This observation facility has already been removed and there is no data other than this period. This data is shown in Table 6-3-5 to Table 6-3-8.

(2) Sarakata River Hydroelectric Power Generation Operation Data

In 2012, Vanuatu Utilities and Infrastructure (VUI) started operating the Sarakata River hydroelectric power station and they recorded the power generating operation data and the water level using the water level mark at the intake weir position since April 2014. For this study, the river flow rate is calculated by this power generation operation data with reference to the method of "The Project for Improvement of Sarakata River Hydroelectric Power Station, JICA, June 2007".

Calculation method and discussion of results are shown in Figure 6-3-4 Flow rate conversion from power generation operation data".

6-2 Climate Study

6-2-1 Overview

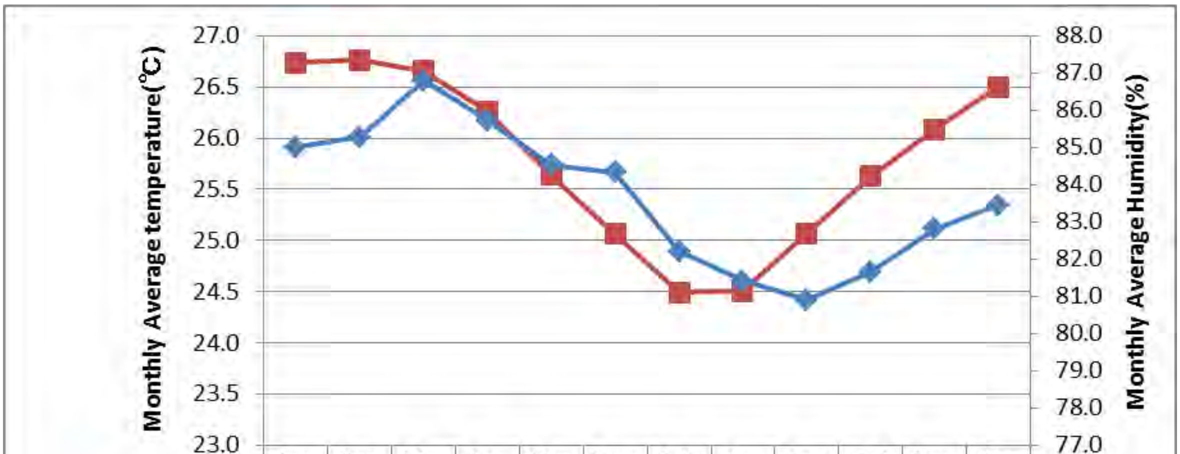
In order to understand the trend of weather on Santo Island, the collected data was analyzed for "temperature / humidity" and "rainfall amount". The analysis was carried out using the data of Pekoa Airport, which is the only long-term observation data in Santo Island.

6-2-2 Climate Study

(1) Temperature / Humidity

In this weather study we discussed the climate data from 1995 to 2014 at Pekoa Airport.

The annual average temperature in Santo is 25.8 ℃. It tends to rise from monthly average air temperature from November to April (26.3℃-26.8℃) and tends to lower from May to October (25.6-24.5 ℃). The annual average humidity is 83.7%. The average monthly humidity tends to rise from 84.3% to 86.8% from January to June, and tends to be as low as 80.9% -83.4% on average from July to December.



	Jan	Fen	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Temperature	26.7	26.8	26.7	26.3	25.6	25.1	24.5	24.5	25.1	25.6	26.1	26.5
Humidity	85.0	85.3	86.8	85.7	84.5	84.3	82.2	81.4	80.9	81.7	82.8	83.4

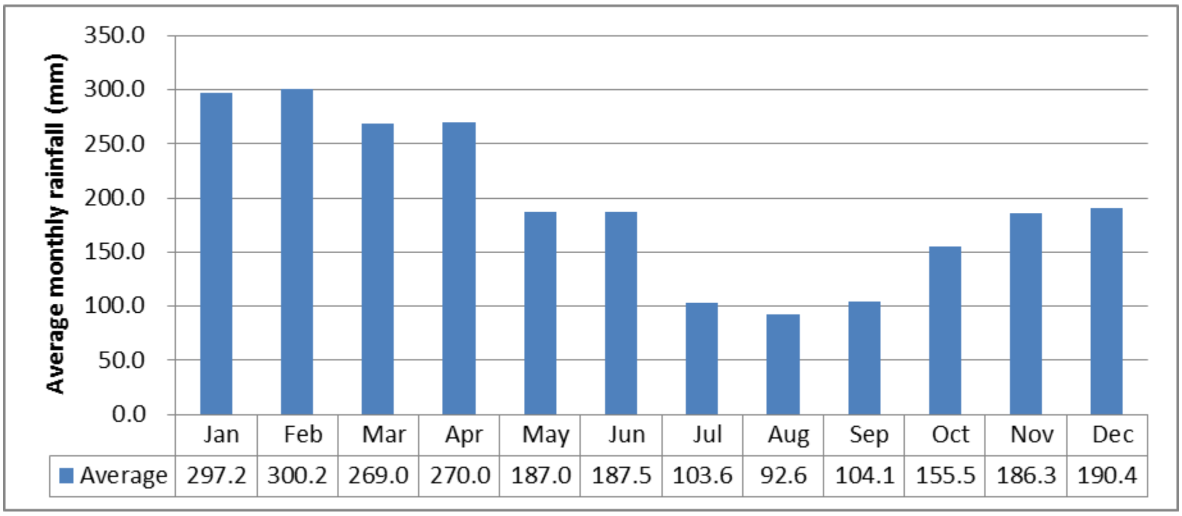
(Source): The Project for Improvement of Sarakata River Hydroelectric Power Station (JICA, 2007)

Figure 6-2-1 Temperature / Humidity（Pekoa Airport, 1995-2006）

(2) Rainfall

1) Monthly Average Rainfall Trend

The rainy season in the southeastern part of Santo is from November to April. The average monthly rainfall is 180 mm - 300 mm, May - October is the dry season and the average monthly rainfall is 90 - 180 mm. The annual average monthly rainfall is 195 mm.

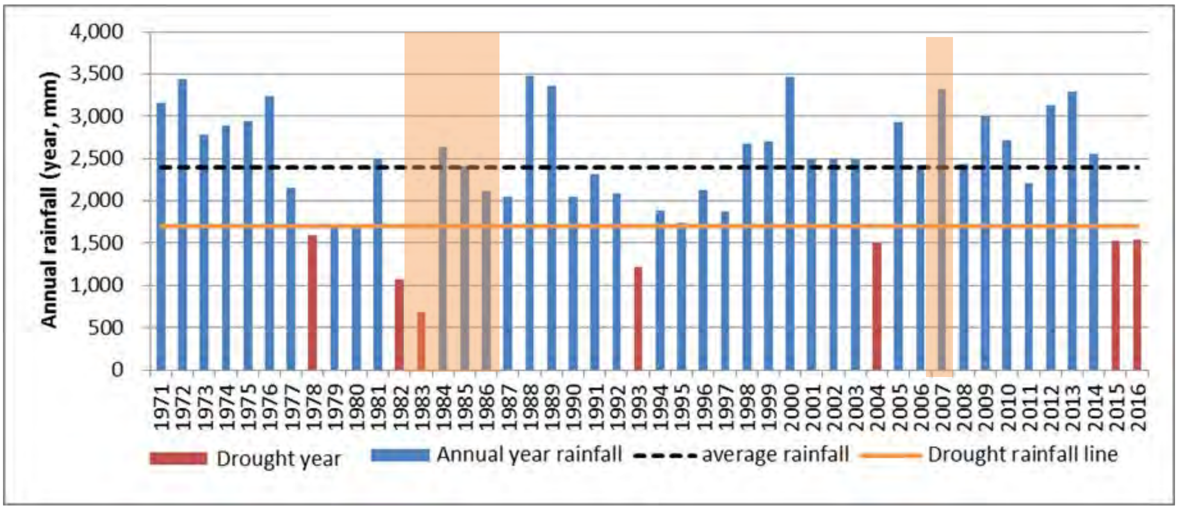


(Source)：Vanuatu Meteorology & Geo-Hazards Department

Figure 6-2-2 Annual Monthly Rainfall（Pekoa Airport, 1971-2016）

2) Long Term Rainfall Trend

The annual average rainfall of Santo Island from 1971 to 2016 is 2344 (mm), the maximum rainfall is 3480 (mm) in 1988, and the minimum rainfall is 685 (mm) in 1983. The annual yearly rainfall data list is shown below:



(Source)：Vanuatu Meteorology & Geo-Hazards Department

Figure 6-2-3 Annual Yearly Rainfall（Pekoa Airport, 1971-2016）

Since there is no clear standard for the drought of rainfall, the drought annual rainfall is assumed to occur once or twice in 10 years with a standard normal distribution (as 15% probability). As the result, the drought annual rainfall of 15% occurrence probability is 1701 (mm). The following table shows the year of the drought rainfall and confirms the ratio with the average rainfall. From this result, it was found that the drought year occurred seven times during the observed period (1974 ~ 2016).

In addition, droughts have occurred over a period of one year to several years, indicating that the occurrence interval is about 10 years since the end of the previous drought. ;

Table 6-2-1　Drought Year Annual Rainfall（1974 - 2016）

Year	Annual (mm)	Average* (mm)	Ratio (%)
1978	1590	2394	66%
1982	1075	2394	45%
1983	685	2394	29%
1993	1212	2394	51%
2004	1504	2394	63%
2015	1532	2394	64%
2016	1541	2394	64%

＊ Average period (1974 – 2016)

Also, when the period of 1975 to 2016 is divided into four sections every 10 years and the annual average rainfall amount is confirmed, the value is increasing by about 8% in 10 years. Specific figures are shown in the table below:

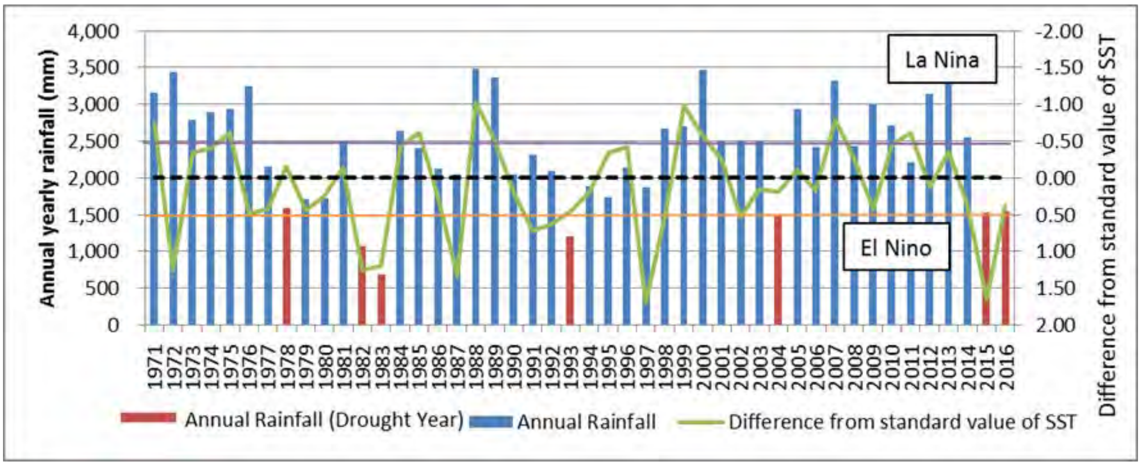
Table 6-2-2　10 Years Period Annual Yearly Rainfall (Pekoa Airport)

item	10years average				increase
	1975-1984	1985-1994	1995-2006	2007-2016	Average ratio
Annual year (mm)	2,026	2,297	2,358	2,573	
increase ratio		113%	103%	109%	108%

(3) El Nino Effect on Drought in Vanuatu

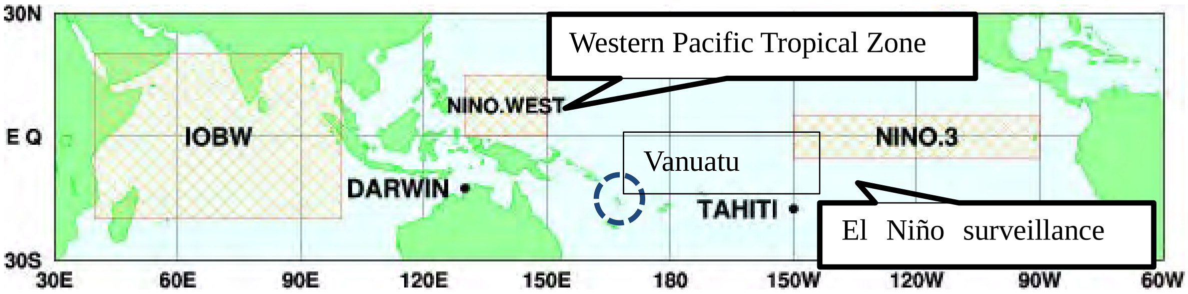
The relationship between the transition of rainfall in Vanuatu and the generation cycle of El Niño phenomenon is shown in Figure 6-2-5.
The El Niño phenomenon is said to occur when the difference from the standerd value of the sea surface temperature (SST) in the El Niño surveillance area (NINO 3) is 0.5 ° C or more. The position of NINO 3 and the positional relationship of Vanuatu are shown in Figure 6-2-5.

The El Niño phenomenon occurred seven times between 1971 and 2016. At the largest El Niño year in 1982 and 2015, droughts in Vanuatu have also occurred. Periodicity in the interval of occurrence of El Niño phenomenon is 4 to 13 years from the end of the phenomenon, and it is not perfectly consistent with the periodicity of drought development in Vanuatu.



(Source): Japan Meteorological Agency

Figure 6-2-4 Relationship Between Transition of Rainfall in Vanuatu and Occurrence Cycle of El Niño Phenomenon



(Source): Japan Meteorological Agency

Figure 6-2-5 Locational Relationship with Vanuatu and El Nino Surveillance Waters and Western Pacific Tropical Zone

6-3 Hydrological Study

6-3-1 Hydrological Study Overview

As a hydrological survey on Santo, we have organized the hydrological information around the Sarakata River, which is the candidate site for this survey.
The aim of the survey is to analyze the collected data on items of "rainfall observation", "flow rate observation", "flow rate conversion from power generation operation data", and to decide the amount of water consumption when a hydroelectric power plant is installed.

The study was based on the following data:
（Rainfall Observation）

- Pekoa Airport: 1974-2017
- Fanafo Village: 2012-2017

（Sarakata River Observation）

- ILES D’EFATE ET DE SANTO EVALUATION DES RESSOURCES EN EAU(ORSTOM): 1981-1985
- “the project for improvement of Sarakata River Hydroelectric Power Plant (JICA,2007)” : April-October. 2006

（Sarakata River Hydropowerplant Operating data

- Operations Monthly Report（VUI）: 2014-2016

6-3-2 Rainfall Observation

(1) The Basic Information of the Rainfall Observation Station

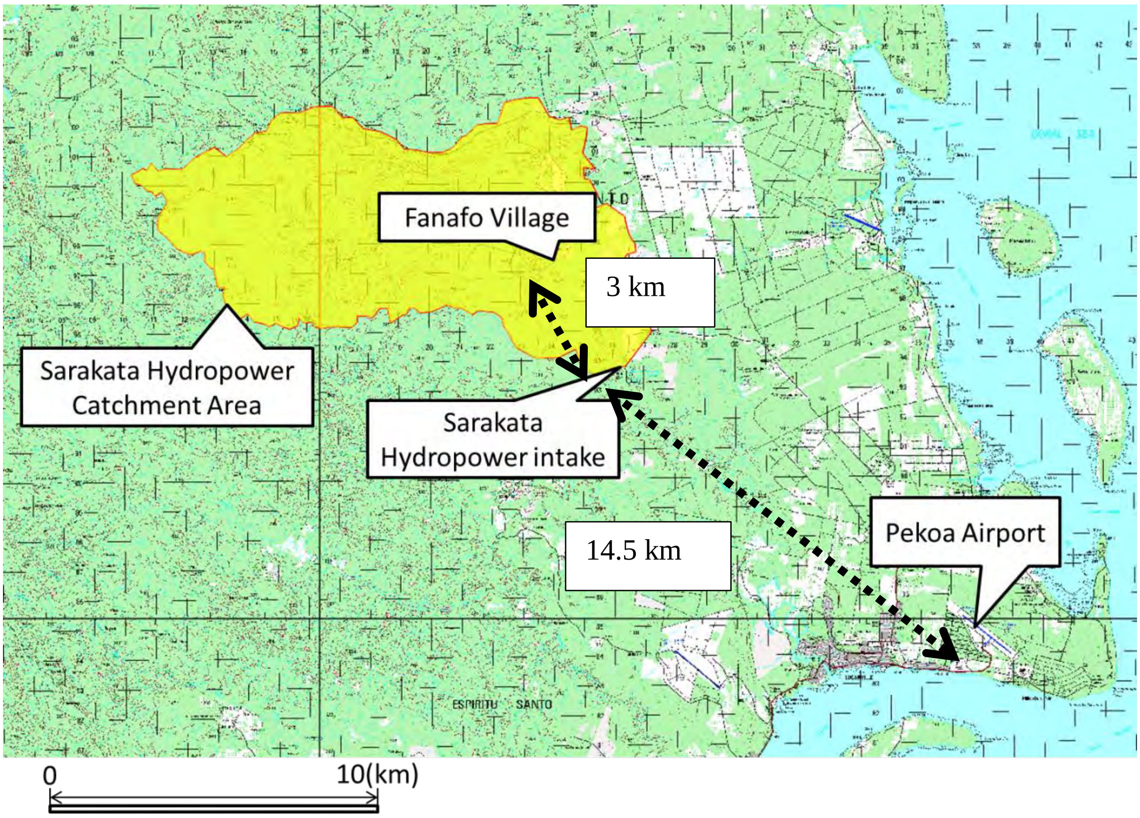
The rainfall observation stations around the Sarakata River are the following two points. The basic information on those points is shown in the table below.

Table 6-3-1 Basic Information of Rainfall Observation Station

Observation	No.	Name/Location	Altitude (m)	Administrator	Observation Period	Year	Type	Observation Method	Condition
Climate	1	Pekoa Airport	45	VMS	1971-2017	43	Storage Turn over	Visually Automatic(2015/Feb～)	Active
Rainfall	2	Fanafo Village	160	VMS	2012-2017	6	Storage	Visually	Active

(2) The Locations of the Rainfall Observation Sites

The locations of the rainfall observation sites around the Sarakata River are shown in the figure below;



(Source: Turtle Bay, Sheet 1516705 (Edition 1-VDLS), Series X721)

Figure 6-3-1 Locational Relationship with each Rainfall Observation Stations

(3) The Rainfall Data

1) Pekoa Airport Rainfall Observation Station

The Pekoa airport rainfall observatory was installed in 1971 by the Vanuatu Meteorology & Geo-Hazards Department (VMGD) as a rainfall observation station in the vicinity of Luganville, which is the center of the economy in Santo. This observatory has been continuously operating up to now, and it is the only long-term observation data on Santo. The observation method was visual observation using a storage type rain gauge until February 2015, but now new automatic rainfall observation equipment has been introduced

2) Fanafo Village Rainfall Observation Station

The Fanafo Village rainfall observation station was installed in 2012 by VMGD which is located about 4.5 km north of the Sarakata hydropower plant, and it has been observing until now. This data for 2012 and 2013 are half-year missing, but from 2014 onwards, it can be handled as data for one year.

Table 6-3-2 Monthly Rainfall Data on Fanafo Village(2012-2017)

(mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2012				470.7	319.6	349.8	133.2						1,273
2013					190.5	236.8	238.2	29.6	158.2	214.3	448.3	134.8	1,651
2014	476.2	316.2	695.9	240.1	146.9	229.4	223	82.2	381.8	608.3	225.5	164.8	3,790
2015	365.6	182.6	465.3	668.8	324.6	105	78.2	112	28.4	43	220.5	294.8	2,889
2016	195.8	92.4	440.2	486.8	36.2	215.6	107.8	80.4	60.1	88.8	273.8	307.6	2,386
2017	141												141
Average	294.7	197.1	533.8	466.6	203.6	227.3	156.1	76.1	157.1	238.6	292.0	225.5	2,301
Maximum	476.2	316.2	695.9	668.8	324.6	349.8	238.2	112.0	381.8	608.3	448.3	307.6	3,790
Minimum	141.0	92.4	440.2	240.1	36.2	105.0	78.2	29.6	28.4	43.0	220.5	134.8	2,386

(Source：Vanuatu Meteorology & Geo-Hazards Department)

The difference between the annual observation rainfall in Pekoa airport and Fanafo Village is the higher amount of rainfall in Fanafo Village (average 61% higher). The reason is that the Fanafo rainfall observatory elevation is higher than the Pekoa airport and located in the mountains.

Table 6-3-3 Comparison of Rainfall Amount（Pekoa Airport, Fanafo Village, 2014-2016）

Year	Annual rainfall (year, mm)		Ratio (%) Fanafo/Pekoa
	Pekoa	Fanafo	
2014	2,555	3,790	148%
2015	1,532	2,889	189%
2016	1,541	2,386	155%
total	5,628	9,065	161%

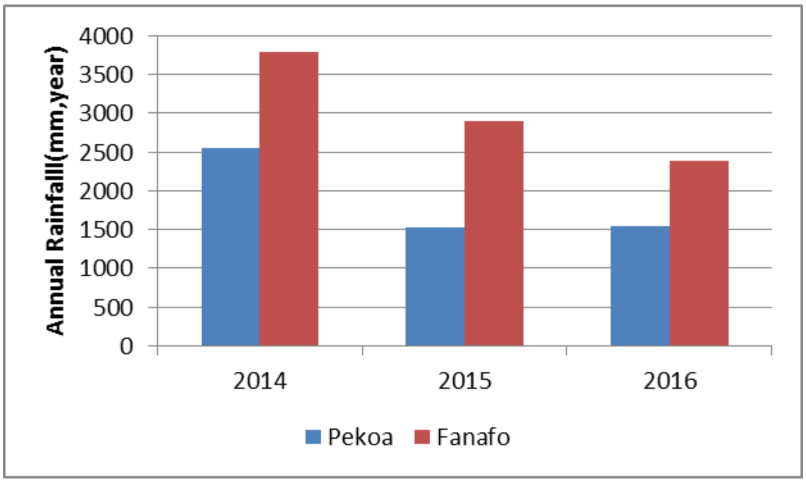


Figure 6-3-2 Difference of Observation Data

6-3-3 Sarakata River Flow Observation

(1) Existing Flow Rate Data

The flow data of the Sarakata River is only observed by ORSTOM, a French company, from 1982 to 1985 and by the report of "the Project for Improvement of Sarakata River Hydroelectric Power Plant (JICA, 2007)" for harf-year of 2006 from the data on power generation operation.

The characteristic of those data are ;

- There is a lack of observation in three years of the ORSTOM data which include the extreme dry year in 1983 and the average flow year in 1984.
- The ORSTOM data was used for the previous studies such as "Basic Design Report on the Project for Sarakata River Hydroelectric Power Development in Vanuatu, JICA, October 1991" and "The Project for Improvement of Sarakata River Hydroelectric Power Station, JICA, June 2007", and "Energy Access Project, ADB, August 2014".
- Flow measurement was carried out at the period from April-October in 2006 in the project of "The Project for Improvement of Sarakata Hydroelectric Power Station (JICA, 2007)" by using of the power generating data provided by UNELCO, which operated the Sarakata River hydroelectric plant. The data was compared with the ORSTOM data of the same month and validated.
- The observation point of each sites are different, ORSTOM point is more downstream than JICA (2007). Those Catchment Areas are ORSTOM (CA=97.1 km2), and JICA(CA=91 km2). Locations are shown on Figure 6-3-3.

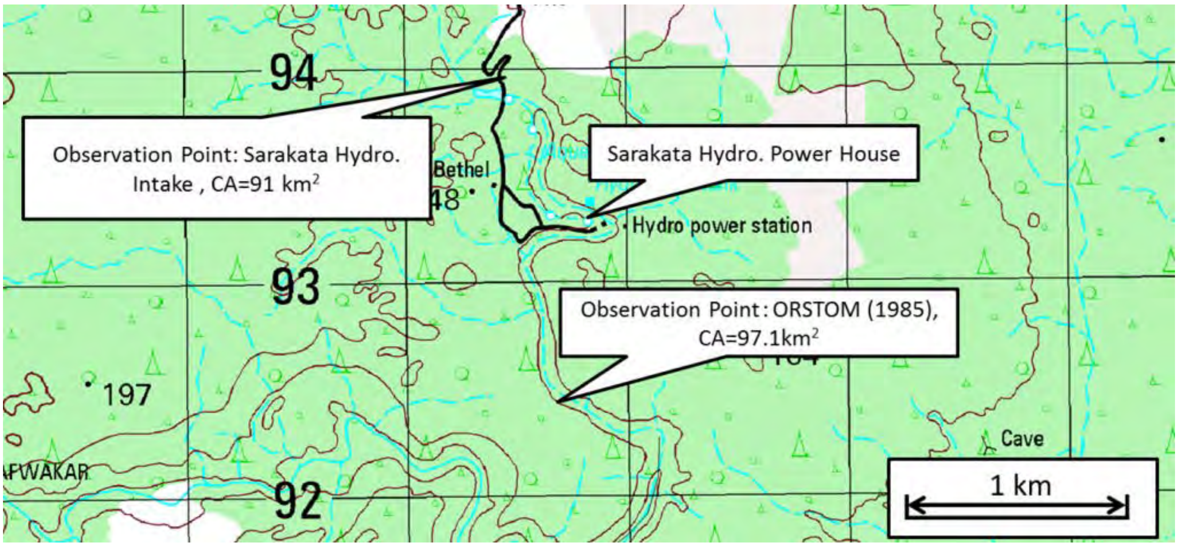


Figure 6-3-3 Location of each Observation Points

The daily flow rate for each data is shown below;

Table 6-3-4 Sarakata River Flow Data(1982)

Name: *Sarakata Flow discharge*					YEAR: *1982*						
				CA=	97.1	km²		n=	335		(m³/s)
Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	?	51.5	7.3	12.9	10.9	8.1	9.1	10.1	6.6	4.7	6.2	13.4
2	?	25.6	7.2	12.5	10.4	7.8	8.9	10.8	6.4	4.6	6.7	10.5
3	?	17.7	6.9	12.8	10.1	7.6	8.5	11.0	6.3	4.5	7.2	9.6
4	?	13.5	6.8	12.4	9.8	7.4	8.1	11.1	6.2	4.4	74.4	9.0
5	?	11.9	6.8	11.9	12.9	7.2	7.6	10.3	6.0	4.4	138.3	8.4
6	?	11.0	6.7	11.8	13.5	7.1	7.1	9.7	5.9	4.3	162.3	7.9
7	?	9.8	6.7	10.8	13.3	7.0	6.7	9.1	5.7	4.3	191.9	7.6
8	?	8.9	7.4	10.1	16.6	6.9	6.2	8.5	5.6	4.4	49.7	7.4
9	?	8.5	15.6	9.4	13.1	7.3	5.8	7.9	5.5	4.4	28.1	7.2
10	?	8.0	15.4	9.1	11.5	9.8	5.7	8.6	5.4	4.3	21.5	7.0
11	?	7.7	9.9	8.9	10.4	7.8	5.7	8.6	5.5	10.1	18.3	6.9
12	?	7.6	8.9	8.8	9.8	7.6	6.0	9.1	5.6	7.4	16.2	6.8
13	?	9.7	8.1	15.9	9.4	7.2	5.8	8.3	5.2	5.8	14.9	6.6
14	?	12.5	7.6	13.0	9.1	7.9	7.2	7.8	5.0	5.3	14.0	6.5
15	?	16.1	7.5	11.9	8.8	7.5	10.5	7.7	4.9	5.0	13.8	6.4
16	?	13.2	7.4	31.3	8.6	7.1	13.5	8.6	4.8	4.8	12.3	6.5
17	?	10.1	8.1	23.9	9.1	6.9	10.9	9.1	4.7	4.6	11.6	6.3
18	?	11.8	8.2	22.6	12.1	6.7	9.0	8.6	4.7	4.4	11.0	6.3
19	?	12.0	11.5	22.9	24.7	6.5	7.7	8.1	4.7	4.4	10.7	6.2
20	?	10.8	13.6	19.0	32.0	6.4	7.0	8.1	4.7	4.3	10.9	6.9
21	?	9.7	13.0	20.6	15.7	6.3	6.5	10.7	4.7	4.3	10.1	6.4
22	?	9.1	10.0	22.0	12.8	6.3	6.2	21.6	4.7	4.1	9.6	6.4
23	?	8.7	12.5	21.2	11.3	6.2	6.0	18.9	4.7	4.0	9.5	12.5
24	?	8.3	23.2	19.0	10.5	6.2	5.9	14.2	5.0	4.0	9.4	12.8
25	?	7.9	35.7	19.2	10.0	6.1	5.8	11.5	4.8	3.9	9.3	9.1
26	?	7.7	67.3	16.1	9.6	6.1	6.3	9.8	4.6	3.8	9.3	8.3
27	?	7.6	37.4	14.5	9.5	6.0	7.8	8.8	4.5	3.8	8.9	8.3
28	?	7.4	26.7	13.2	9.2	6.1	7.2	8.1	4.5	3.8	8.7	7.5
29	?		19.2	12.2	8.8	7.3	8.0	7.7	4.6	4.3	9.8	7.2
30	?		15.9	11.4	8.6	7.4	20.5	7.3	4.6	5.0	13.2	7.1
31	24.9		14.2		8.3		11.7	6.9		5.6		7.7
Total	24.9	343.9	452.5	461.2	370.4	212.1	248.7	306.4	156.3	147.1	917.9	246.7
Ave.	24.9	12.3	14.6	15.4	11.9	7.1	8.0	9.9	5.2	4.7	30.6	8.0

(Source: ILES D'EFATE ET DE SANTO EVALUATION DES RESSOURCES EN EAU, (ORSTOM,1985)

Table 6-3-5 Sarakata River Flow Data (1983)

