Ministry of Public Infrastructure, Industries & Commerce (MPIIC)
Palau Public Utilities Corporation (PPUC)
The Republic of Palau

THE PROJECT
FOR
STUDY ON UPGRADING AND
MAINTENANCE IMPROVEMENT
OF
NATIONAL POWER GRID
IN THE REPUBLIC OF PALAU

FINAL REPORT

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JAPAN INTERNATIONAL COOPERATION AGENCY
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YACHIYO ENGINEERING CO., LTD.
KANSAI ELECTRIC POWER CO., INC.

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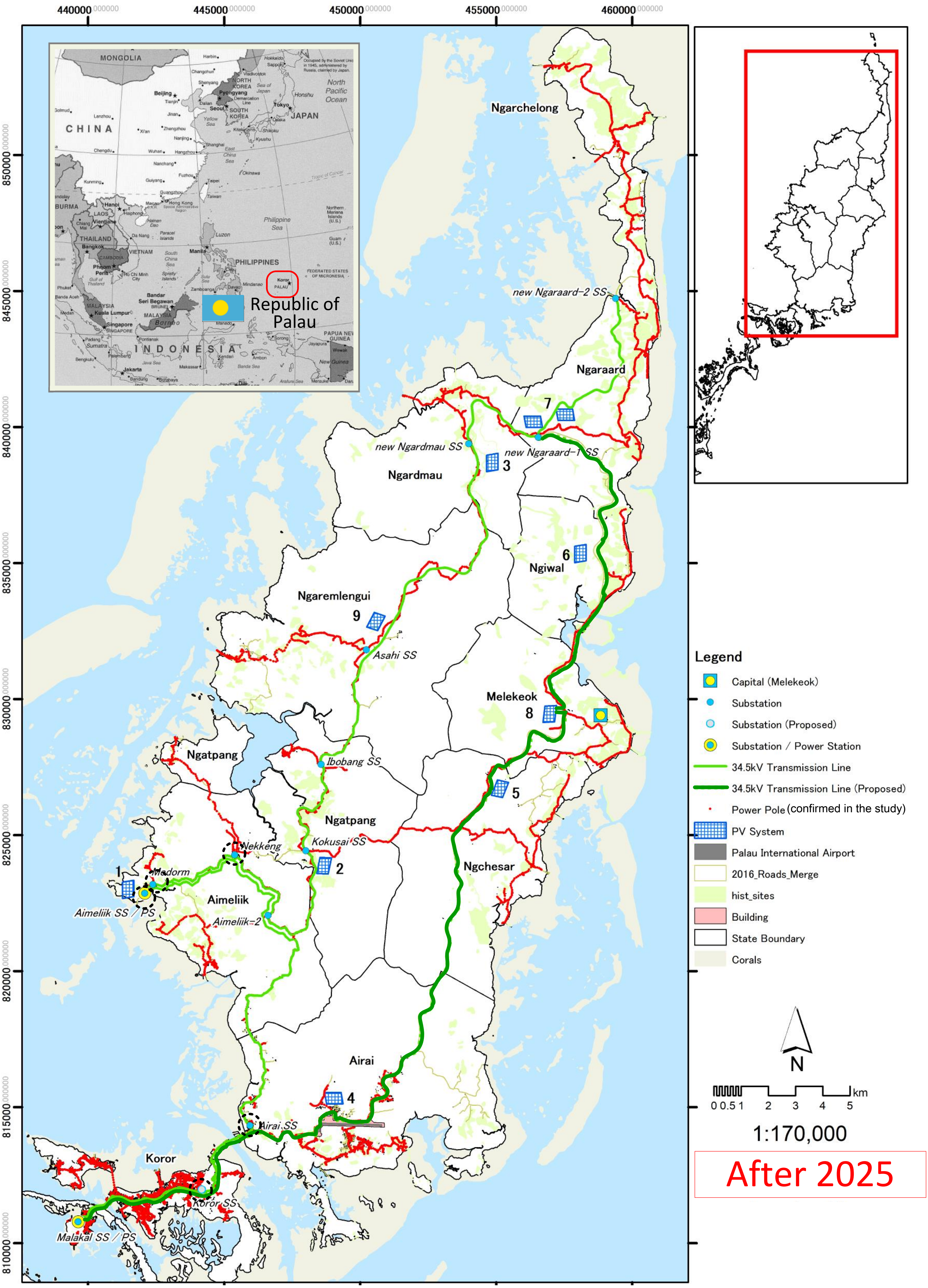
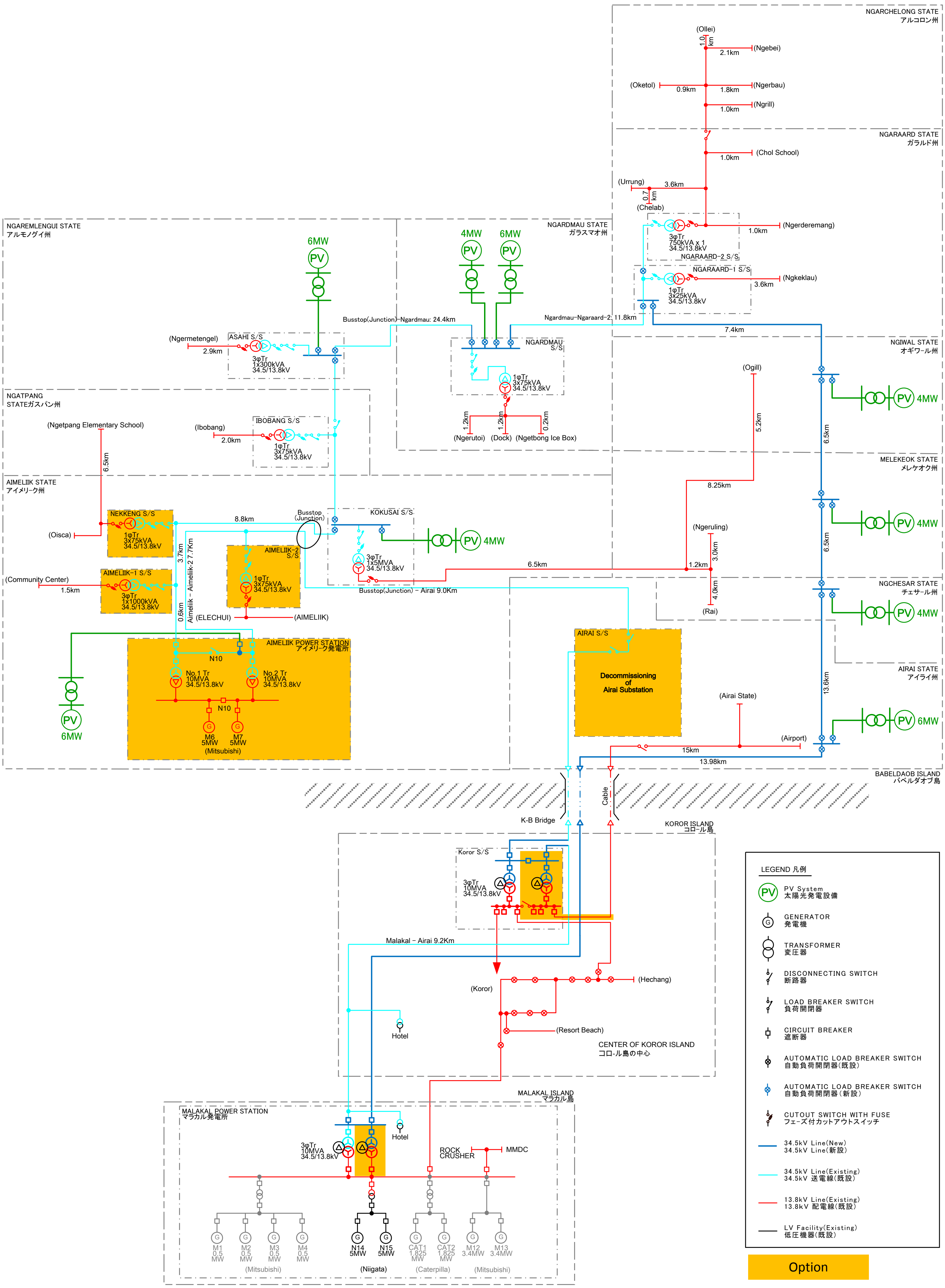


Project Location Map



Power System in Koror & Babeldaob (After 2025)
コロール・バベルダオブ電力系統(2025年以降)

Summary

Chapter 1 Introduction

1-1 Background of the Project

The Republic of Palau (hereinafter referred to as “Palau”) is located in the Pacific Ocean approximately 3,200 km south of Japan. Palau is an island country consisting of some 340 islands covering a total area of 488 km^2, with a population of 17,661 (2015 National Census). Political and economic activities in Palau are centred on Babeldaob Island, where the government capital is based (in Melekeok State), and on Koror Island, where 96% of the total population lives (2015 National Census).

The power transmission and distribution equipment of the Koror-Babeldaob power system (peak power 11~12 MW) is deteriorating and insufficiently maintained, which is leading to difficulties in the supply of stable power.

The Palau Public Utilities Corporation (PPUC) is currently planning a program of repairs and renewals for transmission and distribution equipment to improve this situation. PPUC urgently needs to build a reliable transmission and distribution network in preparation for the future expansion of renewable energy (RE) use. To these ends, the Government of Palau has requested the Government of Japan to formulate a master plan for the transmission and distribution network in consideration of the future expansion of renewable energy use, and to provide technical cooperation to help improve the reliability of the power supply and reduce transmission and distribution losses.

1-2 Outline of the Project

The main Project activities are the formulation of the transmission and distribution system plan and the technology transfer and the outline of the Project is as follows:

(1) Confirmation of current conditions in the power sector

(2) Power demand forecast

(3) Formulation of the transmission & distribution system plan and Power system analysis

(4) Economic and financial analysis

(5) Environmental and social considerations

(6) Pre-F/S (preliminary design)

(7) Technology transfer

1-3 Suggestions for alternatives

The master plan formulated in this project for the upgrading of the transmission and distribution facilities of the power system in Koror-Babeldaob is premised on the introduction of renewable energy. As a result of technical studies on factors such as the weather conditions, power demand forecasting, power system analysis, transmission and distribution facilities planning, and environmental and social considerations, the master plan proposes the construction of nine (9) PV power stations with batteries for the stabilization of the power system.

If alternative plans are proposed and put into practice at the implementation stage of the master plan, it will be necessary to newly review the renewable energy facilities for system stabilization, etc. and to conduct other technical studies on power system analysis, transmission and distribution facilities plans, environmental and social considerations, etc.

Chapter 2 Socioeconomic Conditions and Development Programs

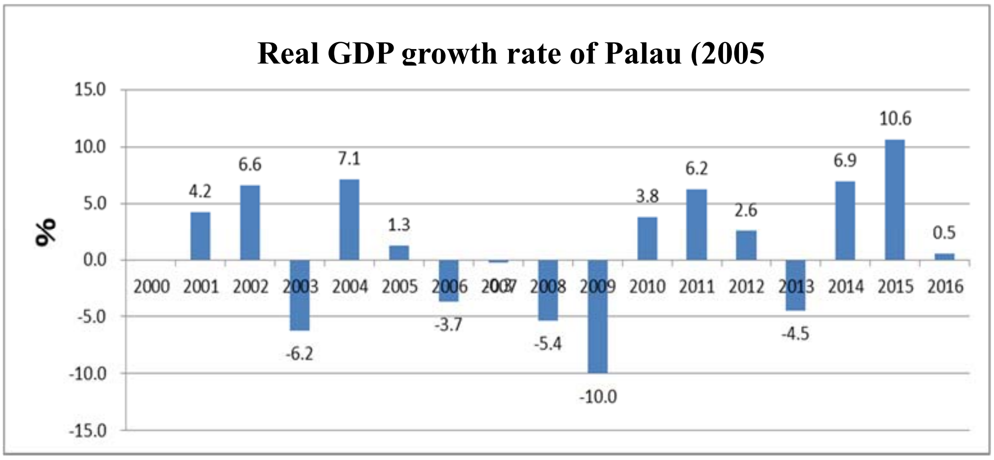
2-1 Review of Socioeconomic Development Plans in Palau

2-1-1 Population Trends (Outlook by MOF and the United Nations)

The Study Team uses MOF population estimates for the power demand forecasts and the state-wise population forecasts are based on the country population estimates. According to the MOF estimates, the number of workers in Palau will not increase from 2015 to 2030. The number of foreign workers, on the other hand, is projected to increase from 5,800 persons in 2005 to 8,200 persons in 2030. The UN Population Division also issues estimates of the future Palau population. The data are described in Chapter 2, Table 2-1-1-2.2 for reference only. The UN estimates are created based on the census data from 2005.

2-1-2 Economic Review

The real GDP growth rates are shown in Figure 2-1-2.1. The Palau economy contracted for several years in the aftermath of the global financial crisis of 2008. The economic contraction led to decreases not only in the numbers of incoming foreign travelers, but also in fund income from COMPACT projects. The Palauan economy recovered in fiscal 2011 and 2012, with GDP growth rates of 6.2% in 2011 and 2.6% in 2012. Advances in the tourism sector in fiscal 2014 and 2015 helped Palau achieve GDP growth rates of 6.9% and 10.6%, respectively, in those years.



Source: MOF

Figure 2-1-2.1 Real GDP growth rate of Palau

However, the recovery of the tourism sector from 2014 has depended on increasing numbers of incoming Chinese travelers. The occupancy rate has increased for low-price hotel rooms, while that for upscale hotel rooms has remained at the same level.

The above phenomenon has increased the social costs burdened by the Palau government. As countermeasures as of the year of 2018, the Palau government is considering the introduction of a "High Value Policy." The details of the policy are now being discussed with ADB. The trends in the numbers of tourists are shown in Table 2-1-2.2.

Table 2-1-2.2 Trends in the numbers of customers

Unit: Upper: person, Lower:%

	2010	2011	2012	2013	2014	2015	2016	2017
Number of Tourists	71,000	95,000	118,928	118,000	125,674	168,767	146,643	120,000
Hotel room occupancy rates	40%	52%	58%	50%	53%	66%	54%	

Source: Economic Review 2016

2-1-3 Impact Evaluation to Power Sector

As the results of the review of social economic development plans, the impacts to power sector are Table 2-1-3.1.

Table 2-1-3.1 Evaluation of social economic development plans

Factors	Contents
Population not increase	The population was not increased from 2000 to 2015. The population was 17,700 in 2015 and become 18,000 in 2030 according to the estimation of MOF. While, the growth rate of number of worker is 0.1 % per year from 2015 to 2030 and foreign worker is 1.4 % per year in the same period. By the above circumstances, domestic consumption in Palau may be reduced due that money transfer to foreign counties is happened by foreign workers. This is negative impact factor for Palau GDP.
Economic and industry policies	In the near future, Palau has difficulties on the shrinkage of COMPACT support, tourism tax reform, repayment of KASP and so on. At the same time, it is expected that the country promotes IT (Information Technology) sector due that undersea communication cable is established in future and enhance the investment for service sector after achieving land holding reform. However, it is difficult that Palau GDP growth rate increase more than around 2.0 % per year of Rebound Scenario in "Economic Review 2017" published by Department of Interior (DOI).
World energy prices	Around half of the imported oil products (LPG, Gasoline, Diesel and Kerosene) are used for power generation in PPUC system. It is predicted that the future world oil price does not increased so high due to the increase of substitution energies like shale oil and gas and renewable energies and promoting energy conversion and improvement efficiency of vehicles. As most of crude oil and oil products are traded by US dollar in the world, it is considered that the world oil prices are increased as much as USA inflation.
Enhancement of Renewable energy, especially, Solar power	The solar system cost drastically has been down since 2016. The bidding cost between the large scale solar power producers and power distributers are decreased drastically in 2016. The cost range is from 4 ¢/kWh to 6 ¢/kWh. The future cost will become 3 ¢/kWh up to 2025 according to IRENA. It is predicted that the solar power cost will have the strongest competitiveness among other power generators like hydropower system, fossil fired generator and nuclear power systems in 2025. At the same time, it is focused that the cost of lithium-ion battery to be used with solar system will be decreased

2-2 Review of Existing Plans on Energies in Palau

2-2-1 National Energy Policy 2010

Some countermeasures are taken under the energy policy in Palau. Following is a list of solutions in Palau's approach to Climate Change.

1) Measures to adapt the physical environment to climate change, including current and future risks.
2) Mitigation measures to reduce GHGs and cooperate with international activities
3) Implementation of the above countermeasures under long-term, least-cost conditions

As Palau imports all of its oil products, the country has selected the following policies, separately from the above policies, for reducing its import oil products.

1) Promote energy efficiency and conservation
2) Diversify energies and install renewable energies
3) Promote energy supply security and reliability

The following organizations have been instituted to achieve the above targets, and the required laws have been enacted.

1) Establish a National Energy Committee (NEC)
   The organization was established in February 2016. The NEC members are the President's Office, Senate, and Lower house, the Chamber of Commerce, PPUC, Palau Community College (PCC), and the Energy Administration.
2) Promoting Energy Efficiency and Conservation (EE&C)
   EE&C is promoted by independent activities in Palau with no official mandates.
3) Renewable energies
   The use of solar and wind power systems is important for generating electricity. In order to introduce them, it will be necessary to install volt-ampere meters and introduce a Feed In Tariff (FIT) system to connect solar and wind power to the power grid. The National Development Bank of Palau has a loan program for renewable energies to promote their introduction.
4) Power sector
   The functions required of PPUC include not only power and water supply, but also the following.
   - Sales activity for oil products, including LPG
   - Loan business to support the introduction of renewable energy in households
   - Support for decentralized generation of private entities

2-2-2 Intended Nationally Determined Contributions of Palau

The Palau government submitted a set of INDCs (Intended Nationally Determined Contributions) to UNFCCC (United Nations Framework Convention on Climate Change) at COP21 (Conference of the Parties 21: Paris Agreement). These INDCs were prepared in November 2015.

2-2-3 Palau Energy Roadmap

2-2-3-1 Outline of the Palau Energy Roadmap 2017

The Palau Energy Roadmap published in February 2017 was developed in collaboration with IRENA (International Renewable Energy Agency). The Roadmap sets out the procedures to be taken for least cost power system development with details on both Palau's existing energy policy and the NDCs (Nationally Determined Contributions) for COP21. The contents of the Energy Roadmap are as follows:

1) Wind condition survey for wind power installation into Palau
2) Solar radiation survey for solar panel installation
3) Power demand analysis and forecasts
4) Optimized power generation systems from 2020 to 2025
5) Required investments
6) Generation mix from 2020 to 2025
7) Considerations on the Roadmap

The results of the wind condition survey and the solar radiation and solar power potential are showed in Clouse 2-2-3-2 and Clouse 2-2-3-3.

Chapter 3 Current Situation of Power Demand and Supply

The sectoral power demand and supply from 2000 to 2016 are shown in Table 3.1. T/D (Transmission and Distribution) loss includes unbilled category of PPUC tariff system. It means that T/D loss is consisted of technical loss in transmission and distribution grids and social loss such as non-payers of power consumption.

Also, the evaluations of the power demand and supply activities from year 2000 to 2016 are as Table 3.2.

Table 3.1 Actual power consumption by sector

	Commercial (MWh)	Public (MWh)	Residential (MWh)	T/D loss (MWh)	Total (MWh)	T/D loss rate (%)
	A	B	C	D	E=A+B+C+D	D/E*100
2000	31,921	18,669	26,137	23,697	100,424	23.6
2001	34,043	19,545	28,287	20,337	102,212	19.9
2002	32,004	18,570	27,999	22,822	101,395	22.5
2003	33,030	20,238	29,222	19,644	102,134	19.2
2004	31,964	20,767	29,135	24,022	105,888	22.7
2005	37,656	21,686	29,862	20,720	109,924	18.8
2006	31,720	21,692	26,758	19,342	99,512	19.4
2007	32,977	22,912	26,806	19,951	102,645	19.4
2008	32,393	21,719	24,300	23,741	102,153	23.2
2009	22,567	20,651	22,432	15,502	81,152	19.1
2010	24,729	19,891	22,975	15,480	83,075	18.6
2011	24,713	20,364	21,742	14,719	81,539	18.1
2012	24,950	20,238	18,629	3,616	67,434	5.4
2013	23,042	20,998	21,042	10,325	75,407	13.7
2014	24,506	21,124	21,146	9,886	76,662	12.9
2015	24,423	19,421	23,080	14,292	81,216	17.6
2016	25,205	19,846	25,877	12,732	83,661	15.2

Source: Actual data of PPUC as of July 2017

Table 3.2 the evaluation of the power demand and supply activities

Factors	CONTENTS
Trends of Demand and Supply	Sectoral power demand of Commercial and Residential sectors from 2013 have increased. T/D loss rates (T/D loss divided by Send out) are decreased drastically after 2012. The power consumptions of the water and waste water pumps are on the way to decrease in line with the progress of their improvement programs.
WWO target of un-billing reduction	Through "Koror Airai Water Improvement Project (KAWIP) "and higher maintenance technologies acquired from "Leak detection Program", the un-billing rate is decreased from 44 % in 2013 to 20 % after the year of 2018.
Generation and Send out	By the fire of Aimeliik in 2011, PPUC power generation decreased in 2012 and 2013. However, PPUC has installed 4 tentative power generators (each 500kW) in Malakal and the generation is increased after 2014. And it is now increased to the level of Lehman shock in 2008. In future, the power generation of PPUC will be implemented in the two power stations. (Aimeliik and Malakal)
Load data	The peak load of Palau is from 8 pm to 10 pm, therefore, the battery system, Hybrid system of PV and Hydro-power, Flywheel system and so on are required when introducing PV system linked to the grid
Customer trends	The customer growth rate from 2011 to 2016 is 0.9 % per year, the growth rate almost same to the population growth rate. It is the reason that electrification of Palau is near 100 % and the fire of Aimeliik power generators in 2011.
Power tariffs	Although power tariffs of Palau links to international oil products prices, it is expected that the future the oil products prices do not increased so high. In 2008, the power tariff of Residential sector (First category) was 0.33 US$/kWh. However it is decreased to 0.17 US$/kWh due to the reduction of crude oil price.