Name:	*Sarakata Flow discharge*				YEAR:	*1983*					
				CA=	97.1	km²		n=	333		(m³/s)
Date	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1	9.6	6.3	6.0	5.1	5.8	4.7	4.1	3.6	3.1	5.0	?	19.6
2	10.8	6.6	5.8	5.0	6.2	7.4	4.1	3.6	3.0	4.4	?	14.9
3	9.3	6.3	5.6	5.0	5.7	6.6	4.1	3.5	2.9	4.0	?	12.6
4	16.0	6.0	5.4	5.0	5.5	5.8	4.1	3.5	2.9	3.7	?	10.3
5	16.0	5.7	5.2	5.1	5.3	5.4	4.0	3.4	2.9	3.6	?	9.0
6	15.2	5.6	7.1	5.2	5.9	5.2	3.9	3.4	3.0	4.2	?	8.7
7	13.6	5.5	6.1	5.0	5.5	5.4	3.8	3.3	3.5	4.5	?	9.2
8	11.6	5.4	5.8	4.9	5.4	5.3	3.8	3.4	4.1	4.3	?	7.9
9	12.3	5.5	6.2	4.8	5.2	6.1	3.8	3.6	3.4	3.9	?	7.2
10	16.3	5.3	6.3	17.0	5.9	6.7	3.8	3.5	3.2	3.7	?	6.8
11	13.4	5.5	7.3	8.6	5.7	5.8	3.8	3.5	3.2	3.6	?	6.4
12	20.4	8.8	9.0	11.0	5.3	6.3	4.3	3.5	3.1	3.4	?	6.0
13	26.3	8.8	11.3	8.2	5.3	12.2	4.1	3.5	3.0	3.4	?	5.8
14	21.2	7.3	8.5	6.8	5.5	10.8	4.0	3.4	2.9	4.6	?	5.7
15	14.9	6.3	7.2	6.3	5.5	8.7	4.0	3.4	3.0	3.7	?	5.5
16	12.3	6.0	7.0	5.9	5.3	7.5	4.0	3.4	2.8	3.6	?	7.5
17	10.9	6.9	6.9	5.7	5.4	6.8	3.9	3.3	2.8	3.5	?	7.8
18	9.9	8.6	6.4	6.4	5.3	6.4	3.9	3.2	2.9	4.6	?	10.0
19	9.7	14.6	6.4	5.8	5.1	6.0	3.8	3.2	3.2	4.5	?	13.6
20	13.3	13.7	6.7	8.5	5.0	5.8	3.8	3.4	3.9	4.1	?	11.6
21	12.1	10.0	7.4	9.3	4.9	5.5	3.7	3.5	3.5	3.9	?	9.4
22	9.5	8.2	7.9	7.4	5.1	5.3	3.7	3.3	3.5	?	?	10.9
23	9.1	7.4	6.7	6.7	6.1	5.1	3.7	3.1	3.7	?	18.6	10.1
24	9.2	6.8	6.5	6.6	5.8	5.0	3.6	3.1	3.5	?	11.9	9.4
25	8.3	6.5	6.6	6.1	6.0	4.8	3.6	3.3	3.3	?	11.2	8.2
26	7.9	6.4	6.2	5.8	6.4	4.7	3.7	3.3	3.1	?	10.4	7.5
27	7.6	6.1	6.0	5.5	5.8	4.5	3.7	3.3	3.0	?	12.9	6.8
28	7.2	6.2	5.8	5.4	5.4	4.4	3.6	3.2	3.0	?	31.6	6.6
29	7.0		5.6	5.7	5.2	4.3	3.6	3.2	3.0	?	25.0	6.4
30	6.7		5.5	5.4	5.0	4.1	3.6	3.2	3.2	?	15.6	6.4
31	6.5		5.3		4.8		3.6	3.1		?		6.3
Total	374.0	202.0	205.5	199.1	169.8	182.5	119.3	103.9	95.4	84.1	137.1	274.1
Ave.	12.1	7.2	6.6	6.6	5.5	6.1	3.8	3.4	3.2	4.0	17.1	8.8

(Source: ILES D'EFATE ET DE SANTO EVALUATION DES RESSOURCES EN EAU, (ORSTOM,1985))

Table 6-3-6 Sarakata River Flow Data (1984)

Name: *Sarakata Flow discharge* YEAR: *1984*
CA= 97.1 km^2 n= 352 (m^3/s)

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	6.9	9.7	6.9	12.5	7.4	13.2	9.6	5.8	4.2	3.5	15.6	8.3
2	6.1	9.2	6.7	17.6	10.4	15.3	9.4	5.7	4.1	3.4	12.7	9.3
3	6.1	8.4	6.5	14.5	16.0	20.6	9.6	5.6	4.1	3.3	9.6	8.5
4	7.1	7.9	7.6	11.3	14.9	15.9	10.1	5.5	4.0	3.3	8.4	7.6
5	9.6	7.6	6.6	9.9	10.7	14.4	9.6	5.4	4.0	3.2	7.8	6.9
6	9.7	7.4	6.4	9.2	9.3	15.3	9.0	5.4	4.1	3.2	8.4	6.6
7	12.3	13.2	6.5	11.5	8.6	14.4	8.8	5.3	4.0	3.2	8.3	6.0
8	9.4	15.5	8.2	13.5	12.3	15.2	8.5	5.2	4.0	3.2	7.1	6.0
9	8.7	13.7	11.6	10.6	12.2	13.6	8.4	5.1	3.9	4.1	6.3	7.4
10	9.5	11.7	10.1	10.1	14.5	12.7	8.4	5.0	3.8	4.5	5.9	7.3
11	9.1	10.4	8.3	8.9	12.2	12.1	8.2	5.0	3.7	3.6	6.5	8.7
12	8.0	10.9	9.7	8.4	16.9	11.7	7.9	4.9	3.7	3.4	12.4	7.4
13	8.2	9.0	8.9	8.2	12.5	11.4	7.8	4.9	3.7	5.1	9.4	6.7
14	8.4	9.4	9.7	8.0	10.6	15.8	7.6	4.8	3.6	6.7	8.2	7.5
15	12.8	11.2	9.9	7.8	9.5	140.0	7.4	4.7	3.5	4.8	16.8	9.3
16	32.0	9.2	10.5	7.7	8.9	58.8	7.3	4.7	3.5	4.1	16.3	7.9
17	30.0	8.7	8.7	7.9	17.4	26.6	7.2	4.7	3.5	3.7	14.3	7.1
18	20.9	9.7	7.8	9.0	15.9	20.5	7.2	4.7	3.5	3.7	13.7	?
19	16.8	11.9	8.2	8.9	11.8	19.4	7.1	4.8	3.5	4.4	13.2	?
20	14.3	11.6	9.3	8.9	10.5	18.0	6.9	7.6	3.5	5.1	10.7	?
21	12.1	9.3	7.7	8.9	11.0	15.9	6.7	5.6	3.4	4.8	9.6	?
22	12.3	8.8	8.0	8.9	11.4	14.7	6.5	7.9	3.4	4.3	10.1	?
23	12.9	8.2	8.9	8.9	11.5	13.8	6.4	6.1	3.4	4.1	9.1	?
24	10.3	8.0	7.6	8.9	9.8	12.9	6.3	5.3	3.3	3.8	8.5	?
25	9.5	8.8	8.2	8.9	9.1	12.2	6.3	4.9	3.4	4.7	7.7	?
26	10.0	8.5	9.4	8.9	8.7	11.5	6.3	4.7	3.3	5.0	7.2	?
27	10.0	7.7	12.7	8.9	12.0	11.1	6.2	4.7	3.3	5.4	6.7	?
28	9.9	7.4	12.1	8.5	47.6	10.6	6.0	4.5	3.6	7.1	6.5	?
29	14.5	7.1	9.7	7.9	32.5	10.2	5.9	4.3	3.4	6.7	8.7	?
30	14.1		8.9	7.6	19.2	9.8	5.8	4.3	3.4	49.7	9.5	?
31	11.2		12.2		15.2		5.8	4.3		28.3		?
Total	372.7	280.2	273.1	290.9	430.6	607.5	234.1	161.1	109.9	203.7	295.0	128.3
Ave.	12.0	9.7	8.8	9.7	13.9	20.2	7.6	5.2	3.7	6.6	9.8	7.5

(Source: ILES D'EFATE ET DE SANTO EVALUATION DES RESSOURCES EN EAU, (ORSTOM,1985))

Table 6-3-7 Sarakata River Flow data (1985)

Name:	*Sarakata Flow discharge*				YEAR:	*1985*					
				CA=	97.1	km^2		n=	105		(m^3/s)
Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	?	?	?	5.8	?	7.2	?	?	6.9	?	?	?
2	?	?	?	5.4	?	6.6	?	?	6.7	?	?	?
3	?	?	?	5.2	?	6.1	?	?	15.0	?	?	?
4	?	?	?	5.0	?	5.8	?	?	14.2	?	?	?
5	?	?	?	4.9	?	5.5	?	?	10.4	?	?	?
6	?	?	?	4.9	?	5.4	?	?	8.7	?	?	?
7	?	?	?	4.9	?	5.2	?	?	8.1	?	?	?
8	?	?	?	5.3	?	14.6	?	?	12.7	?	?	?
9	?	?	?	5.6	?	9.3	?	?	11.2	?	?	?
10	?	?	?	5.3	?	7.0	?	?	9.4	?	?	?
11	?	?	?	16.1	?	6.2	?	?	8.6	?	?	?
12	3.6	?	?	9.5	?	5.9	?	?	8.2	?	?	?
13	3.6	?	?	11.7	?	5.6	?	?	8.1	?	?	?
14	4.2	?	7.2	13.0	?	5.2	?	?	9.8	?	?	?
15	24.4	?	9.5	10.1	?	5.1	?	5.4	?	?	?	?
16	27.5	?	9.5	9.0	?	5.3	?	5.4	?	?	?	?
17	14.3	?	8.6	10.2	?	12.0	?	5.6	?	?	?	?
18	?	?	7.0	9.6	?	12.3	?	6.6	?	?	?	?
19	?	?	6.2	?	?	8.3	?	7.8	?	?	?	?
20	?	?	5.8	?	?	7.0	?	8.4	?	?	?	?
21	?	?	5.5	?	?	6.5	?	8.8	?	?	?	?
22	?	?	5.4	?	?	6.2	?	11.5	?	?	?	?
23	?	?	5.8	?	?	6.5	?	11.0	?	?	?	?
24	?	?	6.4	?	?	5.9	?	10.5	?	?	?	?
25	?	?	6.6	?	4.5	5.6	?	9.6	?	?	?	?
26	?	?	7.0	?	4.9	?	?	8.1	?	?	?	?
27	?	?	7.0	?	8.1	?	?	7.6	?	?	?	?
28	?	?	6.3	?	41.4	?	?	10.3	?	?	?	?
29	?		6.0	?	14.9	?	?	8.4	?	?	?	?
30	?		6.6	?	9.8	?	?	7.7	?	?	?	?
31	?		6.7		8.0		?	7.2		?		?
Total	77.5	0.0	123.3	141.6	91.6	176.0	0.0	139.7	137.8	0.0	0.0	0.0
Ave.	12.9	#####	6.8	7.9	13.1	7.0	#####	8.2	9.8	#####	#####	######

(Source: ILES D'EFATE ET DE SANTO EVALUATION DES RESSOURCES EN EAU, (ORSTOM,1985))

Table 6-3-8 Sarakata River Flow Data (2006)

Name:	*Sarakata Flow discharge*				YEAR:	*2006*					
				CA=	91	km^2		n=	214		(m^3/s)
Date	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1				7.6	7.0	7.5	4.4	3.5	5.3	9.6		
2				7.7	7.4	8.3	4.4	3.3	5.0	9.1		
3				10.2	10.4	8.3	4.4	4.0	5.0	14.8		
4				10.8	6.8	8.1	4.4	27.5	5.0	11.5		
5				9.9	7.3	7.1	4.4	63.1	4.6	9.3		
6				9.1	11.2	7.1	4.4	28.1	4.6	7.3		
7				8.0	10.9	6.4	4.4	15.2	4.9	5.9		
8				6.8	10.9	4.2	4.0	10.7	4.7	5.5		
9				7.0	8.8	4.2	4.0	9.7	4.5	5.9		
10				6.9	10.0	4.0	3.6	8.3	4.3	5.9		
11				7.5	9.8	4.0	3.6	7.1	4.2	5.5		
12				7.2	8.6	4.0	4.0	6.9	4.6	5.1		
13				8.9	6.6	4.2	3.6	5.7	5.1	5.1		
14				7.1	7.8	4.4	3.6	6.2	4.7	4.9		
15				6.9	7.5	4.4	3.6	6.4	5.0	5.5		
16				7.5	6.9	4.4	3.6	6.0	4.6	6.9		
17				6.8	7.2	4.4	3.6	6.9	4.7	7.2		
18				6.9	7.3	4.4	3.4	7.1	5.0	8.1		
19				7.4	7.3	4.4	3.4	6.4	4.5	7.1		
20				6.9	23.9	4.2	3.2	5.7	4.5	7.3		
21				7.1	13.2	4.2	3.5	4.4	4.6	7.0		
22				9.2	9.9	4.0	3.5	5.3	4.2	7.0		
23				9.9	8.1	4.0	3.5	6.1	4.1	7.2		
24				7.2	17.7	4.2	3.5	5.6	5.2	9.0		
25				7.9	9.9	4.2	3.3	5.4	5.6	9.5		
26				7.0	12.4	4.4	3.7	4.9	5.4	8.1		
27				7.5	11.5	4.4	3.7	5.0	4.7	7.3		
28				7.3	9.9	4.4	3.7	4.9	5.2	8.3		
29				7.2	8.4	4.4	3.7	5.1	8.8	8.4		
30				7.0	8.2	4.4	3.5	5.1	7.6	8.9		
31					7.5		8.5	4.8		7.7		
Total	0.0	0.0	0.0	234.2	300.1	150.2	121.9	294.4	150.3	235.7	0.0	0.0
Ave.	#####	#####	#####	7.8	9.7	5.0	3.9	9.5	5.0	7.6	#####	#####

(Source: The Project for Improvement of Sarakata River Hydroelectric Power Station (JICA, 2007))

(2) Evaluation of the Validity of Existing Flow Data on Sarakata River

In order to confirm the validity of existing flow data of Sarakata River, the flow data will be evaluated with the runoff ratio. The runoff ratio is figured out by dividing the annual rainfall by the runoff height, and the annual runoff height is figured out by dividing annual flow amount to Catchment Area.

Since there is no observation data in the catchment area, the rainfall data shall be calculated by correcting the average rainfall data at Pekoa Airport due to the rainfall difference in mountain data in "6-3-2 .Ⅲ Rainfall data".

The calculation of runoff ratio is shown below:

(Runoff ratio) = (runoff height*) / (Annual rainfall)

(Runoff height*) = (Annual flow amount) / (Catchment Area)

Table 6-3-9 Runoff Ratio of Sarakata River (1982-1984)

Year	Annual flow amount	Catchment area	Runoff height	Annual rainfall	Corrected rainfall	Average Runoff ratio	Remarks
	(m^3)	(km2)	(mm)	(mm)	(mm)	(%)	
	ΣQ	CA	H=ΣQ/CA	Ry	Ry'=Ry×1.61	H/Ry'	
1982	3.36E+11	97.1	3460	1075	1731	200%	
1983	1.85.E+11	97.1	1910	685	1103	173%	
1984	2.93.E+11	97.1	3014	2635	4243	71%	
total			8384	4395	7077	118%	

As a result, it was found that the runoff rate in 1982 to 1985 was over 100%. In particular, the runoff rates in the dry seasons (in 1982 and 1983) are high, and in general, the rainfall observation is simpler than the flow rate observation, so it is considered that there were some problems with the flow rate observation.

6-3-4 Conversion Flow Rate from Power Generation Operation Data

(1) Overview

Since there is a doubt about the validity of the past flow data of the Sarakata River, this study shall figure out the conversion flow rate as new flow data from the power generation operation data of the Sarakata River hydropower plant. Calculation of this flow rate is a conversion method including multiple estimations, so it is adopted after validity is confirmed by runoff ratio.

(2) Calculation Method for Conversion Flow Rate

Power generation operation data recorded by VUI, which is operating the Sarakata River hydroelectric power plant, includes water level data at the intake weir and power generation output data. In this study, the Sarakata river flow rate (Q) is estimated by summing up the amount of the overflow rate of the intake weir by calculation from the water level data (Q1) and the amount of power generation water used (Q2), and the amount of the overflow rate of the headtank(Q3).
The calculation and its specifications are shown as below;

(Culculation）

$Q1 + Q2 + Q3 = Q$

※Q1 & Q3 ＝ $1.8 \times L \times H^{3/2}$

(L=width of weir(m), H＝water level(m))

(Specifications)

Intake weir width = 38.1 (m)
Headtank spillway width = 10 (m)
Overflow water level at intake weir = 2.73 (m)

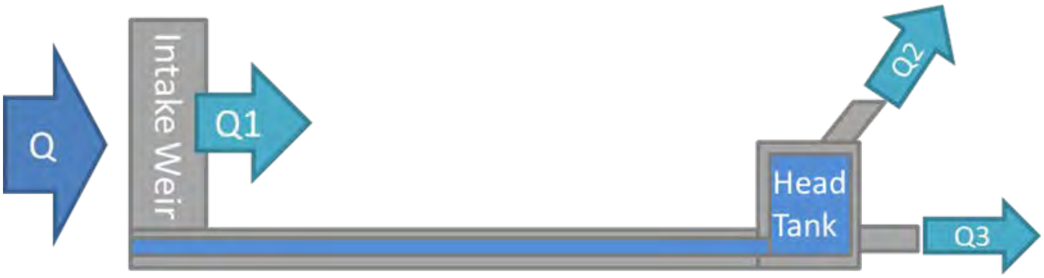


Figure 6-3-4 Image of Culculation Method for Voncersion Flow Rate

(3) The Runoff Ratio of Conversion Flow Rate from Power Generation Operation Data

The conversion flow rate will be evaluated by runoff ratio. The calculation method is shown as “6-3-3 Evaluation of the validity of existing flow data of Sarakata River”.
The evaluation results are shown below. The run-off ratio is 77% for three years in total. The result of 2015 over 100% but 2014 and 2016 results are lower such as 56% and 65%. Therefore, the result of this conversion flow rate shall be evaluated with validated value.

Table 6-3-10 Average Runoff Ratio (Conversion flow of operation data)

Year	Annual flow amount (m^3) ΣQ	Catchment area (km2) CA	Runoff height (mm) H=ΣQ/CA	Annual rainfall (mm) Ry	Average Runoff ratio (%) H/Ry	Remarks
2014	1.0.E+11	91	1299	2302	56%	April - December
2015	2.2.E+11	91	2834	2740.8	103%	Except June and October
2016	1.0.E+11	91	1354	2077.9	65%	
Total			5487	7120.7	77%	

(4) The Method of Correcting River Flow.

There is a problem to handle the conversion flow as a typical river flow. Because the period during which the flow rate can be calculated is 2 years 9 months, and also, this period is a drought year. Therefore, the general flow rate of the Sarakata river flow will be corrected by the ratio of comparing the monthly average rainfall data for the same period as the operational data with the monthly average rainfall data over the entire period.

As discussed in "6-2 Rainfall amount", the rainfall increases as a long-term trend, but this time, the average rainfall over the entire period was used as the safety side.

The monthly rainfall amount ratio between the same period of operational data and the entire period is shown below. The result shows that the entire period rainfall data is 54% higher than the same period of operational data.

Table 6-3-11 Difference of Observation Rainfall

Monthly average rainfall (mm, Pekoa)		Ratio
Operational data period	entire period	
Rm1	Rm2	Rm2/Rm1
126.93	195.29	154%

The calculation of the general flow (Qc’) by correcting the conversion flow (Qc) is shown below:

(Calculation)
Qc (Conversion flow)×(Correction, =1.54)＝Qc’ (general flow)

The flow duration curve and the flow duration table are shown below. The result of this study is 10~25% less than the river flow data of 1982-1985.

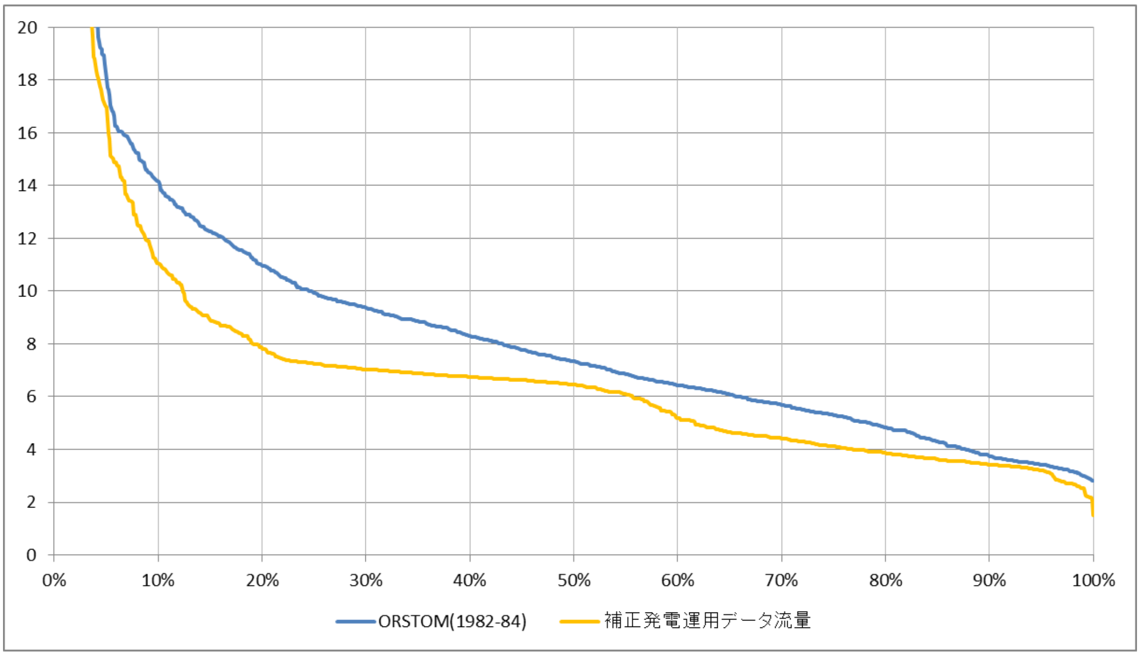


Figure 6-3-5　Flow Duration Curve of Sarakata River, CA=91 km^2

Table 6-3-12 Flow Duration Table (1/3)

Day		Discharge
No	%	(m^3/s)
1	0.1%	150.84
2	0.2%	144.05
3	0.4%	121.07
4	0.5%	115.39
5	0.6%	105.84
6	0.7%	102.12
7	0.8%	78.36
8	0.9%	70.70
9	1.1%	69.76
10	1.2%	57.92
11	1.3%	57.21
12	1.4%	51.99
13	1.5%	49.99
14	1.6%	46.80
15	1.8%	44.14
16	1.9%	43.77
17	2.0%	38.79
18	2.1%	38.10
19	2.2%	34.76
20	2.4%	34.48
21	2.5%	33.26
22	2.6%	30.94
23	2.7%	30.52
24	2.8%	29.31
25	2.9%	26.60
26	3.1%	23.44
27	3.2%	21.18
28	3.3%	21.04
29	3.4%	20.68
30	3.5%	20.64
31	3.7%	19.67
32	3.8%	18.88
33	3.9%	18.82
34	4.0%	18.34
35	4.1%	18.17
36	4.2%	18.05
37	4.4%	17.74
38	4.5%	17.65
39	4.6%	17.42
40	4.7%	17.26
41	4.8%	17.06
42	4.9%	17.00
43	5.1%	16.97
44	5.2%	15.99
45	5.3%	15.77
46	5.4%	15.11
47	5.5%	15.06
48	5.7%	15.03
49	5.8%	14.88
50	5.9%	14.88
51	6.0%	14.77
52	6.1%	14.74
53	6.2%	14.72
54	6.4%	14.31
55	6.5%	14.31
56	6.6%	14.21
57	6.7%	14.15
58	6.8%	13.69
59	6.9%	13.68
60	7.1%	13.51
61	7.2%	13.41
62	7.3%	13.41
63	7.4%	13.40
64	7.5%	13.37
65	7.7%	12.91
66	7.8%	12.89
67	7.9%	12.72
68	8.0%	12.49
69	8.1%	12.47
70	8.2%	12.47
71	8.4%	12.32
72	8.5%	12.24
73	8.6%	12.14
74	8.7%	12.04
75	8.8%	11.95
76	9.0%	11.90
77	9.1%	11.89
78	9.2%	11.75
79	9.3%	11.57
80	9.4%	11.44
81	9.5%	11.26
82	9.7%	11.23
83	9.8%	11.13
84	9.9%	11.07

Day		Discharge
No	%	(m^3/s)
85	10.0%	11.06
86	10.1%	11.01
87	10.2%	10.98
88	10.4%	10.90
89	10.5%	10.84
90	10.6%	10.84
91	10.7%	10.83
92	10.8%	10.69
93	11.0%	10.66
94	11.1%	10.63
95	11.2%	10.58
96	11.3%	10.58
97	11.4%	10.47
98	11.5%	10.44
99	11.7%	10.43
100	11.8%	10.35
101	11.9%	10.32
102	12.0%	10.30
103	12.1%	10.26
104	12.2%	10.26
105	12.4%	9.96
106	12.5%	9.93
107	12.6%	9.63
108	12.7%	9.58
109	12.8%	9.49
110	13.0%	9.47
111	13.1%	9.41
112	13.2%	9.39
113	13.3%	9.33
114	13.4%	9.32
115	13.5%	9.32
116	13.7%	9.27
117	13.8%	9.24
118	13.9%	9.19
119	14.0%	9.18
120	14.1%	9.16
121	14.3%	9.09
122	14.4%	9.07
123	14.5%	9.07
124	14.6%	9.07
125	14.7%	9.07
126	14.8%	9.01
127	15.0%	8.90
128	15.1%	8.86
129	15.2%	8.86
130	15.3%	8.86
131	15.4%	8.84
132	15.5%	8.84
133	15.7%	8.81
134	15.8%	8.78
135	15.9%	8.76
136	16.0%	8.70
137	16.1%	8.69
138	16.3%	8.67
139	16.4%	8.67
140	16.5%	8.67
141	16.6%	8.65
142	16.7%	8.64
143	16.8%	8.64
144	17.0%	8.61
145	17.1%	8.59
146	17.2%	8.55
147	17.3%	8.50
148	17.4%	8.49
149	17.6%	8.49
150	17.7%	8.42
151	17.8%	8.39
152	17.9%	8.39
153	18.0%	8.38
154	18.1%	8.30
155	18.3%	8.30
156	18.4%	8.29
157	18.5%	8.29
158	18.6%	8.29
159	18.7%	8.19
160	18.8%	8.15
161	19.0%	8.05
162	19.1%	8.02
163	19.2%	7.99
164	19.3%	7.98
165	19.4%	7.96
166	19.6%	7.96
167	19.7%	7.95
168	19.8%	7.88
169	19.9%	7.88

Day		Discharge
No	%	(m^3/s)
170	20.0%	7.81
171	20.1%	7.79
172	20.3%	7.79
173	20.4%	7.78
174	20.5%	7.68
175	20.6%	7.67
176	20.7%	7.67
177	20.8%	7.65
178	21.0%	7.64
179	21.1%	7.62
180	21.2%	7.59
181	21.3%	7.52
182	21.4%	7.52
183	21.6%	7.48
184	21.7%	7.47
185	21.8%	7.44
186	21.9%	7.44
187	22.0%	7.41
188	22.1%	7.41
189	22.3%	7.39
190	22.4%	7.38
191	22.5%	7.38
192	22.6%	7.36
193	22.7%	7.35
194	22.9%	7.35
195	23.0%	7.35
196	23.1%	7.35
197	23.2%	7.35
198	23.3%	7.33
199	23.4%	7.32
200	23.6%	7.32
201	23.7%	7.32
202	23.8%	7.32
203	23.9%	7.30
204	24.0%	7.30
205	24.1%	7.30
206	24.3%	7.30
207	24.4%	7.28
208	24.5%	7.28
209	24.6%	7.27
210	24.7%	7.27
211	24.9%	7.27
212	25.0%	7.25
213	25.1%	7.25
214	25.2%	7.25
215	25.3%	7.24
216	25.4%	7.22
217	25.6%	7.22
218	25.7%	7.22
219	25.8%	7.21
220	25.9%	7.19
221	26.0%	7.18
222	26.1%	7.18
223	26.3%	7.18
224	26.4%	7.18
225	26.5%	7.18
226	26.6%	7.18
227	26.7%	7.16
228	26.9%	7.16
229	27.0%	7.16
230	27.1%	7.16
231	27.2%	7.15
232	27.3%	7.15
233	27.4%	7.15
234	27.6%	7.15
235	27.7%	7.15
236	27.8%	7.13
237	27.9%	7.13
238	28.0%	7.11
239	28.2%	7.11
240	28.3%	7.10
241	28.4%	7.10
242	28.5%	7.10
243	28.6%	7.08
244	28.7%	7.08
245	28.9%	7.08
246	29.0%	7.08
247	29.1%	7.07
248	29.2%	7.05
249	29.3%	7.05
250	29.4%	7.05
251	29.6%	7.05
252	29.7%	7.04
253	29.8%	7.04
254	29.9%	7.04

Day		Discharge
No	%	(m^3/s)
255	30.0%	7.04
256	30.2%	7.04
257	30.3%	7.02
258	30.4%	7.02
259	30.5%	7.02
260	30.6%	7.02
261	30.7%	7.02
262	30.9%	7.01
263	31.0%	7.01
264	31.1%	7.01
265	31.2%	6.99
266	31.3%	6.99
267	31.4%	6.99
268	31.6%	6.99
269	31.7%	6.98
270	31.8%	6.98
271	31.9%	6.98
272	32.0%	6.98
273	32.2%	6.98
274	32.3%	6.96
275	32.4%	6.96
276	32.5%	6.96
277	32.6%	6.96
278	32.7%	6.96
279	32.9%	6.95
280	33.0%	6.95
281	33.1%	6.95
282	33.2%	6.95
283	33.3%	6.93
284	33.5%	6.93
285	33.6%	6.93
286	33.7%	6.93
287	33.8%	6.93
288	33.9%	6.91
289	34.0%	6.91
290	34.2%	6.91
291	34.3%	6.91
292	34.4%	6.91
293	34.5%	6.90
294	34.6%	6.90
295	34.7%	6.90
296	34.9%	6.90
297	35.0%	6.88
298	35.1%	6.88
299	35.2%	6.87
300	35.3%	6.87
301	35.5%	6.87
302	35.6%	6.85
303	35.7%	6.85
304	35.8%	6.85
305	35.9%	6.85
306	36.0%	6.85
307	36.2%	6.85
308	36.3%	6.85
309	36.4%	6.84
310	36.5%	6.84
311	36.6%	6.82
312	36.7%	6.82
313	36.9%	6.82
314	37.0%	6.82
315	37.1%	6.82
316	37.2%	6.82
317	37.3%	6.82
318	37.5%	6.82
319	37.6%	6.81
320	37.7%	6.81
321	37.8%	6.81
322	37.9%	6.79
323	38.0%	6.79
324	38.2%	6.79
325	38.3%	6.79
326	38.4%	6.78
327	38.5%	6.78
328	38.6%	6.78
329	38.8%	6.78
330	38.9%	6.78
331	39.0%	6.78
332	39.1%	6.78
333	39.2%	6.78
334	39.3%	6.76
335	39.5%	6.76
336	39.6%	6.76
337	39.7%	6.76
338	39.8%	6.75
339	39.9%	6.75

Table 6-3-13 Flow Duration Table (2/3)

Day		Discharge
No	%	(m^3/s)
340	40.0%	6.75
341	40.2%	6.75
342	40.3%	6.73
343	40.4%	6.73
344	40.5%	6.73
345	40.6%	6.73
346	40.8%	6.73
347	40.9%	6.71
348	41.0%	6.71
349	41.1%	6.71
350	41.2%	6.71
351	41.3%	6.71
352	41.5%	6.71
353	41.6%	6.71
354	41.7%	6.70
355	41.8%	6.70
356	41.9%	6.70
357	42.0%	6.70
358	42.2%	6.70
359	42.3%	6.68
360	42.4%	6.68
361	42.5%	6.68
362	42.6%	6.68
363	42.8%	6.68
364	42.9%	6.68
365	43.0%	6.67
366	43.1%	6.67
367	43.2%	6.67
368	43.3%	6.67
369	43.5%	6.67
370	43.6%	6.67
371	43.7%	6.67
372	43.8%	6.65
373	43.9%	6.65
374	44.1%	6.65
375	44.2%	6.65
376	44.3%	6.65
377	44.4%	6.65
378	44.5%	6.65
379	44.6%	6.64
380	44.8%	6.64
381	44.9%	6.64
382	45.0%	6.64
383	45.1%	6.62
384	45.2%	6.62
385	45.3%	6.62
386	45.5%	6.62
387	45.6%	6.61
388	45.7%	6.61
389	45.8%	6.61
390	45.9%	6.59
391	46.1%	6.59
392	46.2%	6.59
393	46.3%	6.58
394	46.4%	6.58
395	46.5%	6.58
396	46.6%	6.58
397	46.8%	6.58
398	46.9%	6.58
399	47.0%	6.56
400	47.1%	6.56
401	47.2%	6.56
402	47.3%	6.56
403	47.5%	6.55
404	47.6%	6.55
405	47.7%	6.55
406	47.8%	6.53
407	47.9%	6.53
408	48.1%	6.53
409	48.2%	6.53
410	48.3%	6.51
411	48.4%	6.51
412	48.5%	6.51
413	48.6%	6.50
414	48.8%	6.50
415	48.9%	6.50
416	49.0%	6.50
417	49.1%	6.48
418	49.2%	6.48
419	49.4%	6.48
420	49.5%	6.47
421	49.6%	6.47
422	49.7%	6.47
423	49.8%	6.47
424	49.9%	6.45

Day		Discharge
No	%	(m^3/s)
425	50.1%	6.45
426	50.2%	6.45
427	50.3%	6.44
428	50.4%	6.44
429	50.5%	6.44
430	50.6%	6.42
431	50.8%	6.42
432	50.9%	6.42
433	51.0%	6.39
434	51.1%	6.39
435	51.2%	6.36
436	51.4%	6.36
437	51.5%	6.34
438	51.6%	6.34
439	51.7%	6.34
440	51.8%	6.34
441	51.9%	6.34
442	52.1%	6.34
443	52.2%	6.31
444	52.3%	6.30
445	52.4%	6.30
446	52.5%	6.27
447	52.7%	6.27
448	52.8%	6.24
449	52.9%	6.24
450	53.0%	6.21
451	53.1%	6.21
452	53.2%	6.21
453	53.4%	6.19
454	53.5%	6.19
455	53.6%	6.19
456	53.7%	6.19
457	53.8%	6.18
458	53.9%	6.18
459	54.1%	6.18
460	54.2%	6.16
461	54.3%	6.16
462	54.4%	6.16
463	54.5%	6.14
464	54.7%	6.13
465	54.8%	6.10
466	54.9%	6.10
467	55.0%	6.10
468	55.1%	6.08
469	55.2%	6.08
470	55.4%	6.07
471	55.5%	6.02
472	55.6%	6.02
473	55.7%	5.98
474	55.8%	5.94
475	55.9%	5.94
476	56.1%	5.94
477	56.2%	5.94
478	56.3%	5.94
479	56.4%	5.93
480	56.5%	5.90
481	56.7%	5.90
482	56.8%	5.84
483	56.9%	5.82
484	57.0%	5.81
485	57.1%	5.78
486	57.2%	5.74
487	57.4%	5.70
488	57.5%	5.67
489	57.6%	5.67
490	57.7%	5.65
491	57.8%	5.64
492	58.0%	5.61
493	58.1%	5.61
494	58.2%	5.59
495	58.3%	5.57
496	58.4%	5.48
497	58.5%	5.48
498	58.7%	5.48
499	58.8%	5.47
500	58.9%	5.44
501	59.0%	5.44
502	59.1%	5.42
503	59.2%	5.42
504	59.4%	5.41
505	59.5%	5.34
506	59.6%	5.31
507	59.7%	5.28
508	59.8%	5.24

Day		Discharge
No	%	(m^3/s)
509	60.0%	5.19
510	60.1%	5.17
511	60.2%	5.17
512	60.3%	5.13
513	60.4%	5.13
514	60.5%	5.13
515	60.7%	5.13
516	60.8%	5.13
517	60.9%	5.13
518	61.0%	5.11
519	61.1%	5.11
520	61.2%	5.07
521	61.4%	5.07
522	61.5%	5.07
523	61.6%	5.05
524	61.7%	4.94
525	61.8%	4.94
526	62.0%	4.94
527	62.1%	4.93
528	62.2%	4.91
529	62.3%	4.90
530	62.4%	4.90
531	62.5%	4.90
532	62.7%	4.85
533	62.8%	4.84
534	62.9%	4.84
535	63.0%	4.84
536	63.1%	4.84
537	63.3%	4.82
538	63.4%	4.82
539	63.5%	4.82
540	63.6%	4.80
541	63.7%	4.77
542	63.8%	4.77
543	64.0%	4.77
544	64.1%	4.73
545	64.2%	4.71
546	64.3%	4.71
547	64.4%	4.68
548	64.5%	4.68
549	64.7%	4.68
550	64.8%	4.67
551	64.9%	4.67
552	65.0%	4.67
553	65.1%	4.65
554	65.3%	4.64
555	65.4%	4.64
556	65.5%	4.62
557	65.6%	4.60
558	65.7%	4.60
559	65.8%	4.60
560	66.0%	4.60
561	66.1%	4.60
562	66.2%	4.59
563	66.3%	4.59
564	66.4%	4.59
565	66.5%	4.59
566	66.7%	4.57
567	66.8%	4.56
568	66.9%	4.56
569	67.0%	4.56
570	67.1%	4.54
571	67.3%	4.54
572	67.4%	4.53
573	67.5%	4.53
574	67.6%	4.53
575	67.7%	4.53
576	67.8%	4.53
577	68.0%	4.51
578	68.1%	4.51
579	68.2%	4.50
580	68.3%	4.50
581	68.4%	4.50
582	68.6%	4.50
583	68.7%	4.47
584	68.8%	4.47
585	68.9%	4.45
586	69.0%	4.45
587	69.1%	4.45
588	69.3%	4.44
589	69.4%	4.44
590	69.5%	4.44
591	69.6%	4.44
592	69.7%	4.44
593	69.8%	4.44

Day		Discharge
No	%	(m^3/s)
594	70.0%	4.42
595	70.1%	4.42
596	70.2%	4.40
597	70.3%	4.40
598	70.4%	4.40
599	70.6%	4.40
600	70.7%	4.39
601	70.8%	4.37
602	70.9%	4.34
603	71.0%	4.34
604	71.1%	4.33
605	71.3%	4.33
606	71.4%	4.33
607	71.5%	4.33
608	71.6%	4.31
609	71.7%	4.31
610	71.8%	4.30
611	72.0%	4.30
612	72.1%	4.30
613	72.2%	4.30
614	72.3%	4.28
615	72.4%	4.28
616	72.6%	4.27
617	72.7%	4.27
618	72.8%	4.25
619	72.9%	4.24
620	73.0%	4.24
621	73.1%	4.24
622	73.3%	4.20
623	73.4%	4.19
624	73.5%	4.19
625	73.6%	4.17
626	73.7%	4.17
627	73.9%	4.17
628	74.0%	4.17
629	74.1%	4.16
630	74.2%	4.16
631	74.3%	4.16
632	74.4%	4.13
633	74.6%	4.11
634	74.7%	4.11
635	74.8%	4.11
636	74.9%	4.11
637	75.0%	4.11
638	75.1%	4.11
639	75.3%	4.10
640	75.4%	4.10
641	75.5%	4.10
642	75.6%	4.08
643	75.7%	4.07
644	75.9%	4.05
645	76.0%	4.05
646	76.1%	4.05
647	76.2%	4.05
648	76.3%	4.03
649	76.4%	4.03
650	76.6%	4.02
651	76.7%	4.02
652	76.8%	4.00
653	76.9%	3.99
654	77.0%	3.99
655	77.1%	3.99
656	77.3%	3.97
657	77.4%	3.97
658	77.5%	3.97
659	77.6%	3.97
660	77.7%	3.97
661	77.9%	3.97
662	78.0%	3.97
663	78.1%	3.96
664	78.2%	3.96
665	78.3%	3.93
666	78.4%	3.93
667	78.6%	3.93
668	78.7%	3.93
669	78.8%	3.93
670	78.9%	3.93
671	79.0%	3.93
672	79.2%	3.93
673	79.3%	3.91
674	79.4%	3.91
675	79.5%	3.90
676	79.6%	3.90
677	79.7%	3.88
678	79.9%	3.88

Table 6-3-14 Flow Duration Table (3/3)

Day		Discharge
No	%	(m^3/s)
679	80.0%	3.87
680	80.1%	3.85
681	80.2%	3.85
682	80.3%	3.83
683	80.4%	3.83
684	80.6%	3.83
685	80.7%	3.82
686	80.8%	3.82
687	80.9%	3.82
688	81.0%	3.82
689	81.2%	3.80
690	81.3%	3.80
691	81.4%	3.80
692	81.5%	3.79
693	81.6%	3.77
694	81.7%	3.76
695	81.9%	3.76
696	82.0%	3.76
697	82.1%	3.76
698	82.2%	3.74
699	82.3%	3.74
700	82.4%	3.74
701	82.6%	3.74
702	82.7%	3.73
703	82.8%	3.73
704	82.9%	3.71
705	83.0%	3.71
706	83.2%	3.71
707	83.3%	3.71
708	83.4%	3.71
709	83.5%	3.71
710	83.6%	3.70
711	83.7%	3.68
712	83.9%	3.68
713	84.0%	3.65
714	84.1%	3.65
715	84.2%	3.65
716	84.3%	3.65
717	84.5%	3.65
718	84.6%	3.65
719	84.7%	3.65
720	84.8%	3.65
721	84.9%	3.63
722	85.0%	3.62
723	85.2%	3.60
724	85.3%	3.60
725	85.4%	3.60
726	85.5%	3.60
727	85.6%	3.59
728	85.7%	3.59
729	85.9%	3.59
730	86.0%	3.57
731	86.1%	3.57
732	86.2%	3.57
733	86.3%	3.57
734	86.5%	3.57
735	86.6%	3.57
736	86.7%	3.56
737	86.8%	3.56
738	86.9%	3.56
739	87.0%	3.54
740	87.2%	3.54
741	87.3%	3.54
742	87.4%	3.54
743	87.5%	3.54
744	87.6%	3.54
745	87.8%	3.53
746	87.9%	3.51
747	88.0%	3.51
748	88.1%	3.51
749	88.2%	3.50
750	88.3%	3.50
751	88.5%	3.48
752	88.6%	3.48
753	88.7%	3.48
754	88.8%	3.48
755	88.9%	3.48
756	89.0%	3.48
757	89.2%	3.47
758	89.3%	3.47
759	89.4%	3.45
760	89.5%	3.45
761	89.6%	3.45
762	89.8%	3.45
763	89.9%	3.43

Day		Discharge
No	%	(m^3/s)
764	90.0%	3.43
765	90.1%	3.43
766	90.2%	3.43
767	90.3%	3.43
768	90.5%	3.42
769	90.6%	3.40
770	90.7%	3.40
771	90.8%	3.40
772	90.9%	3.39
773	91.0%	3.39
774	91.2%	3.39
775	91.3%	3.39
776	91.4%	3.39
777	91.5%	3.37
778	91.6%	3.37
779	91.8%	3.37
780	91.9%	3.37
781	92.0%	3.37
782	92.1%	3.36
783	92.2%	3.36
784	92.3%	3.36
785	92.5%	3.36
786	92.6%	3.34
787	92.7%	3.34
788	92.8%	3.34
789	92.9%	3.34
790	93.1%	3.33
791	93.2%	3.33
792	93.3%	3.33
793	93.4%	3.33
794	93.5%	3.33
795	93.6%	3.30
796	93.8%	3.28
797	93.9%	3.26
798	94.0%	3.26
799	94.1%	3.26
800	94.2%	3.25
801	94.3%	3.23
802	94.5%	3.23
803	94.6%	3.23
804	94.7%	3.23
805	94.8%	3.22
806	94.9%	3.20
807	95.1%	3.19
808	95.2%	3.19
809	95.3%	3.17
810	95.4%	3.17
811	95.5%	3.14
812	95.6%	3.14
813	95.8%	3.14
814	95.9%	3.11
815	96.0%	3.05
816	96.1%	3.00
817	96.2%	2.94
818	96.3%	2.86
819	96.5%	2.86
820	96.6%	2.85
821	96.7%	2.82
822	96.8%	2.80
823	96.9%	2.79
824	97.1%	2.79
825	97.2%	2.77
826	97.3%	2.74
827	97.4%	2.73
828	97.5%	2.73
829	97.6%	2.73
830	97.8%	2.71
831	97.9%	2.70
832	98.0%	2.70
833	98.1%	2.66
834	98.2%	2.66
835	98.4%	2.65
836	98.5%	2.60
837	98.6%	2.59
838	98.7%	2.56
839	98.8%	2.54
840	98.9%	2.53
841	99.1%	2.53
842	99.2%	2.39
843	99.3%	2.26
844	99.4%	2.22
845	99.5%	2.22
846	99.6%	2.19
847	99.8%	2.19
848	99.9%	2.06
849	100.0%	1.51

6-4 Topographic and Geological Information

6-4-1 Overview of Topographic and Geological Information

The study of topographic and geological information was based on 1/50.000 topographic map and geological map, and past study reports. The list of map and reports are shown below;

(The 1/50,000 topographic map)

- Turtle Bay, Sheet 1516705 (Edition 1-VDLS), Series X721
- Navolala, Sheet 1516608 (Edition 1-VDLS), Series X721
- Tasriki, Sheet 1516612 (Edition 1-VDLS), Series X721
- Luganville, Sheet 1516709 (Edition 1-VDLS), Series X721.

(The Geological map)

- GEOLOGY OF SOUTH SANTO (1:100,000 New Hebrides Geological Survey Sheet 4)

(The Past study reports)

- The Project for Improvement of Sarakata River Hydroelectric Power Station (JICA, 2007)
- TA 8285-VAN: Energy Access Project (ADB, 2014)

6-4-2 The Topographic Condition of Santo Island and around the Sarakata River

(1) Topographic Information of Santo Island

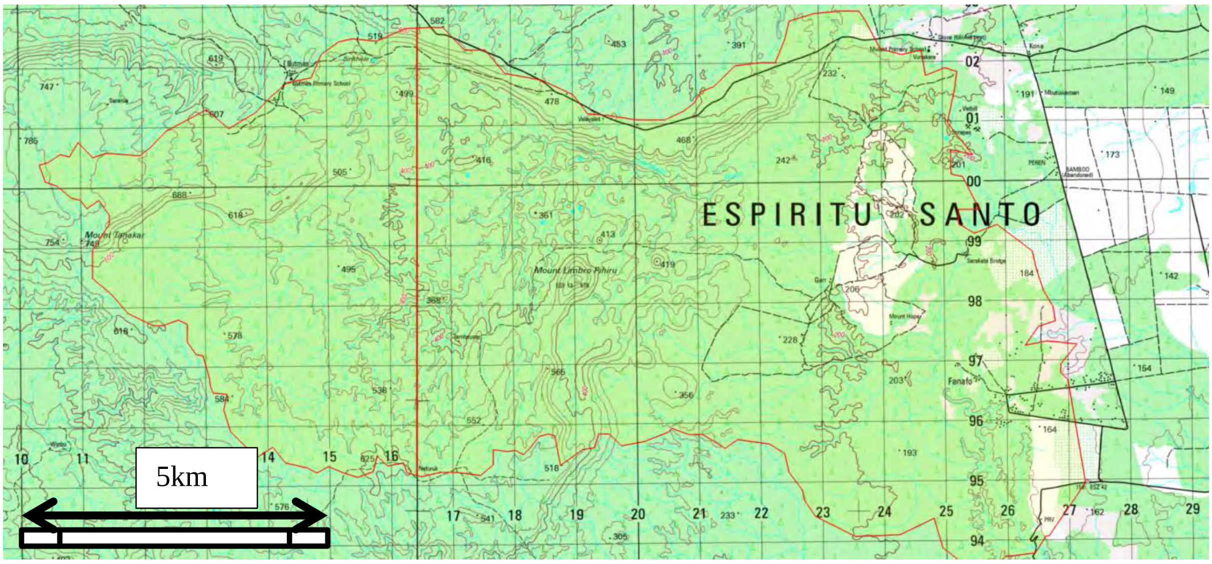
Espiritu Santo Island (Santo Island) is located at 15 degree of south latitude and 167 degree of east longitude, and is the largest island of Vanuatu with 4,010 km^2. On the west side of the island, there are the highest peak of Vanuatu country called Mt.Tabwemasana (altitude 1,878 m) and three 1,700-meter high mountains around it, and the 1,500 m class mountains continue to the northwest Cumberland peninsula.

(2) Topographic Information around the Sarakata River.

The Sarakata River is an important river which flow from the center of Santo to the southeast direction beside the Luganville, the largest city of Santo Island. The catchment area of the Sarakata River hydroelectric power plant installed about 12 km north from the city of Luganville is 91 km^2 spreading 16 km east to west and most of the area is undeveloped old forest. However, some parts are developed around the project site and there are farm of cattle, plantations, and 500 people's village.

The riverbed gradient of the Sarakata River flows from the elevation of about 760 m in the center of Santo to about 12 km in the east direction with a gradient of about 3.6 / 100, and about 6 km in the south direction with a gradient of about 6 / 1000, and it reaches to the Sarakata River hydraulic power plant intake weir.

Topographic map of catchment area is as follows:



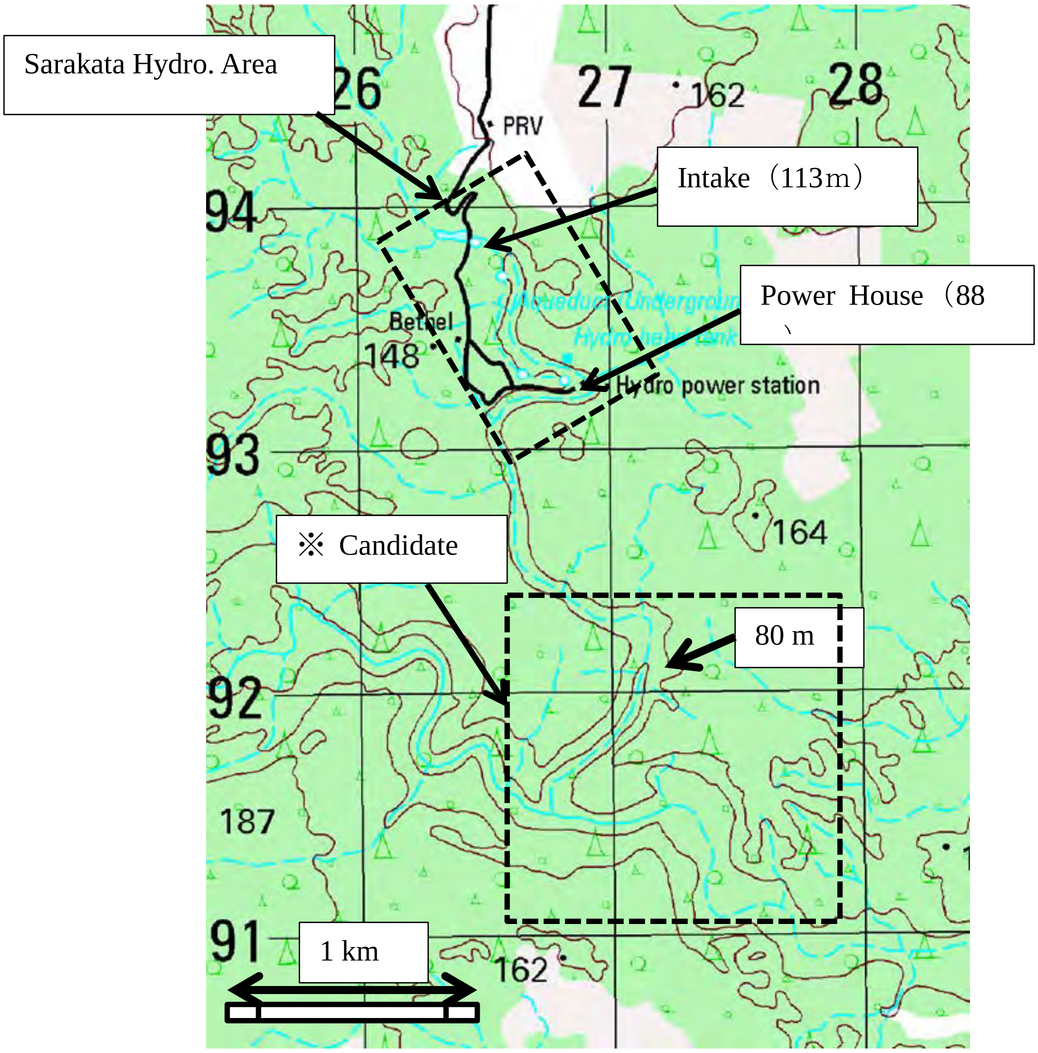
(Source: Turtle Bay, Sheet 1516705 (Edition 1-VDLS), Series X721, Navolala, Sheet 1516608 (Edition 1-VDLS), Series X721)

Figure 6-4-1 The Catchment Area of the Sarakata River Hydroelectric Power Plant
（Catchment Area＝91 km2）

(3) Topographic Information around Project Sites

The topographical map around the Sarakata River hydroelectric power plant is shown below.
There is a head for generating power due to a large waterfall between the water intake weir and the power plant of the Sarakata River hydroelectric power plant, but the basic riverbed gradient in this area is a gently sloping terrain of about 4.5 / 1,000.

In the vicinity of the candidate site, there are six local small waterfalls of 2.5 m in height (total height is 15 m) which were confirmed from the 80m altitude point of the Sarakata River to the chain point of the Sarakata River and the Tafwakar River.



※Candidate site will be discussed at Capter 7

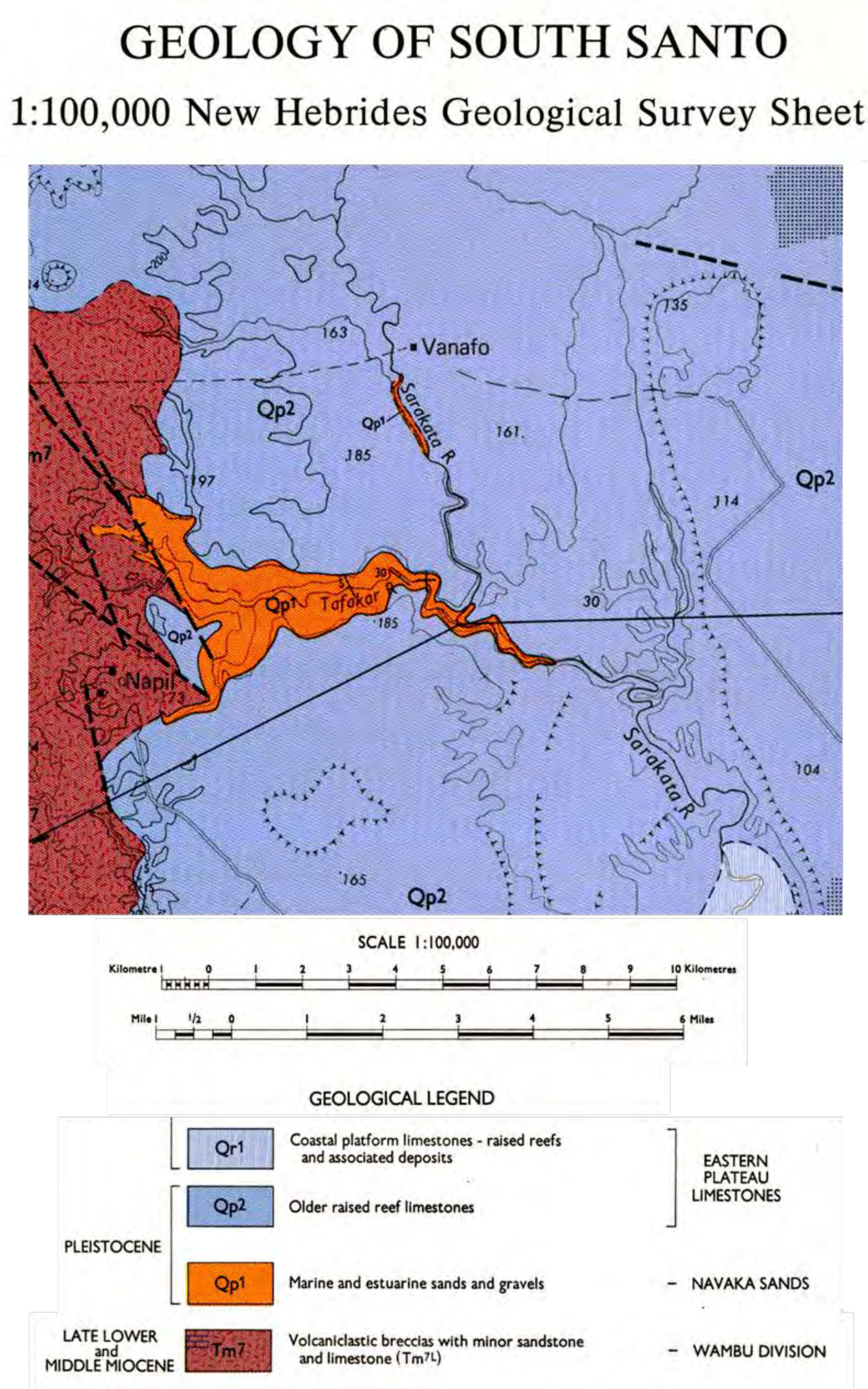
(Source: Turtle Bay, Sheet 1516705 (Edition 1-VDLS), Series X721)

Figure 6-4-2 Topographic Map（Around Sarakata Hydroelectric Power Plant）

6-4-3 Geological Information

JICA, when it did the investigation work for constructing the Sarakata project undertook some geological assessment of the area. The extract from the report is provided below:

The southeastern portion of Santo Island, which includes the Project area, consists of elevated coral limestone dating from the Pleistocene epoch of the Quaternary period which occurred approximately two million years ago. In the Sarakata River basin, only a very alight amount of igneous breccia and sandstone can be found, the rest of the land is entirely covered by elevated coral limestone, and there are no significant faults at all (Figure6-4-3). Due to the above-mentioned geological features and the process by which they were created, the topography of the Project area consists of flat land with gentle rolling hills. The Sarakata River erodes the flat land as it flows downstream, and forms a V-shaped channel and falls in the Project area. Results of the seven test pits dug in the Project area as part of the on-site survey show that the surface soil covering is from 0.8 - 1.40 meters deep, and the soil consists of clay light brown to brown in colour.



※Candidate site will be discussed at Capter 7

(Source: GEOLOGY OF SOUTH SANTO (1:100,000 New Hebrides Geological Survey Sheet 4)

Figure 6-4-3 Georogical Map（Around Sarakata Hydroelectric Power Plant）

Chapter 7 Study of Potential Sites for Grant Aid Purpose

As for power development by renewable energy on Santo Island, hydropower, mega solar, wind power, and biomass power are possible generation plans. The Study Team examined the candidate sites of these development plans by the desk study and field survey, and comprehensively judged the optimum development plan in this survey, as from economic efficiency, impact on social environment, land acquisition, access road.

7-1 Establishment of Outline Plan and Estimation of Project Cost

7-1-1 Establishment of Outline Plan

In 2007-2009, the installed capacity of Sarakata hydropower plant reached 1,200 kW by Japanese grant aid in Vanuatu. Also, further plan for the additional expansion power plant was planned by ADB in 2014. All facilities such as intake, headrace, and powerhouse, are located in right bank side and existing hydro power plant is applied to. However, for additional amount of river flow, the intake dam should be increased by 0.4 meters height. In this study, the feasibility of the ADB proposal and other candidate sites were compared and examined.

In this study, the Study Team also planned development plans in downstream from the existing Sarakata hydropower plant, and compared the total 4 plans. Detailed comparison and recommended cases are described in "Chapter 7.2 Comparative Review of Hydropower Candidate Sites ". The examination of mega solar and wind power plants other than hydropower is described in "Chapter 7.3 Comparison of alternatives by power source".

7-1-2 Estimation of Project Cost

The Study Team basically carried out estimation of project cost by method described in the Reference "Guidance of Construction Cost Integration of Hydropower Development: (METI, 2013)", and added necessary items that were separately allocated by local characteristics. 1) Building, 2) Civil work, 3) Electromechanical equipment, 4) Temporary facilities, 5) Total expense, 6) Sub total, 7) Relevant cost, 8) Transmission facilities, and 9) Total (without contingency) are calculated.

Land compensation fee shall be borne by the government of Vanuatu. Total cost is about 2,600 Million Yen for hydropower development plan with capacity of 800 kW.

7-2 Comparative Review of Hydropower Candidate Sites

As for formulation of development scale, the Study Team proceeded to organize water discharge data of Sarakata River, to study basic layout of facilities, and development scale for formulating development plan of new Sarakata hydropower plant project.

7-2-1 Review Summary

The process of organizing is shown as follows:

（Process）

① Set up study conditions

② Organize basic concepts such as power output calculation, construction cost calculation, and economic analysis

③ Set up parameter (plant discharge) for case study approach

④ Organize details to be studied such as power output calculation, construction cost calculation, and economic analysis

⑤ Study optimum development scale

References for the study are shown as follows.

（References）

① Middle and Small Hydropower Generation Guidebook (New Energy Foundation :NEF, 5th edition, 2013)

② Guidance of Construction Cost Integration of Hydropower Development (Ministry of Energy, Trade and Industry：METI, 2013)

7-2-2 Basic Study Concept

Study conditions are shown in the followings.