Source: Study Team

Chapter 4 Power Demand Forecasts

4-1 Methodology of Power Demand Forecasts

The trends of the past power consumptions and the current situation should be analyzed for forecasting the future power demand of Palau, and it is required that the structural factors of the power demand forecasts should be found out. As it can be considered that the power demands are reflected by the behavior of social and economic activities, the structures of power demand model should be designed for analyzing the following functions.

1) Social economic changes should be linked to the model
2) Impact of power tariff change should be considered in the model
3) Analyzing capability of sectoral power demand should be established in the model
4) Power demand forecasting functions by state should be built in the model
5) International comparison of power demands is available in the model

The power demand model is built up in line with the previous flow (Figure 4-1.1). The following are technical procedures.

1) Regarding the future social economic activities, those are decided after discussing with counterparts on the existing social economic strategies, power development plans and policies.

2) Regarding technology of the model building, econometric method is used. And application software Simple.E" is used for model building. The software is MS-EXCEL add-in application.

The structural flow for power demand forecasting model is as the following Figure 4-1.1. "Precondition block" includes social economic strategies and plans, energy prices, power tariffs, the target indicators for power development plans and so on. "Power demand forecasting block" includes sectoral power demand forecasts, power supply forecasts and regional power demand forecasts.

Precondition Block		Power demand forecasting block
(1) Prediction of social economic indicators - Country and state population - Nominal& real GDP - Number of customer (2) Activities and Plans of consumers - Commercial & Tourism policy - New hotel and Public facility investments - Income of Residential sector (3) Prediction of energy price & power tariffs - Crude oil and oil products price - Power tariffs (4) Predictions of future energy directions - Renewable energy policy - Energy conversion plan - Energy conservation policy (5) Evaluation of demand forecasts - Evaluation of indicators for Int. comparison - Comparison of power consumption per capita - Evaluate existing power demand forecast	⇨	(1) Sectoral power energy demand forecasts - Sectoral GDP elasticity calculation - Sectoral tariff elasticity calculation - Sectoral energy efficiency rate - Sectoral forecast equation building - Sectoral power energy demands (MWh) - Transmission & distribution loss (2) Generation forecasts - Load Factor - Own use - New load - Power generation (kWh) - Peak demand (kW) (3) State wise power demand forecasts - State wise number of customers - State wise power consumption per customer - State wise new loads - State wise peak demands (4) Power demands from off grid system

Note: Selected sectors are Commercial, Public Residential and Transmission / Distribution loss

Figure 4-1.1 Block flow for power demand forecasting model

4-2 Power demand by state (MWh)

The State wise power demand (MWh) from 2016 to 2030 are Table 4-2.1 . The state demands are forecastsed by country wide sectoral power demand, state wise population, state wise customers and state wise new power deamnds

Table 4-2.1 State Power Demand of Commercial Sector(Unit: MWh)

	2016	2017	2018	2019	2020	2025	2030	2035
Aimeliik	97	99	105	110	117	134	148	162
Airai	3,570	3,642	3,878	4,124	4,387	6,808	7,687	8,661
Koror	20,716	21,016	22,246	23,525	26,493	33,495	36,439	39,594
Melekeok	438	444	471	498	527	1,487	1,974	2,059
Ngaraard	189	192	203	215	227	1,620	2,385	2,416
Ngardmau	51	52	55	58	61	70	77	85
Ngaremlengui	79	80	84	89	94	108	119	130
Ngatpang	23	23	25	26	27	31	35	38
Ngchesar	4	4	4	4	4	5	6	6
Ngarchelong	10	10	11	12	12	208	531	662
Ngiwal	28	28	30	32	34	38	42	46
Koror+Babeldaob	25,205	25,590	27,111	28,692	31,984	44,005	49,442	53,860

Note: Elasticity of existing Commercial power deamnd is 0.4 to GDP growth rate
Note: The new demand to Commercial is calculated by investment for the sector as of september 2017
Note: The total power demand of the states meets to the country wide power demand of Commercial sector.
Source: Study Team

4-3 State Peak demand (kW)

The state peak demands are calculated by the state power demand (MWh) and country wide load factor. The ressults are as Table 4-3.1.

Table 4-3.1 State Peak Demand (Unit: kW)

	2016	2017	2018	2019	2020	2021	2022	2023	2024
Aimeliik	453	459	470	481	492	505	514	524	533
Airai	2,535	2,587	2,680	2,776	2,909	3,071	3,209	3,351	3,496
Koror	7,985	8,127	8,445	8,775	9,396	9,807	10,176	10,554	10,941
Melekeok	438	445	459	472	487	503	515	668	712
Ngaraard	88	89	93	96	100	104	106	143	157
Ngardmau	37	38	39	40	41	43	44	45	46
Ngaremlengui	100	102	105	108	111	114	116	119	121
Ngatpang	61	62	64	65	67	69	70	72	73
Ngchesar	46	46	48	49	50	52	53	54	55
Ngarchelong	79	80	82	84	87	89	91	104	117
Ngiwal	49	50	52	53	54	56	57	58	60
Total	11,870	12,090	12,530	13,000	13,790	14,410	14,950	15,690	16,310

	2025	2026	2027	2028	2029	2030	2031	2032	2035
Aimeliik	543	551	559	568	570	573	576	578	586
Airiai	3,656	3,745	3,844	3,937	3,997	4,058	4,120	4,182	4,367
Koror	11,395	11,650	11,911	12,178	12,327	12,477	12,628	12,782	13,254
Melekeok	792	841	927	1,031	1,054	1,078	1,090	1,103	1,141
Ngaraard	356	373	427	445	496	510	511	513	519
Ngardmau	47	48	49	50	50	51	52	52	54
Ngaremlengui	124	126	128	131	132	133	134	135	139
Ngatpang	74	76	77	78	79	80	80	81	83
Ngchesar	56	57	58	60	60	61	61	62	64
Ngarchelong	131	145	159	173	186	198	211	224	226
Ngiwal	61	62	63	64	65	65	66	66	68
Total	17,240	17,670	18,200	18,710	19,020	19,280	19,529	19,778	20,501

Chapter 5 Power System Planning and System Analysis

5-1 Power System Planning

As shown on Table 5-1.1, the government of Palau aims to achieve RE fraction of 45% by 2025. Because the amount of generated energy in 2025 is expected to be about 115 GWh, in order to achieve the target, 52 GWh or more needs to be supplied by RE sources. Although there are many types of RE sources such as wind power generation or hydropower generation, considering the natural condition in Palau, photovoltaic power generation (PV) would be suitable RE source.

It is important to keep a balance between supply and demand in order to operate the power system stably. If this balance is lost, the frequency of the system fluctuates, in the worst case, it leads to a blackout. On the other hand, RE sources have a feature that its output depends on a weather conditions.

Therefore, when penetrating a large amount of RE sources to the power system, their output fluctuation should be absorbed by some method. At the view point of long-term, PV may produce a surplus energy in daytime. In order to raise RE fraction, it is necessary to utilize the surplus energy in night time as well as absorbing it.

On the other hand, at the view point of short-term, the output may fluctuates rapidly and widely in daytime due to the influence of the weather condition. It is necessary to absorb the short-term fluctuation, too.

Therefore, installing a battery system is one of the common countermeasure to absorb the output fluctuation caused by RE sources.

This clause describes the outline of the results on calculating the amount of PV and battery systems required to achieve RE fraction of 45% by 2025.

(1) First, from the viewpoint of long-term fluctuation, the capacities required in 2025 have been calculated by using a supply and demand balance simulation. This study divides PV system in two types. One is a rooftop PV which is major type in Palau currently. The other is PV power station with MW class capacity. Considering the status so far, it is estimated that rooftop PV with total 3 MW of panel capacity will be installed by 2025. PV power stations have share of providing the large amount of energy which cannot be supplied sufficiently by rooftop PV only.

(2) As a result, the necessary capacity of the PV power station has been calculated to be as 44 MW in panel and 22 MW in PCS and that of battery for absorbing long-term fluctuation to be 12 MW-73 MWh.

(3) Based on the above results, the capacity of the battery necessary for absorbing the short-term fluctuation has been calculated by the algebraic method. As a result, the capacity required in 2025 has been calculated to be 17.6 MW-9.4 MWh.

This study has arranged the sites of PV power station in a distributed manner in Babeldaob Island, tentatively. This arrangement might have effect to reduce a fluctuation rate of PV output. This effect is known as the smoothing effect. When the sites in a distributed manner, each output changes individually.

In other words, the fluctuation rate obtained from a resultant output might be less than that of individual one. This suggests that the arrangement in a distributed manner would contribute to reduce the capacity of battery for absorbing the short-term fluctuation. Palau has no data to verify the smoothing effect. Therefore, it is recommended to study this effect before installing the large amount of PV.

Table 5-1.1 RE roadmap

		Unit	Phase1		Phase2			Phase3	
			2019	2020	2021	2022	2023	2024	2025
Rooftop PV (Rooftop)	Panel	kW	970	1,200	1,400	1,700	2,000	2,400	3,000
	PCS	kW	810	1,000	1,170	1,420	1,670	2,000	2,500
PV system (PV station)	Panel	kW	10,000	16,000	16,000	22,000	30,000	40,000	44,000
	PCS	kW	5,000	8,000	8,000	11,000	15,000	20,000	22,000
Battery system (Against long-term fluctuation)	Battery	kWh					34,500	57,500	92,000
		kW					6,000	10,000	16,000
	PCS	kW					6,000	10,000	16,000
Battery system (Against short-term fluctuation)	Battery	kWh	2,300	3,500	3,500	4,800	6,500	8,600	9,400
		kW	4,000	6,400	6,400	8,800	12,000	16,000	17,600
	PCS	kW	4,000	6,400	6,400	8,800	12,000	16,000	17,600

5-2 Power system analysis

5-2-1 Present power system

PPUC installed power meters to measure the power flow of transmission lines only to Aimeliik Power Station, Malakal Power Station, and Airai Substation. Thus, the actual transmission line power flow and power load of every substation in the power system are not known. Before starting the power system analysis, the power load of each substation is assumed by dividing the actual power flows measured at the two power stations and Airai Substation by the transformer capacities of the substations connected to each transmission line.

As the results, the maximum power flow is 7.3 MW, on the transmission line between Aimeliik Power Station and Aimeliik 2 Substation. Since the transmission capacity is 21.5 MW, a level considered sufficient-to-large compared to the maximum flow, no possibility of overload is foreseen. Regarding the voltage status of the 34.5 kV transmission network, the highest voltage is 1.04 PU, at Aimeliik Power Station and the lowest is 1.01 PU, at Asahi Substation and the other substations. As the voltages range, the voltages are sustained appropriately from 0.95 PU to 1.05 PU throughout the power system.

5-2-2 Problems and countermeasures of the power system of Palau

Power system analysis of present power system including fault current and system stability, the first problem identified by the power system analysis on the present grid is that stable operation is not realized when the power system is separated into two systems: one is from Aimeliik Power Station and the other is from Malakal Power Station, when the existing one circuit on the 34.5 kV transmission line between these two power stations is open. In addition, since the circuit breakers are installed only at Aimeliik Power Station and Malakal Power Station, regardless of the actual locations of faults somewhere along the 28 km total length of this transmission line, all sections of this line will have to be open and the power outage will continue until power transmission is resumed after the fault is resumed.

Secondly, although the Koror area, the important area in Palau, accounts for 85% of the total power demand in this country, the aging 34.5/13.8 kV Airai Substation constructed in 1985 actually serves more than half of the power supply to this area. Finally, to enhance the power supply reliability to Melekeok area (where power is transmitted through 14 km of only one 13.8 kV feeder) and Koror International Airport (where power is supplied through one feeder) will also have to be improved.

Countermeasures against the above issues are studied based on the utilization of renewable energy.

5-2-3 Results of the power system analysis

The power system analysis was conducted for the following cases: in 2020, an intermediate year when Step 1 will have been completed, in 2023, an intermediate year when Step 2 will have been completed, and in 2025, the final target year. The peak demand each year is forecasted to take place at around 19:00, when no RE power is generated.

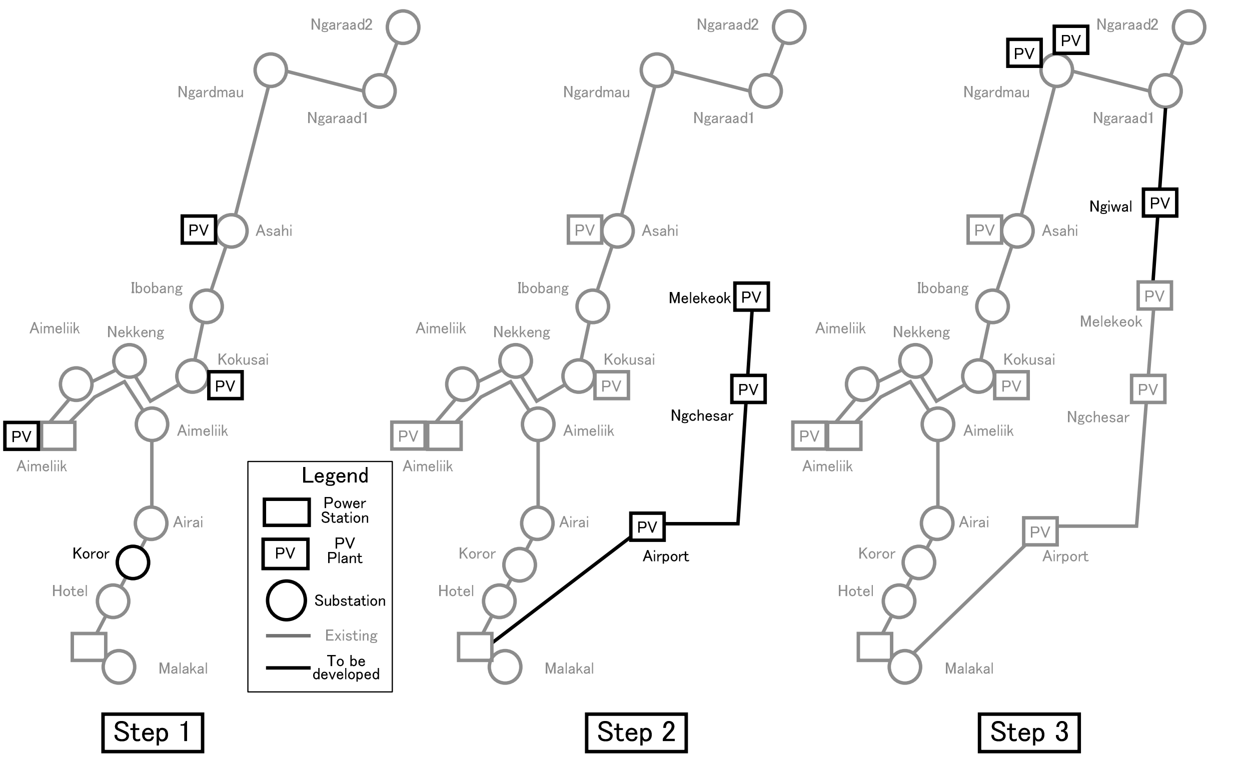


Figure 5-2-3.1 Steps to augment the power system

For the evaluation of the system stability when RE is used, the stability analysis is conducted under a daytime condition when the minimum number of units, that is, two diesel engine generators, run with 50% of output with the application of the highest load (refer to chapter 5-2-3-2), so as to assume the most severe condition. The precise times are 14:00 in August, 2020, 11:00 in August, 2023, and 11:00 in August, 2025.

5-2-4 Conclusion of Power System Analysis

The results of the analyses for the existing system, intermediate systems, and final system in 2025 demonstrate no observable problems with respect to the voltage, power flow, and fault current.

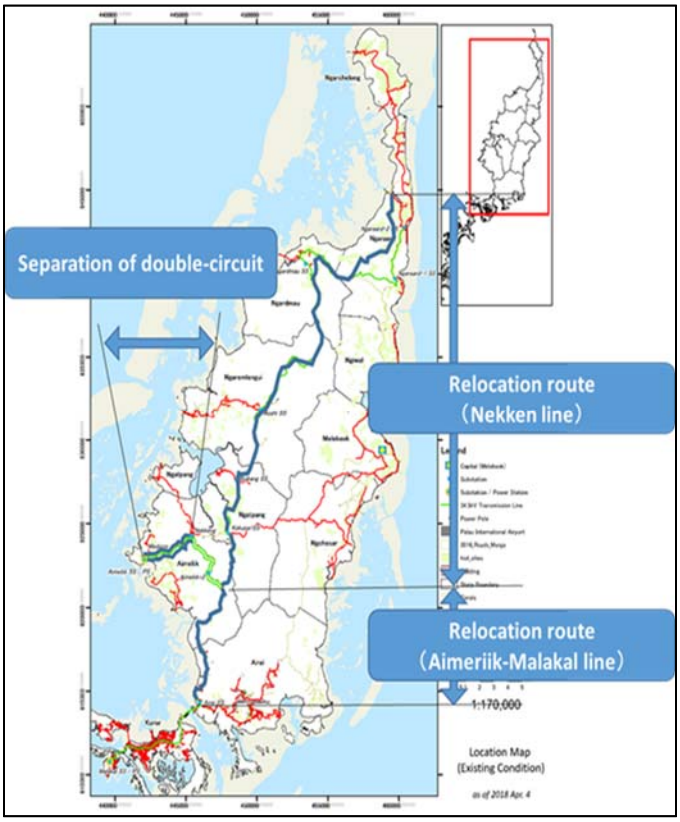
From the viewpoint of stability, the existing and intermediate systems become unstable because the existence of only one current leads to a loss of interconnection between the two power stations. In year 2025, with the completion of the loop transmission network, however, the interconnection between Aimeliik Power Station and Malakal Power Station will be maintained in the event of a transmission line fault at any location, and the system will remain stable. In addition, since most of the substations will be connected to the doubling circuits, the power supply to the substations in the Koror-Babeldaob network will be maintained even during transmission line faults, which will remarkably improve the reliability of the power supply.

We must say that the introduction of a 45% ratio of energy generated by RE under the JICA master plan is a tremendously challenging project of a type the world has never experienced. A deeper examination of the unknowns and deeper analyses from diverse views will be required.

Chapter 6 Planning of Power Transmission, Distribution and Substation

Based on the Scenario Settings of Renewable Energy Road Map, field surveys to confirm the condition of the existing facilities and results of SEA, expanding and upgrading plans, which include PV power station construction step (phase by phase) and also power supply reliability, have been formulated as shown in the Table 6.1.

Phase-1 Relocations of existing lines



Phase-2&-3 New Construction of Transmission lins

Figure 6.1 Phasing of Construction / Relocation of Transmission Lines

Table 6.1 Improvement of Transmission, Distribution and Substation Facilities (by Step)

Step	Year to be commissioned	Renewable Energy Road Map	Expanding / Upgrading of Facilities	Remarks
1	～2020	Phase1	-Relocation of 34.5kV Transmission Line -Relocation of Substation facilities -New construction of a Substation (Koror substation)	(High Urgency) Necessary for adequate maintenance and improvement of power supply reliability
2	2021～2023	Phase2	-New construction of Transmission Line	(Looping) Improvement of power supply reliability along with construction of PV system
3	2024～2025	Phase3	-New construction of Transmission Line	(Complete Looping) Improvement of power supply reliability along with construction of PV system
Recommend	～2030	－	-Replacement of Substation facilities -Decommissioning of Airai substation	(Recommendation) Simple replacement of substation equipment by reaching 40 year old of the aged equipment

Furthermore, the substation improvement and repair plan after year 2025, for coinciding with power demand increasing, deterioration of equipment, improvement of maintenance manageability, are shown in the Table 6.2.

Table 6.2 Recommended Countermeasures for Substations (for reference after 2025)

Countermeasure	Target	Content	Remark
Countermeasures against the aging substation facilities	Aimeliik substation	Simple replacement of facilites	Even though longer life period of the facilities is expected by fixing visual inspection, periodical check and adequate maintenance, it is recommended to carry out deterioration (Analysis for Gas-in-oil or insulation oil characteristic test) or transformers before reaching 40 years and determine the target facilities for replacement.
	Aimeliik-1 substation	Simple replacement of facilites	Ditto
	Nekkeng substation	Simple replacement of facilites	Ditto
	Aimeliik-2 substation	Simple replacement of facilites	Ditto
	Airai substation	Decommission	Koror substation will be able to supply power for both Koror and Airai states after switchover the load allocation from Airai substation.
Future Power Demand and Improvement of maintenance manageability	Koror substation	2-bank transformers	One of two transformers will be able to maintain while the other supply power without power interruption.
	Malakal substation	2-bank transformers	Ditto

Chapter 7 Environmental and Social Considerations

7-1 Implemented study for environmental and social impact

(1) Examination of development alternatives

1) Preliminary scoping and comparative evaluation of the environmental and social aspects of the alternatives on the PV panels, wind turbines, and storage batteries as the main components used for the introduction of renewable energy were conducted.
2) Preliminary scoping and comparative evaluation of the environmental and social aspects of the alternatives on the transmission & distribution network and substations were conducted.

(2) Consultation with stakeholders

Collecting the opinions of public and private stakeholders had, two (2) times at 2nd field survey and 4th field survey, been conducted.

(3) Reflecting stakeholders' opinions to the MP

Elaborating the MP considering stakeholders' opinions and concerns addressed in stakeholder's meetings above.