（Conditions）

① The Study Team carried out calculations of power output, etc. by the method described in Reference “Middle and Small Hydropower Generation Guidebook: (NEF, 5th edition, 2013)” and Maximum output, Gross head, Effective head, Rated rotational speed, Specific speed, Overall efficiency, Annual power generation, Plant factor, etc. are calculated.

② The Study Team basically carried out estimation of construction cost by method described in Reference “Guidance of Construction Cost Integration of Hydropower Development: (METI, 2013)”, and added necessary items that were separately allocated by local characteristics. 1) Building, 2) Civil work, 3) Electromechanical equipment, 4) Temporary facilities, 5) Total expense, 6) Sub total, 7) Interest during construction, 8) Relevant cost, 9) Transmission facilities, and 10) Total (without contingency) are calculated.

③ As for economic analysis, unit construction cost per kWh was calculated from construction cost (PHP) and power generation (kWh), and then the lowest cost case was selected for basic layout option. Moreover, unit construction cost per kW was calculated in reference.

7-2-3 Basic Layout Options

The Study Team carried out topographical analysis and site survey of topographical, existing roads, land use, and existing housings. After that study of basic layout options were implemented based on these analysis and survey results.

(1) Location of the Intake Dam

The intake dam should be located in rational area where larger amount of power generation (kWh) can be acquired. The study team researched longitudinal slope of Sarakata River, development plan of third-party projects, and the intake dam site of this project.

As a result of map study and site survey, enlargement of the intake dam of existing Sarakata hydropower plant and utilize for new hydropower plant is one of hydropower development plan. Moreover, as a result of surveying downstream from existing Sarakata hydro power plant and upstream from the point where rivers converge, there are candidate sites where can be used to construct the optimum scale of intake dam. The Study Team finally judged that location of the intake dam shown in Figure 7-2-1 was reasonable position based on results of our site survey and organizing references.

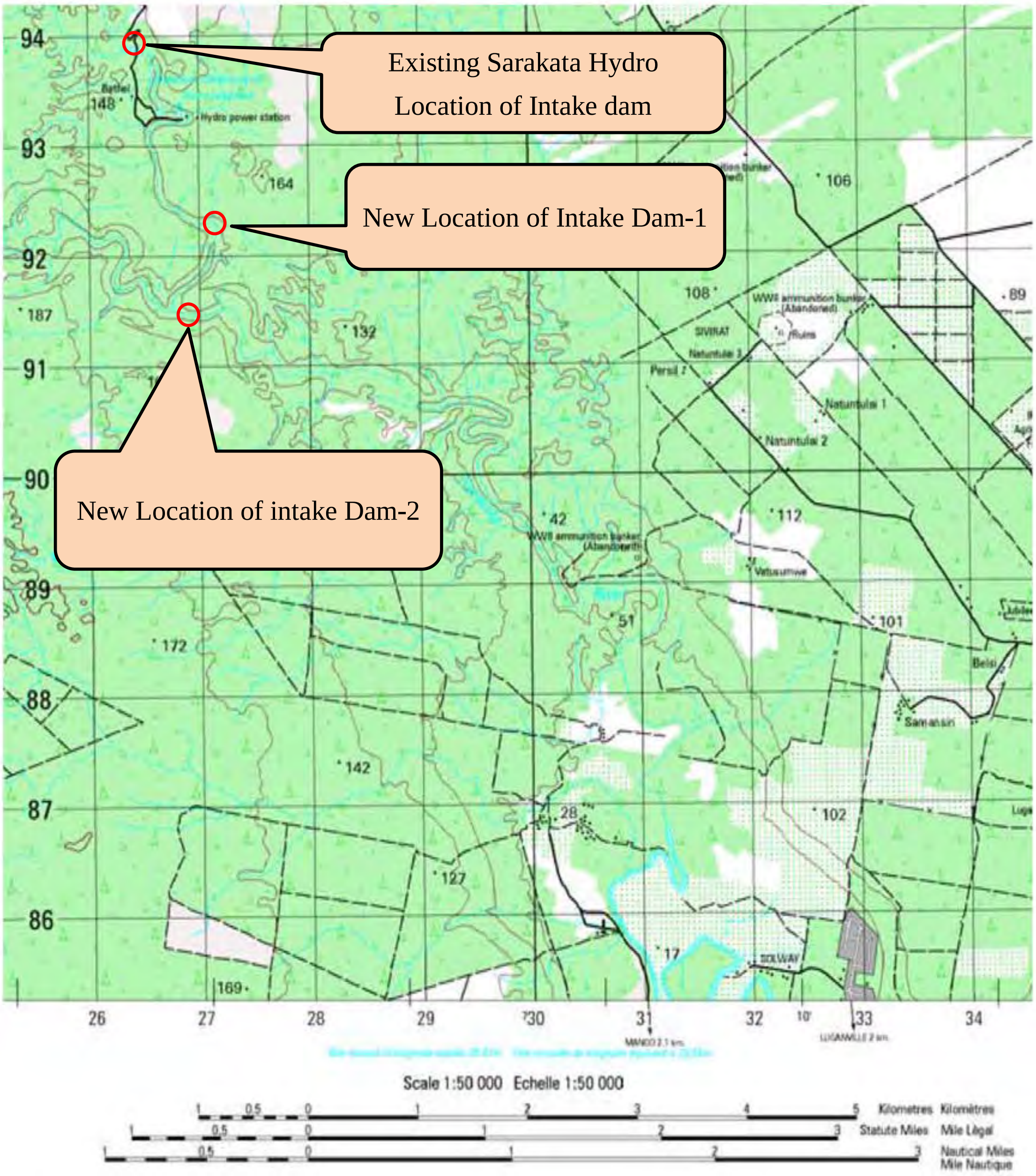


Figure 7-2-1 Topographical Map around Sarakata Hydropower

（S=1/50,000, Source：Turtle Bay, Vanuatu, 1516705 X721）

(2) Study of Basic Layout

The Study Team carried out 4 basic layout options based on site survey of topographical, existing roads, land use, and existing housings as shown in the Figure 7-2-2.

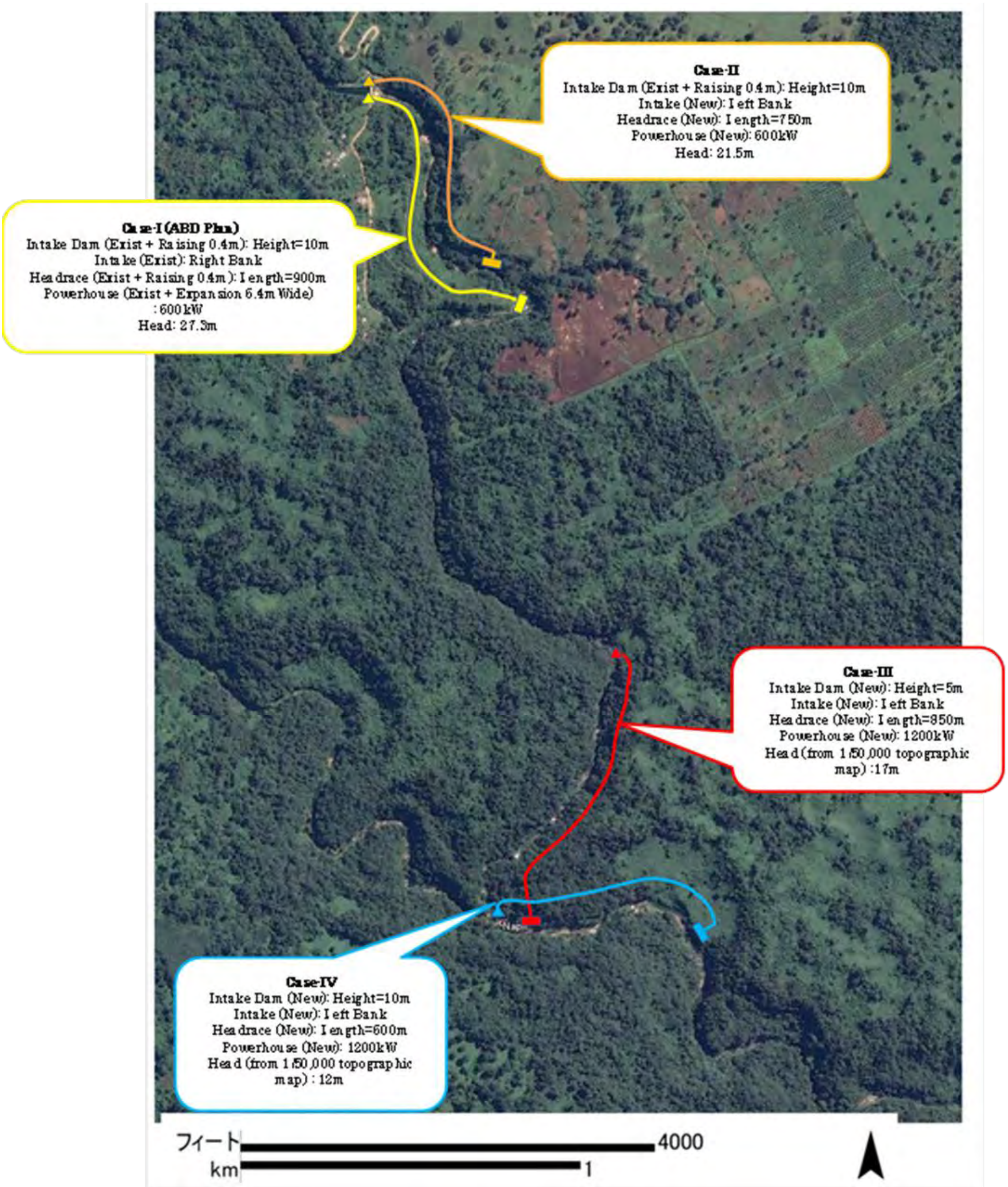


Figure 7-2-2 Basic Layout of New Sarakata River Hydropower Plant Candidate Sites

- Case- I

Basic layout, location and route of each facility for Case-I (Dam and Headrace type, Right bank route) are described in the following. This case is same as 600 kW extension plan in ADB's "Feasibility Study of Sarakata-1 Extension Project: 2014".

（Location and Route）

・All facilities such as intake, headrace, and powerhouse, are located in right bank side and existing hydro power plant is applied to. However, for additional amount of river flow, the intake dam should be increased 0.4 meters height.

・Gross head is 27.3 m

Photo7.2.3-1 Existing Intake Dam

Photo7.2.3-2 Existing Headrace

Photo7.2.3-3 Existing Head Tank

Photo7.2.3-4 Existing Powerhouse

➢ Case-II

Basic layout, location and route of each facility for Case-II (Dam and Headrace type, Left bank route) are described as follows.

（Location and Route）

・Location of the intake is same as Case-I, but, for additional amount of river flow, existing intake dam should be increased 0.4 meters height.

・As for location of the powerhouse, there is a suitable landscape for water head by being located in downstream from the waterfall. The powerhouse is located in left bank side and approximately 750 m downstream from existing intake dam.

・The headrace is open channel based on location of the intake and the headtank, and landscape of the headrace route. Length of the headrace is 750 m.

・Gross head is 24.0 m (≒10.0 m + 14 m) as shown in the followings

- ✓ Gross head = (Head obtained by intake dam) + (Head obtained by headrace)
- ✓ Head obtained by intake dam: 10.0 m
- ✓ Head obtained by headrace: 14.0 m based on information from topo map

Photo7.2.3-5 Existing Intake Dam

Photo7.2.3-6 Candidate Headrace Site

Photo7.2.3-7 Candidate Powerhouse Site

➢ Case-III

Basic layout, location and route of each facility for Case-III (Dam and Headrace type, Left bank route) are described as follows.

（Location and Route）

- The intake is located in left bank side and downstream from existing Sarakata hydro power plant and upstream from the point where rivers converge.
- Dam height is 5.0 m in consideration of influence on backwater to existing Sarakata hydro power plant.
- As for location of the powerhouse, there is a suitable landscape for water head located in downstream from the point where rivers converge. The powerhouse is located in left bank side and approximately 900 m downstream from the intake.
- The headrace is open channel based on location of the intake and the headtank, and landscape of the headrace route. Length of the headrace is 850 m.
- Gross head is 15.0 m as shown in the followings
  - ✓ Gross head = (Head obtained by intake dam) + (Head obtained by headrace) – (Elevation of outlet)
  - ✓ Head obtained by intake dam: 5.0 m
  - ✓ Head obtained by headrace: 13.5 m based on information from topo map

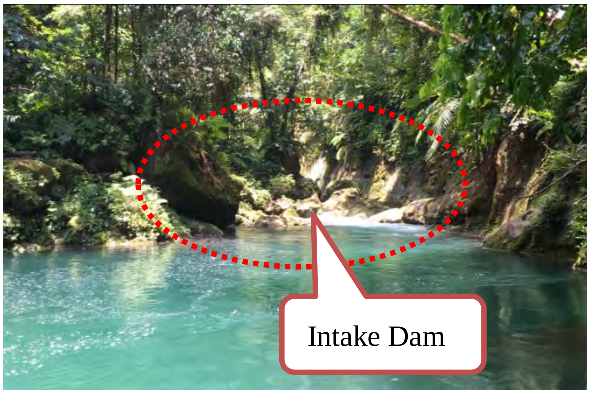


Photo7.2.3-8 Candidate Intake Dam Site

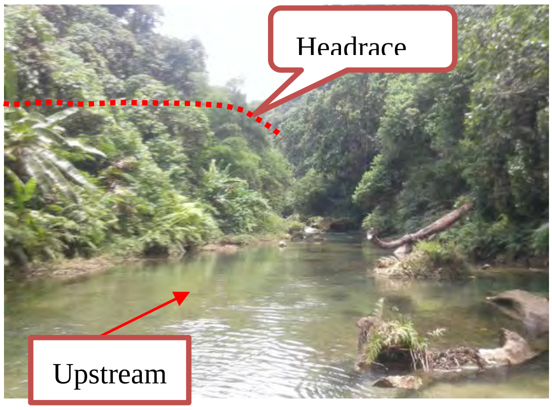


Photo7.2.3-9 Candidate Headrace Site

Photo7.2.3-10 Candidate Powerhouse Site

- Case-IV

Basic layout, location and route of each facility for Case-IV (Dam and Headrace type, Left bank route) are described as follows.

（Location and Route）

- The intake is located in left bank side and downstream from the point where rivers converge.
- Dam height is 10.0 m as same as existing Sarakata hydro power plant.
- As for location of the powerhouse, the powerhouse is located in left bank side and approximately 650 m downstream from the intake where is a suitable landscape for water head.
- The headrace is open channel based on location of the intake and the headtank, and landscape of the headrace route. Length of the headrace is 650 m.
- Gross head is 11.5m as shown in the followings
    - ✓ Gross head = (Head obtained by intake dam) + (Head obtained by headrace) – (Elevation of outlet)
    - ✓ Head obtained by intake dam: 10.0 m
    - ✓ Head obtained by headrace: 5.0 m based on information from topo map

Photo7.2.3-11 Candidate Intake Dam Site

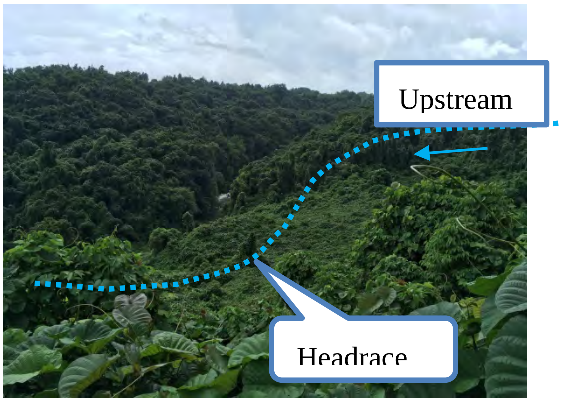


Photo7.2.3-12 Candidate Headrace Site

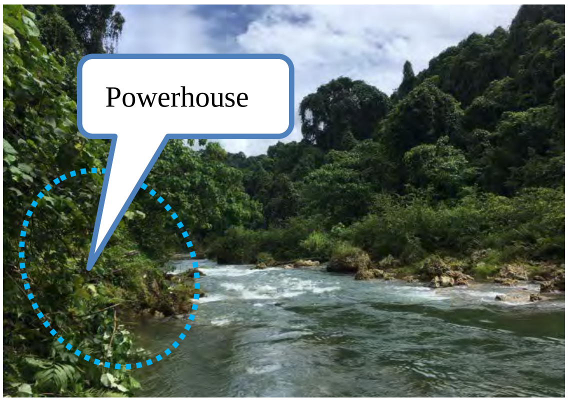


Photo7.2.3-13 Candidate Powerhouse Site

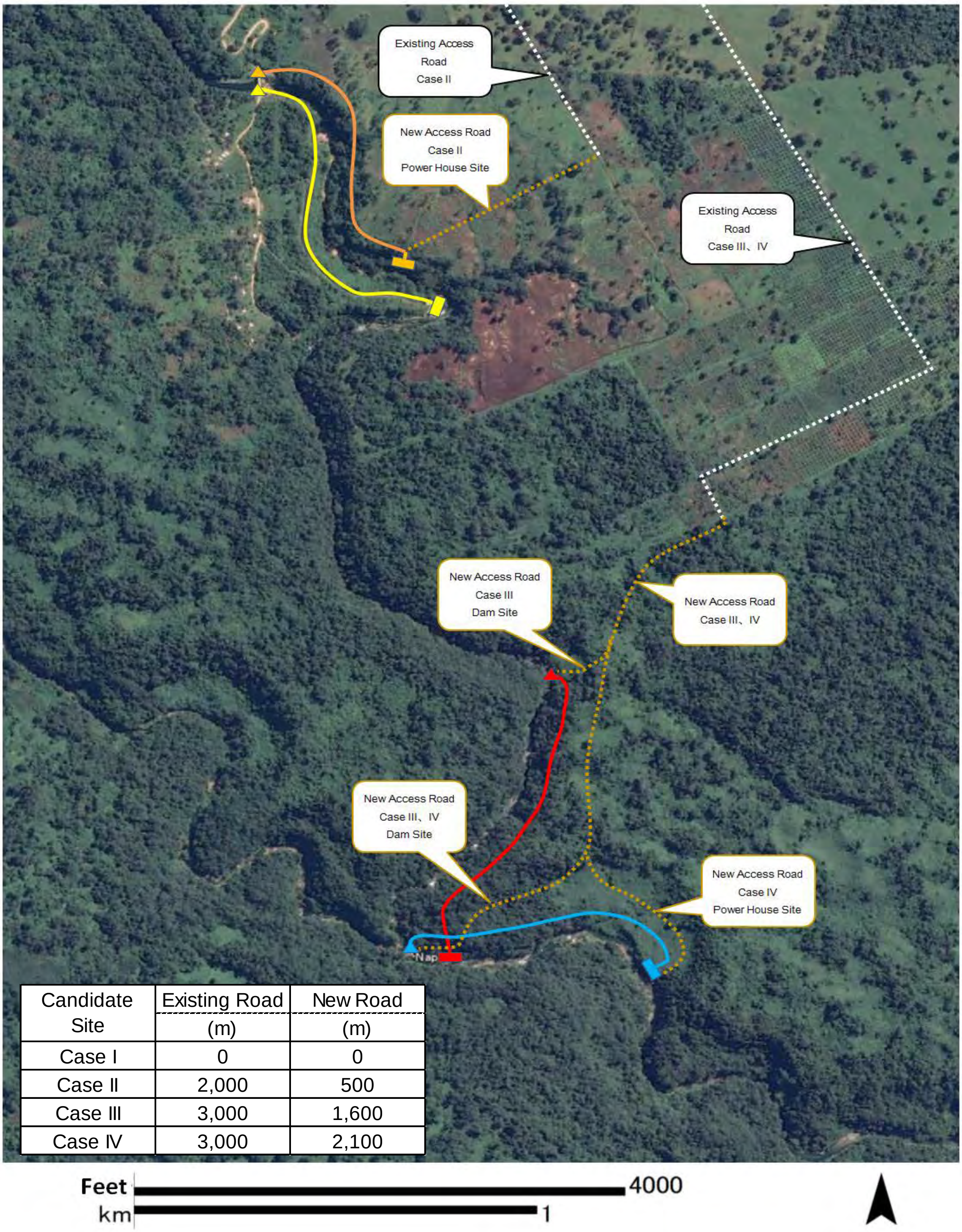
Basic layout plans for Case I to IV are shown in the Table 7-2-1.

Table 7-2-1 Basic Layout Plans

Item			Unit	Use facilities of existing Sarakkata hydroelectric power station		New Construction	
				Case I (ADB Plan)	Case Ⅱ	Case Ⅲ	Case Ⅳ
River Name			-	Sarakata River			
Catchment Area			km^2	91	91	94.8	149.5
Power Generation Plan		Power Generation Type	—	Dam Waterway Type, Inflow Type	Dam Waterway Type, Inflow Type	Dam Waterway Type, Inflow Type	Dam Waterway Type, Inflow Type
Power Generation Plan		Total Head	m	27.3	24.0	15.0	11.5
Power Generation Plan		Number of Turbine and Generator	Unit	1	2	2	2
Facility Overview		Intake Dam	—	Concrete Gravity Type (Existing +0.4m Raise)、 Overflow Height =10.0m Crest Length = 60m	Concrete Gravity Type (Existing +0.4m Raise)、 Overflow Height =10.0m Crest Length = 60m	Concrete Gravity Type、 Overflow Height = 5.0m、 Crest Length = 50m	Concrete Gravity Type、 Overflow Height = 10.0m、 Crest Length = 70m
Facility Overview	Water Way	Intake	—	Side Intake System (Existing Right Bank)	Side Intake System (New Establishment Left Bank)	Side Intake System (New Establishment Left Bank)	Side Intake System (New Establishment Left Bank)
Facility Overview	Water Way	Settling Basin	—	Concrete made, 1 (existing + 0.2 m raise)	Concrete made, 1 (New Establishment)	Concrete made, 1 (New Establishment)	Concrete made, 1 (New Establishment)
Facility Overview	Water Way	Headrace Cannel	—	Open Chaneel (0.4m Raise), Extension = 900m	Open Chaneel, 750m Extension	Open Chaneel, 850m Extension	Open Chaneel, 650m Extension
Facility Overview	Water Way	Head Tank	—	Concrete made, 1 (New Establishment)	Concrete made, 1 (New Establishment)	Concrete made, 1 (New Establishment)	Concrete made, 1 (New Establishment)
Facility Overview	Water Way	Penstock	—	Exposure Type、Steel、 Length = 56m	Exposure Type、Steel、 Length = 38m	Exposure Type、Steel、 Length = 25m	Exposure Type、Steel、 Length = 30m
Facility Overview		Power House	—	Ground type (extension + 6.4 m width)	Ground Type	Ground Type	Ground Type
Facility Overview		Turbine	—	Horizontal Francis Turbine, 1 unit	Tubular Turbine, 2 units	Tubular Turbine, 2 units	Tubular Turbine, 2 units
Facility Overview		Generator	—	Three-phase Synchronous Generator, 1 unit	Three-phase Synchronous Generator, 2 unit	Three-phase Synchronous Generator, 2 unit	Three-phase Synchronous Generator, 2 unit

7-2-4 Basic Plan of the Access Roads

The Study Team carried out topographical analysis and site survey of topographical, existing roads, land use, and existing housings. And then study of access roads were implemented based on these analysis and survey results.



Candidate Site	Existing Road (m)	New Road (m)
Case I	0	0
Case II	2,000	500
Case III	3,000	1,600
Case IV	3,000	2,100

Figure 7-2-3 Access Roads Map

7-2-5 Study of Grid System Plan

The Study Team carried out topographical analysis and site survey of existing distribution lines, land use, and existing housings. And then study of grid system was implemented based on these analysis and survey results.

(1) Connection Point

New 20kV T/L is connected to the transformer facilities of existing Sarakata hydro plant where the nearest facility is.

There is no extension of the new transmission line in Case-I that uses existing facilities. The extension of the new transmission line in Case-II that the powerhouse will be installed on the other side of the existing Sarakata powerhouse is less than 50 m. The extension of the new transmission line in Case-III and IV is 5.4 km. However, whether the existing transmission line has enough capacity to accommodate the new hydropower plant or not is a subject to study in the future. In the case of insufficient capacity, additional costs such as replacement of the transmission line and reinforcement of the support will occur.

(2) Transmission Method

It is assumed that overhead transmission and underground transmission are available for the Sarakata project. The Study Team selected overhead transmission method since construction cost per distance was cheaper.

(3) Number of Circuits

It is assumed that single circuit T/L (main circuit only) and double circuit T/L (main and sub circuit) are available for the Sarakata project. The Study Team selected single circuit T/L since construction cost could be reduced.

(4) 20 kV T/L Support Structure

The Study Team carried out site survey for understanding existing power grid line around the project site and confirmed condition of 20 kV T/L support structures. Therefore, the Study Team selected a reinforced concrete pole for support structures in the Sarakata project.

7-2-6 Organizing River Flow Durations

(1) River Flow Durations at the Intake Dam

As for river flow duration at the intake dam site, corrected discharge data (2014 - 2016) of Sarakata hydropower plant from VUI is used for this study. Since operational data is from existing Sarakata hydropower plant, river flow discharge data for Case- III and IV was converted by catchment area ratio (River Discharge at the Intake m3/s ＝ River Discharge at the intake of existing Sarakata hydropower m^3/s × Catchment Area Ratio).

Table 7-2-2 Catchment Area Ratio: Case-III, IV

Item	Catchment Area		Ratio
	Existing Sarakata Hydro.	Candidate Site, Intake Point	
	km^2	km^2	%
CaseⅢ	91.00	94.80	104%
CaseⅣ	91.00	149.50	164%

Converted river duration curves of Case-III and IV are shown in the following Figure 7-2-4.

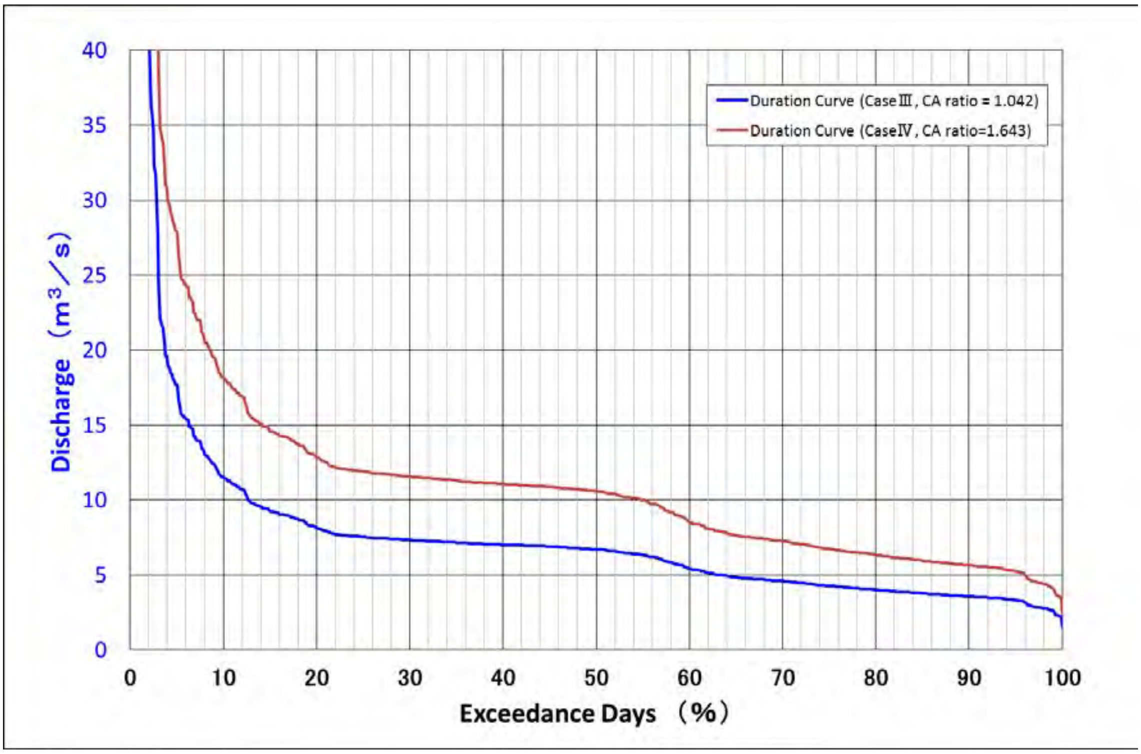


Figure 7-2-4 Flow Duration Curves of the Intake Dam Site (Case III and IV)

(2) Available River Discharge at Existing Sarakata Hydropower Plant Site

For the existing Sarakata hydraulic power, the flow rate Q = 5.8 m^3/s is used for the facility of 1,200 kW. Case-I is an extension plan and Case-II utilizes river water from existing Sarakata dam, these two cases will use only remaining part of river flow other than amount of river flow for the existing Sarakata hydropower.

The flow rate that can be used for Case-I and Case-II is the red hatched part shown in Figure 7-2-5, and according to ADB's expansion plan, the flow rate Q = 3.0 m^3/s is required for the facility of 600 kW. In case of the river duration curve, which were reviewed from the original, only about 16% days of the year for which the facility can be operated at full capacity. Also, the plan, which will be developed in the existing Sarakata hydropower, would result in a failure to secure the flow rate.
Therefore, Case-I and Case-II are excluded from the study of comparison.