7-2 Proposed environmental and social impact mitigation measures and monitoring system

The following table shows the expected environmental and social impact avoidance/mitigation measures formulated based on the aforementioned scoping and evaluation results and on-site survey results. A development site location that avoids or mitigates environmental and social impacts and a basic design that takes stakeholders' opinions into account should be considered as thoroughly as possible at the stage of the SEA. Avoidance/mitigation measures that can be taken prior to the construction stage (shown in bold) are particularly important.

Table7-2.1 Expected environmental and social impact avoidance/mitigation measures

Item		Avoidance/mitigation measure
Environmental	Air pollution	・ Appropriate operation and management of construction activity ・ Installation of countermeasures against noise and vibration at construction sites (e.g., soundproof sheets, etc.)
	Soil pollution	
	Noise and vibration	
	Flora and fauna	・ **Careful consideration on the location of development site and basic designs to avoid/mitigate environmental and social impacts as much as possible** ・ **Examination of an optimal plan to minimize unavoidable environmental and social impacts, in consideration of stakeholder opinions** ・ Recovery of the natural environment by backfilling, afforestation, etc.
	Preserved area	
	Biodiversity	
Social	Land acquisition/ involuntary resettlement	
	Human health hazard	・ Careful consideration of occupational health conditions at construction sites
	Risk of accidents	・ Implementation of safety control measures, preparation and training for accidents (e.g., evacuation, firefighting, etc.)

Three responsible organizations are named in the proposed monitoring system, stage by stage: PPUC's Project Planning & Implementation Department in the planning stage, contractors in the construction stage, and PPUC in the operation stage. EQPB oversees these responsible organizations through the planning, construction, and operation phases. PPUC also regularly reports the status of monitoring to EQPB and shares the same among stakeholders, as necessary.

Chapter 8 Finance and Economic Analysis

The Palau Public Utility Corporation (PPUC) is a public corporation established to manage and operate the electric power operation (EPO) and water and wastewater operation (WWO) of the Republic of Palau. PPUC runs its business by a form of autonomous management approved by the government.

The PPUC Board of Directors consists of seven directors appointed by the President with advice and consent from the Senate. It is an agency under the direct control of the executive office of the President and is the only energy supply company in the Republic of Palau.

8-1 Financial analysis

Capital and capital surplus, which are capital items on the balance sheet of the PPUC electric power business, are too small to fund the large capital investments necessary for ongoing business growth in the future. The current PPUC electricity fee, which is set based on the fuel cost (Fuel) and business operation cost (Energy), falls well short of a level that would allow PPUC to accumulate sufficient retained earnings. To achieve mid- to long-term business operations without depending on government subsidies and financial support from international donor agencies, it will be important to accumulate profits necessary for capital investment through electric power sales income and to add a profit margin to that for the electricity tariff.

8-2 Economic analysis

The investment analysis of the master plan that shows the return of 10 % for FIRR and 9% for EIRR. These results shows economic feasibility of the investment for the Master Plan.

The PV generation cost is lower than the cost of the current distributed energy generation (DEG). Also, PV generation cost is steady comparing with DEG generation that rely on the fuel. Palau may be able to supply PV power to the end consumer more inexpensively versus DEG at the time of fuel shortages. It will therefore be reasonable, from a managerial point of view, for PPUC to make a full-scale entry into RE through PV as a power business operator.

(1) **IPP introduction**

With the introduction of IPPs, the possibility of achieving the Palau national goal of RE 45% becomes more feasible. The total PV investment required for this project is an easily investable amount for a large IPP operator, and the financial burden of PPUC and the Palau government is greatly reduced by the introduction of IPPs. Meanwhile, IPP introduction requires an electricity wholesale price that meets the investment return level of private enterprises. PPUC needs to investigate such pros and cons regarding an introduction of IPP.

Chapter 9 Technology Transfer

9-1 Maintenance of transmission and distribution equipment

For the technology transfer of the power transmission and distribution lines in this Project, we set up two pilot Projects ("Tree Management" and "Facility maintenance and management") to reinforce the management system for the maintenance of the facilities.

9-1-1 Tree Management

In order to reduce the power failures, the following actions were carried out on the Nekken transmission line as the tree management.

(1) **Installation of vine guards**

In order to prevent the faults caused by vine whose growth speed is faster than general trees, the JICA study team (the Team) proposed to PPUC to use the Vine Guard and also periodic patrols to the installation sites of vine guard, in order to confirm their effects and become establish periodic patrol work.

As a result of periodic patrol after installation, it is confirmed that the attached vine guards effectively prevented the vines from rolling up the utility poles and guy wires. Also, for the vine periodic patrol work, we prepared a management table of vine guard and became established a system for continuously managing at problem sites.

(2) **Installation of overcurrent indicators to detect frequent tree contact section**

The Team installed overcurrent indicators in Nekken transmission line to detect frequent faults occurring sections for accumulating data of transient faults. Through the activities of this pilot project, the following items were implemented and instructed to PPUC.

1) Subdivision of detected section by installing overcurrent indicators

Nineteen sets of overcurrent indicators were additionally installed in Nekken line to establish a frequent fault sections detection system on the lines.

2) Improvement of the system to explore the causes of faults

To identify the fault locations and causes, and link them to appropriate maintenance measures. The Team proposed conducting patrols to specify the cause, even for transient faults and established a rule for the patrol procedures.

3) Preparation of an analysis form for detection of frequent fault sections

We prepared a form of management sheet for recording the fault sections detected by the overcurrent indicators and grasping the tendency of fault occurrence by summarizing the number of faults recorded for a certain period.

9-1-2 Facility maintenance and management

The Team guided and instructed to PPUC that the way of preventive maintenance work of facility along with the PDCA cycle.

(1) **Preparation of standards related to facility maintenance work**

The facility maintenance guideline stipulating the policies and philosophies of the patrol and inspection work was prepared. Also the periodic patrol checkpoint manual was prepared

(2) **Preparation of periodic inspection report and repair status management form**

We prepared a form for reporting the results of periodic inspection and repair status management. File of this form is stored in a common server to establish a system that enables information-sharing and status management of maintenance work.

(3) **Implementation of periodic inspection and repair work**

1) Implementation of periodic inspection for preventive maintenance

SCD (System Control Division) implemented periodical patrol for transmission lines and trunk of distribution lines as one of preventive maintenance.

2) Implementation of action based on the result of periodic inspection

The report of inspection results was succeeded to PDD (Power distribution division) appropriately, and corresponding action of repair work were implemented steadily one after another.

9-1-3 Recommendations on reinforcing transmission and distribution facility maintenance

The items necessary for steady implementation of preventive maintenance work and necessary to be intensively reinforced from now on are as follows.

* Reinforce of organization and human resources, and clarify of business operations
* Multi-Skilling up of Line worker
* Establishment of standards and thorough informing
* Completion of facility management data and drawings

9-2 Maintenance of substation equipment

In PPUC, due to the aging of each substation equipment and insufficient periodic patrol and inspection, Power outages are frequently occurred by the equipment failure.

Then, the Team implemented technical transfer in substation equipment maintenance based on the periodic Inspection (patrol).

9-2-1 Contents of technical transfer for Substation Equipment

(1) **Formation of the business operation system**

In equipment maintenance, the business operation system is not formed in PPUC. So, the Team proposed PDCA cycle for implementation of maintenance works based on the inspection patrol.

Based on the PDCA cycle, the Team proposed that formulation of patrol plan from the past patrol results, accident results and so on. And also proposed the actual patrol, recording of the patrol results, and equipment repair. Then, the Team contributed the formation of business operation system.

(2) **Making the patrol checklist and record form**

In order to not be held the patrol and inspection sufficiently, PPUC cannot grasp the equipment conditions. Therefore, the aging equipment is not carried out maintenance. So, the Team formed the equipment maintenance system by making the patrol checklist and record form. Moreover, the Team implemented the technical transfer on the patrol duty, such as teaching the check point and notes.

(3) **Supplying the maintenance materials**

In PPUC, they haven’t replaced the silica gel of transformer since transformer is installed. It means that it is difficult to secure the insulation of transformer, and there are the risk to prevent the stable power supply to consumers. Then, we made sure stable power supply by supplying the new silica gel and conducted replacement works.

And, in the substation equipment such as Disconnecting Switch, rust were so much remarkable, and there are the risk to prevent the stable power supply. Then, the Team supplied the grease for maintenance.

In addition to supply the maintenance materials, the Team proposed to PPUC that they implement periodical maintenance by themselves.

(4) **Making the equipment drawing**

PPUC don’t manage the equipment drawing such as the Single Line Diagram, so they cannot grasp the latest equipment specifications. So we made and supplied the latest Single Line Diagram of each substation.

(5) **Improvement the awareness on safety**

In PPUC, the safety confirmation before working such as voltage check is not conducted. So, we explained the necessary and importance of voltage check for safety, in addition to supply the voltage checker. Moreover, we proposed to always carry the voltage checker while working such as the patrol.

9-2-2 Recommendations on substation facility maintenance

In order to contribute to stable power supply in Palau, we propose the following improvement contents in maintenance operation management of substation equipment.

- Formation the business implement system based on PDCA cycle

- Grasping and management of equipment condition by using the patrol checklist
- Implementation of equipment maintenance periodically
- Management the latest drawing of equipment such as Single Line Diagram
- Being thorough on safety top priority behavior
- Implement of technical succession in PPUC

Chapter 10 Pre–Feasibility Study

10-1 Basic Concept

Based on the transmission and distribution master plan, a pre-feasibility study for the project will be carried out after a comparative examination.

10-2 Methodology to select the priority project

The transmission & distribution lines and substation facilities that are not influenced by the introduction of grid-connected PV system, are extracted from the components of the transmission and distribution master plan, and the priority project are selected as by the following procedure.

STEP 1 : Extract components based on the results of the transmission and distribution master plan in order to determine a project package.
STEP 2 : Set up the criteria for the priority evaluation (Mavimum score is 5.0).
STEP 3 : Grading for the priority evaluation
STEP 4 : Select the target projects for the pre-feasibility study

The evaluation results are shown in Table 10-2.1. Although Project 2 was evaluated to have higher priority, both projects will be targets for the pre-feasibility study.

Table 10-2.1. Results of the evaluation of the projects for the pre-feasibility study

Priority	Project	Achievement	Com. ID	Project	Evaluation Score	Pre-FS Study	Remarks
1	2	Improvement of Power Supply Reliability	 1-3 1-4 2-1 2-2 3-1 3-1	**Construction of Koror Substation** Construction of Koror Substation 34.5/13.8kV 1 bank 10MVA Construction of 13.8kV distribution line (1 feeder) **Construction of 34.5kV Transmission Line** Construction of 34.5kV Transmission Line (Malakal – Melekeok) Expansion of 34.5kV outgoing bay at Malakal Substation Construction of 34.5kV Transmission Line (Melekeok – Ngaraard 1) Expansion of 34.5kV feeders at Ngaraard 1 Substation	4.30	Yes	Tentative rough cost estimation is approx. 16.9 million USD
2	1	Improvement of Maintenance Manageability	 1-1 1-2 1-2 1-2	**Improvement of 34.5kV Existing Transmission Line** Relocation of 34.5kV Transmission Line (Airai – Aimeliik - Ngaraard 2) Replacement of Ngardmau Substation facilities Replacement of Ngaraard 1 Substation facilities Replacement of Ngaraard 2 Substation facilities	4.10	Yes	Tentative rough cost estimation is approx. 13.0 million USD

Remarks: Evaluation Score: Low1<Average3<High5,
Concerning Priority 1, the cost related to the RE roadmap is not included in the estimation.
Source: JICA Study Team

10-3 Preliminary planning for the Priority Projects

10-3-1 Improvement of the Existing Transmission Lines (Project 1)

10-3-1-1 Improvement of the existing transmission and distribution line

The preliminary design for the improvement of the existing transmission & distribution lines (T/D lines) has been conducted to secure adequate maintenance and power supply reliability of the power system. The following construction works for T/D lines are planned.

- ◆ 34.5 kV transmission lines (Nekken transmission line and Aimeliik - Malakal transmission line)
  - * Relocation of the transmission line (sections along Compact Road)
  - * Separation to the double-circuit of the transmission line (a section between Aimeliik power station and Nekken substation)
- ◆ 13.8 kV distribution
  - * Construction of new distribution lines (Ngaraard 1 and Ngaraard 2 substation area)
  - * Diversion of the existing 34.5 kV line to a 13.8 kV line (Ngaradmau substation area)

The preliminary design and the cost estimation for the improvement of T/D lines has been outlined based on the method used for the new construction of T/D lines to be described later.

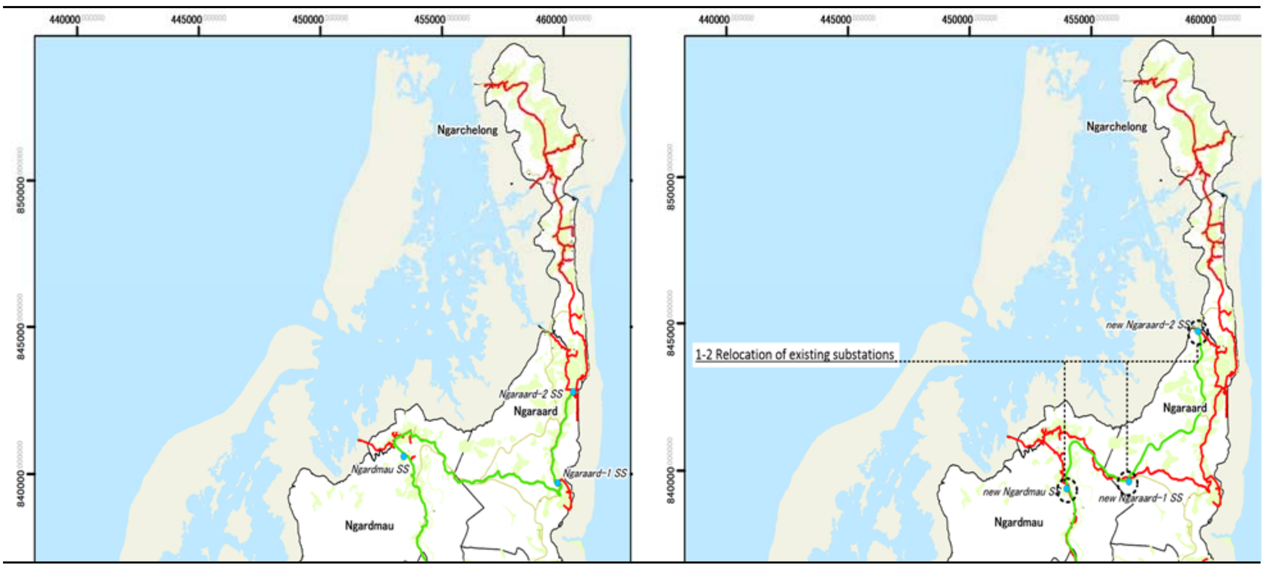
10-3-1-2 Replacement of substation facilities

(1) **Targets for substations facility to be relocated**

The following substation facilities will be relocated along the relocated T/D lines.

① Ngaradmau ② Ngaraard 1 ③ Ngaraard 2

(2) **Relocated places for three (3) substations above are shown in Figure-10-3-1-2.1.**



Before After

Figure 10-3-1-2.1 Relocation of substation facilities

10-3-2 Construction of New Transmission Lines (Project 2)

10-3-2-1 Construction of new transmission and distribution lines

The preliminary design work has been conducted for the construction of the transmission, distribution, and substation equipment necessary for building the power system based on the master plan.

(1) **The new construction of transmission and distribution lines**

The following transmission and distribution lines shall be newly constructed.
The plans for the new construction of T/D lines are as follows.

- ◆ 34.5 kV transmission line (from Malakal power station to Ngaraard1 substation)
- ◆ 13.8 kV distribution line (Koror substation feeder)

(2) **Selection of the transmission and distribution line (T/D lines) route**

The line routes for the T/D lines have been selected in consideration of the following requirements.

1) The safety and efficiency of the works necessary for construction and maintenance of the T/D lines shall be secured. (It will be easy to use the construction equipment.)
2) The lines can be easily patrolled and inspected.
3) Routes subject to any of the following conditions should be avoided, insofar as possible.
   - ◆ Roads not sufficiently maintained, as poorly maintained road conditions would imperil any trucks and linesmen that entered them.
   - ◆ Roads in mountainous or damp terrain that is difficult to pass through.
   - ◆ Places foreseen to be susceptible to high risk of equipment damage from landslides and floods.
4) Selection of the T/D lines system type (overhead or underground)
5) Finalization of the transmission and distribution line route

The following routes for the T/D lines have been selected in consideration of the above-mentioned policy.

- ◆ Line route on Babeldaob Island
- ◆ Line route around KB bridge
- ◆ Line route in Koror Island

6) 6) Measures to avoid long-term power outages during construction work
7) 7) Availability of the Construction equipment and materials (poles, wires, cables, etc.)

10-3-2-2 Construction of a new substation

(1) **Alternatives to Airai substation**

The examination of alternatives to Airai substation singled out Koror substation as a major candidate in Chapter 6. Tables 10-3-2-2.1 of Chapter 10 in the main text provides the examination results in more detail.

(2) **Candidate sites for Koror substation**

Although the possibility of private land use is clearly shown to be high, in the examination of the three proposed sites (as shown on Figure 10-3-2-2.1 of the main text) for construction of the substation in Koror, the 2nd candidate (Candidate-B) is recommendable in terms of location, with advantages such as the space of an environmental side and a lot, and connection established power lines.

10-4 Economic Analysis

The project in Palau this time will be a power transmission plan by a loop system. As a result, the FIRR economic analysis of the master plan to be applied to each listed project will have the same numerical return. Hence, it would be inappropriate to calculate the power supply benefit separately for each project. Therefore, the weightings adopted in the judgment on the economic efficiency of each product were based on the amount of money expended for the main purpose of rehabilitating the transmission system, that is, for measures focused on ease of maintenance, improved power supply reliability, etc.

The implementation of transmission and distribution projects brings about the following decreases in maintenance and inspection costs and improvements in power outages. The data on cost-cutting and the treatment of logs in relation to transmission cable maintenance were provided by PPUC.

- Period for cost estimation: FY2017 (October 2016 - September 2017)
- Project Area: Transmission and distribution area by PPUC

(1) **Cost reduction for maintenance: 291,374 USD**

Personnel expenses US$ 150,488. Vehicles for construction US$ 32,000. Other equipment US$ 108,886 (Above amounts are deducted costs from the construction cost. This cost calculated based on the model case as alternatives of actual values, calculated by PPUC Power distribution department).

(2) **Estimated cost reduction for maintenance and operation**

Cost for outside maintenance contractors: US$ 99,692
(This cost is based on the track records to outside contractors calculated by the PPUC Procurement Department.)

(3) **Estimated reduction of power blackouts**

Power supply value of US17,100 based on the blackout power supply of 57,000 kWh by the current transmission system (30¢／kWh).

10-5 Environmental and Social Considerations

10-5-1 Scoping

Since the components of the priority project are roughly divided into the new construction (including extension) or relocation of power transmission lines and the establishment or renewal of substation equipment, we have scoped the environmental and social impacts for each of these kinds. The results are shown in Table 10-5-1.1 (transmission line) and Table 10-5-1.2 (substation equipment) of the main text.

10-5-2 Survey on Environmental and Social Considerations Based on the Scoping

Regarding the survey items expected to have negative impacts, studied and surveyed based on the scoping: the existing distribution lines / substation facilities, newly established / migration destination candidate sites, distribution of protected areas / historic sites by GIS data, and the views and expectations of PPUC officials (through face-to-face interviews). Field surveys and estimates on environmental and social impacts were also carried out based on the results of the above, and the necessary measures were examined. The results are shown in Table 10-5-2.1 of the main text.

10-5-3 Evaluation of environmental and social impacts

Table 10-5-3.1 of the main text (transmission line) and Table 10-5-3.2 of the main text (substation equipment) show the results of the evaluation of the environmental and social impacts of the priority project based on the results of the scoping and site survey in the previous section.

10-5-4 Proposal of monitoring structure and monitoring method

Table 10-5-4.1 shows the monitoring items and monitoring methods used to keep track of the environmental and social impacts assumed at the construction and operation stages of the priority project.

As one of the organizations responsible for monitoring, we propose that the monitoring be performed by a construction contractor at the construction stage and PPUC at the operation stage.