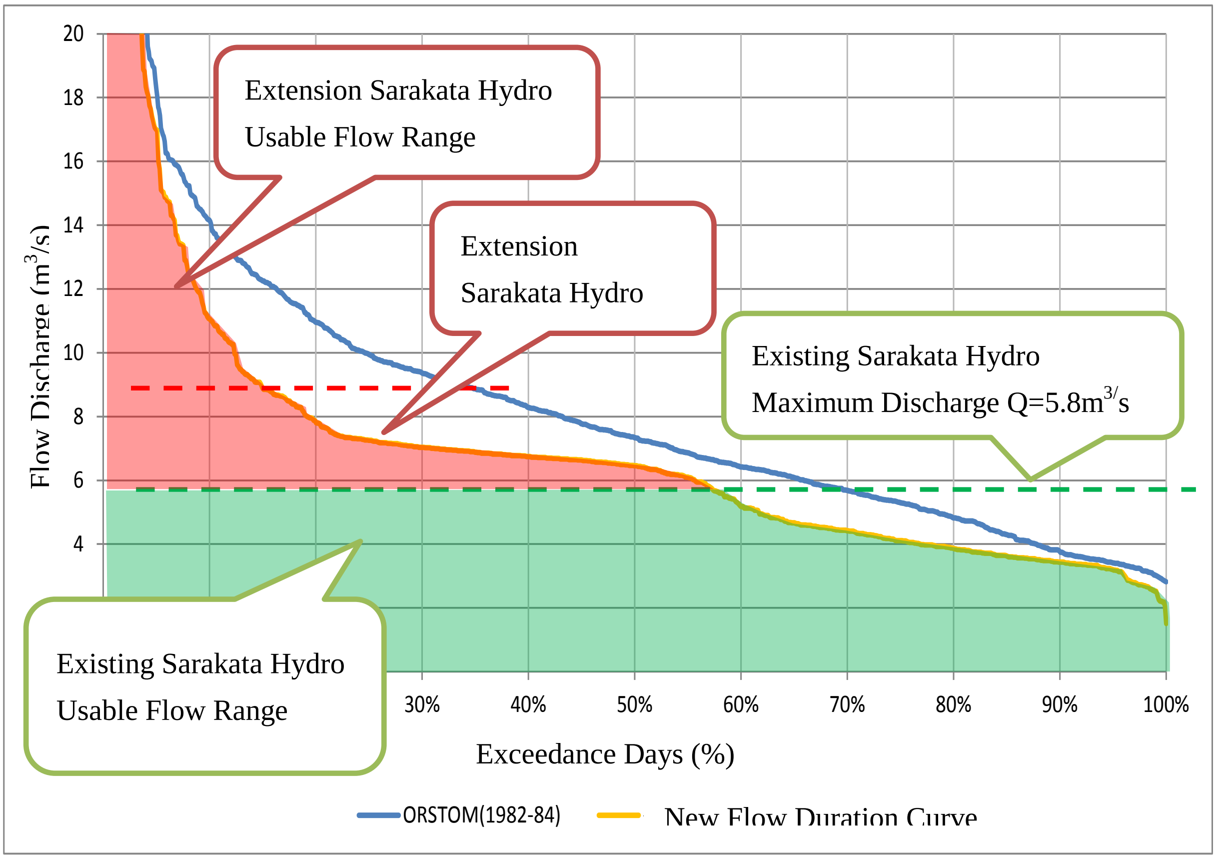


Figure 7-2-5 Available River Discharge at Existing Sarakata Hydropower Plant Site

7-2-7 River Flow Utilization Factor

River flow utilization factors calculated by flow duration data of Case-III and IV are shown in the following Table 7-2-3 to Table 7-2-4. River duration curves and flow utilization factors for Case-III and IV are shown in the following Figure 7-2-6 to Figure 7-2-7.

Table 7-2-3 River Flow Utilization Factors: Case-III

No.	River Duration			Sectional Difference	Sectional Average Day	Sectional Total Discharge	Utilization Flow	Annual Total River Flow of each Discharge	Flow Utilization Factor
	Exceedance Days		Discharge						
	%	日	m^3/s	m^3/s	日	m^3/s-day	m^3/s-day	m^3/s	%
		A_i	B_i	C_i	D_i	E_i	F_i	G_i	
				･i＝1 :B_i ･i＝2～7 :$B_i－B_{i-1}$	･i＝1 :A_i ･i＝2～7 :$(A_i＋A_{i-1})/2$	$=C_i×D_i$	･i＝1 :E_i ･i＝2～7 :$\Sigma(E_i～E_1)$	$=B_i×365$	$=F_i/G_i×100$
			*1						
1	0	365	1.57	1.57	365	573.05	573.05	573.05	100.0
2	10	329	3.57	2.00	347	694.00	1,267.05	1,303.05	97.2
3	20	292	4.01	0.44	311	136.62	1,403.67	1,463.65	95.9
4	30	256	4.60	0.59	274	161.66	1,565.33	1,679.00	93.2
5	40	219	5.39	0.79	238	187.63	1,752.96	1,967.35	89.1
6	50	183	6.72	1.33	201	267.33	2,020.29	2,452.80	82.4
7	60	146	7.02	0.30	165	49.35	2,069.64	2,562.30	80.8
8	70	110	7.33	0.31	128	39.68	2,109.32	2,675.45	78.8
9	75	91	7.55	0.22	101	22.11	2,131.43	2,755.75	77.3
10	80	73	8.13	0.58	82	47.56	2,178.99	2,967.45	73.4
11	85	55	9.27	1.14	64	72.96	2,251.95	3,383.55	66.6
12	90	37	11.52	2.25	46	103.50	2,355.45	4,204.80	56.0
13	100	0	157.17	145.65	19	2,694.53	5,049.98	57,367.05	8.8

Table 7-2-4 River Flow Utilization Factors: Case-IV

No.	River Duration			Sectional Difference	Sectional Average Day	Sectional Total Discharge	Utilization Flow	Annual Total River Flow of each Discharge	Flow Utilization Factor
	Exceedance Days		Discharge						
	%	日	m^3/s	m^3/s	日	m^3/s-day	m^3/s-day	m^3/s	%
		A_i	B_i	C_i	D_i	E_i	F_i	G_i	
				･i＝1 :B_i ･i＝2～7 :B_i-B_{i-1}	･i＝1 :A_i ･i＝2～7 :$(A_i+A_{i-1})/2$	$=C_i\times D_i$	･i＝1 :E_i ･i＝2～7 :$\Sigma(E_i \sim E_1)$	$=B_i\times 365$	$=F_i/G_i\times 100$
			*1						
1	0	365	2.47	2.47	365	901.55	901.55	901.55	100.0
2	10	329	5.64	3.17	347	1,099.99	2,001.54	2,058.60	97.2
3	20	292	6.32	0.68	311	211.14	2,212.68	2,306.80	95.9
4	30	256	7.26	0.94	274	257.56	2,470.24	2,649.90	93.2
5	40	219	8.50	1.24	238	294.50	2,764.74	3,102.50	89.1
6	50	183	10.60	2.10	201	422.10	3,186.84	3,869.00	82.4
7	60	146	11.08	0.48	165	78.96	3,265.80	4,044.20	80.8
8	70	110	11.56	0.48	128	61.44	3,327.24	4,219.40	78.9
9	75	91	11.91	0.35	101	35.18	3,362.42	4,347.15	77.3
10	80	73	12.82	0.91	82	74.62	3,437.04	4,679.30	73.5
11	85	55	14.62	1.80	64	115.20	3,552.24	5,336.30	66.6
12	90	37	18.16	3.54	46	162.84	3,715.08	6,628.40	56.0
13	100	0	247.83	229.67	19	4,248.90	7,963.98	90,457.95	8.8

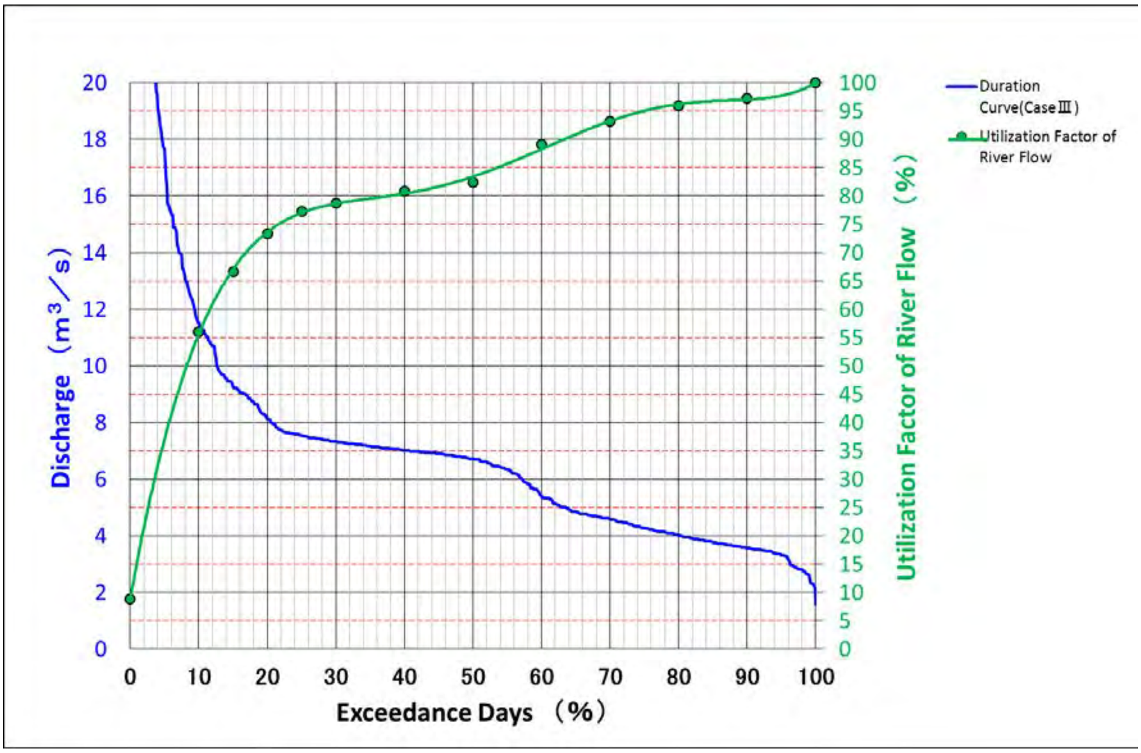


Figure 7-2-6 River Duration Curve & Flow Utilization Factor of the Intake Dam Site Case-III (Enlarge Y-Axis)

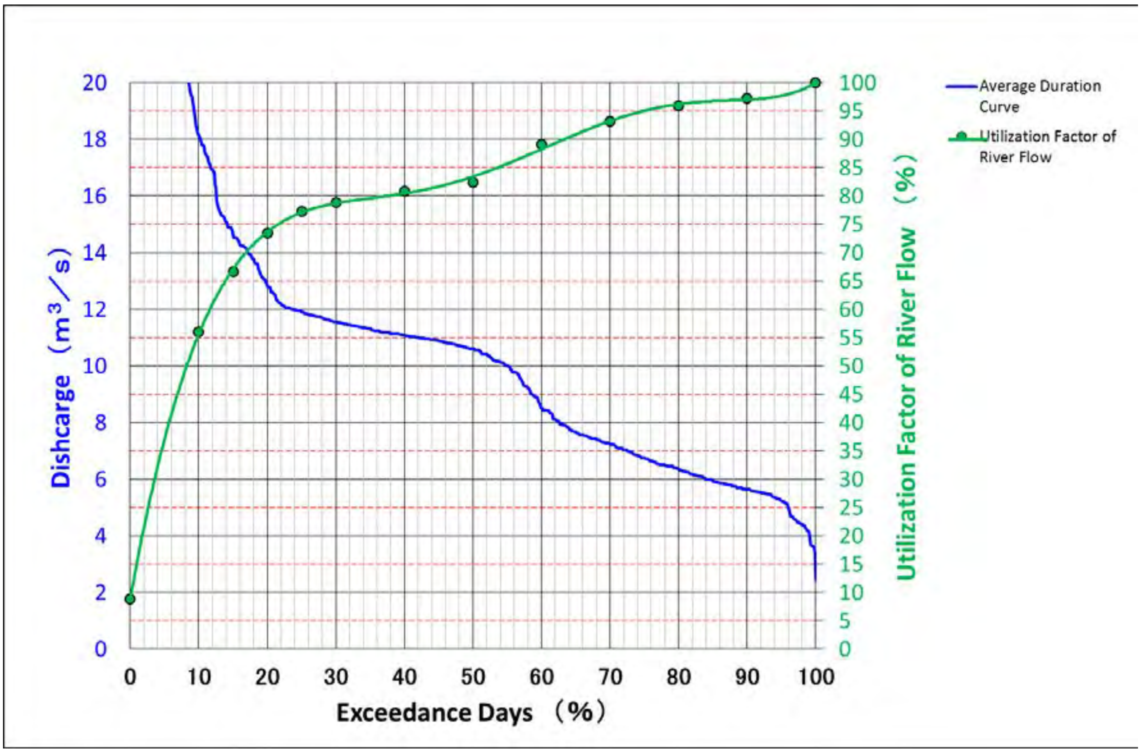


Figure 7-2-7 River Duration Curve & Flow Utilization Factor of the Intake Dam Site Case-IV (Enlarge Y-Axis)

7-2-8 River Discharge for Case Study of Optimum Plant Discharge

In order to set the parameters (the plant discharge for studying of "Chapter 7.2.10 Optimum Development Scale"), discharges of 60% to 90% of flow utilization factor were calculated.

Discharges of 60% to 90% of flow utilization factor are shown in the following Table 7-2-5 to 7-2-6. Taking every factor into consideration, the Study Team found that optimum plant discharge should range from 7.97 m^3/s to 10.91 m^3/s for Case-III, from 12.57 m^3/s to 17.20 m^3/s for Case-IV.

Table 7-2-5 River Discharge: Case-III

Item	Flow Utilization Factor (%)							Remarks
	60	70	75	80	85	90	Average	
	*1	*1	*1	*1	*1	*1	*2	
Exceeance Days (%)	11.42	16.25	21.79	37.57	53.83	62.78	21.08	
Discharge (m3/s)	10.91	9.03	7.75	7.09	6.43	5.03	7.97	

*1 Discharge of 60 to 90% Flow Utilization Factors are reading value from Flow Duration Curve and Data.
*2 Average Discharge＝(60% Discharge＋90% Discharge)／2

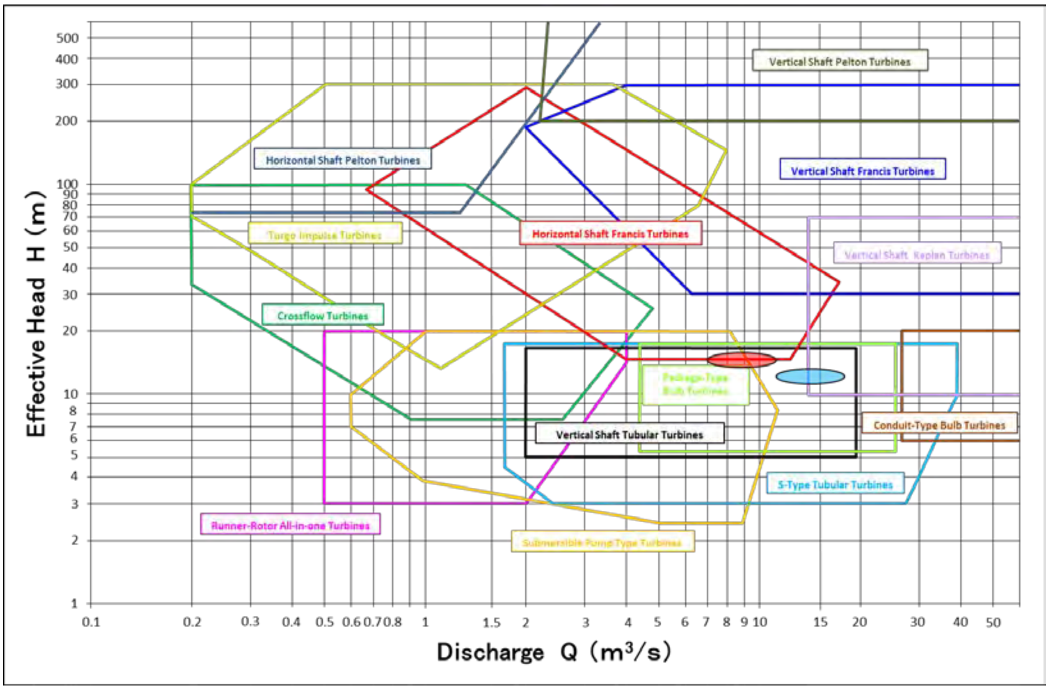
Table 7-2-6 River Discharge: Case-IV

Item	Flow Utilization Factor (%)							Remarks
	60	70	75	80	85	90	Average	
	*1	*1	*1	*1	*1	*1	*2	
Exceeance Days (%)	11.42	16.25	21.79	37.57	53.24	62.78	21.08	
Discharge (m3/s)	17.20	14.24	12.22	11.18	10.19	7.94	12.57	

*1 Discharge of 60 to 90% Flow Utilization Factors are reading value from Flow Duration Curve and Data.
*2 Average Discharge＝(60% Discharge＋90% Discharge)／2

7-2-9 Study of Turbine

Tubular turbine is adopted by using the following turbine selection chart from the relationship between the effective head and the river flow usage of Case III and IV.


Vertical Shaft Pelton Turbines
Horizontal Shaft Pelton Turbines
Vertical Shaft Francis Turbines
Turgo Impulse Turbines
Horizontal Shaft Francis Turbines
Vertical Shaft Kaplan Turbines
Crossflow Turbines
Vertical Shaft Tubular Turbines
Conduit-Type Bulb Turbines
S-Type Tubular Turbines
Runner-Rotor All-in-one Turbines
Submersible Pump Type Turbines
Effective Head H (m)
500
400
300
200
100
90
80
70
60
50
40
30
20
10
8
7
6
5
4
3
2
1
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 1 1.5 2 3 4 5 6 7 8 9 10 15 20 30 40 50
Discharge Q (m³/s)

7-2-10 Study of Optimum Development Scale

(1) Case-III

As a result, unit construction cost per kWh in Case-D (Install Capacity: 800kW=400kW×2 units, Maximum discharge: 7.10m3/s, Effective head: 13.4m) is the cheapest as shown in the following Table 7-2-7 and Figure 7-2-8. Therefore, the Study Team selected Case-III-D as the optimum development plan.

Table 7-2-7 Results of Study of Optimum Development Scale: Case III

Item			Unit	Case Ⅲ					
				A	B	C	D	E	F
Generatio Plan	Generatoin type		—	Dam Waterway Type, Inflow Type					
	Install Capacity	Total	kW	1,200	1,000	900	800	700	600
		Single	kW	600	500	450	400	350	300
	Plant Discharge	Total	m^3/s	10.90	9.00	7.80	7.10	6.40	5.00
		Single	m^3/s	5.46	4.52	3.88	3.55	3.22	2.52
	Head	Gross Head	m	15.0					
		Effective Head	m	13.4					
	No. of turbine & generator		Unit	2					
	Annual Power Generation		kWh	6,137,582	5,913,877	5,685,075	5,507,089	5,149,941	4,393,971
	Effective Power Generation		kWh	5,646,575	5,440,767	5,230,269	5,066,522	4,737,946	4,042,453
Project facilities and equipment description	Intake Dam		—	Concrete Gravity Type、Overflow Height = 5.0m、Crest Length = 50m					
	Headrace		—	Open Channel , No Pressure type, Concrete, Rectangular, 1 Strip, L = 850 m					
	Power House		—	Ground Type					
	Turbine		—	Tubular Turbine, 2 units					
	Generator		—	Three-phase Synchronous Generator, 2 unit					
Utilization	Plant factor		%	92	92	92	92	92	92
	Utilization factor		%	60	70	75	80	85	90
	Energy Availability factor		%	53.7	62.1	66.3	72.3	77.3	76.9
Construction Cost *1	Total		Mil. Yen	3,320	2,970	2,740	2,600	2,480	2,180
Cost Analysis	Unit Constr. Cost / kW		10^3Yen/kW	2,760	2,986	3,035	3,239	3,537	3,617
	Unit Constr. Cost / kWh		Yen/kWh	586.6	548.9	522.2	511.5	522.6	536.8
	Rating		—	6	5	2	1	3	4

* Yellow Haching case is the optimal scale case.
*1 The total construction cost is an approximate value for investigating the optimum scale, not the final total construction cost.

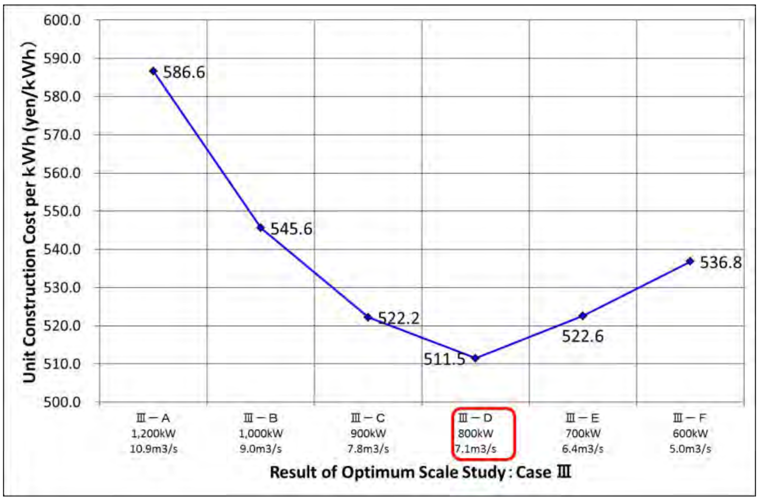


Figure 7-2-8 Results of Study of Optimum Development Scale: Case III

(2) Case IV

As a result, unit construction cost per kWh in Case-C (Install Capacity: 1,000kW=500kW×2 units, Maximum discharge: 12.20m3/s, Effective head: 10.1m) is the cheapest as shown in the following Table 7-2-8 and Figure 7-2-9. Therefore, the Study Team selected Case-IV-C as the optimum development plan.

Table 7-2-8 Results of Study of Optimum Development Scale: Case IV

Item			Unit	Case Ⅳ A	B	C	D	E	F
Generatio Plan	Generatoin type		–	Dam Waterway Type, Inflow Type					
	Install Capacity	Total	kW	1,400	1,200	1,000	900	850	700
		Single	kW	700	600	500	450	425	350
	Plant Discharge	Total	m^3/s	17.20	14.20	12.20	11.20	10.20	7.90
		Single	m^3/s	8.60	7.12	6.11	5.59	5.10	3.97
	Head	Gross Head	m	11.5					
		Effective Head	m	10.1					
	No. of turbine & generator		Unit	2					
	Annual Power Generation		kWh	7,187,090	6,916,665	6,691,072	6,371,977	6,027,200	5,198,033
	Effective Power Generation		kWh	6,612,123	6,363,332	6,155,786	5,862,219	5,545,024	4,782,190
Project facilities and equipment description	Intake Dam		–	Concrete Gravity Type、Overflow Height = 10.0m、Crest Length = 70m					
	Headrace		–	Open Channel , No Pressure type, Concrete, Rectangular, 1 Strip, L = 650 m					
	Power House		–	Ground Type					
	Turbine		–	Tubular Turbine, 2 units					
	Generator		–	Three-phase Synchronous Generator, 2 unit					
Utilization	Plant factor		%	92	92	92	92	92	92
	Utilization factor		%	60	70	75	80	85	90
	Energy Availability factor		%	53.9	60.5	70.3	74.4	74.5	78.0
Construction Cost *1	Total		Mil. Yen	4,190	3,800	3,470	3,300	3,160	2,800
Cost Analysis	Unit Constr. Cost / kW		10^3Yen/kW	2,990	3,159	3,461	3,664	3,710	3,989
	Unit Constr. Cost / kWh		Yen/kWh	633.0	595.8	562.2	562.5	568.7	583.9
	Rating		–	6	5	1	2	3	4

* Yellow Haching case is the optimal scale case.
*1 The total construction cost is an approximate value for investigating the optimum scale, not the final total construction cost.

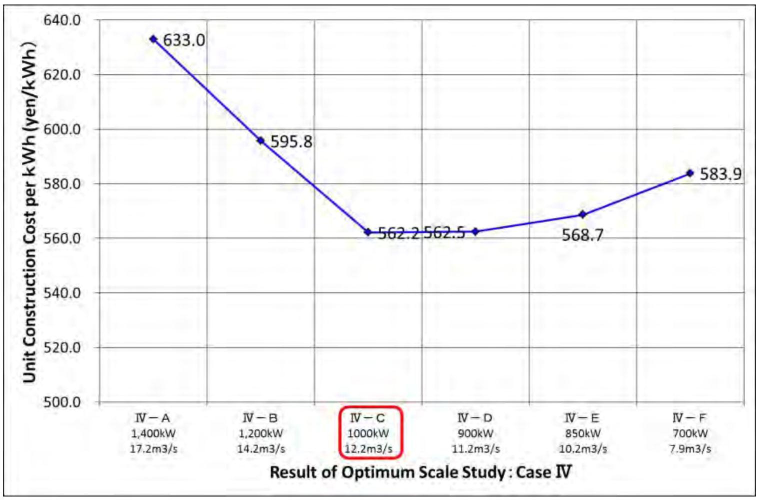


Figure 7-2-9 Results of Study of Optimum Development Scale: Case IV

7-2-11 Recommend Candidate Site of Hydropower Plant Development

Results of study of optimum development scale by each hydropower plant sites are shown in the following Table 7-2-9.

As a result of site survey, water head in Case-III is about 15m due to the presence of several small waterfalls. Therefore, water head in Case-III is larger than Case-IV which is located in left bank side and downstream from the point where rivers converge. Since the planned powerhouse site is also on the upstream side, the total access road distance is shorter. For this reason, the total project cost in Case-III is economical. On the other hand, since the left bank side of the intake dam is a steep slope and hard rock, excavation of the water conduit will not be easy. Because Study Team could not carry out site survey of the planned headrace area, we will acquire a detailed topographic map and carry out on-site investigation of the planned headrace area, and plan the headrace route in next step.

In Case-IV, the larger amount of water discharge can be secured by installing an intake dam in downstream from the confluence point of mainstream and tributary of Sarakata river, but the disadvantage is that the water head cannot be obtained because of the gradual inclination. All of the headrace sections can be constructed in the open channel and the extension distance of the headrace is shorter than Case-III.

As a result of above site survey, the project cost per kWh calculated from the facility plan and roughly estimated cost in Case-III with a capacity of 800kW is the cheapest, therefore **Case-III is an eligible development plan**.

Table 7-2-9 Results of Study of Optimum Development Scale

Candidate Site	Facility Output (kW)	Project Cost (Million Yen)	Annual Power Generation (kWh)	Project Cost per kWh (Yen/kWh)
Case-III	800	2,600	5,066,522	511.5
Case-IV	1,00	3,470	6,155,786	562.2

7-2-12 Economic Analysis

Economic analysis is conducted to analyze the influence on national or regional economy. As a method, "alternative method" is used and diesel power generation is assumed as an alternative means. We also use Economic internal rate of return (EIRR) and cost benefit method (B / C) as an evaluation index of economic analysis.

The Economic Internal Rate of Return (EIRR) is calculated from the benefits of this project in comparison with the alternative diesel power generation. Specifically, the Study Team calculated the benefit of this project in comparison with the introduction and operation cost of diesel power generation of the same scale (800 kW in case III, 1,000 kW in case IV) and calculate EIRR. The conditions of hydroelectric power plants (Cases III, IV) and corresponding scale alternate diesel power plants are as shown in the following Table 7-2-10, 7-2-11.