THE PROJECT FOR
STUDY ON UPGRADING AND MAINTENANCE IMPROVEMENT OF NATIONAL POWER GRID IN THE REPUBLIC OF PALAU

Contents

Abbreviation

45%REtarget@2025	National renewable energy target of 45% by 2025
AAC	All aluminum conductor
ACSR	Aluminum conductor steel reinforced
ADB	Asian Development Bank
ADF	Asian Development Fund
ADO	Automotive diesel oil
CDM	Clean Development Mechanism
CFL	Compact fluorescent lamp
CFO	Chief Financial Officer
CIF	Cost + Insurance + Freight
CIP	Capital Improvement Project
CO2	Carbon Dioxide
COC	Chamber of Commerce
COFA	Compact of Free Association
Compact	RoP Compact of Free Association (with the United States)
COP21	Conference of the Parties 21
CPI	Consumer Price Index
CRF	Capital Recovery Factor
CRIEPI	Central Research Institute of Electric Power Industry
CTF	Compact Trust Fund
CV	Cross-linked polyethylene insulated vinyl sheath
DEG	Diesel Energy Generator
DOI	Department of Interior
DSM	Demand Side Management
EA	Environmental Assessment
EDF	European Development Fund
EE&C	Energy Efficiency and Conservation
EEAP	Energy Efficiency Action Plan
EIB	European Investment Bank
EIRR	Economic internal rate of return
EIS	Environmental Impact Statement
EPDC	Electric Power Development Company
EPO	Electric Power Operations
EQPB	Environmental Quality Protection Board?
ETR	Electricity Tariff Rate
EU	European Union
FCI	Fault current indicator
FDI	Foreign Direct Investment
FIB	Foreign Investment Board
FIC	Financial Institutions Commission
FIRR	Financial internal rate of return
FIT	Feed In Tariff
FOB	Free On Board
FY	Fiscal year
GCF	Green Climate Fund
GDE	Gross Domestic Expenditure
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GIS	Geographic Information System?
GNI	Gross National Income
GOP	Government of Palau
GWh	Giga watt hours
HDCC	Hard-drawn copper stranded conductor

HFO	Heavy Fuel Oil
HPO	Historic Preservation Office
ICT	Information and Communication Technology
ICT	Information and Communication Technology
IEA	International Energy Agency
IEEJ	The Institute of Energy Economics, Japan
IMF	International Monetary Fund
INDC	Intended Nationally Determined Contribution
IPP	Independent Power Producer
IRENA	International Renewable Energy Agency
JAMSTEC	Japan Agency for Marine-Earth Science and Technology
JCM	Joint Crediting Mechanism
JICA	Japan International Cooperation Agency
KASP	Koror–Airai Sanitation Project
KAWIP	Koror–Airai Water Supply Improvement Project
kV	kilo-Volts
kW	Kilo-Watt
kWh	Kilo-Watt-Hour (Thousands of Watt Hours of energy)
kWh/gal	Kilowatt hours per US gallon (engine fuel efficiency)
kWp	Kilo-Watts peak power (at standard conditions) from PV panels
LBS	Load breaker switch
LCOE	Levelized Cost Of Energy
LED	Light Emitting Diode
LPG	Liquefied Petroleum Gas
LRMC	Long run marginal cost
LV	Low Voltage
METI	Ministry of Economy, Trade and Industry of Japan
MIGA	Multilateral Investment Guarantee Agency
MOE	Ministry of Education
MOF	Ministry of Finance
MOS	Ministry of State
MPIIC	Ministry of Public Infrastructure, Industries and Commerce
MRD	Ministry of Resources and Development
MV	Medium Voltage
MVA	Mega Volt Ampere
MW	Mega Watt
MWh	Mega-Watt-hour
NDBP	National Development Bank of Palau
NDC	Nationally Determined Contribution
NEC	National Energy Committee
NEDO	New Energy and Industrial Technology Development Organization
NEP	National Energy Plan
NGO	Non-Governmental Organization
NREL	National Renewable Energy Laboratory
O&M	Operation and Maintenance
ODA	Official Development Assistance
OJT	On-the-job training
OP	Office of the President
OPS	Office of Planning & Statistics
OTEC	Ocean Thermal Energy Conversion
PALARIS Office	Palau Land Resource Information Systems Office
PCC	Palau Community College
PDCA	Plan Do Check Action
PECS	Palau Energy Conservation Strategy

PEFA	Public Expenditure and Financial Accountability
PHA	Palau Housing Authority
PICRC	Palau International Coral Reef Center
PICTA	Pacific Island Countries Trade Agreement
PIEPSAP	Pacific Islands Energy Policies and Strategic Action Planning
PIFS	Pacific Islands Forum Secretariat
PNCC	Palau National Communications Corporation
PNMDP	Palau National Master Development Plan
PPA	Power Purchase Agreement
ppm	parts per million
PPP	Public Private Partnership
PPR	Palau Pacific Resort Hotel
PPUC	Palau Public Utilities Corporation
PRI	Political risk insurance
PSIP	Palau Sector Investment Program
PU	Per Unit
PV	Photovoltaic
RE	Renewable Energy
REMAP	Renewable Energy Roadmap 2017
REMS	Renewable Energy Management System
RMI	Republic of the Marshall Islands
ROP	Republic of Palau
S/S	Substation
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SCADA	Supervisory Control & Data Acquisition System
SCD	System Control Division
SDR	Social Discount Rate
SEA	Strategic Environmental Assessment
SGP	GEF Small Grants Program
SHS	Solar Home System
SID	Small Island Developing Countries
SIDS	Small Island Developing States
SIS	Small Island States
SOC	State Of Charge
SP	Sewer Pump
SVR	Step Voltage Regulator
T/D loss	Transmission and Distribution Loss
TA	Technical Assistance
U.S.	United States
UNDESA	United Nations Department of Economic and Social Affairs
UNDP	United Nations Development Program
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
USD	United States Dollar
UVR	Under-Voltage Relay
WB	World Bank
WHO	World Health Organization
WP	Water Pump
WSIP	Water Sector Improvement Program (ADB)
WT	Wind Turbine
WTI	West Texas Intermediate
WWO	WWOD – Water and Wastewater Operations Division

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CHAPTER 1 Introduction

Chapter 1 Introduction

1-1 Background of the Project

The Republic of Palau (hereinafter referred to as “Palau”) is located in the Pacific Ocean approximately 3,200 km south of Japan. Palau is an island country consisting of some 340 islands covering a total area of 488 km^2, with a population of 17,661 (2015 National Census). Political and economic activities in Palau are centered on Babeldaob Island, where the government capital is based (in Melekeok State), and on Koror Island, where 96% of the total population lives (2015 National Census).

The power supply equipment of the Koror-Babeldaob power system (peak power 11~12 MW) serving these two islands is deteriorating and insufficiently maintained, which is leading to difficulties in the supply of stable power. Frequent power outages are occurring in Ngatpang State, Ngchesar State, Aimeliik State, etc., requiring urgent remedial measures. The troubles are assumed to stem from the following causes: deterioration of equipment in substations, equipment malfunctioning due to insufficient periodic maintenance, earth faults caused when the transmission and distribution lines come into contact with trees, and so on.

The Palau Public Utilities Corporation (PPUC) is currently planning a program of repairs and renewals for transmission and distribution equipment to improve this situation. PPUC urgently needs to build a reliable transmission and distribution network in preparation for the future expansion of renewable energy (RE) use. To these ends, the Government of Palau has requested the Government of Japan to formulate a master plan for the transmission and distribution network in consideration of the future expansion of renewable energy use, and to provide technical cooperation to help improve the reliability of the power supply and reduce transmission and distribution losses.

1-2 Outline of the Project

The outline of the Project is as follows:

(1) Confirmation of current conditions in the power sector

a) Power and energy policy, legal systems, and organizational structure in Palau
b) Social and economic conditions and development plans in Palau
c) Organizational structure and capacity of the Ministry of Public Infrastructure, Industries and Commerce (MPIIC) and the Palau Public Utilities Corporation (PPUC)
d) Power demand and supply situation
e) Current conditions of the power source equipment and power systems
f) Power development plans
g) Power tariffs and fuel prices
h) Business condition of PPUC

(2) Power demand forecast

a) Sorting of issues in the National Energy Policy
b) Assessment of the power demand and supply of MP 2008
c) Assessment of the power demand outlook prepared by PPUC and other agencies
d) Collection of data on the demand and supply of power and energy

(3) Formulation of the transmission and distribution system plan

a) Confirmation of the current status of the existing system
b) System analysis
c) Formulation of the Transmission and Distribution System Master Plan toward 2030
d) Review of the current conditions and potential for the introduction of renewable energy
e) Updating of the Roadmap for the Introduction of Renewable Energy

(4) Economic and financial analysis

a) Review of PPUC's financial condition
b) Economic and financial analysis

(5) Environmental and social considerations

a) Strategic environmental assessment (SEA) focused on the formulation of the power system development plan
b) Pre-Feasibility Study (Pre-F/S) for priority projects

(6) Pre-F/S (preliminary design)

a) Preliminary design
b) Project cost estimation

(7) Technology transfer

a) Selection of pilot projects
b) Implementation of the technology transfer
c) Preparation of a manual

1-3 Process for Formulating the Transmission and Distribution System Plan and Technology Transfer

The main Project activities are the formulation of the transmission and distribution system plan and the technology transfer. The individual processes are shown in Figure 1-3.1.

1-4 Suggestions for alternatives

The master plan formulated in this project for the upgrading of the transmission and distribution facilities of the power system in Koror-Babeldaob is premised on the introduction of renewable energy. As a result of technical studies on factors such as the weather conditions, power demand forecasting, power system analysis, transmission and distribution facilities planning, and environmental and social considerations, the master plan proposes the construction of nine PV power stations with batteries for the stabilization of the power system.

If alternative plans are proposed and put into practice at the implementation stage of the master plan, it will be necessary to newly review the renewable energy facilities for system stabilization, etc. and to conduct other technical studies on power system analysis, transmission and distribution facilities plans, environmental and social considerations, etc.

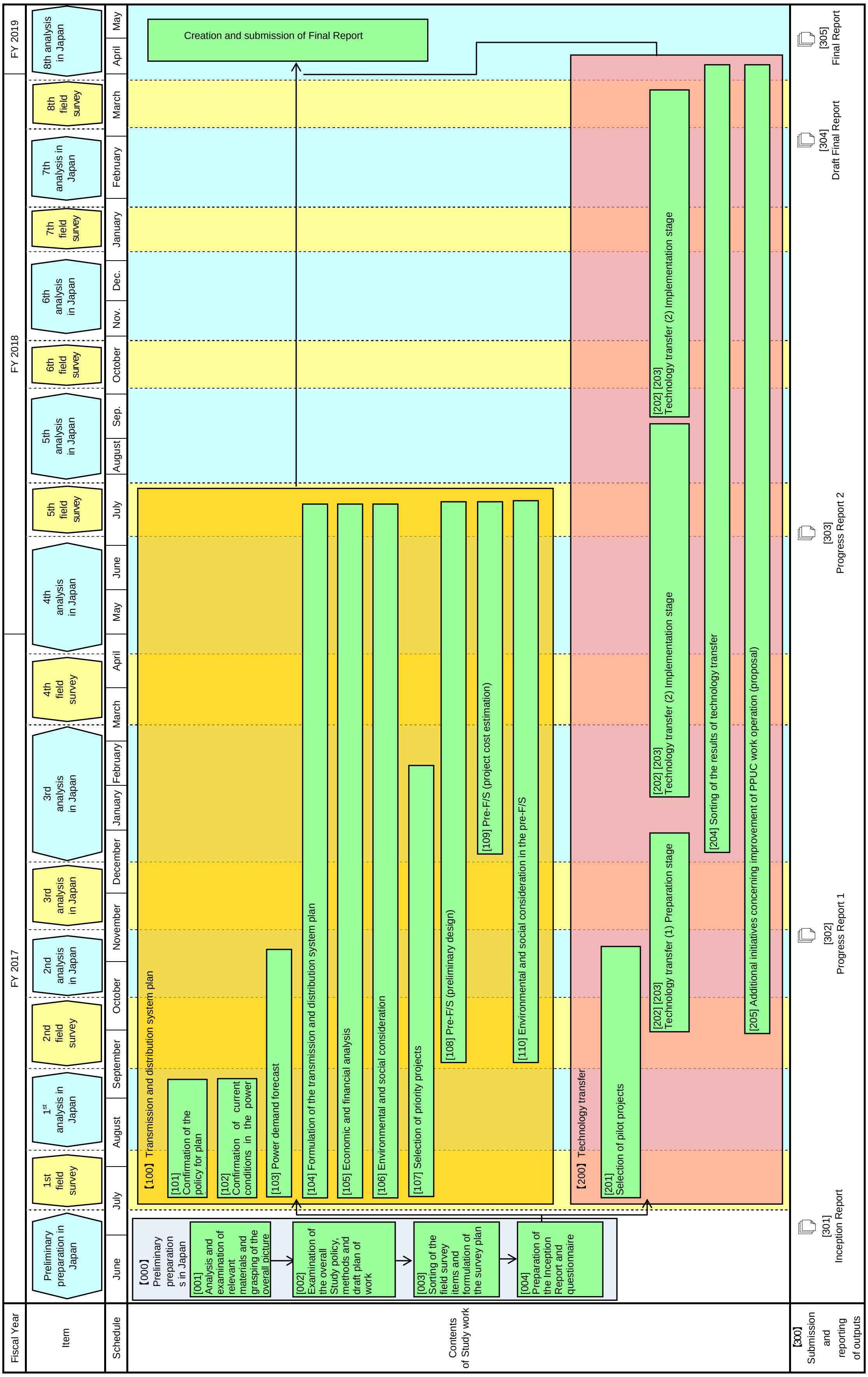


Figure 1-3.1 Study Implementation Work Flow

CHAPTER 2 Socioeconomic Conditions and Development Programmes

Chapter 2 Socioeconomic Conditions and Development Programmes

2-1 Review of Socioeconomic Development Plans in Palau

2-1-1 Population Trends (Outlook by MOF and the United Nations)

2-1-1-1 Population census

Population statistics in Palau are published by MOF (Ministry of Finance). The following Table 2-1-1-1.1 presents data from the national censuses conducted in the years 2000, 2005, and 2015, along with population census data for a consumer survey conducted in 2012. According to the census surveys, the population increased by 897 persons from 2000 to 2005 (average growth rate of 0.9% per year) but then decreased by 2,217 persons from 2005 to 2012 (average growth rate of -2.3% per year). The decrease of the population was mainly caused by the global financial crisis of 2008. The severe economic downturn of 2008 depressed the tourism industry of Palau, compelling both foreign and Palauan workers to relocate to other countries. The population has since increased by 50 persons from 2012 to 2015, and foreign workers in Palau have gradually increased in line with the recovery of the Palauan economy.

Table 2-1-1-1.1 Palau population census trends

	2000	2005	2012	2015	2005/00	2012/05	2015/12	2015/00
Unit	persons	persons	persons	persons	%	%	%	%
Aimeliik	272	270	281	334	-0.1	0.8	3.5	1.4
Airai	2,104	2,723	2,537	2,455	5.3	-1.4	-0.7	1.0
Koror	13,303	12,776	11,665	11,754	-0.8	-1.8	0.2	-0.8
Melekeok	239	391	299	277	10.3	-5.2	-1.5	1.0
Ngaraard	638	581	453	413	-1.9	-4.9	-1.8	-2.9
Ngardmau	221	166	195	185	-5.6	3.3	-1.0	-1.2
Ngaremlengui	367	317	309	350	-2.9	-0.5	2.5	-0.3
Ngatpang	280	464	257	282	10.6	-11.1	1.9	0.0
Ngchesar	267	254	287	291	-1.0	2.5	0.3	0.6
Ngarchelong	286	488	281	316	11.3	-10.5	2.4	0.7
Ngiwal	193	223	226	282	2.9	0.3	4.5	2.6
Koror+Babeldaob	18,170	18,653	16,790	16,939	0.5	-2.1	0.2	-0.5
その他	761	1,175	821	722	9.1	-6.9	-2.5	-0.4
合計	18,931	19,828	17,611	17,661	0.9	-2.3	0.1	-0.5

Note: Others include the populations of Angaur, Hatohobei, Kayangei, and Peleliu
Source：Ministry of Finance

2-1-1-2 Future population

Table 2-1-1-2.1 below shows estimates of the future numbers of workers in Palau. According to the MOF estimates, the number of workers in Palau will not increase from 2015 to 2030. The number of foreign workers, on the other hand, is projected to increase from 5,800 persons in 2005 to 8,200 persons in 2030. Hence, the foreign worker ratio to the total number of workers reached 52% in 2015 and is projected to grow to 61% by 2030. Most of the incoming foreign workers are expected to come from the Philippines.

Table 2-1-1-2.1 Numbers of foreign workers and ratio to total workers

Unit: person

	Palauan worker	Foreign worker	Total	Ratio (%)
	(A)	(B)	(C)	(B)/(C)
2015	5,292	5,832	11,124	52
2016	5,397	6,213	11,610	54
2017	5,397	6,124	11,521	53
2018	5,397	6,358	11,755	54
2019	5,397	6,820	12,217	56
2020	5,397	7,340	12,737	58
2021	5,397	7,621	13,018	59
2022	5,397	7,545	12,942	58
2023	5,397	7,605	13,002	58
2024	5,397	7,634	13,031	59
2025	5,397	7,718	13,115	59
2026	5,397	7,869	13,266	59
2027	5,397	7,964	13,361	60
2028	5,397	8,078	13,475	60
2029	5,397	8,187	13,584	60
2030	5,397	8,286	13,683	61
2020/15	0.4	4.7	2.7	
2025/20	0.0	1.0	0.6	
2030/25	0.0	1.4	0.9	
2030/15	0.1	2.4	1.4	

Source: Ministry of Finance

The MOF population projections up to 2030 are based on the above estimates. The historical data from 2000 to 2015 are created by interpolating the census data from 2000, 2005, 2012, and 2015. The negative impacts of the Lehman Shock are reflected in the population changes during this period.

The UN Population Division also issues estimates of the future Palau population. The data are described in Table 2-1-1-2.2 for reference only. The US estimates are created based on the census data from 2005. The Study Team uses MOF population estimates for the power demand forecasts. The state-wise population forecasts are based on the country population estimates.

Table 2-1-1-2.2 Projected Palau Population Estimates from MOF and the UN

Unit	MOF estimates Person	Growth rate %	UN estimates Person	Growth rate %
2005	**19,828**	**0.8**	**19,907**	**0.5**
2006	19,721	-0.5	20,012	0.5
2007	19,353	-1.9	20,118	0.5
2008	18,991	-1.9	20,227	0.5
2009	18,636	-1.9	20,344	0.6
2010	18,288	-1.9	20,470	0.6
2011	17,946	-1.9	20,606	0.7
2012	**17,611**	**-1.9**	20,756	0.7
2013	17,385	-1.3	20,919	0.8
2014	17,380	0.0	21,097	0.9
2015	**17,661**	**1.6**	21,291	0.9
2016	17,714	0.3	21,518	1.1
2017	17,767	0.3	21,747	1.1
2018	17,820	0.3	21,979	1.1
2019	17,873	0.3	22,213	1.1
2020	17,927	0.3	22,450	1.1
2021	17,981	0.3	22,683	1.0
2022	18,034	0.3	22,919	1.0
2023	18,088	0.3	23,157	1.0
2024	18,142	0.3	23,397	1.0
2025	18,197	0.3	23,640	1.0
2026	18,251	0.3	23,864	0.9
2027	18,306	0.3	24,090	0.9
2028	18,361	0.3	24,318	0.9
2029	18,416	0.3	24,548	0.9
2030	18,471	0.3	24,780	0.9
2035	18,750	0.3	25,770	0.8
2040	19,030	0.3	26,570	0.6
2030/15	0.3%		1.0%	

Note: Census data are shown in bold.
The statistics include both Palauan and foreign workers
The MOF estimates are based on the 2015 census.
The estimates from the United Nations Population Division are based on the 2005 census.
The population estimates after 2031 are calculated based on the projected annual growth rate of 2030.
UN estimates are published up to 2040.
Sources: MOF and UN Population Division

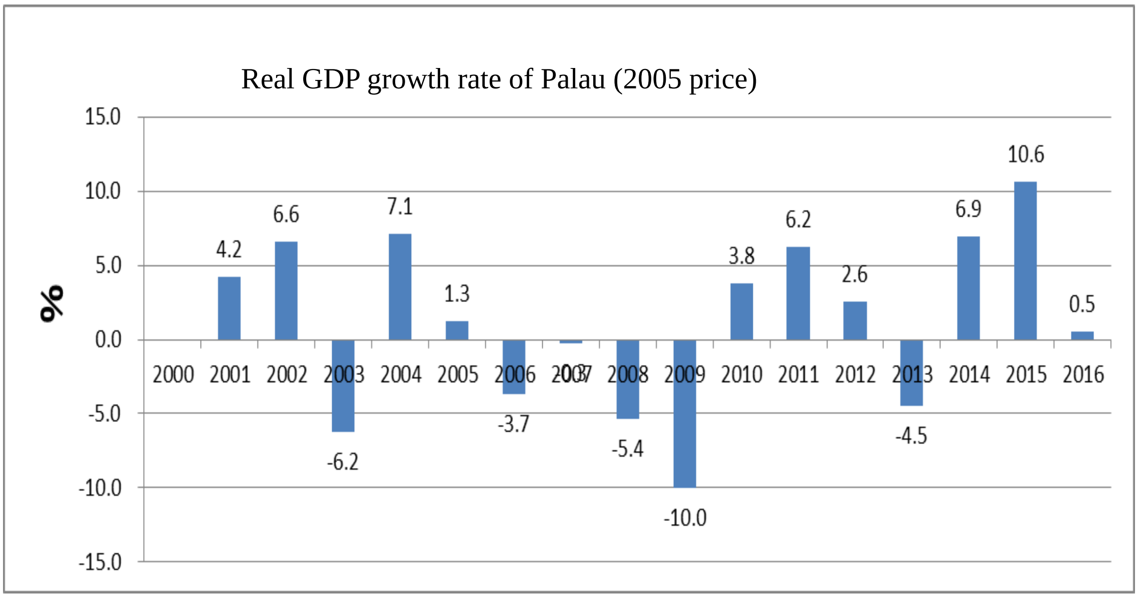
2-1-2 Economic Review

The "Palau Economic Review 2016" published by United States DOI (Department of Interior) is the fourth and latest version, issued as of September 2017. The review covers the following five agendas:

a) Review of Palauan economic development
b) Development of and policies for the tourism industry
c) Readjustment of public policies and reform agendas
d) Efficiency plan under the COFA (Compact of Free Association) and Simulation
e) Readjustment of middle- and long-term economic plans

2-1-2-1 Review of economic development

The real GDP growth rates are shown in Figure 2-1-2-1.1. The Palau economy contracted for several years in the aftermath of the global financial crisis of 2008. The economic contraction led to decreases not only in the numbers of incoming foreign travelers, but also in fund income from COMPACT projects. The Palauan economy recovered in fiscal 2011 and 2012, with GDP growth rates of 6.2% in 2011 and 2.6% in 2012. Advances in the tourism sector in fiscal 2014 and 2015 helped Palau achieve GDP growth rates of 6.9% and 10.6%, respectively, in those years.



Source: MOF

Figure 2-1-2-1.1 Real GDP growth rate of Palau

However, the recovery of the tourism sector from 2014 has depended on increasing numbers of incoming Chinese travelers. The occupancy rate has increased for low-price hotel rooms, while that for upscale hotel rooms has remained at the same level.

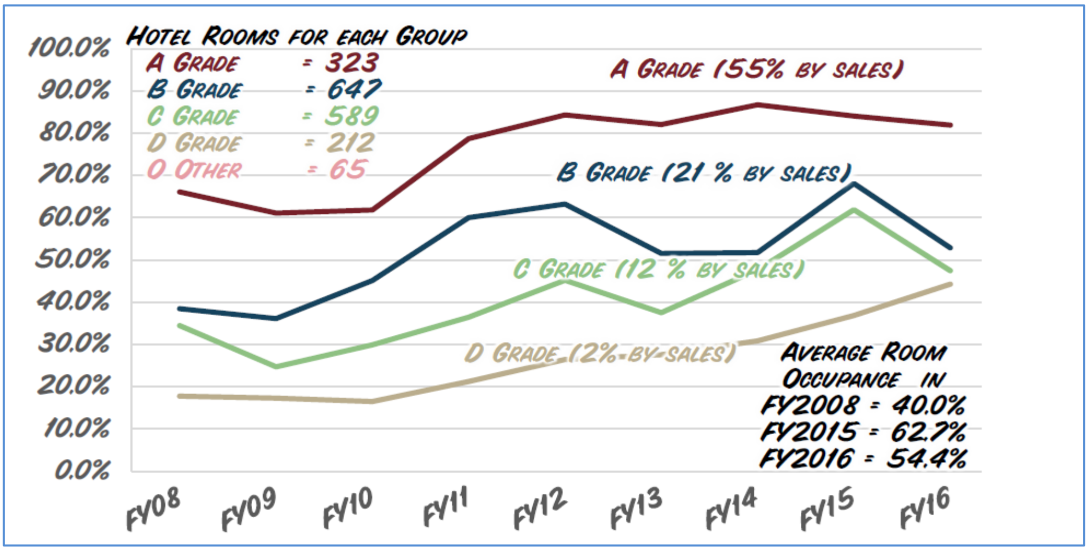
The above phenomenon has increased the social costs burdened by the Palau government. As countermeasures as of the year of 2018, the Palau government is considering the introduction of a “High Value Policy.” The details of the policy are now being discussed with ADB. The trends in the numbers of tourists are shown in Table 2-1-2-1.1 and the occupancy rates by grade are shown in Figure 2-1-2-1.2.

Table 2-1-2-1.1 Trends in the numbers of customers

Unit: Upper: person, Lower:%

	2010	2011	2012	2013	2014	2015	2016	2017
Number of Tourists	71,000	95,000	118,928	118,000	125,674	168,767	146,643	120,000
Hotel room occupancy rates	40%	52%	58%	50%	53%	66%	54%	

Source: Economic Review 2016



Note: "By sales" for each grade means the sales amount.
Source: Economic Review 2016 (page 47), US Department of Interior

Figure 2-1-2-1.2 Room occupancy rate by hotel grade

2-1-2-2 Development and policies of Palauan industries

(1) COMPACT support

The Palau government signed a Compact Review Agreement with the USA in 2010. The agreement is favorable for Palau as a country overall. Under the terms of the agreement, COMPACT is to continue for 15 years from 2010. New funds for COMPACT have already been prepared by the USA. There is some apprehension that the contents of COMPACT will be revised after 2024 to reduce or halt infrastructure investment. The Palauan economy is likely to contract if this comes to be.

(2) Submarine communication cable

The Palau government has a plan to develop the Information and Communication sector using a new submarine communication cable. This cable has connected Indonesia, Philippines, Palau, Yap, and Guam with each other since December 2017. According to ADB, high-level communication service is expected to be established in Palau in the future.

(3) Tax reform on tourism

There is a view that the traveler's tax should be changed in line with the increasing numbers of incoming travelers. As a concrete step, the immigration fee and environmental impact fee were raised from US$20 to US$40 and from US$30 to US$60, respectively, in January 2018. A traveler pays these taxes when purchasing air tickets.

(4) Repayment of KASP

As of September 2017, Palau is implementing the Koror-Airai Sanitation Project (KASP), a project funded not by grant funding, but an ADB loan. Hence, an increase in the wastewater tariff can be expected for repayment of the loan. The total repayment amount is $27 million as of Sept. 2017. Palau is required to repay the amount in a $2 million installment every year. As of September 2017, $6 million has been repaid, leaving a remaining balance of $21 million.

(5) Landholding reform

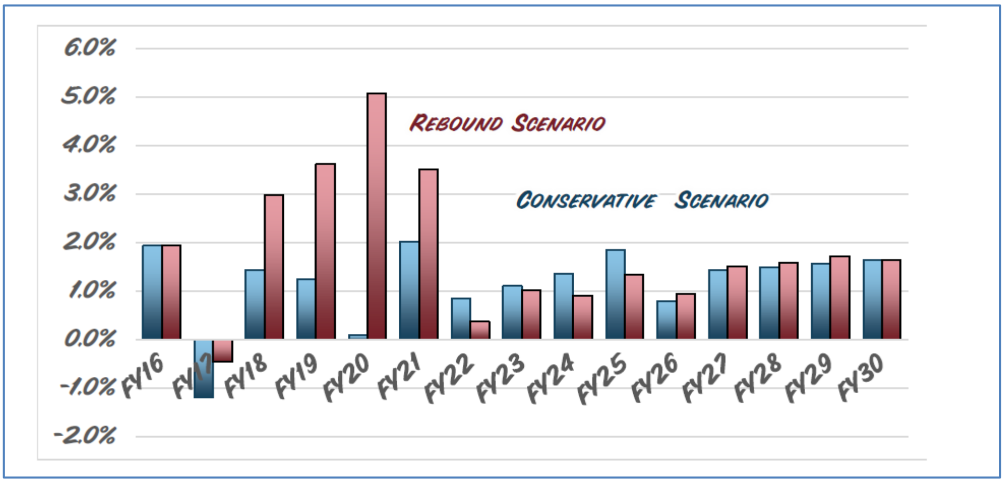
According to World Bank survey on the ease of doing business, Palau ranks 136th out of the 190 rated countries in the world. In response, ADB has started to reform the private landholding system of Palau. Opacity and uncertainty in the owners of the landholdings have delayed tourism investment.

(6) Economic growth as a precondition for the forecasts

According to Economic Review 2016, the average economic growth under the "Conservative scenario" in the Economic Review 2016 is 1.0% per year from 2016 to 2021, while that under the "Rebound Scenario" is 2.8% per year over the same period. The main reasons for the growth projections are expected measures to promote hotel investment, increases in hotel occupancy rates, and the implementation of a new COMPACT.

2-1-2-3 Middle- and long-term economic outlook

In the middle- and long-term economic outlook in Economic Review 2016, the average GDP growth rates under both the Rebound scenario and Conservative scenario are less than 2.0% per year from 2022 to 2030 (see Figure 2-1-2-3.1).



Source: Economic Review 2016(page 128)

Figure 2-1-2-3.1 GDP growth rates in two scenarios

2-1-3 World Crude Oil Price

Table 2-1-3.1 shows the WTI crude oil spot price up to 2040 according to "World Energy Outlook 2016 and 2017" published by the International Energy Agency (IEA) and the "Asia/ World Energy Outlook 2016" published by The Institute of Energy Economics, Japan (IEEJ).

Under the reference scenario, the main countries implement their current energy policies and environmental regulations. Under the low price scenario, countries around the world convert from fossil energies to renewable energies and implement energy efficiency and conservation policies.

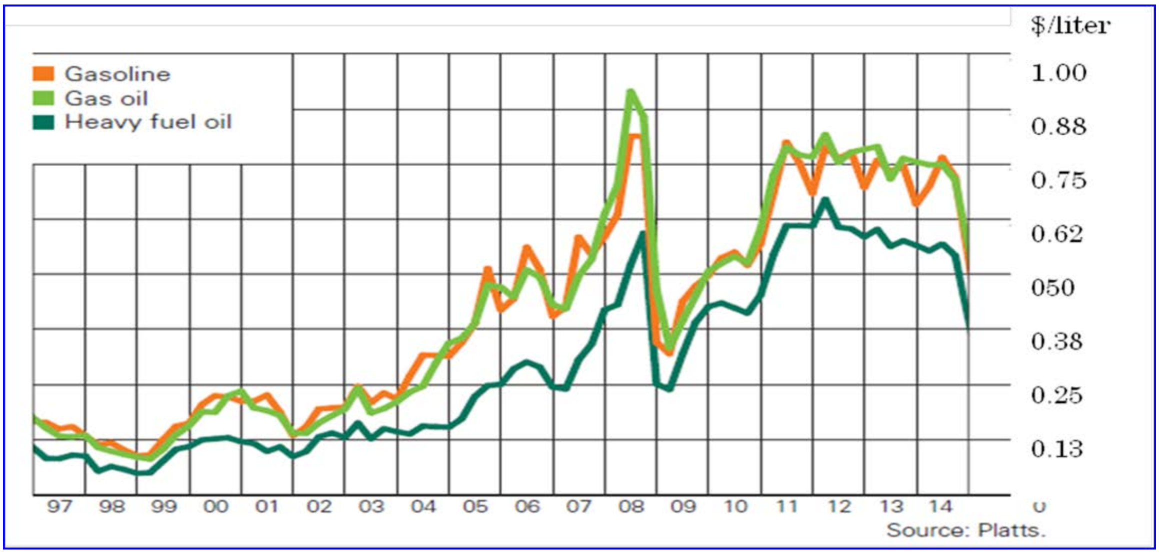
Some EU countries make new regulations to reduce fossil energy consumption. One of the regulations requires the fuel conversion of vehicles from fossil energies to electricity and hydrogen by 2040. It therefore remains unclear whether WTI crude oil prices will increase in line with the forecasts in the following table.

Table 2-1-3.1 WTI crude oil price forecasts

Unit: US$/bbl

	Scenario	2017	2020	2030	2040
IEA	Reference	50	80	94	111
	Low price		55	70	85
IEEJ	Reference	50	75	100	125
	Low price		70	75	80

Note: The WTI crude oil price is an important index for the USA and world crude oil markets. Other important crude oil prices include the “Brent crude oil price” used in the EU and the “Dubai crude oil price” used in the middle east.
Source: IEA: World Energy Outlook 2016 and 2017, IEEJ: Asia/ World Energy Outlook 2016



Note: The US gulf coast oil export prices are almost the same as the Singapore oil export prices.

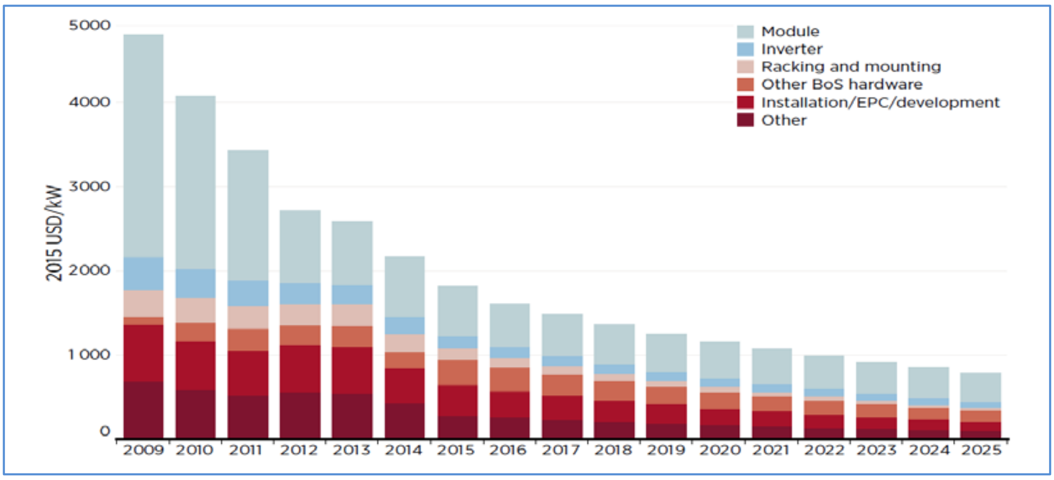
Figure 2-1-3.1 Trends of the US gulf coast oil export FOB prices

2-1-4 Solar System Costs

Figure 2-1-4.1 shows the future PV costs according to “The Power to Change: Solar and Wind Cost Reduction to 2025” published by IRENA in June 2016. The average PV generation costs is calculated to be 7.8 cent per kWh when the construction cost is set to US$2,000 / kW (the 2015 level), the capital cost is 7% per year, and the plant factor is 60% during the daytime (8 am – 16 pm). The PV generation cost in 2025 is calculated to be 3.3 cents per kWh when the construction cost is set at $US 800 /kW.

Note 1) Cost in 2015 = { US$2,000/kW / depreciation period of 20 years ）
+ Weighted Average Capital Cost } ÷（8 hours＊60%＊1kW＊365 days）

Note 2) Cost in 2025= {US$800/kW / depreciation period of 20 years
+ Weighted Average Capital Cost } ÷（8 hours＊60%＊1 kW*365 days）



Source: "The Power to Change Solar and Wind Cost Reduction Potential to 2025" by IRENA

Figure 2-1-4.1 Construction cost of solar panel

Table 2-1-4.1 shows the prices of the winners in the bidding for completion of large-scale PV power systems in several countries in 2016. The lowest price is 2.42 ¢/kWh in the UAE; the highest is 6.00 ¢/kWh in Zambia.

Table 2-1-4.1 Bidding prices for PV systems

Country	Date	Tender price
Mexico	Mar 2016	3.60 ¢/kWh
Dubai	May 2016	2.99 ¢/kWh
Zambia	Jun 2016	6.00 ¢/kWh
Chile	Aug 2016	2.91 ¢/kWh
India	Sep 2016	4.48 ¢/kWh
UAE	Sep 2016	2.42 ¢/kWh

Source: Seminar Paper of the Institutes of Energy Economics, Japan

2-1-5 Evaluation of Impacts on the Power Sector

The impacts on the power sector deduced from the review of social and economic development plans are shown in Table 2-1-5.1.

Table 2-1-5.1 Evaluation of social and economic development plans

Factors	Contents
No population increase	The population did not increase from 2000 to 2015. The population was 17,700 in 2015 and is forecasted to reach 18,000 in 2030, according to the estimates of MOF. The projected growth rates of the number of workers and number of foreign workers from 2015 to 2030 are 0.1% and 1.4% per year. With growth at these rates, the domestic consumption in Palau may be reduced by the transfer of money to foreign countries by the foreign workers. Outgoing money transfers have a negative impact on the Palau GDP.
Economic and industrial policies	In the near future, Palau will face difficulties stemming from a shrinkage of COMPACT support, tourism tax reform, repayment of KASP, and other factors. At the same time, the country is expected to promote the IT (Information Technology) sector with the future establishment of an undersea communication cable and enhanced investment into the service sector once landholding reform is achieved. It will be difficult, however, to achieve Palau GDP growth rates of more than around 2.0% per year under the Rebound Scenario described in the “Economic Review 2017” published by the Department of Interior (DOI).
World energy prices	Around half of the imported oil products (LPG, Gasoline, Diesel and Kerosene) are used for power generation in the PPUC system. The future world oil price is not expected to increase by wide rates, given the increase in substitution energies such as shale oil and gas and renewable energies, along with the promotion of energy conversion and improvements in the efficiency of vehicles. As most crude oil and oil products are traded using US dollars in the world, world oil prices are expected to increase by a rate comparable to USA inflation.
Enhancement of renewable energy, especially, solar power	The cost of solar generation systems has declined drastically since 2016. The bidding cost between the large-scale solar power producers and power distributers decreased drastically in 2016. The cost now ranges from 4 ¢ /kWh to 6 ¢ /kWh. The future cost will drop to 3 ¢ /kWh up to 2025, according to IRENA. The solar power cost is projected to be the most competitive among other forms of power generation such as hydel power systems, fossil-fired generators, and nuclear power systems in 2025. At the same time, the cost of lithium-ion batteries to be used with solar systems will decrease.

2-2 Review of Existing Plans on Energies in Palau

2-2-1 National Energy Policy 2010

Some countermeasures are taken under the energy policy in Palau. Following is a list of solutions in Palau’s approach to Climate Change.

a) Measures to adapt the physical environment to climate change, including current and future risks.
b) Mitigation measures to reduce GHGs and cooperate with international activities
c) Implementation of the above countermeasures under long-term, least-cost conditions

As Palau imports all of its oil products, the country has selected the following policies, separately from the above policies, for reducing its import oil products.

a) Promote energy efficiency and conservation
b) Diversify energies and install renewable energies
c) Promote energy supply security and reliability

The following organizations have been instituted to achieve the above targets, and the required laws have been enacted.

(1) Establish a National Energy Committee (NEC)

The organization was established in February 2016. The NEC members are the President's Office, Senate, and Lower house, the Chamber of Commerce, PPUC, Palau Community College (PCC), and the Energy Administration. The Energy Administration serves as the Secretariat of the NEC.

(2) Promoting Energy Efficiency and Conservation (EE&C)

EE&C is promoted by independent activities in Palau with no official mandates. As the following activities demonstrate, most EE&C activities and guidelines are applied to governmental buildings.

- Outdoor air-conditioning equipment should be shielded.
- Promoting the use of energy-efficient appliances (refrigerators, freezers, washing machines, air conditioners)
- Raising EE&C awareness by introducing CFLs and LEDs for lighting.
- Introducing highly energy-efficient vehicles and public transportation systems

(3) Renewable energies

The use of solar and wind power systems is important for generating electricity. In order to introduce them, it will be necessary to install volt-ampere meters and introduce a Feed In Tariff (FIT) system to connect solar and wind power to the power grid. The National Development Bank of Palau has a loan program for renewable energies to promote their introduction. According to PPUC, the number of solar power generation systems connected to the grid is around 80 and the total capacity is 2,356 kW, as of May 2017. Most of them are located in Koror and Airai.

(4) Power sector

The functions required of PPUC include not only power and water supply, but also the following.

- Sales activity for oil products, including LPG
- Loan business to support the introduction of renewable energy in households
- Support for decentralized generation of private entities

2-2-2 Intended Nationally Determined Contributions of Palau

The Palau government submitted a set of INDCs (Intended Nationally Determined Contributions) to UNFCCC (United Nations Framework Convention on Climate Change) at COP21 (Conference of the Parties 21: Paris Agreement). These INDCs were prepared in November 2015. The following government proposals for climate change mitigation appear in them.

(1) Time frame

Starting year: 2020 Year of completion: 2025

(2) Type of Commitment

The targets focus on reduced GHG emissions from transportation equipment and waste products.

(3) Reference / Base year

The base year for the CO_2 reduction is 2005. Emissions in 2005 totaled 88,000 CO_2 tons.

(4) Estimated reduction targets

Reduce GHG emissions by 22% of the 2005 level by 2025.

Increase the share of renewable energy out of total energy consumption to 45%.

Increase the share of renewable energy out of total generation to 45% in the power sector.

Improve energy efficiency by 35% over the 2005 level by 2025.

(5) Coverage

Power generation sector

Transportation sector

Waste products sector

(6) PV introduction for achieving INDC

Large-scale PV projects and rooftop PV

Water pumping PV

Reduction of transmission and distribution loss

(7) Promotion of energy efficiency and conservation for achieving INDC

Increase the energy efficiency program

Institute a tropical energy-efficiency building code

Adopt the energy star appliance standard

Implement an energy labeling scheme and system

Significantly expand the cool roof program

Expand the energy audit program to include both government and non-government buildings

Enhance the building managers working group and improve the wastewater infrastructure

(8) Control methane gas from waste products

Collect methane gas from landfill

(9) CO_2 reduction in the transportation sector

Diesel produced from waste food oil used in public buses

2-2-3 Palau Energy Roadmap

2-2-3-1 Outline of the Palau Energy Roadmap 2017

The Palau Energy Roadmap published in February 2017 was developed in collaboration with IRENA (International Renewable Energy Agency). The Roadmap sets out the procedures to be taken for least cost power system development with details on both Palau's existing energy policy and the NDCs (Nationally Determined Contributions) for COP21. The contents of the Energy Roadmap are as follows:

a) Wind condition survey for wind power installation into Palau
b) Solar radiation survey for solar panel installation
c) Power demand analysis and forecasts
d) Optimized power generation systems from 2020 to 2025
e) Required investments
f) Generation mix from 2020 to 2025
g) Considerations on the Roadmap

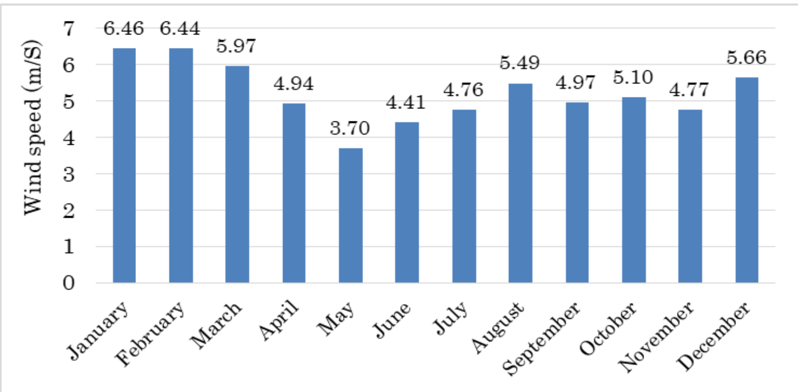
2-2-3-2 Wind condition survey and wind power potential

A wind condition survey covering three monitoring points was implemented by the US National Renewable Energy Laboratory (NREL) in 2012. The results are summarized in Table 2-2-3-2.1 and Figure 2-2-3-2.1.