Table 7-2-10 New Sarakata Hydropower Development (Case Ⅲ) and Alternative Diesel Prerequisites

Item	New Sarakata River Hydro.	Alternative (Diesel)
Construction Cost	23.56 Million US$	0.945 Million US$ 1,182 US$/kW
Fuel Cost	－	0.971 Million US$/year Annual Generation (kWh) × 0.1917US$/kW
O/M	0.227 Million US$/Year 1% of Construction Cost	0.058 Million US$/year 6.1% of Construction Cost
Capacity	800 kW	800kW
Generation Amount	5,066MWh/year	5,066MWh/year
Operation Year	40 Years	15 Years

Table 7-2-11 New Sarakata Hydropower Development (Case IV) and Alternative Diesel Prerequisites

Item	New Sarakata River Hydro.	Alternative (Diesel)
Construction Cost	31.46 Million US$	1.182 Million US$ 1,182 US$/kW
Fuel Cost	—	1.18 Million US$/year Annual Generation (kWh) × 0.1917US$/kW
O/M	0.306 Million US$/Year 1% of Construction Cost	0.072 Million US$/year 6.1% of Construction Cost
Capacity	1,000 kW	1,000kW
Generation Amount	6,155MWh/year	6,155MWh/year
Operation Year	40 Years	15 Years

The economic analysis results for Case III and IV are shown in Table 7-2-12. Calculation processes of these economic analyses are shown in Table 7-2-13 and Table 7-2-14

Table 7-2-12 Economic Analysis Results (Case III, IV)

Index	CaseⅢ	CaseⅣ
EIRR	2.14%	1.45%
B/C (Discount Rate=1%)	1.2	1.1

Table 7-2-13 Economic Analysis (Case-III)

Case Ⅲ

Economic Cost			
Construction Cost	23.56	million US$	
Construction Cost (Exclude Transmissi	22.65	million US$	
O&M Cost	0.227	million US$/year	(=Construction Cost x 1%)
Economic Benefit			
Construction Cost of the Alternative	0.945	million US$	(=Unit Price of Diesel Generation 1,182 US$/kW x Capacity 800 kW)
O&M Cost of the Alternative	0.058	million US$/year	(=Construction Cost x 6.1%)
Fuel Cost of the Alternative	0.971	million US$/year	(=Fuel Price 0.1917US$/kWh x Annual Generation 5.066GWh)
Project Life	15	years	

EIRR	**2.14%**			
NPV(B-C)	**5.2**	million US$	(Discout Rate=	**1.00%**
B/C	**1.2**		(Discout Rate=	**1.00%**

Unit: Million US$

Year	Items	**Economic Cost (C)**			**Economic Benefit (B)**				
		Construction	O&M Cost	**Total Cost (1)**	Construction Cost of the Alternative	O&M Cost ot the Alternative	Fuel Cost of the Alternative	**Total Benefit (2)**	**Net (2)-(1)**
0	Construction Perio	23.557		**23.557**	0.945			**0.95**	**(22.612)**
1	Operation		0.227	**0.227**		0.058	0.971	**1.03**	**0.802**
2			0.227	**0.227**		0.058	0.971	**1.03**	**0.802**
3			0.227	**0.227**		0.058	0.971	**1.03**	**0.802**
4			0.227	**0.227**		0.058	0.971	**1.03**	**0.802**
5			0.227	**0.227**		0.058	0.971	**1.03**	**0.802**
6			0.227	**0.227**		0.058	0.971	**1.03**	**0.802**
7			0.227	**0.227**		0.058	0.971	**1.03**	**0.802**
8			0.227	**0.227**		0.058	0.971	**1.03**	**0.802**
9			0.227	**0.227**		0.058	0.971	**1.03**	**0.802**
10			0.227	**0.227**		0.058	0.971	**1.03**	**0.802**
11			0.227	**0.227**		0.058	0.971	**1.03**	**0.802**
12			0.227	**0.227**		0.058	0.971	**1.03**	**0.802**
13			0.227	**0.227**		0.058	0.971	**1.03**	**0.802**
14			0.227	**0.227**		0.058	0.971	**1.03**	**0.802**
15			0.227	**0.227**	0.945	0.058	0.971	**1.97**	**1.748**
16			0.227	**0.227**		0.058	0.971	**1.03**	**0.802**
17			0.227	**0.227**		0.058	0.971	**1.03**	**0.802**
18			0.227	**0.227**		0.058	0.971	**1.03**	**0.802**
19			0.227	**0.227**		0.058	0.971	**1.03**	**0.802**
20			0.227	**0.227**		0.058	0.971	**1.03**	**0.802**
21			0.227	**0.227**		0.058	0.971	**1.03**	**0.802**
22			0.227	**0.227**		0.058	0.971	**1.03**	**0.802**
23			0.227	**0.227**		0.058	0.971	**1.03**	**0.802**
24			0.227	**0.227**		0.058	0.971	**1.03**	**0.802**
25			0.227	**0.227**		0.058	0.971	**1.03**	**0.802**
26			0.227	**0.227**		0.058	0.971	**1.03**	**0.802**
27			0.227	**0.227**		0.058	0.971	**1.03**	**0.802**
28			0.227	**0.227**		0.058	0.971	**1.03**	**0.802**
29			0.227	**0.227**		0.058	0.971	**1.03**	**0.802**
30			0.227	**0.227**	0.945	0.058	0.971	**1.97**	**1.748**
31			0.227	**0.227**		0.058	0.971	**1.03**	**0.802**
32			0.227	**0.227**		0.058	0.971	**1.03**	**0.802**
33			0.227	**0.227**		0.058	0.971	**1.03**	**0.802**
34			0.227	**0.227**		0.058	0.971	**1.03**	**0.802**
35			0.227	**0.227**		0.058	0.971	**1.03**	**0.802**
36			0.227	**0.227**		0.058	0.971	**1.03**	**0.802**
37			0.227	**0.227**		0.058	0.971	**1.03**	**0.802**
38			0.227	**0.227**		0.058	0.971	**1.03**	**0.802**
39			0.227	**0.227**		0.058	0.971	**1.03**	**0.802**
40			0.227	**0.227**		0.058	0.971	**1.03**	**0.802**
Total		**23.557**	**9.060**	**32.617**	**2.836**	**2.307**	**38.846**	**43.989**	**11.372**
			NPV	30.69				35.88	5.196
			(Discout Rate at	1.00%)					

Table 7-2-14 Economic Analysis (Case-IV)

Case IV

Economic Cost			
Construction Cost	31.46	million US$	
Construction Cost (Exclude Transmission)	30.55	million US$	
O&M Cost	0.306	million US$/year	(=Construction Cost x 1%)
Economic Benefit			
Construction Cost of the Alternative	1.182	million US$	(=Unit Price of Diesel Generation 1,182 US$/kW x Capacity 1,000 kW)
O&M Cost of the Alternative	0.072	million US$/year	(=Construction Cost x 6.1%)
Fuel Cost of the Alternative	1.180	million US$/year	(=Fuel Price 0.1917US$/kWh x Annual Generation 6.155GWh)
Project Life	15	years	

EIRR	**1.45**	%		
NPV(B-C)	**2.7**	million US$	(at Disouct Rat	**1.00%**
B/C	**1.1**		(at Disouct Rat	**1.00%**

Unit: Million US$

Year	Items	Economic Cost (C)			Economic Benefit (B)				
		Construction	O&M Cost	**Total Cost (1)**	Construction Cost of the Alternative	O&M Cost ot the Alternative	Fuel Cost of the Alternative	**Total Benefit (2)**	**Net (2)-(1)**
0	Construction Period	31.460		**31.460**	1.182			**1.18**	**(30.278)**
1	Operation		0.306	**0.306**		0.072	1.180	**1.25**	**0.946**
2			0.306	**0.306**		0.072	1.180	**1.25**	**0.946**
3			0.306	**0.306**		0.072	1.180	**1.25**	**0.946**
4			0.306	**0.306**		0.072	1.180	**1.25**	**0.946**
5			0.306	**0.306**		0.072	1.180	**1.25**	**0.946**
6			0.306	**0.306**		0.072	1.180	**1.25**	**0.946**
7			0.306	**0.306**		0.072	1.180	**1.25**	**0.946**
8			0.306	**0.306**		0.072	1.180	**1.25**	**0.946**
9			0.306	**0.306**		0.072	1.180	**1.25**	**0.946**
10			0.306	**0.306**		0.072	1.180	**1.25**	**0.946**
11			0.306	**0.306**		0.072	1.180	**1.25**	**0.946**
12			0.306	**0.306**		0.072	1.180	**1.25**	**0.946**
13			0.306	**0.306**		0.072	1.180	**1.25**	**0.946**
14			0.306	**0.306**		0.072	1.180	**1.25**	**0.946**
15			0.306	**0.306**	1.182	0.072	1.180	**2.43**	**2.128**
16			0.306	**0.306**		0.072	1.180	**1.25**	**0.946**
17			0.306	**0.306**		0.072	1.180	**1.25**	**0.946**
18			0.306	**0.306**		0.072	1.180	**1.25**	**0.946**
19			0.306	**0.306**		0.072	1.180	**1.25**	**0.946**
20			0.306	**0.306**		0.072	1.180	**1.25**	**0.946**
21			0.306	**0.306**		0.072	1.180	**1.25**	**0.946**
22			0.306	**0.306**		0.072	1.180	**1.25**	**0.946**
23			0.306	**0.306**		0.072	1.180	**1.25**	**0.946**
24			0.306	**0.306**		0.072	1.180	**1.25**	**0.946**
25			0.306	**0.306**		0.072	1.180	**1.25**	**0.946**
26			0.306	**0.306**		0.072	1.180	**1.25**	**0.946**
27			0.306	**0.306**		0.072	1.180	**1.25**	**0.946**
28			0.306	**0.306**		0.072	1.180	**1.25**	**0.946**
29			0.306	**0.306**		0.072	1.180	**1.25**	**0.946**
30			0.306	**0.306**	1.182	0.072	1.180	**2.43**	**2.128**
31			0.306	**0.306**		0.072	1.180	**1.25**	**0.946**
32			0.306	**0.306**		0.072	1.180	**1.25**	**0.946**
33			0.306	**0.306**		0.072	1.180	**1.25**	**0.946**
34			0.306	**0.306**		0.072	1.180	**1.25**	**0.946**
35			0.306	**0.306**		0.072	1.180	**1.25**	**0.946**
36			0.306	**0.306**		0.072	1.180	**1.25**	**0.946**
37			0.306	**0.306**		0.072	1.180	**1.25**	**0.946**
38			0.306	**0.306**		0.072	1.180	**1.25**	**0.946**
39			0.306	**0.306**		0.072	1.180	**1.25**	**0.946**
40			0.306	**0.306**		0.072	1.180	**1.25**	**0.946**
Total		**31.460**	**12.221**	**43.681**	**3.545**	**2.884**	**47.197**	**53.626**	**9.944**
			NPV	41.08				43.75	2.667
			(at Discout rat	1.00%)					

7-3 Comparison of Alternatives by Power Source

In order to satisfy 100% power generation by renewable energy on Santo Island, installation of mega solar or wind power are considered as the same scale power source other than hydropower. As shown in the following location map, mega solar is installed at the land of Vanuatu government or the state government of Sanma (area of about 2 ha at 1,000 kW) which is close to the transmission line along the east coast. Wind power generation is installed on the hill of Port Olry which conducts the wind power potential survey.

Port Olry is outside from the grid area now, and it is about 40 km to Luganville. However, if distribution line extension project by the ADB scheme is completed, grid connection becomes easy.

In addition to this, we will also consider plans to make bio-diesel power generation using biofuels made from copra as an existing diesel power plant. The potential of geothermal power generation in Santo Island has not been confirmed.

Figure 7-3-1 Location of Candidate Sites for Powerhouses

7-3-1 Social Environment at Development Sites

The social environmental problems are considered when the development by each power supply is carried out at the candidate sites in Santo Island. Besides, the three sites of hydropower, wind power, mega solar, and Bio-Diesel are not included in the nature reserve registered by law.

(1) Wind Power

- Bird strike of rare birds may occur
- Noise problem may occur in the vicinity due to noise / low frequency sound when there are settlements in the suburbs
- In order to use the land of the government, land acquisition and involuntary resettlement will not occur

(2) Mega Solar

- Site is a coastal area and there is concern about the impact on the landscape
- In order to use the land of the government, land acquisition and involuntary resettlement will not occur

(3) Hydropower

- The temporary impact on the environment during construction is assumed, but it is limited
- Impacts on river ecosystem and organisms are assumed at the dry season
- Involving acquisition of land and compensation business. Non-voluntary resettlement may not occur

(4) Bio-Diesel

- Any particular impact on environment is not predicted
- In order to use the existing diesel power plant, land acquisition and involuntary resettlement will not occur

7-3-2 Daily Power Generation

According to the monthly report of VUI, as shown in Figure 7-3-2 and Table 7-3-.1 the maximum Peak Load in Santo Island was 1,932 kW which occurred on 1st December 2016 (Thursday 2016) and the maximum power generation was 34,430 kWh. About the breakdown of power generation, the power generation of the existing Sarakata hydropower plant was 24,590 kWh and the remaining was generated by diesel power generation. In the case of aiming for 100% power generation by renewable energy, it is necessary to supply power generation equivalent to the amount of power generation generated by diesel power plants.

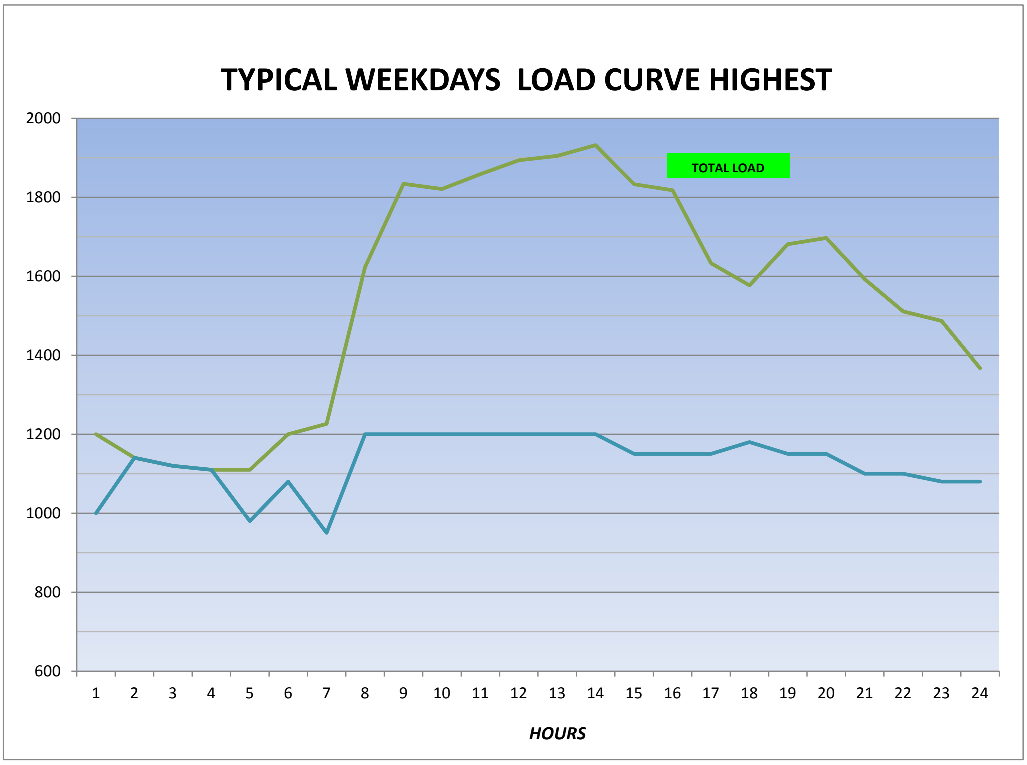


Figure 7-3-2 Peak Load Curve (01/12/2016)

Table 7-3-1 Maximum Power Generation in Santo Island（01/12/2016）

Power Generation per day	kWh
Maximum Power Generation in December	34,430
Sarakata Hydro Power Generation	24,590
Diesel Generator Power Generation	9,840

7-3-3 Comparison of New Power Development Plans and Existing Diesel Power

(1) New Hydropower Plant

As a result of study in Chapter 7.2, the power facilities is located in downstream from existing Sarakata hydro power plant and upstream from the point where rivers converge.with capacity of 800kW is the optimum development plan. Comparing this development plan and actual power generation by diesel power plants on December 1, 2016 is shown in Figure 7.3.3. The maximum power generation by the new hydropower plant set at 800 kW, and the Study Team assumed available power generation from the actual power generation of existing Sarakata hydropower on same day.

Comparison between the actual diesel power generation and the assumed power generation of the new hydropower is shown in Figure 7-3-3. The assumed power generation of the new hydropower plant exceeds the diesel power generation in all time zones. It means that there is a reserve capacity.

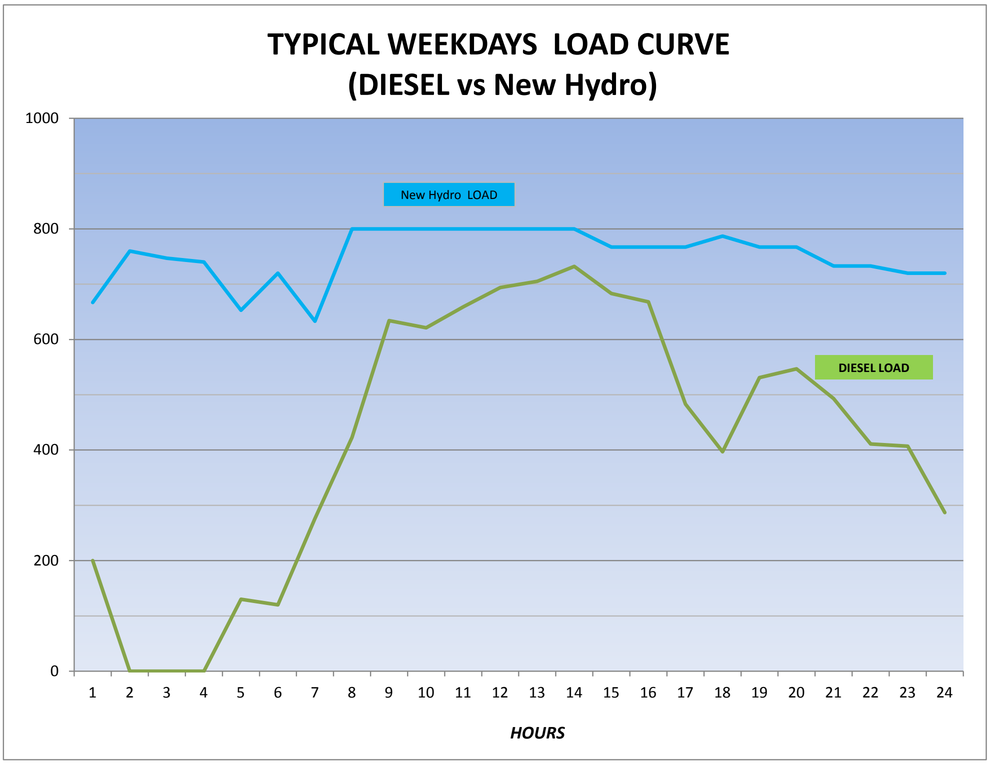


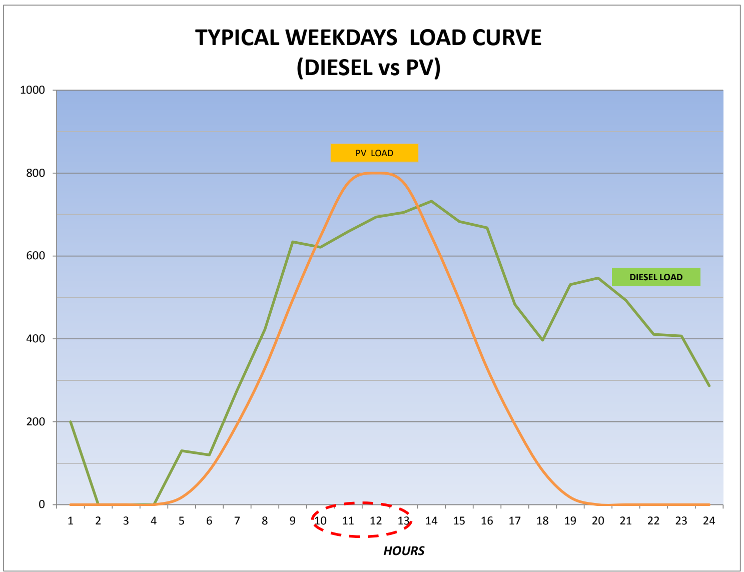
Figure 7-3-3 Load Curve of Diesel Power and New Hydropower (01/12/2016)

(2) Mega Solar

The Study Team carried out comparison between diesel power generation and mega solar with capacity of 800kW that is same scale as new hydropower generation. Weather condition for mega solar is fine weather during the whole day and assumed to generate from 5:00 in the morning to 7:00 in the evening. The output was supposed to generate maximum 800 kW at noon, and it was set as a power generation pattern that generated about 40% at 3 hours and around 60% at 5 hours mainly around noon.

Comparison between actual diesel power generation and assumed power generation of mega solar is shown in Figure 7-3-4. The power generation of mega solar exceeds the diesel power generation for 4 hours from 10 am to 2 pm, but it is lower than the diesel power generation from 5 am to 10 am in the morning and 2 pm to 7 pm in the afternoon. Since the inability to secure the necessary power generation, diesel power plants must be used together. Also, VUI has to rely on diesel power generation for 10 hours at night from 7 pm to 5 am.

It is expected that the rechargeable battery will be able to be charged during the daytime that exceeds the diesel power generation. This battery should be able to charge the surplus power generation capacity. The battery is intended to alleviate the influence on the grid system where the power generation of the mega solar suddenly changes depending on the weather.



TIME	Diesel kW	PV kW	Diesesl-PV kW
1	200	0	200
2	0	0	0
3	0	0	0
4	0	0	0
5	130	18	112
6	120	82	38
7	276	194	82
8	423	329	94
9	634	494	140
10	621	647	-26
11	659	776	-117
12	694	800	-106
13	705	776	-71
14	732	647	85
15	683	494	189
16	668	329	339
17	483	194	289
18	397	82	315
19	531	18	513
20	547	0	547
21	493	0	493
22	411	0	411
23	407	0	407
24	287	0	287
	Reserve PV power (kWh)		321

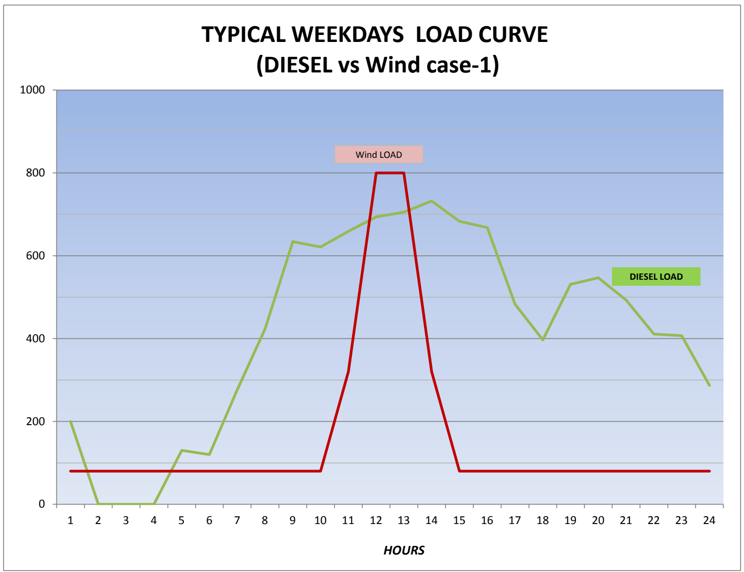
Figure 7-3-4 Load Curve of Diesel Power and Mega Solar (01/12/2016)

(3) Wind Power

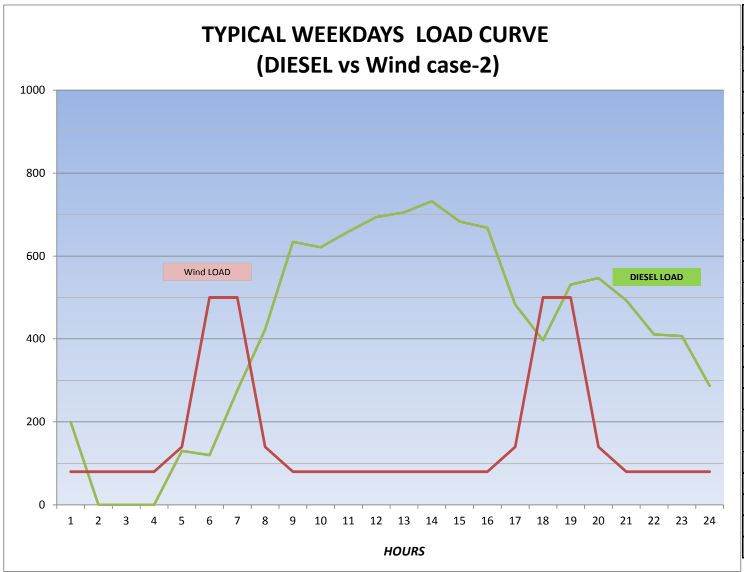
The Study Team carried out comparison between diesel power generation and wind power with capacity of 800kW that is same scale as new hydropower generation. Although it is difficult to assume wind weather conditions, we assumed the following four patterns. It is assumed that the operation ratio will be 20% in all cases. Case-1 occurs maximum output with 800 kW once in the day, Case-2 occurs strong winds blown twice a day, Case-3 occurs strong winds blown 3 times a day, and Case-4 occurs similar wind blown all day. 10% of the rated output is constantly generated as the limit value.

Comparison between actual diesel power generation and assumed power generation of wind power is shown in Figure 7-3-5. No matter which pattern is chosen, it is below the diesel power generation and it is impossible to secure the necessary output, so diesel power generation must be used together.

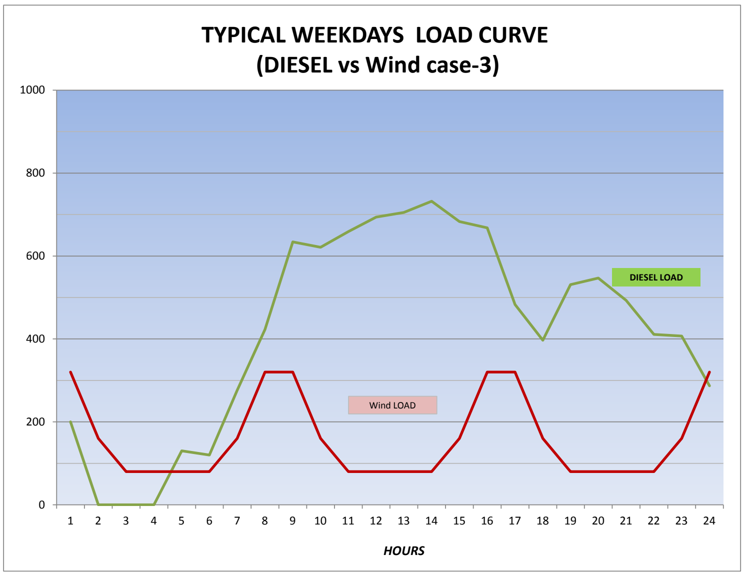
It is expected that battery charge will be possible in any case in the midnight night when the usage of diesel power plant is low. This battery should be able to charge the surplus power generation capacity. The battery is intended to alleviate the influence on the grid system where the power generation of the wind power suddenly changes depending on the weather.



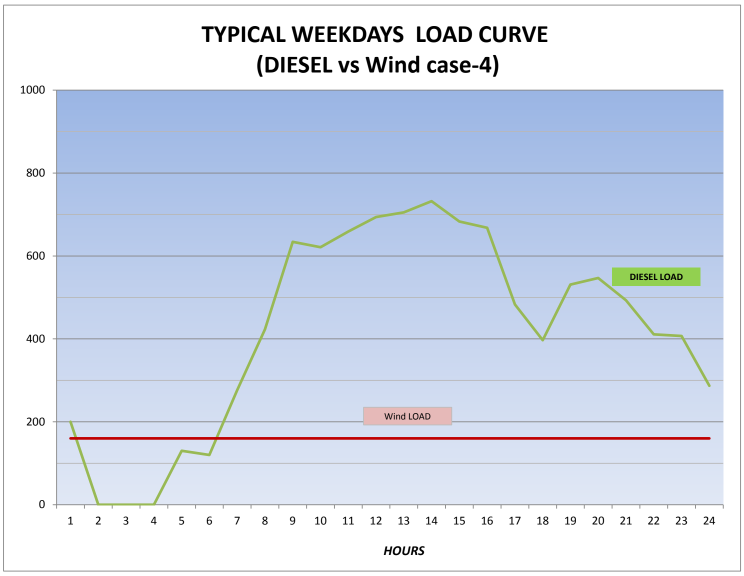
TIME	Diesel kW	Wind - 1 kW	Diesesl-Wind kW
1	200	80	120
2	0	80	-80
3	0	80	-80
4	0	80	-80
5	130	80	50
6	120	80	40
7	276	80	196
8	423	80	343
9	634	80	554
10	621	80	541
11	659	320	339
12	694	800	-106
13	705	800	-95
14	732	320	412
15	683	80	603
16	668	80	588
17	483	80	403
18	397	80	317
19	531	80	451
20	547	80	467
21	493	80	413
22	411	80	331
23	407	80	327
24	287	80	207
	Reserve PV power (kWh)		441



TIME	Diesel kW	Wind - 2 kW	Diesesl-Wind kW
1	200	80	120
2	0	80	-80
3	0	80	-80
4	0	80	-80
5	130	140	-10
6	120	500	-380
7	276	500	-224
8	423	140	283
9	634	80	554
10	621	80	541
11	659	80	579
12	694	80	614
13	705	80	625
14	732	80	652
15	683	80	603
16	668	80	588
17	483	140	343
18	397	500	-103
19	531	500	31
20	547	140	407
21	493	80	413
22	411	80	331
23	407	80	327
24	287	80	207
	Reserve PV power (kWh)		957



TIME	Diesel kW	Wind - 3 kW	Diesesl-Wind kW
1	200	320	-120
2	0	160	-160
3	0	80	-80
4	0	80	-80
5	130	80	50
6	120	80	40
7	276	160	116
8	423	320	103
9	634	320	314
10	621	160	461
11	659	80	579
12	694	80	614
13	705	80	625
14	732	80	652
15	683	160	523
16	668	320	348
17	483	320	163
18	397	160	237
19	531	80	451
20	547	80	467
21	493	80	413
22	411	80	331
23	407	160	247
24	287	320	-33
	Reserve PV power (kWh)		473



TIME	Diesel kW	Wind - 4 kW	Diesesl-Wind kW
1	200	160	40
2	0	160	-160
3	0	160	-160
4	0	160	-160
5	130	160	-30
6	120	160	-40
7	276	160	116
8	423	160	263
9	634	160	474
10	621	160	461
11	659	160	499
12	694	160	534
13	705	160	545
14	732	160	572
15	683	160	523
16	668	160	508
17	483	160	323
18	397	160	237
19	531	160	371
20	547	160	387
21	493	160	333
22	411	160	251
23	407	160	247
24	287	160	127
	Reserve PV power (kWh)		550

Figure 7-3-5 Load Curve of Diesel Power and Wind Power (01/12/2016)

(4) Bio-diesel Power Generation

The Study Team investigated biomass power generation which power is generated by biofuel on Santo Island. In Vanuatu, electricity was generated by mixing coconut oil extracted from copra with diesel fuel, and power generation was carried out in Port Olry village at Santo Island for a while. Although it is possible to reduce the cost of introducing existing diesel generators, it is important to compare with other renewable energy development by operating with biofuels are cheaper than diesel fuel.

The investigation results are shown below.;

1) Coconut Oil Price

Regarding the price of coconut oil in Vanuatu, the Study Team confirmed the hearing survey results (shown as Table 7-3-2) and the market price by World Bank (shown as Figure 7-3-6). Two partners who conducted hearings are VUI, a power company in Santo, and Mr. Wong She Shing (WSS) for individual developer in Santo. The results are shown below.

Table 7-3-2 Hearing Survey Result

Name	Coconut oil price	
	VT/mt	VT/L*
VUI	65,000	70.33
Mr. WSS	80,000	86.55

*1,000 L = 0.92427 mt

Year	Coconut oil ($/mt)	Coconut oil (VT/mt)	Coconut oil (VT/L)
2007	919	100,850	109.1
2008	1,224	134,339	145.3
2009	725	79,613	86.1
2010	1,124	123,318	133.4
2011	1,730	189,884	205.4
2012	1,111	121,918	131.9
2013	941	103,233	111.7
2014	1,280	140,474	152.0
2015	1,110	121,772	131.7
2016	1,475	161,851	175.1
Average	1,164	127,725	138.2

1USD=109.754VUV
1,000L=0.92427mt

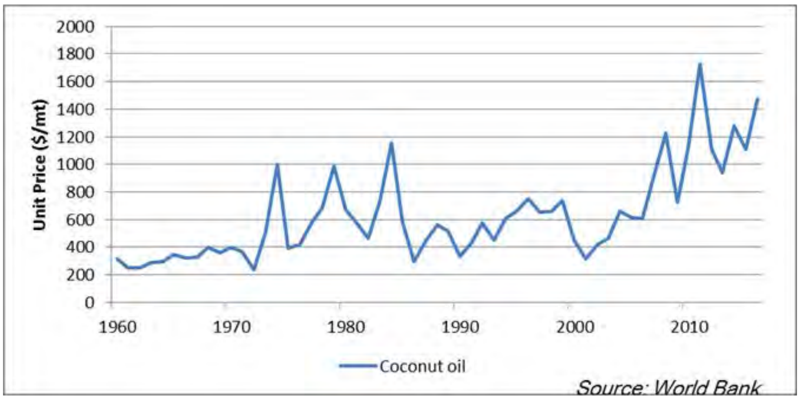


Figure 7-3-6 World Bank Market Price

2) Mixing of Coconut Oil and Diesel Fuel

For mixed fuel of coconut oil and diesel fuel in Vanuatu, UNELCO, the Electric Island electric power company, is examining the applicability in power generation. As a result of the examination, it is possible to perform mixed combustion at a high rate every year, and in the generation result of 2013, electricity generation was carried out at 39.7% ratio. According to UNELCO's submitted Vanuatu Electricity Road Map 2015-2020 (VERM 2015-2020), it is possible to generate electricity only with coconut oil (100%), and now they are working to build value chains for stable supply of coconut oil. In addition, at VERM 2015-2020, it is technically possible to cover 75% of the electricity generation on Efate Island already with electricity generated by Coconut oil.