Table 2-2-3-2.1 Results of the wind condition survey

Site names	Ngaraard	Ngardmau	Melekeok
Height of measurement at the site (m)	50	153	62
Number of months measurements were taken	20	16	21
Generation at 50 meter height (Watt/meter^2)	293	126	157

Note: The survey was conducted by the US National Renewable Energy Laboratory
Source: Palau Energy Roadmap 2017 (8 pages),



Note: The survey was conducted by the US National Renewable Energy Laboratory.
Source: Palau Energy Roadmap 2017 (8 pages)

Figure 2-2-3-2.1 Wind condition in Ngaraard

The survey indicates that the east coastline of Babeldaob is one of the suitable areas for wind generation by dint of a north-western wind, though the level of wind is still insufficient. Wind generators established there would have to be installed at a 30 meter height on top of poles.

The Roadmap proposes the installation of a 5.5 MW PV system in 2020 and 11.5 MW wind power system by 2025.

2-2-3-3 Solar radiation survey and solar power potential

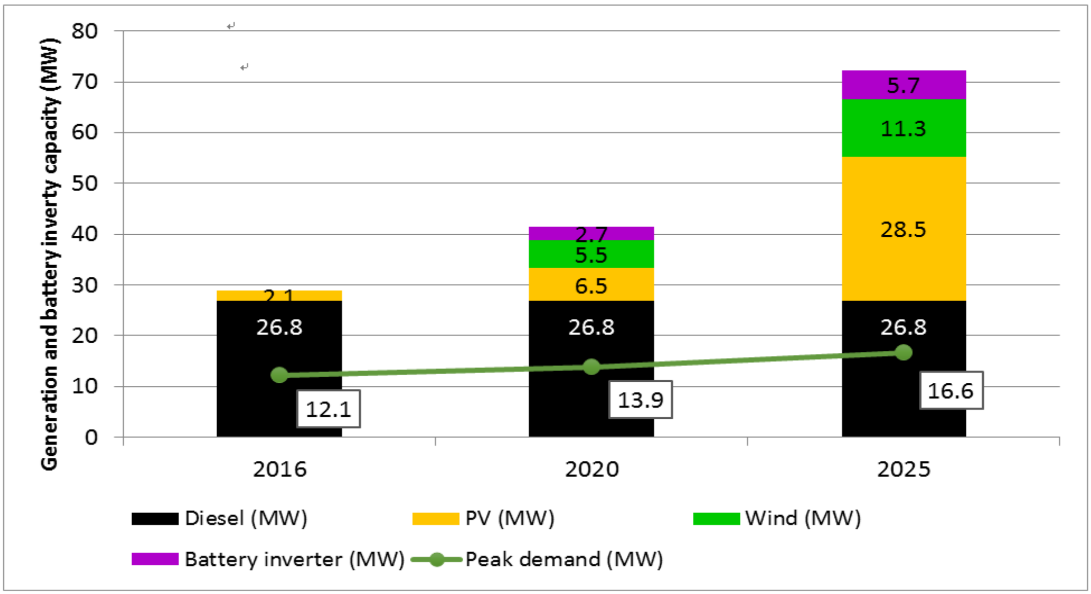
A solar radiation survey was implemented in Ngardmau state and Melekeok state. As the results in Table 2-2-3-3.1 show, solar power is expected in Palau because sufficient solar radiation is available throughout the year.

Table 2-2-3-3.1 Results of the solar radiation survey

Month	Solar resource (kWh / m2 / day)	
	Ngardmau	Melekeok
January	4.83	4.26
February	4.88	4.65
March	5.45	5.18
April	5.26	4.61
May	5.27	5.21
June	4.38	4.28
July	4.7	3.79
August	4.39	4.41
September	4.16	3.72
October	4.4	4.03
November	4.55	4.46
December	4.47	4.12
Annual average	4.73	4.39

Note: The surveyed was carried out by the National Renewable Energy Laboratory.
Source: Palau Energy Roadmap 2017 (10 pages)

Figure 2-2-3-3.1 shows the future power generation mix of Palau according to the Roadmap. IRENA proposes the following power generation mix in Palau in 2025: Diesel 26.8 MW, PV 28.5 MW, Wind 11.3 MW, Battery 5.7 MW. The peak demand, meanwhile, is forecasted to reach 13.9 MW in 2020 and 16.6 MW in 2025.



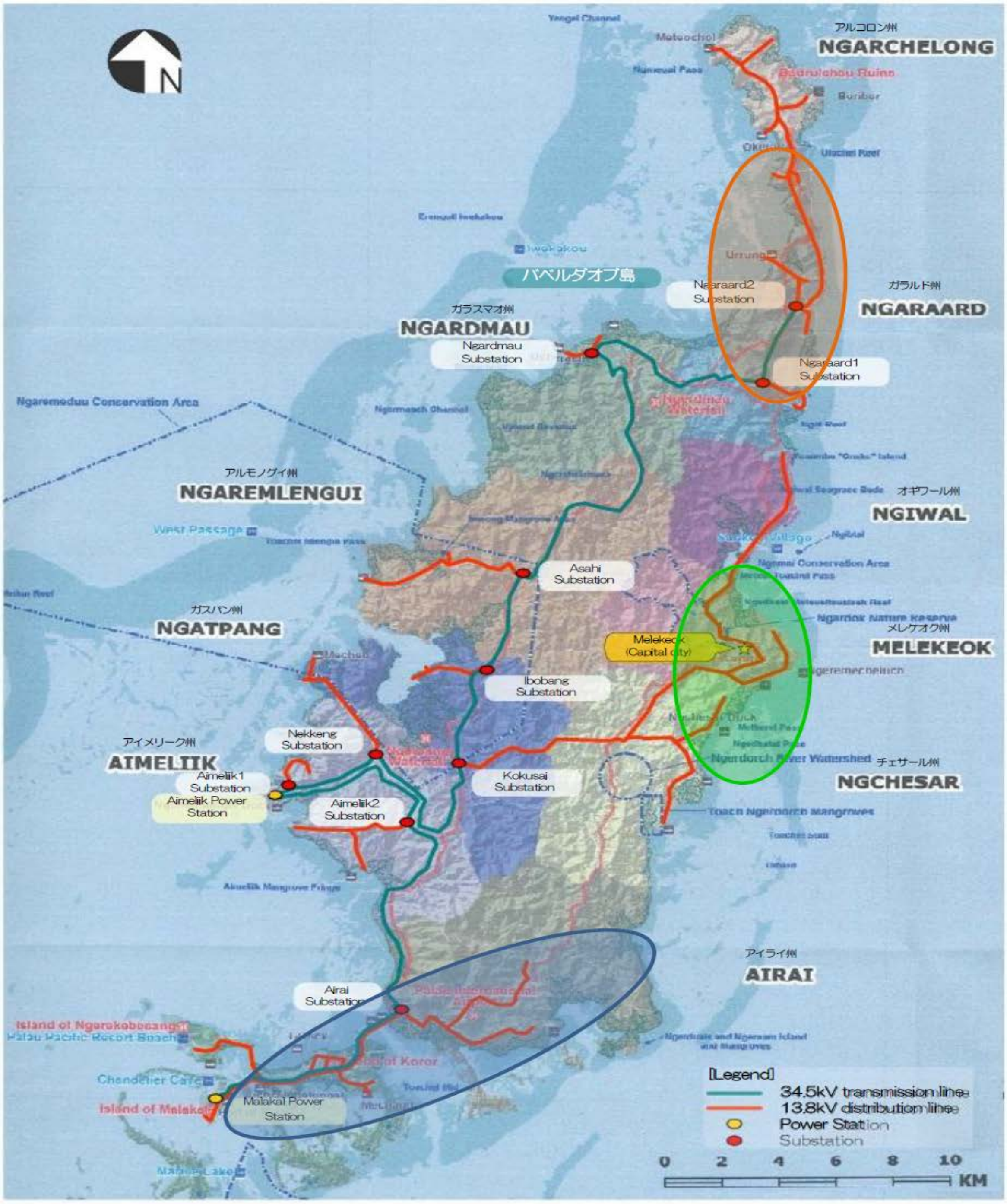
Source: Palau Energy Roadmap 2017 (18 pages)

Figure 2-2-3-3.1 Palau least-cost generation mix in 2016, 2020, and 2025

2-2-4 Infrastructure Investment Plans

2-2-4-1 Future investment

According to the Bureau of Budget & Planning in the Ministry of Finance, Capital Improvement Program, Foreign Investment Board, and some State Governments, the future investment plans (investment entities, capital funds, schedules, and areas) are concentrated in the three areas shown in Figure 2-2-4-1.1: Koror-Airai state area, Melekeok-Ngchesar state area, and Ngraard-Ngarchelong state area.



Source: Study team

Figure 2-2-4-1.1 Future significant investment areas

2-2-4-2 Hotel investment plans

According to the Foreign Investment Board of Palau, there are 100 investment plans as of July 2017. About 60 of the above plans are power-intensive projects. The plans generally focus on hotel construction, resort development, and long-stay-style apartments. The following table summarizes the 53 project plans whose investment sites have been decided (as of July 2017).

Table 2-2-4-2.1 Hotel and resort construction plans (as of July 2017)

NO	Name	Registry	Rooms	Investment	Location
1	PALASIA RESORT,	197-1996	165	8 million	Medalaii, Koror State
2	ROYAL PALAU ENTERPRISES,	252-1999	157	10,000	Malakal, Koror State
3	SEA PASSION CORPORATION	337-2004	77	100,000	Malakal, Koror State
4	MAXWELL INTERNATIONAL,	363-2005	26	1,350,000	MDock, Koror State
5	TOWARD ENTERPRISE PALAU	383-2007	140	50,000	Malakal, Koror State
6	AIRAI WATER PARADISE, INC.	407-2009	72	624,300	Ngetkib, Airai State
7	BLUE OCEAN CORPORATION	441-2010	24	75,000	Ngerbodel, Koror State
8	ANDREA VITALOSOVA/ALIIIBAMOU	458-2011	8	268,890	Ngerkebesang, Koror State
9	ISLAND PARADISE RESORT CLUB	466-2011	68	16,668,330	Malakal, Koror State
10	PALAU BO SHENG INVESTMENT,	481-2012		500,000	Meketii(T-Dock), Koror State
11	HIRONOBU OSUKA/ALTECH PTY	488-2013	20	16,195	Medalaii, Koror State
12	PALAU AVENDA INVESTMENTS,	500-2013	30	100,000	Angau State
13	PALAU PACIFIC STAR	506-2013	180	30 million	Klubed Airai, State
14	WILD ORCHID MARINE HOTEL	510-2014	180	5.38 million	Malakal, Koror State
15	JING PING INCORPORATED	517-2014	50	500,000	TDock(Meketii), Koror State
16	NISHI CORPORATION INC.	537-2014	3	600,000	Ngesekes, Koror State
17	KYUNG SUK YU /BLUE CORNER	538-2014	13	120,000	Ngesekes, Koror State
18	CHINA TOURISM DEVELOPMENT	543-2014	65	2,680,000	Ikellau, Koror State
19	WANJIN PALAU DEVELOPMENT	544-2014	6	100,000	Ngerkebesang, Koror State
20	BELAU CHINA INCORPORATED	547-2015	21	800,000	(in process of relocating)
21	VILLA VILLA CORPORATION	557-2015	7	715,000	Ngerbechedesau, Koror State
22	F & B UNITED DEVELOPMENT	560-2015	43	11,800	Ikellau, Koror State
23	BAOYUFENG VACATION HOTEL	561-2015	80	5,000,000	Ngermid, Koror State
24	YING CHUN LI / APEX INTERNATIONAL	563-2015	20	2,000,000	Melkeok State
25	ECOGREEN CONSULTING	568-2015	18	2,765,000	Meyuns, Koror State
26	SCL COMPANY, INC.	571-2015	20	1,000,000	Dngeronger, Koror State
27	SKY ASIA INTERNATIONAL GROUP	572-2015	200	20,000,000	Melkeok State
28	DAVID JOHN CLARE/EPIMU PACIFIC	573-2015	5	85,000	Ngerkebesang, Koror State
29	PALAUTUNA, INC.	574-2015	50	1,500,000	Kemur Meyuns, Koror State
30	TURTLE HOTEL DEVELOPMENT	575-2015	100	4,000,000	Ngerkebesang, Koror State
31	PALAU CENTRAL, INC.	579-2015	80	5,250,000	Ikellau, Koror State
32	TRIUMP IA CORPORATION	582-2015	120	16,045,000	Ngerkebesang, Koror State
33	LONGHUI INTERNATIONAL INVESTMENT	584-2016	200	5,000,000	Ngerkebesang, Koror State
34	SINO PACIFIC INVESTMENT	585-2016	10	1,050,000	Malakal, Koror State
35	SUNNY PALAU ENTERPRISES	586-2015	12	500,000	Ngerkesoal, Koror State
36	PALAU REAL ESTATE TRADING CENTER,	587-2016	100	10,000,000	Malakal, Koror State
37	PALAU MAJESTY DEVELOPMENT,	588-2016	98	35 million	Medalaii, Koror State
38	ZHAODE PALAU LIMITED	589-2016	200	5 million	Ngchesechang, Airai State
39	THE SEA SKY INTERNATIONAL DEV.	592-2016	514	10,000	Ibul, Aimeliik State
40	THE BAY SHORE COMPANY	593-2016	18	120,000	Malakal, Koror State
41	WALLANT INTERNATIONAL TRADE	594-2016	100	480,000	Ked, Airai State
42	HOPSUN DEVELOPMENT	596-2016	64	1.2 million	Ngerbechedesau, Koror State
43	CHU KAN FUNG JEFFREY DBA RESORT	600-2016	52	500,000	Omis, Melekeok State
44	PALAU BANYAN TREE INVESTMENT	601-2016		4,500,000	Melkeok State
45	ASIA PACIFIC (PALAU) HOTELS,	602-2016	321	70,000,000	Koror State
46	RAINBOW OCEAN HOTEL	603-2017	8	2,000,000	Ngermid, Koror State
47	SOUTH PACIFIC CAPITAL INVESTMENT	607-2017	4	5.4 million	Smau Isaland, Peleliu State
48	PALAU INTERNATIONA INVESTMENT	608-2017	318	84.4 million	Ngerchelong & Ngaraard State
49	ECO PACIFIC INTERNATIONAL	611-2017	12	2.9 million	Kemure Meyuns, Koror State
50	ASIA INTERNATIONAL REAL ESTATE	612-2017	50	5 million	Ngelas Ngerkebesang, Koror State
51	BELUU SEA VIEW RESORT	620-2017	16	5 million	Rowell Ngerkebesang, Koror State
52	JIUZHOU INTERNATIONAL GROUP	623-2017	150	10 million	Choll Hamlet, Ngaraard State
53	PALAU BLUE GOLD INVESTMENT	624-2017	500	50 million	Ngermiich Ngeruluobel, Airai State

Note: Seven projects whose construction sites are undecided have been omitted.
Source: Foreign Investment Board

2-2-4-3 Investment plan by state

(1) Koror and Airai states

a) As of July 2017, there are 64 hotel investment proposals from foreign enterprises and countries, most of which are concentrated in the Koror and Airai states. More than 30 of the hotel projects are now under construction. A total of around 2,000 rooms are being constructed under the investments.

b) The Palau government has plans to move several public facilities (the hospital, school, harbor, etc.) from Koror to Airai state, where the international airport is located. The population of Airai and investment for infrastructure projects are expected to increase in the future.

c) A resort development is planned in Airai cape, and the government has a plan to build a prison alongside COMPACT road in Airai and Ngchesar states. As of September, the prison is under construction.

(2) Melekeok and Ngchesar states

a) The development of Melekeok and Ngchesar states is expected to be promoted, as the capital functions are being moved from Koror to Melekeok. As of September 2017, the offices of the Ministry of Finance, Ministry of States and Ministry of Education have already moved from Koror. As of September 2017, the other ministries have only small staffs working in one-room offices in government buildings.

b) According to MOF, the movement of the capital to Melekeok will take 10 more years to complete. Most of the staff currently working in Melekeok state commute from Koror to Melekeok in their own vehicles.

c) Melekeok at present only consists of government buildings. The Palau government has a plan to move the foreign embassies near COMPACT road in Melekeok in the future.

d) According to Foreign Investment Board, there are two large-scale hotel projects with 50 rooms in Melekeok and Ngchesar states.

(3) Ngarchelong and Ngaraard states

a) Most of the existing resort areas in Palau are located in the southern part of Koror. There are recent resort development plans for diving and fishing in Ngarchelong and Ngaraard states.

b) In parallel with the resort development, two large-scale hotel projects are planned out in Ngarchelong and Ngaraard states.

2-2-4-4 Other investment plans

a) Continued COMPACT investment up to 2024

b) Golf course construction and road reconstruction plans in Ngatpang state

c) Promotion of the IT sector once Palau begins using the undersea communication cable connecting it with other countries.

d) Expectation of renewable energy investment (solar, wind, bio energy, etc.)

e) Switchover to energy-efficient home appliances, buildings, and lighting.

2-2-5 Evaluation of the Existing Plans

Table 2-2-5.1 summarizes the existing energy and power-related plans considered in the evaluation of future power demand in Palau.

Table 2-2-5.1 Power demand evaluation from existing plans

Factors	Contents
National Energy Policy 2010	The Palau government has policies in place to promote energy efficiency & conservation (EE&C), introduce renewable energies, strengthen PPUC functions and improve the water supply system for climate change mitigation and the safeguarding of Palau's energy supply. The EE&C policy links especially to power demand. The current EE&C policy focuses on both the Government and Commercial sectors, including power consumption in hotels. The above factors are considered in the power demand forecasts.
INDCs (Intended Nationally Determined Contributions)	The INDC targets are to (1) reduce GHG emissions by 22% of the 2005 level by 2025, (2) Increase the share of renewable energy out of total energy consumption to 45% by 2025, (3) Improve energy efficiency by 35% in 2025, compared to the 2005 level. The above have big impact on power demand and power generation.
Palau Energy Roadmap 2017	The generation mix in 2025 according to the Palau Energy Roadmap is: Diesel 26.8 MW (current capacity kept), PV 28.5 MW, Wind 11.3 MW, and Battery 5.7 MW. The report mentions that the above configuration is the least cost for Palau when all petroleum products are imported. The introduction of a dispersed power system to Palau is recommended. As a result, the demand pattern of PPUC is expected to change in the future.
Infrastructure investment review	According to the Bureau of Budget & Planning of MOF, the Capital Improvement Program, the Foreign Investment Board, and some State Governments, infrastructure investment concentrates in three blocks: (1) Koror-Airai states (2) Melekeok – Ngchesar states (3) Ngraard - Ngarchelong states

Source: Study Team

CHAPTER 3 Current Situation and Issues of the Power Sector

Chapter 3 Current Situation and Issues of the Power Sector

3-1 Current Situation of the Power Sector

3-1-1 Status of Power Demand and Supply

3-1-1-1 Sectoral Power Demand and Supply

The sectoral power demand and supply and growth rate from 2000 to 2016 are shown in Table 3-1-1-1.1 and Table 3-1-1-1.2. T/D loss includes the unbilled category under the PPUC tariff system. This means that T/D loss consists of both technical loss in transmission and distribution grids and social loss such as non-payment for power consumption by consumers.

Table 3-1-1-1.1 Actual power consumption by sector

	Commercial (MWh)	Public (MWh)	Residential (MWh)	T/D loss (MWh)	Total (MWh)	T/D loss rate (%)
	A	B	C	D	E=A+B+C+D	D/E*100
2000	31,921	18,669	26,137	23,697	100,424	23.6
2001	34,043	19,545	28,287	20,337	102,212	19.9
2002	32,004	18,570	27,999	22,822	101,395	22.5
2003	33,030	20,238	29,222	19,644	102,134	19.2
2004	31,964	20,767	29,135	24,022	105,888	22.7
2005	37,656	21,686	29,862	20,720	109,924	18.8
2006	31,720	21,692	26,758	19,342	99,512	19.4
2007	32,977	22,912	26,806	19,951	102,645	19.4
2008	32,393	21,719	24,300	23,741	102,153	23.2
2009	22,567	20,651	22,432	15,502	81,152	19.1
2010	24,729	19,891	22,975	15,480	83,075	18.6
2011	24,713	20,364	21,742	14,719	81,539	18.1
2012	24,950	20,238	18,629	3,616	67,434	5.4
2013	23,042	20,998	21,042	10,325	75,407	13.7
2014	24,506	21,124	21,146	9,886	76,662	12.9
2015	24,423	19,421	23,080	14,292	81,216	17.6
2016	25,205	19,846	25,877	12,732	83,661	15.2

Source: Actual data of PPUC as of July 2017

Table 3-1-1-1.2 Growth rate of power consumption by sector

Unit: %

	Commercial	Public	Residential	T/D loss	Total
2001/00	6.6	4.7	8.2	-14.2	1.8
2002/01	-6.0	-5.0	-1.0	12.2	-0.8
2003/02	3.2	9.0	4.4	-13.9	0.7
2004/03	-3.2	2.6	-0.3	22.3	3.7
2005/04	17.8	4.4	2.5	-13.7	3.8
2006/05	-15.8	0.0	-10.4	-6.7	-9.5
2007/06	4.0	5.6	0.2	3.1	3.1
2008/07	-1.8	-5.2	-9.3	19.0	-0.5
2009/08	-30.3	-4.9	-7.7	-34.7	-20.6
2010/09	9.6	-3.7	2.4	-0.1	2.4
2011/10	-0.1	2.4	-5.4	-4.9	-1.8
2012/11	1.0	-0.6	-14.3	-75.4	-17.3
2013/12	-7.6	3.8	13.0	185.5	11.8
2014/13	6.4	0.6	0.5	-4.3	1.7
2015/14	-0.3	-8.1	9.1	44.6	5.9
2016/15	3.2	2.2	12.1	-10.9	3.0
2016/2000	-1.5	0.4	-0.1	-3.8	-1.1

Note: The demand reduction in 2009 was due to the global financial crisis of 2008.
The demand reduction in 2012 was due to a fire at the Aimeliik power station.
Source: Study Team

3-1-1-2 Power Consumption by the Water Supply Sector

As of September 2017, the Water and Waste Operation Division (WWO) of PPUC was implementing the Koror Airai Water Improvement Project (KAWIP) to replace old asbestos water distribution pipelines, with JICA support. Through the implementation of the KAWIP and Leak Detection Program of JICA, the unbilled rate of PPUC-WWO is expected to decrease from 44% of the actual value in 2014 to 20% after 2018. The above activities contribute to power saving by PPUC-WWO. (PPUC-WWO accounts for around half of the total government power consumption, as shown in Table 3-1-1-2.1 and Table 3-1-1-2.2.)

Table 3-1-1-2.1 Power consumption by PPUC-WWO water pumps

Unit: kWh

NO	Name	FY2014	FY2015	FY2016	Oct 2016 / Jun 2017
1	WP STATION- NGERIKIIL (WWO)	1,691,736	1,638,456	1,566,096	1,140,342
2	WP STATION - NGERULUOBEL (A)	1,774,138	1,025,658	791,098	697,083
3	WP STATION- AIMELIIK	31,798	31,577	29,520	27,855
4	WP- NGATPANG	16,767	15,489	13,518	8,225
5	WP STATION- NGERKEAI	25,954	16,746	16,677	11,098
6	WP STATION- NGERMID	16,266	18,839	16,800	19,200
7	WP STATION - NGERULUOBEL(B)	353,964	775,804	867,524	650,133
8	WP STATION- NGERULUOBEL(B)	7,473	4,965	3,800	4,669
9	WP- IMEONG	555	516	469	1,858
10	WP- PELELIU (1)	1,986	3,891	3,322	1,174
11	WP- NGARDMAU	24,997	23,721	20,385	8,870
12	WP- NGARAARD	582	3,491	4,025	3,015
13	WP- IBOBANG	39,398	27,306	19,054	14,060
14	WP STATION- NGEREMLENGUI (2)	18,815	20,385	18,844	21,097
15	WP- OLLEI	36,000	37,844	37,848	29,130
16	WP STATION- IBOBANG	4,402	3,220	4,042	2,943
17	WP- NGERCHELONG	12,602	9,040	16,503	0
18	WP- NGIWAL(1)	25,162	21,247	21,643	13,038
19	WP- ANGAUR(2)	56,467	57,895	69,308	51,237
20	WP- SIMIZU	25,232	9,748	139	100
21	WP- PELELIU (2)	13,632	17,202	24,180	12,483
22	WP- MELEKEOK	62,880	130,240	75,440	79,200
23	WP- NEKKEN	47,623	49,218	47,257	33,543
24	WP- NGIWAL(2)	1,176	2,335	3,305	3,553
25	WP- ELAB	0	7,919	7,760	4,200
26	WP- KAYANGEL	3,746	5,184	12,236	5,522
		4,293,351	3,957,936	3,690,793	2,843,628

Note: WP, Water Pump

Source: PPUC-Water and Waste Operations

Table 3-1-1-2.2 Power consumption by PPUC-WWO wastewater pumps

Unit: kWh

NO	Name	FY2014	FY2015	FY2016	Oct 2016 / Jun 2017
1	SP STATION NGEBEKEUU-9F	1,773	2,078	1,453	912
2	SP STATION NGERBECHED-10C	1,488	3,664	1,754	854
3	SP STATION IKELAU-1A	14,588	12,570	11,084	9,373
4	SP STATION MEKETII - 11G	6,805	5,879	971	3,206
5	SP STATION NGERBODEL-16B	6,446	2,716	5,125	6,000
6	SP STATION MEDALAII-19M	4,548	3,801	5,112	3,517
7	SP STATION NGERKESOAOL-18L	5,254	2,868	2,526	2,280
8	SP STATION M-DOCK-E2	7,374	1,878	1,635	3,523
9	SP STATION MEDALAII-21N	4,363	3,668	2,897	4,118
10	SP STATION NGERCHEMAI-4B	19,362	16,793	15,652	17,360
11	SP STATION NGERMID-7E	19,437	42,045	53,897	20,411
12	SP STATION NGERMID-8E	6,576	23,320	33,588	35,683
13	SP STATION NGERBECHED-3C	4,577	4,305	3,906	2,998
14	SP STATION MEKETII-15J	5,268	9,311	4,284	12,114
15	SP STATION MEDALAII-12H	6,756	8,626	5,422	4,054
16	SP STATION MEDALAII-LS1	7,010	4,225	26,565	3,249
17	SP STATION IYEBUKL-17B	11,361	9,661	9,267	4,940
18	SP STATION SEMIICH-20B	16,499	13,052	12,034	12,480
19	SP STATION NGERBODEL-5B	6,064	6,032	7,986	3,731
20	SP STATION DNGERONGER-13I	7,382	7,230	6,614	6,951
21	SP STATION MADALAII-E1	794	825	623	2,958
22	SP STATION MEKETII-6D	15,249	35,597	41,858	56,174
23	SP STATION IYEBUKL-2B	30,283	28,376	25,982	31,733
24	SP STATION MEYUNS-A6	1,362	812	947	924
25	SP STATION MEYUNS-A2	3,183	4,211	3,024	2,746
26	SP STATION MEYUNS-A5	1,079	1,559	916	790
27	SP STATION MADALAII-SPS1	114,080	104,960	63,840	60,960
28	SP STATION IYEBUKL-14B	3,164	1,202	1,061	1,632
29	SP STATION MEYUNS-A1	36,240	41,160	64,080	23,640
30	SP STATION MALAKAL-SPS2	339,960	287,800	193,800	218,000
31	SP STATION NGERBECHED-ES2	1,677	1,622	1,229	1,533
32	SP STATION NGERBECHED-ES3	25,692	25,366	10,905	7,202
33	SP STATION NGESEKES-LS3	451	448	414	396
34	SP STATION NGERBECHED-ES1	11,685	10,724	4,509	5,320
35	SP STATION DELEB-LS2	1,150	1,701	2,149	2,488
36	SP STATION BIBIROI-9E	3,507	4,605	4,121	3,092
37	SP STATION ECHANG-A9	2,912	9,493	4,320	3,862
38	SP STATION ECHANG-A10	31,314	21,420	10,248	11,149
39	SP STATION MEYUNS-A3	56,975	98,932	93,120	23,470
40	SP STATION NGERKEBESANG-A7	21,210	23,813	63,162	109,160
41	SP STATION NGERKEBESANG-A8	52,050	52,594	48,864	51,714
42	ST PLANT MALAKAL 2	111,174	118,917	114,376	77,185
43	ST PLANT MALAKAL 1	104,514	122,841	129,471	97,083
44	SP STATION NGERMID-10E	85,120	77,760	60,560	43,080
45	ST PLANT-MELEKEOK	3,290	2,963	1,891	2,111
46	ST PLANT-MELEKEOK	3,935	3,449	2,006	2,401
47	ST PLANT-MELEKEOK	4,084	3,331	2,320	1,747
48	ST PLANT-MELEKEOK	3,749	2,516	2,069	2,237
49	ST PLANT-MELEKEOK	3,741	1,954	1,301	1,407
50	ST PLANT-MELEKEOK	3,477	1,793	910	1,186
51	ST PLANT-MELEKEOK	6,500	3,808	1,072	2,526
52	ST PLANT-MELEKEOK	627	536	316	469
53	ST PLANT-MELEKEOK	5,482	5,578	8,307	5,034
54	SP STATION MEYUNS-A4	35,745	34,737	37,114	29,615
		1,288,386	1,321,125	1,212,657	1,042,778

Note: SP: Sewer Pump
Source: PPUC-Water and Waste Operations

3-1-1-3 Power Generation and Send Out

The power generation and send out from Malakal and Aimeliik power stations are shown in Table 3-1-1-3.1. The fire accident of 2011 halted power generation by the Aimeliik power station in 2012 and 2013, so power was supplied from Malakal power station after the addition of capacity. As of 2017, the current power supply exceeds the level before the year of the global financial crisis. Table 3-1-1-3.2 shows the growth rates of power sent out, the peak demand, and the load factor of PPUC.

Table 3-1-1-3.1 Generation and send out from Malakal and Aimeliik

Years	Generation (MWh)			Sent Out (MWh)		
	Malakal	Aimeliik	Total	Malakal	Aimeliik	Total
2000	42,787	59,947	102,734	41,825	58,599	100,424
2001	55,647	48,916	104,563	54,396	47,816	102,212
2002	56,860	46,867	103,727	55,582	45,813	101,395
2003	59,028	45,455	104,483	57,701	44,433	102,134
2004	60,943	47,380	108,323	59,573	46,315	105,888
2005	60,361	52,091	112,452	59,004	50,920	109,924
2006	48,843	52,958	101,801	47,745	51,767	99,512
2007	50,381	54,625	105,006	49,248	53,397	102,645
2008	53,542	50,961	104,503	52,338	49,815	102,153
2009	32,058	50,961	83,018	31,337	49,815	81,152
2010	38,567	46,419	84,986	37,700	45,375	83,075
2011	37,411	46,003	83,414	36,570	44,969	81,539
2012	68,985	0	68,985	67,434	0	67,434
2013	77,141	0	77,141	75,407	0	75,407
2014	65,364	13,062	78,425	63,894	12,768	76,662
2015	39,532	43,552	83,084	38,643	42,573	81,216
2016	46,968	38,617	85,585	45,912	37,749	83,661

Source: Actual values from PPUC as of 2017

Table 3-1-1-3.2 Peak generation

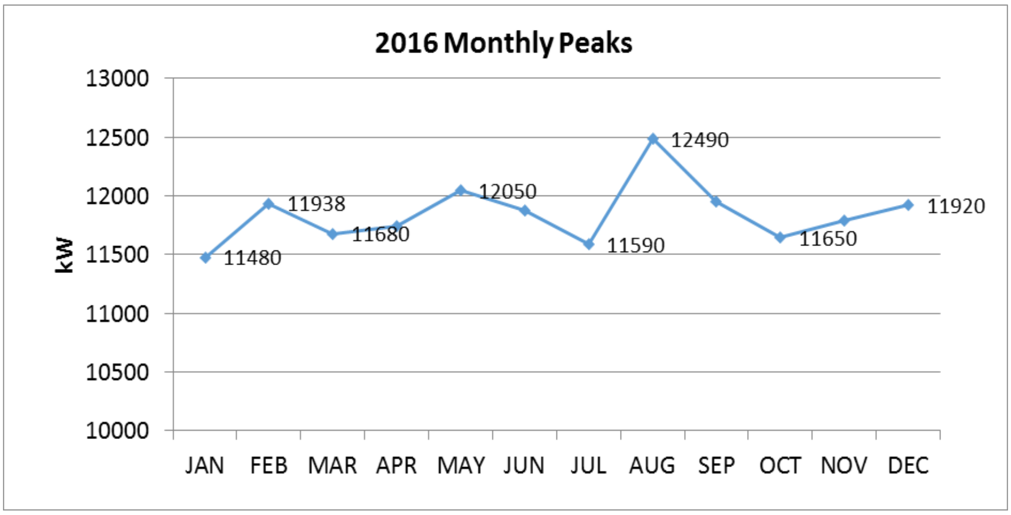
Unit	Sent out	Growth rate	Load Factor	Peak demand	Growth rate
	MWh	%	%	MW	%
2000	100,424		75.0	15.3	
2001	102,212	1.8	75.0	15.6	1.8
2002	101,395	-0.8	75.0	15.4	-0.8
2003	102,134	0.7	75.0	15.5	0.7
2004	105,888	3.7	75.0	16.1	3.7
2005	109,924	3.8	75.0	16.7	3.8
2006	99,512	-9.5	75.0	15.1	-9.5
2007	102,645	3.1	75.0	15.6	3.1
2008	102,153	-0.5	75.0	15.5	-0.5
2009	81,152	-20.6	75.0	12.4	-20.6
2010	83,075	2.4	74.3	12.8	3.4
2011	81,539	-1.8	74.1	12.6	-1.6
2012	67,434	-17.3	63.4	12.2	-3.3
2013	75,407	11.8	72.5	11.9	-2.3
2014	76,662	1.7	77.5	11.3	-4.9
2015	81,216	5.9	77.3	12.0	6.3
2016	83,661	3.0	76.4	12.5	4.2

Source: Actual values from PPUC as of 2017

3-1-1-4 Load data in 2016

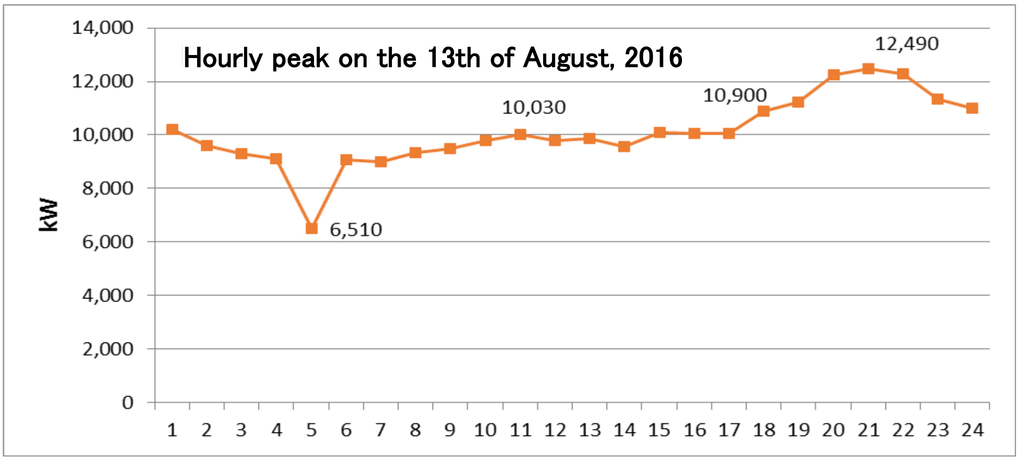
(1) Monthly load data

The following Figure 3-1-1-4.1 shows monthly load data from January to December in 2016. The peak generation (kW base) in 2016 was 12,490 kW at 9 pm on the 13th of August.



Source: PPUC

Figure 3-1-1-4.1 Monthly peak generation

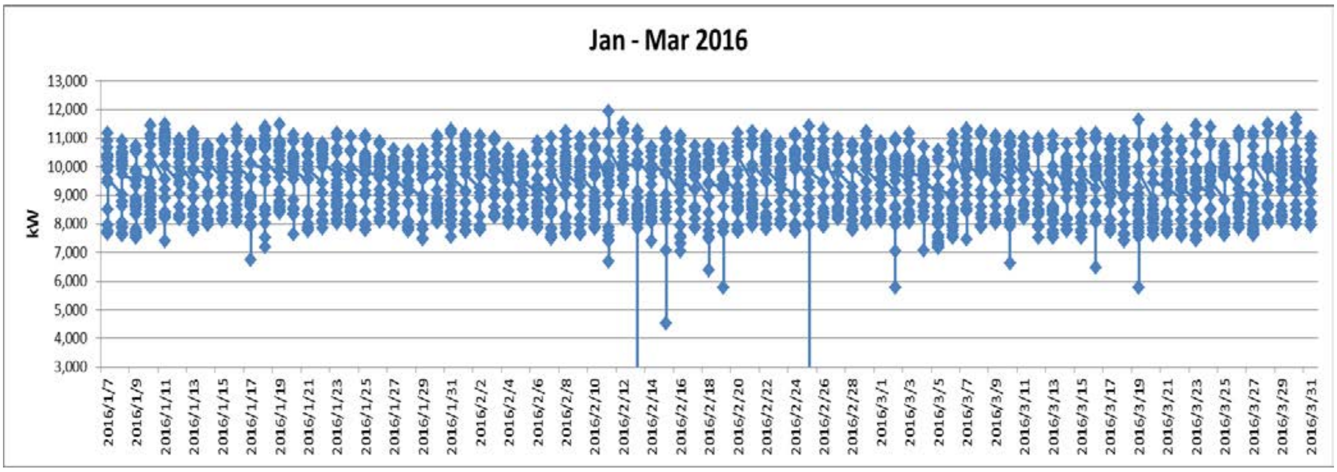


Source: PPUC

Figure 3-1-1-4.2 Daily peak generation on the 13th of August, 2016

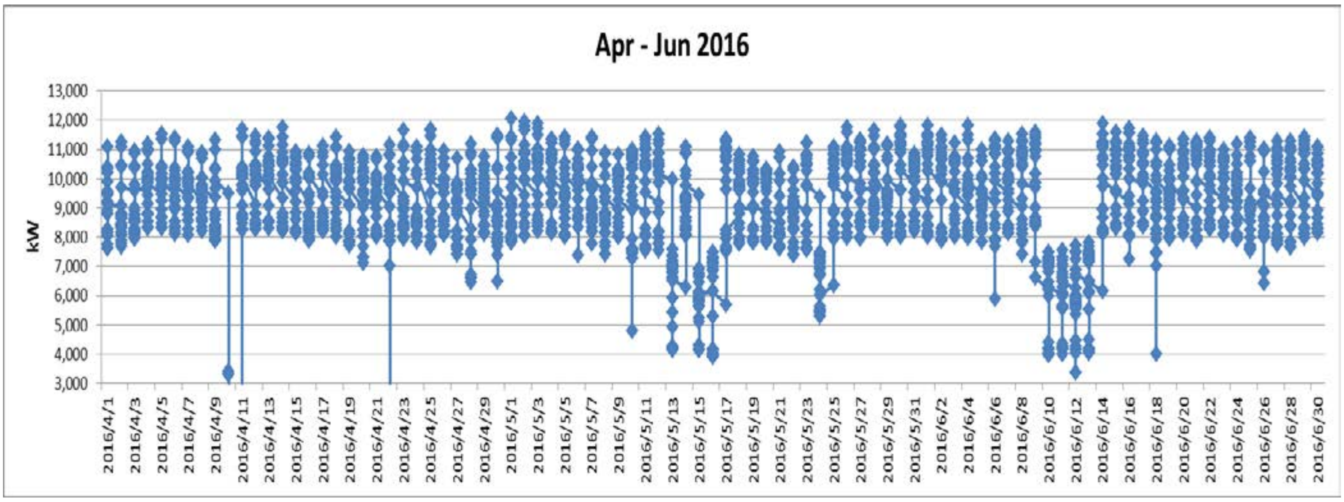
(2) 8,760 hourly load data in 2016

The 8,760 hourly load data in 2016 are shown in Figure 3-1-1-4.3, Figure 3-1-1-4.4, Figure 3-1-1-4.5, and Figure 3-1-1-4.6. Though some of the hourly data are omitted, the figures clearly demonstrate when the peak generation and minimum generation occur.



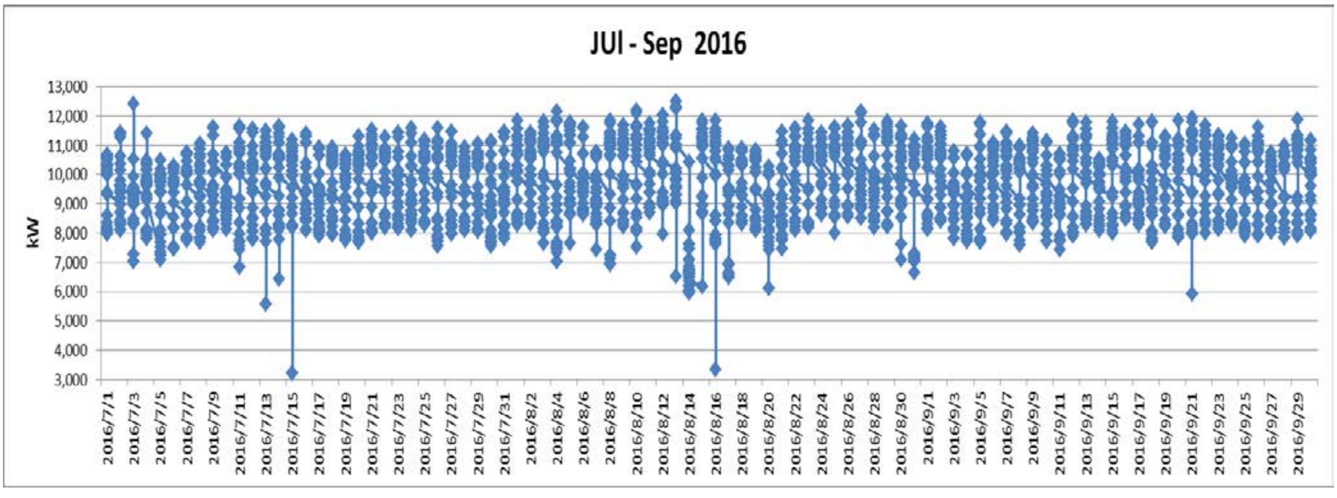
Source: PPUC

Figure 3-1-1-4.3 Hourly load data from January to March in 2016



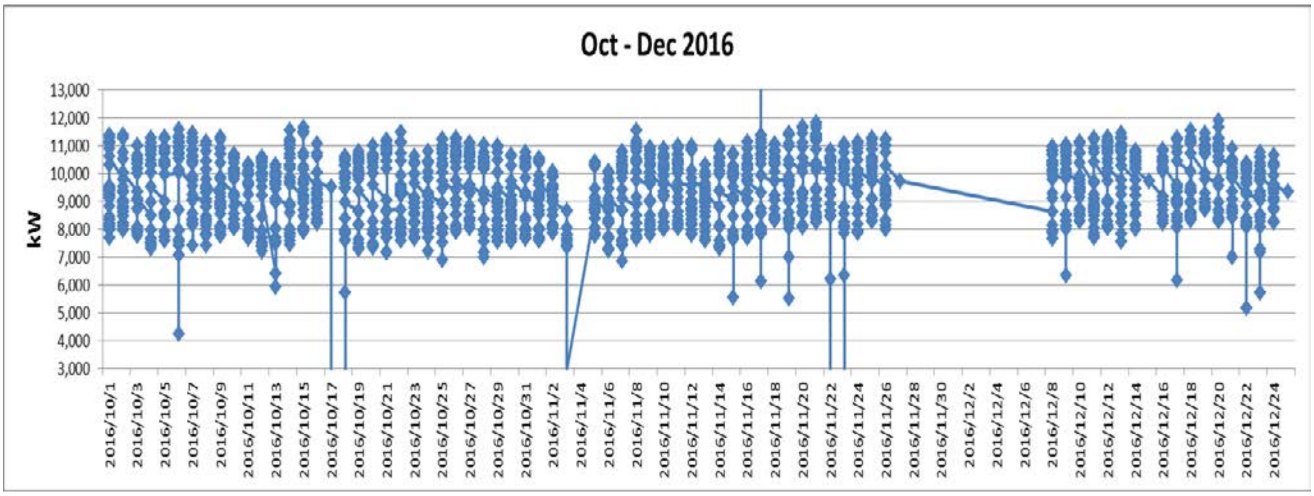
Source: PPUC

Figure 3-1-1-4.4 Hourly load data from April to June in 2016



Source: PPUC

Figure 3-1-1-4.5 Hourly load data from July to September in 2016



Source: PPUC

Figure 3-1-1-4.6 Hourly load data from October to December in 2016

3-1-1-5 Number of Customers

Table 3-1-1-5.1 shows the numbers of customers by sector in each state. The data on customers by sector from 2000 to 2005 are the actual values, while those from 2010 to 2016 are estimated values based on state-wise consumption and sectoral customers throughout the country.