3) Tasks

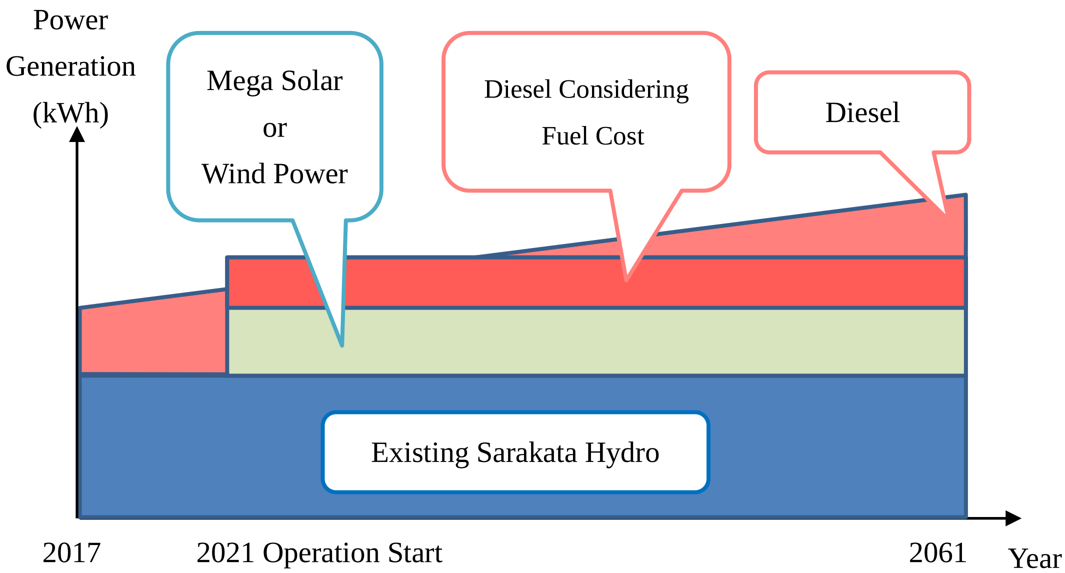
The market price of WB is higher than the hearing survey result price and it is understood that exporting to foreign country is more profitable than selling it as fuel for power generation. Therefore, assuming that the purchase price from producers is equivalent to WB's market price 138.2 VUV / Liter, it will be higher than the diesel fuel cost of 80 VUV/Liter in Vanuatu and the cost of mixing with diesel fuel will also added, the fuel cost will be more increasing. That will be expected to be more disadvantageous in terms of cost than operating diesel power generation.

7-3-4 Result of Comparison

(1) Study Conditions

Considering the durable life of the new Sarakata hydropower plant as 40 years, the project cost per kWh (power generation cost) obtained by dividing all costs (operating maintenance cost, capital cost) by the total power generation was compared with each power source.

Mega solar and wind power plant are largely influenced by weather conditions, and even if facility of the same generation scale of new Sarakata hydropower plant are installed, it is necessary to use a diesel power plant together to generate the same kWh as the new Sarakata hydropower plant. Therefore, its fuel cost is also taken into account as the power generation cost of the mega solar and wind power.



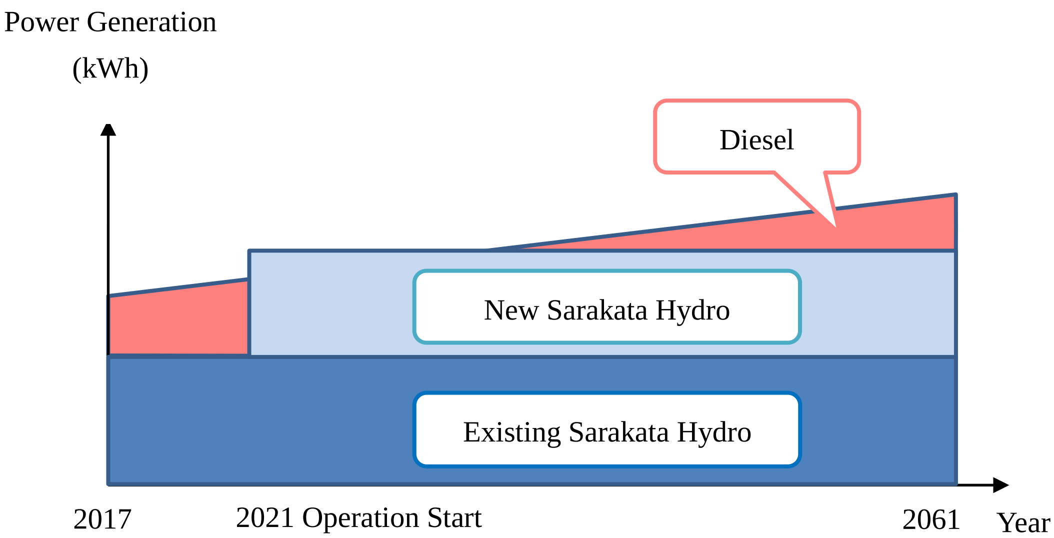


Figure 7-3-7 Annual Power Generation(2017-2061)

The period of installation of each power facility is shown in Figure 7-3-7. Since rechargeable battery is generally said to have a lifetime of 5 years, batteries are installed every 5 years. The operating years of mega solar and wind power shall be 20 years from manufacturer's compensation period and design durable life, and the same scale of facilities will be reinstalled in 20 years.

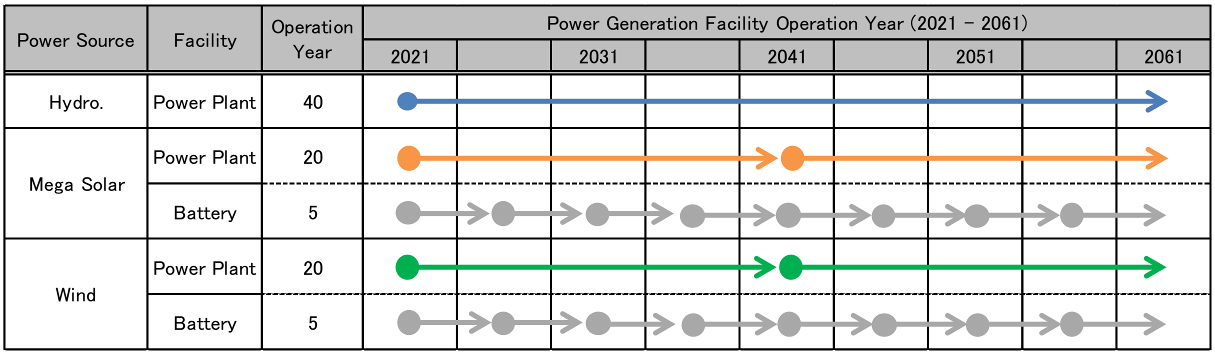


Figure 7-3-8 Period of Installation of Each Power Facility (2021-2061)

For reference, the Study Team added a case which a new diesel power station was continuously used instead of a new hydropower (800 kW) or another renewable energy power plant being constructed.

(2) Result of Comparison

The result of the study is shown in Table 7-3-3. The power generation cost of hydropower was the cheapest at 23.0 Yen, followed by mega solar of 30.1 Yen and wind power of 31.4 Yen. (Reference, Diesel Generation Cost = 30.0 Yen /kWh)

As a reason why power generation cost of mega solar and wind power increased compared with hydraulic power, the following points become problems. The operation ratio is 1/3 or less compared with the hydropower, and the amount of annual power generation is small. Diesel power is used together and fuel cost rises. The lifetime of the battery is as short as 5 years and re-installation is necessary. Since the lifetime of the facilities is half of the hydropower, re-installation is necessary considering the operation for the same period as hydropower. Since biomass power generation by coconut oil is more expensive than diesel fuel, the Study Team judged that it is not a competitive power generation system at Santo Island compared with hydraulic power at present.

Therefore, the Study Team recommends hydropower plant should be developed in Santo Island.

Table 7-3-3 Result of Comparison of Each Power Source

New Power Source			Hydro.	Solar	Wind	Biomass	Existing Diesel	Remarks
Capacity		(kW)	800	800	800	800	800	Same scale as the new Salacata Hydropower
Battery		(kWh)	0	500	900	0	0	Capacity that can be charged with the remaining electric energy amount per day
Construction Cost/kW		(10,000 Yen/kW)	320.0	29.4	30.0	13.0	0.0	From procurement price etc. calculation committee material
Battery Installation Cost/kWh		(10,000 Yen/kWh)	0.0	20.0	20.0	0.0	0.0	From Manufacturer record
Construction Cost (Initial)		(mil. Yen)	2,600	340	420	0	0	
Facility Utilization Ratio		(%)	70%	14%	20%	36%	36%	From procurement price etc. calculation committee material
Operatio Year		Year	40	20～25	20～25	30	15	Hydro.: Operation records in Japan Solar: Manufacturer warranty period Wind: Design life of IEC
Annual Generation	Each Power Source	(kWh)	5,066,522	981,120	1,401,600	5,066,522	0	
	Battery charging amount	(kWh)	0	182,500	328,500	0	0	
	Diesel	(kWh)	0	3,902,902	3,336,422	0	5,066,522	Diesel power generation necessary to generate the same amount as new hydraulic power
	Total	(kWh)	5,066,522	5,066,522	5,066,523	5,066,522	5,066,522	
Required diesel oil amount		(ℓ/Year)	0	1,120,133	957,553	0	1,454,092	1(kWh) = 0.287 (ℓ)
Diesel oil Expenses		(10,000 Yen/Year)	0.0	88.7	75.8	0.0	115.2	Diesel: 1 (ℓ) = 80 (VT), Coconut Oil: 1(ℓ)=138(VT), 1(VT) = 0.99 (Yen)
Power generation cost		(Yen/kWh)	23.0	30.1	31.4		30.0	Operation Year : 40 Years

Chapter 8 Environmental and Social Considerations

8-1 Legislation for Environmental and Social Considerations in Vanuatu

8-1-1 Legistration for Environment in Vanuatu

- Constitution of the Republic of Vanuatu 1980
- Environmental Protection and Conservation Act 2002 DEPC
- Environmental Impact Assessment Regulations 2011 DEPC
- Public Health Act 2006 Department of Public Health
- Water Resources Management Act 2002 DGMWR
- Waste Management Act 2014 DEPC
- Pollution (Control) Act 2013 DEPC
- Foreshore Development Act 2013 Department of Lands
- Wild Birds (Protection) Act 2006 Ministry of Agriculture
- Control of Nocturnal Noise Act 1988 DEPC
- Forestry Act 2006 Department of Forests

8-1-2 The Primary Legistration for Environment

(1) Constitution of the Republic of Vanuatu

Environmental management is enshrined in the 1980 Constitution of the Republic of Vanuatu.

The Constitution provides the overarching administrative and legal mandate for the protection of all Vanuatu lands and other associated environmental resources such that:

> "All land in the Republic of Vanuatu belongs to the indigenous custom owners and their descendants." (Article 73)
>
> "Every person has the following fundamental duties to himself and his descendants and to others to protect Vanuatu and to safe guard the national wealth, resources and environment in the interest of present and of future generations" (Article 7(d)) . "

The protection of land and all associated environmental resources, for future generations is therefore a fundamental responsibility for all people of Vanuatu mandated by the Vanuatu Constitution. Following on from this the sustainable use and management of land in Vanuatu is addressed within existing Vanuatu national laws and policies that supports economic development.

(2) Environmental Protection and Conservation Act

This Act is for Environmental and Conservation in Vanuatu. The defined national environmental legislation is the Environmental Management and Conservation Act No. 12 of 2002 which was amended to Environmental Protection and Conservation Act (CAP 283) in 2011 (the Act).

The Act establishes the protection of the environment within Vanuatu and makes provision for the conservation, sustainable development and management of the environment and the regulation of related activities. This includes land, air and water. Specifically the Act introduces the requirement for environmental assessment and provides for the conservation of biodiversity and the establishment of protected areas in Vanuatu.

In Vanuatu all development, other than residential buildings or custom structures, requires an environmental clearance before construction can commence. Furthermore, any development on the coast requires the written consent of the Minister for Lands through a Forshore Development Consent.

(3) Environmental Impact Assessment Regulations

The Regulations came into force in 2011 under the Environmental Protection and Conservation Act. It establishes the procedures for undertaking the environmental assessment of prescribed activities.

The Regulations contain contents of EIA Report, Public consultation, the role and the composition of EIA review committee etc.

(4) Water Resouces Management Act

The Water Resources Management Act (2002) provides for the protection, management and use of water resources in Vanuatu. The Act is administered by the Ministry of Lands and Natural Resources. The overall responsibilities for water resources management rest with the Department of Geology Mines and Water Resources (DGMWR) under the Ministry of Lands and Natural Resources.

The Act requires that if a land lease grants the right to use any water the lessee must apply to the Director of Water Resources for the right to use the water for any purpose other than the customary rights or for domestic purposes. In determining the application, the Director must be satisfied that the use of water:

- is consistent with any National Water Resouce Management Policy or Plan currently in force;
- is not likely to create a water shortage;
- is not likely create a health nuisance;
- is not likely to adversely affect other lawful users of the water resources;
- is not likely to damage the water resource or its environment;
- is compatible with other usages and works in the immediate area; and
- is consistent with the regulations (if any).

The Director must determine whether to approve the application within 30 days after receiving the application and any further information.

8-1-3 Organizations Related to the Environment

Environmental administration in Vanuatu is responsible for the Department of Environment Protection and Conservation (DEPC) within the Ministry of Land and Natural Resources.

DEPC has 5 main divisions: Biodiversity and Conservation Division, Environmental Planning and

Assessment Division, Provincial Outreach Division, Environmental Protection Division and Finance, Administration & Support Services Division. Currently DEPC have 12 Staff (include a Sanma environment and Extension officer who is manning their Santo Office). They have 8 project staff plus 2 volunteers. Two EIA officers are working under the Environmental Planning and Assessment Division.

8-1-4 National Environmental Impact Assessment (EIA) System

The developer is required to first submit a development consent application (application for environmental permit）.

Preliminary Environmental Assessment (PEA)

The developer is required to apply for Preliminary Environmental Assessment (PEA), except for projects exempted from the EIA process such as residences and traditional structures. PEA is implemented for DEPC to determine that (1) no further assessment is required, (2) no further assessment is required but an environmental management and monitoring plan is required, or (3) full EIA is required.

In determining whether an EIA is required for a project, proposal or development activity, the Director shall consider:

Whether the project, proposal or development activity is likely to cause any environmental, social or custom impact;

- the significance of any identified impact;
- whether any proposed actions are likely to effectively mitigate, minimise, reduce or eliminate any identified significant impact; and
- such other matters as the Director considers necessary or appropriate in the circumstances, or as required under this Act or prescribed by regulations.

The Director must notify the project proponent, in writing, of his or her decision on the need for an EIA within 21 business days after receiving the application, unless a longer duration is agreed with the project proponent.

Determine to Implement EIA and Preparing TOR

Once the project is determined to implement the EIA, the Director must develop a Terms of Reference (TOR) for any work that is undertaken for an EIA. The Director must refer the TOR to the project proponent for written comments. Within 30 business days after receiving any written comments from the project proponent, the Director must make such revisions as considered appropriate, and issue the final written TOR to the project proponent.

EIA Implementation

The project proponent must give a public notice about the project and invite comments from interested parties.

The project proponent must conduct public consultations on the project activity at times and places which are determined by the Director and are convenient for those likely to wish to take part. At least one of the public consultation meetings must be held in the close vicinity of the area of the proposed development. The Director may require the project proponent to conduct public consultations during the developing of the TOR and at completion of the EIA report.

Review of EIA Report

After receiving and reviewing the EIA report, the Director may, by written notice, require the project proponent to correct any deficiencies and/or provide additional information in relation to the EIA report.

The Director must, within 30 business days after receiving an EIA report and any additional information, request an EIA review committee to review the report. The EIA review committee must complete the review and make its recommendations to the Director within 30 days of the submission of the EIA report.

Decision on Application

The Director may, after receiving a recommendation from the review committee, do any of the followings (1) approve the application with or without terms and conditions, (2) refer the matter back to the EIA review committee for further assessment, or (3) reject the application.

The Director must notify the project proponent of his or her decision in writing, within 30 business days after receiving an EIA report and any additional information.

Others

- A project proponentshall bear the costs of carrying out PEA and EIA.
- The Consultant, who is registered under the Regulation, shall carry out EIA.
- It will take 21 days to carry out PEA, and 42days-3 months for EIA.

The chart below shows the flow of EIA process.

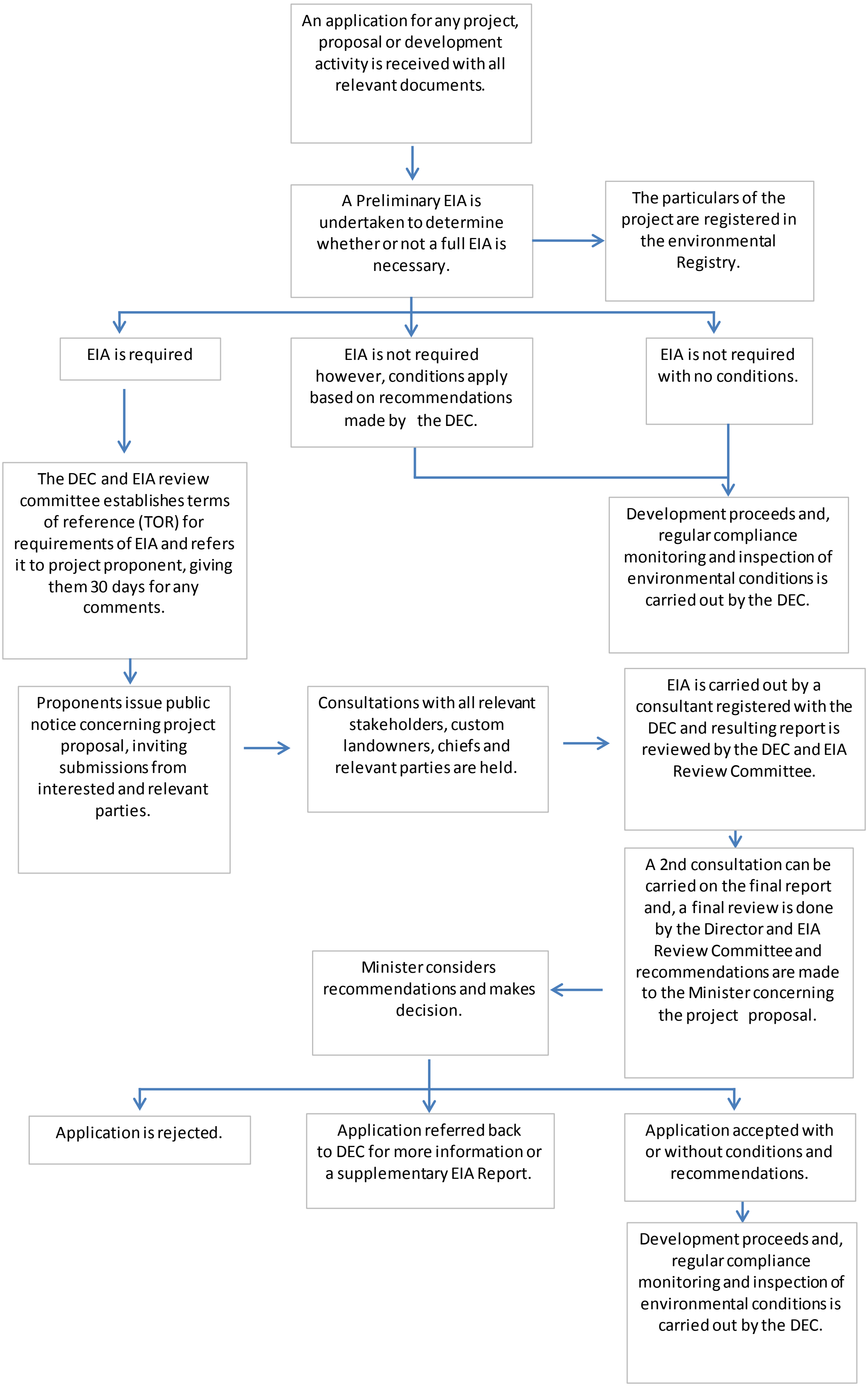


Figure 8-1-1 EIA Process

The Table below shows the comparison between JICA Guidelines for Environmental and Social Considerations and Legistration related to Environmental and Social Consideration in Vanuatu.

Table 8-1-1 Comparison JICA Guideline and Vanuatu Law

Items	Act or Regulation of Vanuatu	JICA Guidelines
Priority alternatives and mitigation measures	An EIA report on a project, proposal or development activity must identify the potential impact of the project on the surrounding environment and population, and suggest possible mitigation measures(EIA Regulations 7.(1)) An EIA report must, to the extent appropriate, include a statement of the various alternatives that have been considered for the project including energy efficiency measures, that are reasonably foreseeable and technically and economically appropriate, including the option of taking no action. (EIA Regulations8.(1))	Environmental impacts that may be caused by projects must be assessed and examined in the earliest possible planning stage. Alternatives or mitigation measures to avoid or minimize adverse impacts must be examined and incorporated into the project plan.
Compiling of EIA report	Activities that are subject to an EIA All projects, proposals or development activities that cause or are likely to cause significant environmental, social and/or custom impacts. (Environmental Conservation and Protection Act 12.(1)) If it appears that any aspect of a project, either individually or cumulatively, may cause a significant impact on the environment, these must be dealt with in the EIA report. (EIA Regulations 7.(2))	EIA reports must be produced for projects in which there is a reasonable expectation of particularly large adverse environmental impacts.

Disclosure of information and participation of affected people	An EIA must be undertaken with the fullest practicable consultation with the project proponent and other relevant interested parties. (Environmental Conservation and Protection Act 18.(4)) If a public consultation meeting is held, notice of it must be given by the project proponent in the manner directed by the Director and must inform the public of where copies of the EIA report can be obtained. (EIA Regulations 14.(3))	For projects with a potentially large environmental impact, sufficient consultations with local stakeholders, such as local residents, must be conducted via disclosure of information at an early stage, at which time alternatives for project plans may be examined.
Carrying out of monitoring program	An environmental management and monitoring plan (EMMP) for a project must be submitted with the EIA report.(EIA Regulations 9.(1))	After projects begin, project proponents etc. monitor whether any unforeseeable situations occur and whether the performance and effectiveness of mitigation measures are consistent with the assessment's prediction.

8-2 Legistration and Organizations Related to Land

8-2-1 Legistration for Land in Vanuatu

Legistration for Land related to this project in Vanuatu are shown below.

- Land Acquisition Act 2006
- Land Acquisition (Forms) Regulations 2006
- Land Leases Act 2013
- Custom Land Management Act No. 33 of 2013
- Customary Land Tribunal Act No.7 of 2001

8-2-2 Organization for Land Acquisition

In Vanuatu, Department of Lands is in charge of implementing Land Acquisition. Department of Land has 3 divisions: Land Division, Registry Division, and Survey Division. Land Division has 3 units: Lease unit, Valuation unit and Planning& Enforcement unit.

Land acquisition is carried out mainly by the Acquiring Officer belonging to the Valuation Unit, and local branch offices of the Ministry of Land and Natural Resources.Provincial government also plays the role of investigation and negotiation etc. Currently there is only one Acquiring Officer in the Department of Lands.

8-2-3 Land Acquisition Act

The Land Acquisition Act (1992) sets out procedures for exercising the government's power to acquire land in public interest. The first step is a decision by the minister that particular land is required for a "public purpose", which the Act defines as "utilization of land necessary or expedient in the public interest and includes a purpose which under any other written law is deemed to be a public purpose". It follows a sequence of steps, from initial notification and investigation to notice of intended acquisition, any appeals, inquiries for compensation, any further appeals, payment of compensation and taking of possession. The Act allows the government to acquire both customary and leased or alienated land, but in practice the government usually negotiates with landowners to avoid compulsory acquisition.

8-2-4 Land Acquisition Procedure

There are 3 kinds of land ownership in Vanuatu: "Customary Land", "Government Owned Land" and "Lease Land" are classified.The provision, which concerns the acquisition of land and easement for public purpose, is stipulated in the Land Acquisition Act (Land Acquision Act 2000).The main procedure is shown below. In general, it takes 5-6 months to acquire the land.

(1) Investigation for Selecting

When the Minister（Minister of Lands and Natural Resources）decides that the land in any particular area is likely needed for any public purpose, he may direct the acquiring officer to investigate the suitability of that Land for that public purpose. In the investigation, Acquiring Officer shall give at least thirty days notice in the prescribed form, which shall be given in the prescribed manner to the custom owners and the persons interested in the land in that area.

The notice shall be in the Bislama, English and French languages and shall state that land in the specified area in the notice is likely required for a public purpose and that all necessary acts may be done on any land in the area in order to investigate the suitability of that land for the public purpose.

After the notice is given and exhibited in any area, any officer authorized by acquiring officer may carry out the investigation. No person shall enter any dwelling house or any enclosed land, which is attached to that dwelling house, unless he has given to the occupant of that house at least seven days' written notice of his intention to do so.

(2) Compensation for Damages Done During Investigations Carried Out on any Land

Any damage to the land, caused by the investigations, is by law, liable for compensation to the existing owners. That officer shall give the custom owner or owners and the persons interested in that land written notice of the amount of compensation, which shall be assessed by him and oany such apportionment of that amount as may have been determined by him. If any person, who is entitled to receive the whole or a portion of the amount of compensation that is assessed in respect of any land mentioned above, is dissatisfied with that amount or with the apportionment of that amount, he may within thirty days of the issued date of the notice, make a written appeal to the Valuer-General against the assessment or apportionment of compensation referred to in that notice. The officer shall where no appeal is made within thirty days after the specified period or, where such appeal is made and the Valuer-General disallows the appeal, within thirty days from the date of decision of the Valuer-General, pay to each person who is entitled for compensation the amount of compensation according to the notice; or where an appeal is made and the Valuer-General allows the appeal within thirty days from the date of determination of the Valuer-General, pay to each person who is entitled for compensation the amount of compensation awarded to him according to the determination.

(3) Notice of the Intended Acquisition and Objections to such Acquisition

Where the Minister decides that a particular land is suitable for a public purpose, or that a particular easement over a particular land should be acquired for a public purpose he shall direct Acquiring officer to provide a notice in the prescribed form to be given in the prescribed manner to the custom owners and the persons interested in the land in that area. The notice shall be in three Languages describing the land or easement which is intended to be acquired. It also states that the Government intends to acquire that land or easement for a public purpose and specify that public purpose and state the written objections to the intended acquisition which may be made to Acquiring officer by the custom owners and persons interested in the land. It shall specify a period within such objections must be made, such period being not less than thirty days from the date on which such notice is given.

When the notice has been issued or exhibited in respect to any land or easement, no custom owner or person interested in that land shall, during the period of 12 months after the date of the issue or exhibition of such notice lease, dispose of that land or easement or do any act which directly or indirectly depreciates or appreciates the value of the land as at the date of such issue or exhibition.

When the time allowed for making objections to the intended acquisition of the land or easement, which was referred in the notice, has expired and any such objections have been made within such time; the Minister shall decide whether to acquire the land or the easement after consulting with Acquiring officer.

(4) Declaration that a Land or an Easement is Required for a Public Purpose

When the Minister decides under section 4 that a particular land or easement should be acquired under this Act, he shall make a written declaration that such land or easement is needed for a public purpose and will be acquired under this Act, and direct the Acquiring Officer to provide such declaration in the Bislama, English and French languages, which shall be published in the Gazette. The publication of a declaration in the Gazette shall be conclusive evidence of the fact that such declaration was duly made.

When the declaration is made, Acquiring officer shall as soon as possible give a notice in the prescribed form in the Bislama, English and French languages, which shall be given in the prescribed manner to the custom owners and the persons interested in the land or easement. The notice shall state that it is intended to acquire such land or easement, specify the public purpose for which it is intended to be acquired and claims for compensation for the acquisition of that land or easement may be made to Acquiring officer.

(5) Notification of the Amount of Compensation

Compensation is determined in consideration of market value, the value of damage sustained during investigation, the value of damage sustained by loss of any growing crops or trees, and any other reasonable expenses and the like. A determination must be in writing and a copy must be given to the customary owner and any other person interested in the land. If they are dissatisfied with a determination, they may make an appeal to the Supreme Cout within 30 days after the date on which the determination is made. If no appeal is made, the decision of Acquiring officer is final.

(6) Notification of Final Determination by Acquiring Officer

Acquiring officer shall within thirty days of the final determination of payable compensation, notify in writing to the persons who are entitled for compensation in respect of the land or easement which is acquired and the final amout of the determined compensation .

(7) Payment

A compensation payment shall be made to the custom owner or owners of the land, and any other person interested in the land, as soon as possible after the appeal period expires. After the notification and payment of compensation is made, the Minister may direct Acquiring officer or any other officer authorized by Acquiring officer to take possession of that land on behalf of the Government; or the notification related to the acquisition of any easement, declares that the acquired land shall be subjected to that easement.

The chart below shows the flow of land acquisition of Ministry of Lands and Natural Resources and Department of Lands.

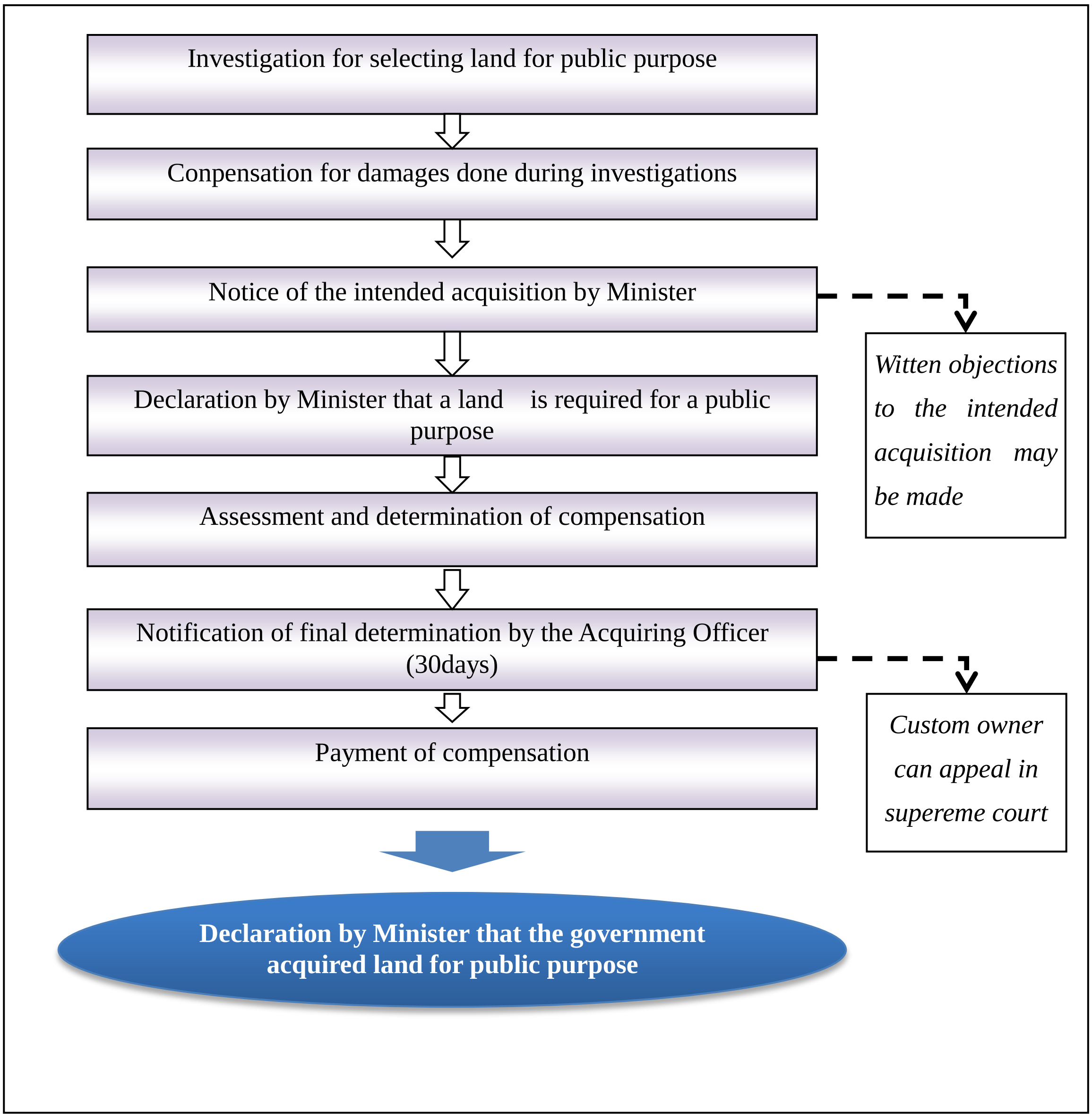


Figure 8-2-1 Flow Chart of Land Acquisition Procedure

8-3 Environment and Social Conditions around Proposed Project Area

8-3-1 Natural Conditions

(1) Vegetation

Although the following endemic species are seen in the Salakata River basin, these are not only distributed at the proposed project site and its surroundings, but they are vegetation widely distributed on Santo Island, therefore there is no specific negative impact anticipated on vegetation by the project implementation.

Family	Genus	Species	Distribution
Agavaceae	Coryline	fruiticosa	Endemic
Araliaceae	Meryta	neo-ebudicum	Endemic
Myrsinaceae	Maesa	ambrymensis	Endemic
Rubiaceae	Psychotria	aneityensis	Endemic
Araceae	Calamus	vanuatuensis	Endemic
Meliaceae	Chisocheton	rex	Endemic
Sterculiaceae	Sterculia	banksiana	Endemic
Rubiaceae	Psychotria	aneityensis	Endemic
Orchidaceae	Dendrobium	sp (butmas)	Endemic
Euphorbiaceae	Endospermum	medollusum	Native

(2) Fauna

There is no present data on terrestrial animals on Santo. The following birds (valuable species) are said to be seen around the existing hdropower plant, but they are seen in various parts of Santo island, and not protected.

- Vanuatu Kingfisher (Halcyon chloris)
- Santoa Cruz Ground Dove (Gallicolumba sanctaecrusis)
- Vanuatu Mountain Honey Eater (Phylidonyris notabilis)

Hunting is prohibited by law as the following four birds have been confirmed to decrease.

- Tanna Fruit Dove
- Silver Capped Fruit Dove
- Pacific Imperial Pigeon
- Mountain Starling（Endemic）

They are seen in various parts of Santo Island. There is no simpact anticipated by the project implementation. .

There is no present survey result data on freshwater fish on Sarakata River. Freshwater organisms commonly found in rivers of Santo live in the Salakata River. Major target caught fishes on Santo Island are Black Mullet, Spotted Bass Jungle Perch, Spotted Flagtail, etc.

8-3-2 Living Conditions

The main sources of household income for Sanma province were from the sales of agriculture, livestock, fishing and other home made products (HIES 2010). Over two quarters of household income in Sanma province were derived from household activities from subsistence farming and the sale of agricultural, livestock, forestry and fisheries product. Overall representing 43% sales of products compared to Port Vila and Luganville in which higher proportions of household income were from other sources, mostly wages and salaries accounting for over 70%.

For Rural Sanma, 64% of all households involve in coconut agricultural activities. Kava is being common grown cash crop in which 63% of all households.

According to an interview at Fanafo village, which is closest to the existing hydropower station, the village sells Kava about 100 kg / month per producer at the market in the Ruganville. The cash income is estimated to be around VUV 50,000 to 90,000.

8-3-3 Land Use Situation

It is necessary to acquire the lands, however there are no residential houses around the proposed project site. As a result, no residential resettlement is required because of the project. Also, the riverbank at the proposed project site is an original forest and there is no use of agriculture. The use of rivers is only for recreation such as swimming. Since it seems that there are households using river water for washing, downstream of the site, when it is expected that the water of the river will become soiled during the construction period, it is necessary to give some notice. There is no use of river water for drinking, so there would be limited impacts.

The proposed site is located two hours walk down from the existing hydro site. The land is sloppy and the undergrowth, which is filled with primary virgin forest on the eastern side of the river. The site currently leased by PRV（Plantations Reunies de Vanuatu）, but the actual identifed site is located at the junction of the two rivers, Sarakata River and Napauk River. The western bank of Saraka River is customaly land.

There are no public roads to access to the site. It will be necessary to create an access road through PRV plantation or through the western side of river owned by a custom owner.

This survey revealed that four groups of land owners would be claiming ownership for the around the proposed site.However, since the ownership of customary land has not been registered, the actual total number of owners is unknown. The Department of Lands and the Customary Land Management Office would identify the ownership.

8-3-4 Stake Holder

The major stakeholders and role of each agency related to the energy sector and development of new hydropower station are shown below.

Table 8-3-1 The Major Stakeholders and Role of each Agency Related to the Energy Sector

Stake Holder	Fanctions & Roles
Ministry of Climate Change & Natural Disaster	Develop Sector Policies, Provide Leadership for implementation of Government Policies Administer
Department of Environment Protection and Conservation	Protect, and preserve Environment from degradation Approve EIA reports Advise Government on Environmental risks.
Luganville municipal Council	Facilitate national projects and programs
Sanma Province	Provide local policies and identify development programs for the province Supports National Programs
Customary land management office	Manage customary land disputes and identify and register customary land owner Convene meetings for the chiefs to resolve Land ownership for private Lease or public interests
Ministry of Lands and Natural Resoueces, department of Lands	Approved and Register Leases Land acquisition for public purposes and compensation
VUI＆UNELCO	Power company
Private sector in Santo	Power consumer
People of Sanma Province	
Custom owners	Land owner of the project candidate site

8-4 Preliminaly Draft Scoping

There is a plan to construct a hydro power plant in this project. It is difficult to identify the environmental and social impacts because the site is not specified at this stage. Therefore, according to the items of the JICA guidelines (April 2010), the table below summarizes the potential environmental impacts.

Table 8-4-1 Preliminaly Draft Scoping

No.	Impact	Rating		Rating reason
		Pre- / construction Phase	Operation Phase	
Pollution Control				
1	Air Quality	B-	D	**Construction phase:** Dust will be generated in the land preparation and other construction work, but the impact will be temporary and will be limited to the surrounding area. **Operation phase:** Dust will not be generated by the operation of the power plant.
2	Water Quality	B-	D	**Construction phase:** Water turbidity will be caused by the excavation work, but the impact will be temporary. **Operation phase:** Water turbidity will not be caused by the operation of the power plant.
3	Soil Quality	D	D	It is not supposed to use with chemical that cause soil contamination.
4	Waste	B-	D	**Construction phase**: General (Domestic), construction waste soil、scrap material will be generated **Operation phase**: General (domestic) waste, Industrial and hazardous wastes would not be generated.
5	Noise and Vibration	B-	D	**Construction phase**: Noise and vibration could be caused by the operation of heavy machinery and trucks, but will be limited to the surrounding area. **Operation phase:** Noise and vibration will not be caused by the operation of the power plant
6	Subsidence	C	C	The impact is unknown
7	Odor	B-	C	**Construction phase:** Bad odors from rotten waste may occur in the case that domestic waste from the workers is not appropriately treated. **Operation phase:** Bad odors from rotten waste may occur in the case that domestic waste from the workers is not appropriately treated, but this would be very local.
8	Sediment	C	C	The impact is unknown.
Natural Environment				
9	Protected Areas	D	D	Protected area is designated far from the potential area

No.	Impact	Rating		Rating reason
		Pre- / construction Phase	Operation Phase	
10	Ecosystem	C	C	Any particular impact is not predicted; however, it will be confirmed further survey.
11	Topography and Geology	C	C	The impact is unknown
12	Water Usage	B-	C	**Construction phase**: there are households that use river water for washing, downstream of the site. Water turbidity will be caused by the construction work, but the impact will be temporary. **Operation phase:** Any particular impact is not predicted; however, it will be confirmed further survey.
Social Environment				
13	Land acquisition and Resettlement	D	D	It is necessary to acquire land at the potential site, however, since there are no local people living in the site, residential resettlement is not predicted
14	Local Economy such as Losses of Employment and Livelihood Means	B+	B+	**Construction phase ・ Operation phase :** Employment of local residents will be expected.
15	Land Use and Utilization of Local Resources	C	C	The impact is unknown.
16	Social Institutions such as Social Infrastructure and Local Decision-making Institutions	D	D	There is no specific negative impact anticipated.
17	Existing Social Infrastructure and Services	B-	B+	**Construction phase:** Increase of traffic volume is anticipated during the construction period. **Operation phase:** Positive impact is expected because develop access roads for the construction work, and electrification of a village in the suburbs can benefit local people.
18	Ethnic Minority Groups, Poor People and Indigenous People	C	C	The impact is unknown.
19	Misdistribution of Benefits and Loss	C	C	The impact is unknown.

No.	Impact	Rating		Rating reason
		Pre- / construction Phase	Operation Phase	
20	Local Conflicts of Interest	B-	B-	**Construction phase・Operation phase:** In land acquisition that occurs in construction of a power plant, disputes over ownership, boundary lines, etc. may occur in Custom land, and decision of compensation amount and payment can be prolonged until under construction or operation.
21	Gender	C	C	Any particular impact is not predicted; however, it will be confirmed further survey.
22	Children's Rights	C	C	Any particular impact is not predicted; however, it will be confirmed further survey.
23	Cultural Heritage	D	D	There is no property registered as UNESCO World Heritage in and around the potential site.
24	Infectious Diseases such as HIV/AIDS	D	D	**Construction phase・Operation phase:** The risk of infectious diseases such as HIV / AIDS will be extremely small as workers would be employed from villages around the potential site.
25	Work Environment (Including Work Safety)	B-	C-	**Construction phase**: Accidents may occur in the construction site. **Operation phase:** Any particular impact is not predicted; however, it will be confirmed further survey.
Other				
26	Accidents	B-	C	**Construction phase**: Accidents may occur in the construction site. Increase of traffic volume may cause traffic accidents **Operation phase**: Any particular impact is not predicted; however, it will be confirmed further survey.

Note: A+/-: Significant positive/negative impact is expected,
B+/-: Positive/negative impact is expected to some extent,
C+/-: Extent of positive/negative impact is unknown (further examination is needed, and the impact may be clarified as the study progresses)
D: No impact is expected.

8-5 Environmental Impact and Mitigation Measures

As the implementation of this project, this section describes the potential negative impact on the environment and the mitigation measures assumed at the present time. These mitigation measures should be reflected in future plans for power plant and facilities. Also, at the stage when the design plan becomes more specific, surveys on environmental impact assessment and social surveys will be conducted, and aim to avoid, mitigate and minimize environmental and social impacts based on the results of both surveys.

(1) Air Quality

Dust will be generated in the land preparation and other construction work, but the impact will be temporary and will be limited to the surrounding area.

Mitigation Measures: Take measures such as watering the access roads and construction site for dust suppression, especially in the dry season, using cover sheets on trucks for the transportation of soil, Suppress debris scattering by using such net, and covering sand storage place with a scattering prevention cover.

(2) Water Quality

There is water turbidity anticipated by excavation work and discharged water from concrete plant, but the impact will be temporary.

Mitigation Measures: To prevent the turbid water from directly flowing into the river, design plans to drain through sand trap.

(3) Waste

Construction waste soil, scrap material and General (Domestic) waste will be generated.

Mitigation Measures: Appropriately store and process industrial waste according to the Waste Management Act and the municipal waste management rules. Different types of waste (e.g. hazardous waste, domestic waste) will be collected and disposed of separately. Striving to reduce the amount of domestic waste generated at the plant.

(4) Noise and Vibration

Noise and vibration could be caused by the operation of heavy machinery and trucks, but will be limited to the surrounding area.

Mitigation Measures: To set a speed limit of heavy trucks to reduce noise. The construction work will be carried out in the daytime, and in principle nighttime construction will not be done.

(5) Odor

In case domestic waste and waste water from the workers' camp is not appropriately treated, bad odors from rotten waste.

Mitigation Measures: Before starting the construction work, workers will be instructed to classify and collect garbage and illegal waste disposal will be prohibited. Garbage will be disposed on a periodic basis to ensure that odor by putrefaction is not produced. Striving to reduce the amount of domestic waste generated at the plant.

(6) Water Usage

There are households that use river water for washing, downstream of the site. Water turbidity will be caused by the construction work, but the impact will be temporary.

Mitigation Measures: To prevent the turbid water from directly flowing into the river, design plans to drain through sand trap. Inform the residents who are using the water of the river in advance the construction period and the possibility that water turbity will be caused by the construction work.

(7) Exsisting Social Infrastructure and Services

Increase of traffic volume is anticipated during the construction period.

Mitigation Measures: Time control of traffic of heavy vehicles will be implemented not to disturb movement of local residents.

(8) Local Conflict of Interest

In land acquisition that occurs in construction of a power plant, disputes over ownership, boundary lines, etc. may occur in Customaly land.

Mitigation Measures: Customaly Land dispute is common in Vanuatu as it is not a registered land. A certain amount of conflict of ownership is inevitable. In the further survey, it should check past case of land dispute in Vanuatu and consider countermeasures to be taken in this project. Owners should be properly disclosed information on land acquisition according to the Land Acquisition Act.

(9) Work Environment

Workers may get involved in accidents while at work

Mitigation Measures: Occupational health and safety training will be provided, and the necessary protective equipment will be provided.

(10) Accidents

Increase of traffic volume may cause traffic accidents.

Mitigation Measures: Occupational health and safety training will be provided, and the necessary protective equipment will be provided.

8-6 Issues and Items for Future Environmental and Social Consideration

The Study Team collected the information on environmental laws and the concerned entities throughout this investigation and summarized them. The environmental and social impact about the hydropower development project would be low and limited. However, this project will be required to implement full EIA because this project site is a new site. Although the impact on ecosystem etc. is not anticipated at the present time, detailed investigation based on Vanuatu law will be required.

In the land of the existing Sarakata hydro power station, land dispute occurred that conflicts with the boundary between the customary land owners. Land acquisition by government and land dispute between the owners was a separated issue from the initial stage. However, it will be a highly sensitive issue for negotiations for land selection and acquisition in development of this project in the future. It may be important to build relationships with local chiefs and customary owners under cooperation with Department of land and local agencies.

Based on these investigation findings, the draft action items are listed below on the environmental and social consideration that Vanuatu governmental organizations should implement in the feasibility study phase. However, it should be noted that these lists are common items because the project site has yet to be determined at present.

・Conduct EIA in accordance with the Vanuatu EIA framework.
・Flora and Fauna survey by a local specialist
・Land acquisition
・Consultation with local governmental organizations and local residents
・Obtain necessary licenses（Water use right, Foreshore (liverbank)development, Building permit, Development Consent）

Following study shall be done after the reconfirmation of the role and responsibility of each organization. In addition, although the laws and regulations are developed, regarding EIA and land acquisition, the enforcement capacities of organizations are recognized to be a problem due to lack of staff members in charge. Thus, it should be considered that VPNU or Japanese government will assist Vanuatu government to implement the tasks on environmental and social consideration in order to conduct them smoothly.

Chapter 9 Overview of Undertakings by Vanuatu Side

In case of conducting a possible Japanese assistance project, Department of Energy (DOE), Ministry of Climate Change Adaption, Meteorology Environment, Energy and Disaster Management, will be the implementing agency for the project. The JICA Survey Team confirmed the undertakings by Vanuatu side, responsible organization and basic procedures relating to tax exemption or tax refund measures in financial cooperation as follows:

9-1 Undertakings by Vanuatu Side

9-1-1 Land Acquisition

The JICA Survey Team confirmed that Vanuatu side will be responsible for land acquisition for the implementation of the Project. For implementing the land acquisition, DOE will request the Department of Lands, Ministry of Lands and Natural Resources, to secure the necessary land for the Project. As mentioned in Chapter 8, land acquisition is mainly performed by the land acquiring officer in the land evaluation office of Department of Lands. Currently, there is only one land acquiring officer, who can carry out land acquisition procedures. In some of the loan projects in Vanuatu, the Vanuatu Project Management Unit (VPMU) is assisting the land acquiring officer to support land acquisition procedures. It is, therefore, recommended that VPMU will be involved in the Project for the smooth land acquisition according to the situation.

9-1-2 Access Road

When the Sarakata 1 hydropower project as a Japanese grant aid project was carried out for the period from 1993 to 1994, the Government of Vanuatu bore the construction cost for the access road to the intake weir of the Sarakata hydropower plant.

The JICA Survey Team asked DOE for a view on whether Vanuatu side would be responsible for all the access road for the Project. Basically, there was a positive response from Vanuatu side, but they were not able to make a commitment at present to bear the access road costs because there is a possibility that it would be difficult for Vanuatu side to bear the full amount depending on the amount of its construction cost.

9-1-3 Licenses and Permissions for the Project

The JICA Survey Team confirmed that Vanuatu side will be responsible for acquisition of licenses and permissions that are necessary for the Project, such as environmental impact assessment.

9-2 Tax Exemption or Tax Refund

DOE will be responsible for arrangement of tax exemption in the case that a Japanese grant aid project for the energy sector is implemented. The DOE has experienced some tax exemption procedures within the Vanuatu government for several grant aid projects. Tax exemption can be applied by issuing a tax exemption certificate to the contractor of the Project implementation.

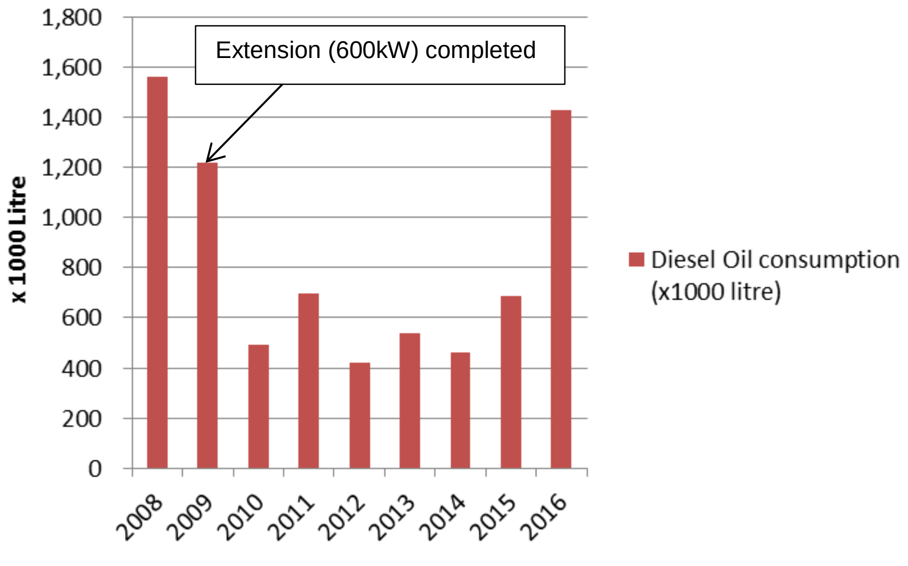
Chapter 10 Effects of Potential Projects

This chapter summarizes the effects expected by the implementation of the hydropower plant project that was evaluated as the optimal possible potential project in Chapter 7. The main features of the hydropower project evaluated as the optimum plan are shown below.

- Installed Capacity : 800 kW
- Annual Possible Power Generation: 5,066,522 kWh
- Roughly Estimated Project Cost : JPY 2,591.3 Million
- Intake Point : around 1 km downstream of the existing Sarakata Hydropower Plant

10-1 Reduction of Diesel Fuel

Up to around 1995, electricity in the Luganville concession area was mainly generated by diesel generators using imported diesel fuel, constituting a heavy burden on Vanuatu's national economy. Under these circumstances, the Government of Vanuatu made a request to the Government of Japan for the implementation of a project to build the Sarakata River Hydroelectric Power Plant to supply electricity to Luganville to reduce the diesel fuel consumption. In response to this request, the Government of Japan implemented the "Project to Construct the Sarakata River Hydroelectric Power Plant on Santo Island" in 1994 and 1995 as a grant aid project, and the hydropower plant with two 300 kW turbine generators (combined installed capacity of 600 kW) started operation to supply electricity to the Luganville concession area. After the hydropower project implemented in 1994 and 1995, in 2009 also, the installed capacity of the Sarakata Hydropower Plant was increased by 600 kW by a Japanese grant aid project. These increases of hydropower generating capacity in the Luganville concession area had contributed to drastic reduction of diesel fuel consumption. However, since the actual electricity demand in the concession area has been steadily rising around 4% annually on average in recent years and it is assumed that it will continue to increase at the same pace in the future, there is a concern that the share of diesel power generation will increase again to meet increasing demand, and consequently the usage of diesel fuel will increase again. Figure 10-1-1 shows the changes of recent diesel fuel consumption in the Luganville concession.



(Source : The JICA Survey Team prepared based on the data provided by URA)

Figure 10-1-1 Changes of Diesel Fuel Consumption in Luganville Concession

The above-mentioned new hydropower plant is expected to reduce the annual amount of diesel fuel consumption by about 1,400 kiloliter in quantity and about VUV 114 million (about 117 million yen in Japanese yen[1]). The annual power generation amount of each power source from 2017 to 2030 and the portion of electricity generated by renewable energy, for two cases of "with new hydropower" (assumed that new hydropower operation will start in 2021) and "without new hydropower", were calculated as shown in Table 10-1-1 and Figure 10-1-2.

Table 10-1-1 Portion of Electricity Generated from Renewable Energy up to 2030 (with/without new hydro)

Year	Forecasted Annual Energy Generation (MWh)	Existing Hydro (MWh)	New Hydro (MWh)	Solar (MWh)	without New Hydro				with New Hydro				Saving Diesel Fuel	
					Diesel	Diesel fuel	Generating electricity from renewable energy sources		Diesel	Diesel fuel	Generating electricity from renewable energy sources		amount*	Cost**
					(MWh)	(KL)	(MWh)	(%)	(MWh)	(KL)	(MWh)	(%)	kiloliters	mil.VUV
2017	10,450	7,684	0	56	2,711	762	7,739	74%	2,711	762	7,739	74%		
2018	10,914	7,684	0	56	3,175	892	7,739	71%	3,175	892	7,739	71%		
2019	11,399	7,684	0	56	3,659	1,028	7,739	68%	3,659	1,028	7,739	68%		
2020	11,905	7,684	0	56	4,165	1,170	7,739	65%	4,165	1,170	7,739	65%		
2021	12,433	7,684	5,066	56	4,694	1,319	7,739	62%	0	0	12,805	100%		
2022	12,985	7,684	5,066	56	5,246	1,474	7,739	60%	180	51	12,805	99%	1,424	114
2023	13,562	7,684	5,066	56	5,822	1,636	7,739	57%	756	213	12,805	94%	1,424	114
2024	14,164	7,684	5,066	56	6,424	1,805	7,739	55%	1,358	382	12,805	90%	1,424	114
2025	14,793	7,684	5,066	56	7,053	1,982	7,739	52%	1,987	558	12,805	87%	1,424	114
2026	15,450	7,684	5,066	56	7,710	2,167	7,739	50%	2,644	743	12,805	83%	1,424	114
2027	16,136	7,684	5,066	56	8,396	2,359	7,739	48%	3,330	936	12,805	79%	1,424	114
2028	16,852	7,684	5,066	56	9,113	2,561	7,739	46%	4,047	1,137	12,805	76%	1,424	114
2029	17,600	7,684	5,066	56	9,861	2,771	7,739	44%	4,795	1,347	12,805	73%	1,424	114
2030	18,382	7,684	5,066	56	10,642	2,990	7,739	42%	5,576	1,567	12,805	70%	1,424	114

* Fuel Consumption Ratio: 0.281 litters/kWh

** Fuel Price = 80VUV/litter

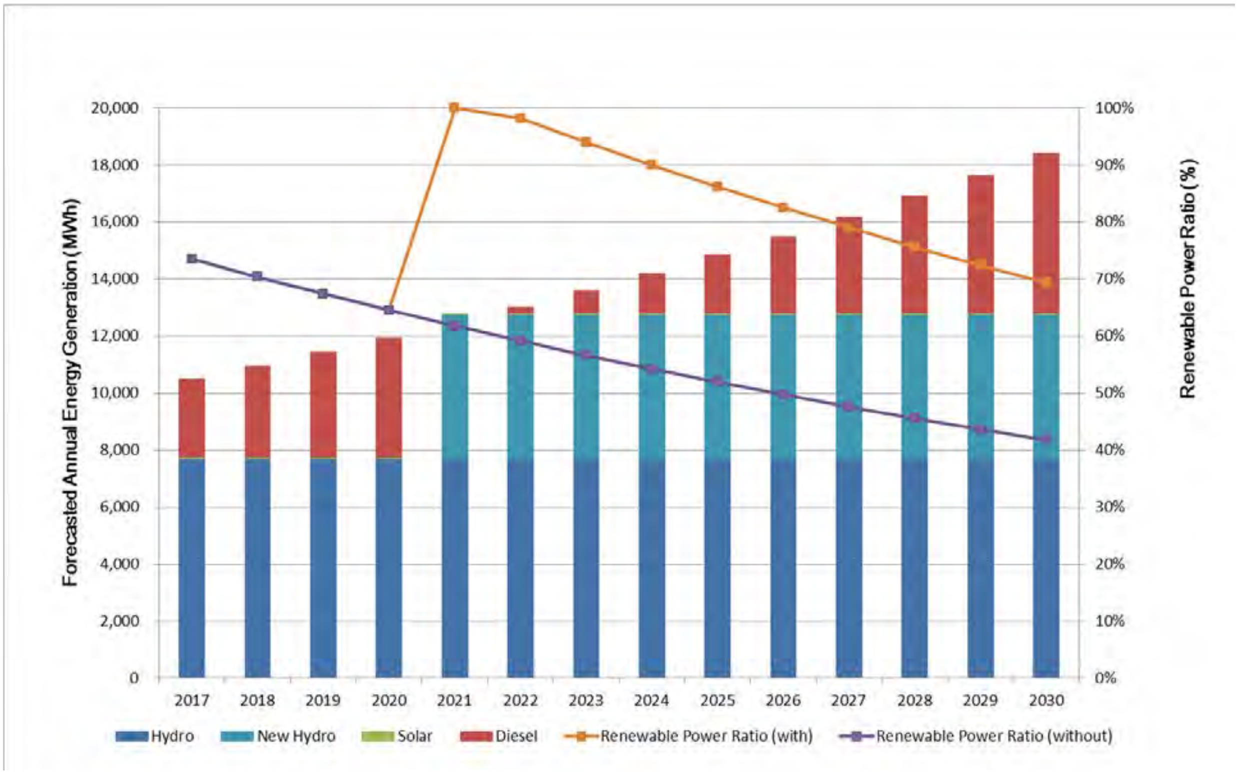


Figure 10-1-2 Portion of Electricity Generated from Renewable Energy up to 2030 (with/without new hydro)

The energy of Vanuatu is heavily dependent on expensive imported fuel, which is a heavy burden on

[1] Exchange rate VUV 1 = JPY 1.03

the national economy. As mentioned above, the hydropower plant project as the possible potential project is expected to greatly contribute to the reduction of reliance on imported fossil fuels which is the basic policy of the Government of Vanuatu.

10-2 Affordable Electricity Services

As mentioned in the previous Section 10-1, the fuel cost can be reduced by VUV 114 million annually (about 117 million yen in the Japanese yen) by introducing a new hydropower plant. This amount is VUV 6 to 8 / kWh in terms of an amount per all the generated electricity (kWh) in the area. There is a possibility of reducing the electricity tariffs equivalent to the same amount, contributing to a reduction in electricity tariffs that are currently higher than that in other Pacific countries. This means that the project is expected to contribute to “ensuring affordable electricity services”, which is one of the major objectives of the NERM.

10-3 Increasing Renewable Energy

The Government of Vanuatu has set the goal of "increasing the share of renewable energy" as a national goal, and sets a target of introducing renewable energy as high as 100% in 2030. As stated in the previous Section 10-1, if a new renewable energy power supply is not introduced to the Luganville concession area, the share of electricity generated by renewable energy will be reduced to 42% in 2030, but introducing of a new hydropower generation as a possible project will enable to improve the share of electricity generated by renewable energy up to 70%. The introduction of a new hydropower plant is recognized to be greatly in line with the objective of the energy policy of Vanuatu.

10-4 Improving Electricity Access

Compared to the surrounding Pacific countries, the electrification ratio of Vanuatu is extremely low with 30% due to geographical conditions. However, the NERM has set the goals that 100% households in and around concession areas will be connected to the grids in 2030, and also 100% households in off good areas that are far from the grids will also be able to have electricity access in 2030. Currently, the Santo Fund, which consists of collecting contributions of 1 VUV/kWh at the electricity tariffs in the Luganville concession area, has been established to function as a source of the grid extension and rural electrification projects in off-grid areas. Since the new hydropower project will make it possible to reduce the power generation cost by introducing a new hydropower plant with an inexpensive generating cost, it is possible to increase the amount of the Santo Fund by increasing amount of contributions billed without raising the electricity tariffs. This increasing amount of the Santo fund will contribute greatly to the improvement of electricity access in Sand and other areas in Vanuatu.

10-5 Positive Impacts to Natural Environment

Introducing of a new hydroelectric power generation will bring about a reduction in diesel power plant operation hours, which will lead to a decrease in the air pollution, emission of carbon dioxide, and noise affecting the residents around the diesel power plant.

10-6 Urgency

As stated in the previous Section 10-1, in the case that a new hydraulic power generation is not introduced, the consumption of expensive diesel fuel will increase year by year and then it is inevitable to raise the electricity tariffs. It will be difficult to increase the reserve amount to the Santo

Fund as a source of electrification and there is a great concern that the speed of electrification will slow down. In addition, the share of electricity generated by renewable energy will also decline. These situations will go against the main goals of the energy policy determined by the Government of Vanuatu. In order to avoid such situations, introduction of a new hydroelectric power plant is considered to be very effective. Taking into consideration the fact that there is a need for some time period for conducting necessary surveys and studies prior to the implementation of the project, urgent response to the project is required.