Table 3-1-1-5.1 State customers by sector

Unit: customers

State	Sector	2000	2005	2010	2011	2012	2013	2014	2015	2016	2016/11
Aimeliik	Commercial	6	8	7	7	7	7	7	7	8	2.0
	Public use	16	21	26	24	25	27	28	26	30	2.6
	Residential	67	95	106	106	113	120	127	123	140	5.6
	Total	89	124	140	137	145	154	162	156	177	4.9
Airiai	Commercial	64	73	68	69	67	67	65	63	65	-1.1
	Public use	38	38	39	38	37	37	36	37	38	-0.5
	Residential	406	578	637	659	664	668	668	679	718	2.4
	Total	508	689	744	766	768	773	770	779	821	2.0
Koror	Commercial	506	692	648	629	617	621	607	590	573	-2.4
	Public use	254	314	298	276	273	276	274	274	271	-1.8
	Residential	2,854	3,208	3,632	3,630	3,675	3,716	3,765	3,809	3,833	1.1
	Total	3,614	4,214	4,577	4,535	4,565	4,612	4,646	4,673	4,678	0.4
Melekeok	Commercial	5	12	13	14	14	13	13	12	12	-1.5
	Public use	10	15	13	12	12	12	12	12	12	-0.9
	Residential	70	100	111	119	120	114	117	119	122	2.1
	Total	85	127	136	145	146	139	142	143	147	1.5
Ngaraard	Commercial	3	5	3	3	3	3	3	3	2	-4.5
	Public use	13	20	23	22	21	22	20	20	19	-3.9
	Residential	99	127	172	177	174	185	172	171	163	-1.1
	Total	115	152	198	201	197	210	195	193	184	-1.4
Ngarchelong	Commercial	1	1	1	1	1	1	1	1	1	1.3
	Public use	12	16	17	16	17	18	18	18	18	1.8
	Residential	78	105	124	129	137	144	153	152	157	4.9
	Total	91	122	141	146	155	163	172	171	176	4.5
Ngardmau	Commercial	1	3	3	3	3	3	3	3	3	0.0
	Public use	6	4	6	6	6	6	6	6	6	0.6
	Residential	46	56	68	71	76	74	78	75	81	3.6
	Total	53	63	77	79	85	83	88	84	90	3.2
Ngaremlengui	Commercial	3	7	5	5	6	6	6	6	5	0.0
	Public use	15	21	18	18	18	19	20	20	19	0.6
	Residential	69	89	97	102	107	108	118	119	115	3.6
	Total	87	117	120	125	130	132	144	145	139	3.0
Ngatpang	Commercial	5	5	4	4	5	4	4	4	4	-1.7
	Public use	22	21	24	24	25	24	24	23	23	-1.1
	Residential	44	55	67	71	76	72	76	73	74	1.8
	Total	71	81	96	99	106	100	105	101	100	1.0
Ngchesar	Commercial	0	0	1	1	1	1	1	1	1	-1.3
	Public use	11	16	9	9	9	10	10	9	9	-0.7
	Residential	76	85	75	80	79	87	89	88	84	2.2
	Total	87	101	86	90	89	98	100	99	94	1.9
Ngiwal	Commercial	3	3	3	2	2	3	2	2	2	-3.5
	Public use	8	14	12	11	11	12	10	11	10	-3.0
	Residential	57	69	86	85	87	91	80	85	86	-0.1
	Total	68	86	101	99	100	105	92	98	99	-0.5
Total	Commercial	597	809	756	739	725	729	713	692	677	-2.2
	Public use	405	500	485	456	454	461	458	457	456	-1.2
	Residential	3,866	4,567	5,175	5,228	5,307	5,380	5,443	5,493	5,573	1.5
	Total	4,868	5,876	6,417	6,424	6,486	6,569	6,614	6,642	6,706	0.9

Source: Study team estimation based on actual data of PPUC as of September 2017

3-1-1-6 Power Tariff

The power tariffs from 2007 to 2017 are shown in Table 3-1-1-6.1. The power tariffs after 2015 decrease due to the drop in crude oil prices. Table 3-1-1-6.2 gives the category names for the abbreviations used in Table 3-1-1-6.1.

Table 3-1-1-6.1 Power tariff table

Unit：US$/kWh

	Residential			Commercial			Government		
abbreviation	RA	RB	RC	CA	CB	CC	GA	GB	GC
2007	0.30	0.34	0.38	0.34	0.34	0.38	0.34	0.34	0.38
2008	0.33	0.41	0.45	0.45	0.45	0.45	0.45	0.45	0.45
2009	0.21	0.29	0.33	0.33	0.33	0.33	0.33	0.33	0.33
2010	0.22	0.33	0.34	0.38	0.38	0.38	0.38	0.38	0.38
2011	0.27	0.35	0.40	0.40	0.40	0.40	0.40	0.40	0.40
2012	0.28	0.35	0.40	0.42	0.42	0.42	0.42	0.42	0.42
2013	0.28	0.36	0.41	0.44	0.44	0.44	0.44	0.44	0.44
2014	0.32	0.39	0.44	0.43	0.43	0.41	0.43	0.43	0.41
2015	0.15	0.23	0.27	0.27	0.26	0.25	0.27	0.26	0.25
2016	0.18	0.25	0.30	0.31	0.30	0.29	0.31	0.30	0.29
2017	0.17	0.25	0.30	0.33	0.32	0.31	0.33	0.32	0.31

Note: The abbreviations in the table are explained in the following table.
Source: Study team estimation based on actual data of PPUC as of September 2017

Table 3-1-1-6.2 Abbreviations used for power tariff categories

	Tariff category before 2011	Tariff category after 2012	Abbreviation
Residential	0 – 500 kWh	0-150 k Wh	RA
	501 – 2000 kWh	151-500 k Wh	RB
	2000 kWh over	500 k Wh+	RC
Commercial	0-150,000 kWh		CA
	150,001-250,000 kWh	Same as before 2011	CB
	250,001 kWh over		CC
Government	0-150,000 kWh		GA
	150,001-250,000 kWh	Same as before 2011	GB
	250,001 kWh over		GC

Source: Study Team

3-1-1-7 Evaluation of Power Demand and Supply

Evaluations of the power demand and supply activities before 2016 are shown in Table 3-1-1-7.1.

Table 3-1-1-7.1 Evaluation of power demand and supply activities

Factors	CONTENTS
Trends of Demand and Supply	The sectoral power demand of the Commercial and Residential sectors has increased since 2013. The T/D loss rates (T/D loss divided by Send out) decreased drastically after 2012. Power consumption by water and wastewater pumps is set to decrease in line with the progress of the programs for improvement.
WWO target for reduction of the un-billed rate	Through the “Koror Airai Water Improvement Project (KAWIP)” and higher maintenance technologies acquired from the “Leak Detection Program,” the un-billed rate expected to decreased from 44 % in 2013 to 20 % after 2018.
Generation and Send out	The fire in Aimeliik in 2011 led to decreased PPUC power generation in 2012 and 2013. PPUC, however, has installed 4 tentative power generators (each 500 kW) in Malakal, which has increased generation since 2014. At present, the generation level has reached that before the financial crisis of 2008. PPUC will generate power in both the Aimeliik and Malakal power stations in the future.
Load data	The peak load of Palau is from 8 pm to 10 pm. Battery, PV, hydel, flywheel systems, etc. are therefore required when introducing a PV system linked to the grid.
Customer trends	The customer growth rate from 2011 to 2016 was 0.9 % per year, or almost the same as the population growth rate. This explains why the electrification of Palau is nearing 100% and why the fire at the Aimeliik power generators broke out in 2011.
Power tariffs	While the power tariffs of Palau are linked to international oil products prices, the future oil products prices are not expected to increase sharply. In 2008, the power tariff of the Residential sector (First category) was 0.33 US$/kWh. Thereafter, however, it decreased to 0.17 US$/kWh due to the reduction of the crude oil price.

Source: Study Team

3-1-2 Trends of Donors

The selection conditions for the projects implemented in Palau by worldwide donors are as follows:

Condition 1: The selected target period is from 2007 to 2017 (10-year span).

Condition 2: The targeted projects are in the energy sector (Oil and RE) and power sector.

Condition 3: The contact organizations for collecting information are as follows.

a) Energy Administration
b) Finance Division of PPUC
c) Renewable Energy Division of PPUC
d) JICA homepage

The projects implemented by donors in Palau are shown in Table 3-1-2.1, Table 3-1-2.2, Table 3-1-2.3, Table 3-1-2.4, and Table 3-1-2.5.

(1) Taiwan

Table 3-1-2.1 List of projects conducted by Taiwan

Year	Description	Funding US$	Location	Donor	Completed /Ongoing
2010	Portable solar light bar @ 3900 units	100,000	Distributed by MOE to numerous elementary schools	Taiwan grant assistance	Completed
2011	Heavy duty 30 W LED Solar street lights @ 20 units 6.6 KW solar PV systems with film-style solar panels	100,000	1 Downtown Koror 2 Palau Energy Office Ikoranges, Airai State	Taiwan grant assistance	Completed
2012	12,430 W solar power on grid system 15,180 W solar power on grid system Solar street lights @ 5 units	200,000	1 Palau High School 2 Palau National Aquaculture center 3 Ngarchelong State	Taiwan grant assistance	Completed
2013	40 KW solar power Generating system	268,800	Koror Elementary School	Taiwan grant assistance	Completed
2014	16.5 KW PV power system	198,900	Palau National Swimming pool	Taiwan grant assistance	Completed
2017	National Hospital, additional support for solar energy, an energy-efficient system, 1 extra generator for low peak usage	1.2 million	Ministry of Health (MOH)	Taiwan	Ongoing
	Total	867,700			

(2) EU - European Union

Table 3-1-2.2 List of projects conducted by EU

Year	Description	Funding US$	Location	Donor	Completed /Ongoing
2012	Service contract - Energy Efficiency and retrofitting of the BPW bld. of Palau	9,800	Koror	EU (SPC / NORTH REP)	Completed
2012	Energy Efficiency retrofitting of BPW / construction works	63,829	Country	EU (SPC / NORTH REP)	Completed
2012	RE framework development and tariff study for PPUC	36,950	Country	EU (SPC / NORTH REP)	Completed
2012	Wind monitoring equipment	75,661	Country	EU (SPC / NORTH REP)	Completed
2013	Grid-tied solar PV design, installation, maintenance and troubleshooting course for PCC	40,470	Country	EU (SPC / NORTH REP)	Ongoing
2013	Policy review and drafting of the Palau Energy bill	43,000	Country	EU (SPC / NORTH REP)	Completed
2014	PCC Track & Field	292,158	Koror	EU (SPC / NORTH REP)	Completed
2014	400 prepayment meters	118,301	PPUC	EU (SPC / NORTH REP)	Completed
2015	1,613 LED street lights	589,848	PPUC	EU (SPC / NORTH REP)	Completed
2015	Project Officer compensation	14,700	Country	EU (SPC / NORTH REP)	Completed
	Total	1,284,717			

(3) ADB, USA and UNDP

Table 3-1-2.3 List of Projects conducted by ADB, USA, and UNDP

Year	Description	Funding US$	Location	Donor	Completed /Ongoing
2013	Solar PV powered well water pump system	0.3 million	Kayangel State	UNDP / SPREP / PIGGAREP sponsored grants	Completed
2013-2022	Sanitation project	27 million	Koror and Airai sewer project	ADB loan	Ongoing
2010-2024	COMPACT agreement for Palau support	5.5 million/year		USA	Ongoing
2013-Conti nue	Economy Review Report		Annual economic report in Palau	DOI ,USA	Ongoing
2017	ADB to finance a series of clean energy projects (Japan Pacific Environment Community Fund)	200 million	11 of the smallest island nations of the Pacific	ADB	Ongoing

(4) Others

Table 3-1-2.4 List of Projects conducted by other donors

Year	Description	Funding US$	Location	Donor	Completed /Ongoing
2016	200 kWp Solar PV Angaur and Peleliu Water Treatment Plant for Angaur 100 X 1.7 kWp Solar PV	5 million	Angaur and Peleliu	UAE	Finish
2016	Development of the National Energy Roadmap	??	Palau Energy Admin	IRENA	Completed
2017	4 stand-alone solar light systems (1.8 kW)	2000	Ngchesar State	Private donation	Completed
2017	Development of a national energy efficiency standard	??	Palau Energy Admin	NREL	Ongoing

(5) Japan

Table 3-1-2.5 List of Projects conducted by Japan

Year	Description	Funding US$	Location	Donor	Completed /Ongoing
2008	Power sector improvement master plan for the Republic of Palau.	0.6 million	Palau	JICA-ODA	Completed
2011	Peleliu State solar powered desalination plant	3.9 million	Peleliu State	Japan Pacific Environment Community Fund (PEC)	Completed
2011	200 kW solar system (WCTC)	JCM	WCTC outlets ACE Hardware, Desekell Mall, West Central warehouse	Japan Joint Crediting Mechanism (JCM) projects	Completed
2011	SDA (Seventh-day Adventist) Elementary School (250 kW)	JCM	Koror	Japan Joint Crediting Mechanism (JCM) projects	Completed
2011	The Project for Upgrading the Electric Power Supply in the Republic of Palau	15.7 million	Aimeliik state	JICA-ODA	Completed
2012	The Project for the Introduction of Clean Energy from Solar Generation Systems	4.4 million	Airai International airport	JICA-ODA	Completed
2012	Surangel and Sons company (250 kW)	JCM	Main Surangel Dept store bld.	Japan Joint Crediting Mechanism (JCM) projects	Completed
2017	Proposed new project to improve (Peleliu State water plant)	1.3 million	Peleliu State	JICA-ODA	Going
	Total	25.9 million			

CHAPTER 4 Power Demand Forecasts

Chapter 4 Power Demand Forecasts

4-1 Review of Existing Power Demand Forecasts

4-1-1 Power Demand in the Power Supply Improvement Master Plan 2008

The preconditions and the power demands described in the “Power Supply Improvement Master Plan 2008” are summarized below.

4-1-1-1 Main social and economic outlooks

The population estimate for Palau in 2025 is based on the 2000 population census. The population is forecasted to increase by 19.4% from 19,100 in 2000 to 22,800 in 2025 (not the annual average growth rate). The annual population growth rate was 1.9% from 2000 to 2001 and is expected to drop to 0.3% from 2024 to 2025. The population estimates are based on these growth rates (see Table 4-1-1-1.1).

Table 4-1-1-1.1 Population estimates up to 2025

Unit: Person

FY	1995	2000	2005	2010	2015	2020	2025
Population	17,300	19,100	21,400	21,900	22,400	22,600	22,800

Source: Power Supply Improvement Master Plan 2008

Regarding economic growth, the IMF (International Monetary Fund) simulated three scenarios for the Palau economy in its Article-IV Consultation Staff Report published in 2005: the COMPACT Finish scenario, COMPACT Continue scenario, and COMPACT Increase scenario. Table 4-1-1-1.2 shows the GDP growth rates by scenario.

Table 4-1-1-1.2 GDP annual growth rates by scenario

Case	Scenario	Actual	Estimated	Forecast		
		2005	2010	2015	2020	2024
Low Case	COMPACT Finish	8.4%	7.1%	3.9%	0.6%	-2.0%
Base Case	COMPACT Continue	8.4%	7.1%	4.8%	2.4%	0.5%
High Case	COMPACT Increase	8.4%	7.1%	5.8%	4.4%	3.3%

Source: Power Supply Improvement Master Plan 2008

4-1-1-2 Review of related polices in Palau

(1) Regional Development Plan of Palau (conducted by JICA, October 2000)

The policy under this Regional Development Plan moved Palau in the same direction as PNMDP2020 (Palau National Master Development Plan) enacted in 1996. The policy advanced a long-term strategy for Palauan private industries, mainly up to 2020.

(2) Public Sector Development Plan 2003-2007

The Palau government formulated the “Palau Sector Investment Program (PSIP)” in April 2003. The program set out a development plan for the 5 years from 2003 to 2007. The development plan defined the strategic sectors of Palau as Tourism, Agriculture, Fishery, Foreign Trade, and Light Industry. PSIP described detailed infrastructure plans focused on transportation, drinking water, wastewater treatment, waste products, energy, and communication to promote these sectors.

(3) Future large power consumers

Power consumption and the large power consumers in the future were estimated based on information from the Foreign Investment Board, Tax Office, State Governments (mainly the Koror government) and Office of Planning and Statistics of MOF.

(4) Large power consumers as auto-producers

PPR (Palau Pacific Resort Hotel) was the only self generator operating independently from the PPUC grid system in Palau. The PPR generator had a peak supply of 800 kW, so the power demand of PPUC was expected to rapidly increase if PPR connected to the PPUC grid. In the master plan, PPR was included as a PPUC consumer in the PPUC demand statistics from after 2009.

(5) Energy Efficiency Action Plan

The Palau government planned to enact its Energy Efficiency Action Plan as of 2008. The government expected to promote energy efficiency and conservation activities in Palau through the plan. Fourteen projects were proposed in the draft report edition of November 2007. According to the government, the government sector was to be the first to begin implementing the plan. After that, the activities were to be expanded to commercial and residential sectors. Power efficiency was expected to improve by 1.5% per year, as of 2008. If the power consumed by water and wastewater pumps decreased from 32%, the Public Sector level as of 2007, the effect of Energy Efficiency Action Plan was expected to be amplified.

(6) Demand survey

The power demand by sector (Commercial, Public and Residential), power tariff system, daily load curve, and sensitive factors related to the same are surveyed under the master plan.

(7) Power tariff system

The power tariff has increased since the introduction of the fuel-cost-adjusted law. The increase will continue in line with high crude oil prices. The PPUC power tariff was expected to be increased gradually to rebalance the finances of PPUC. The power consumption per capita was accordingly predicted to decrease through the effects of the increased tariff and PPUC's power-saving campaign.

(8) Target for load improvement

As of the years of 2007 and 2008, the load factor rate was 73% - 74%. The methods used to suppress the peak demand and reduce power consumption were important.

(9) Transmission and Distribution loss (T/D loss)

When T/D loss is defined by the formula "Power generation – Power sales," the future T/ D loss rate for forecasting power generation was set at 20.8%, the average value of the past 5 years.

4-1-1-3 Results of power demand forecasts

The following table shows the forecast results under the three cases separated by COMPACT support based on the above preconditions.

Table 4-1-1-3.1 Power demand in the power sector improvement master plan 2008

Case	Base		Low		High	
	Generation	Peak	Generation	Peak	Generation	Peak
Unit	MWh	MW	MWh	MW	MWh	MW
2008	104,200	16.3	104,200	16.3	104,200	16.3
2009	113,400	17.7	113,400	17.7	113,400	17.7
2010	121,300	18.9	121,300	18.9	121,300	18.9
2011	123,900	19.4	123,900	19.3	124,000	19.4
2012	127,000	19.8	126,800	19.8	127,300	19.9
2013	129,300	20.2	128,800	20.1	130,000	20.3
2014	132,800	20.7	131,700	20.6	133,900	20.9
2015	136,200	21.3	134,600	21.0	138,100	21.6
2016	139,400	21.8	137,000	21.4	142,200	22.2
2017	142,400	22.2	139,000	21.7	146,400	22.9
2018	145,100	22.7	140,600	22.0	150,500	23.5
2019	148,100	23.1	142,200	22.2	155,100	24.2
2020	150,200	23.5	142,900	22.3	159,000	24.8
2021	151,900	23.7	143,000	22.3	162,900	25.4
2022	153,300	23.9	142,600	22.3	166,700	26.0
2023	154,200	24.1	141,700	22.1	170,300	26.6
2024	154,800	24.2	140,300	21.9	173,800	27.1
2025	154,900	24.2	138,500	21.6	176,900	27.6
2025/10	1.6%	1.6%	0.9%	0.9%	2.5%	2.5%

Source: Power Sector Improvement Master Plan 2008

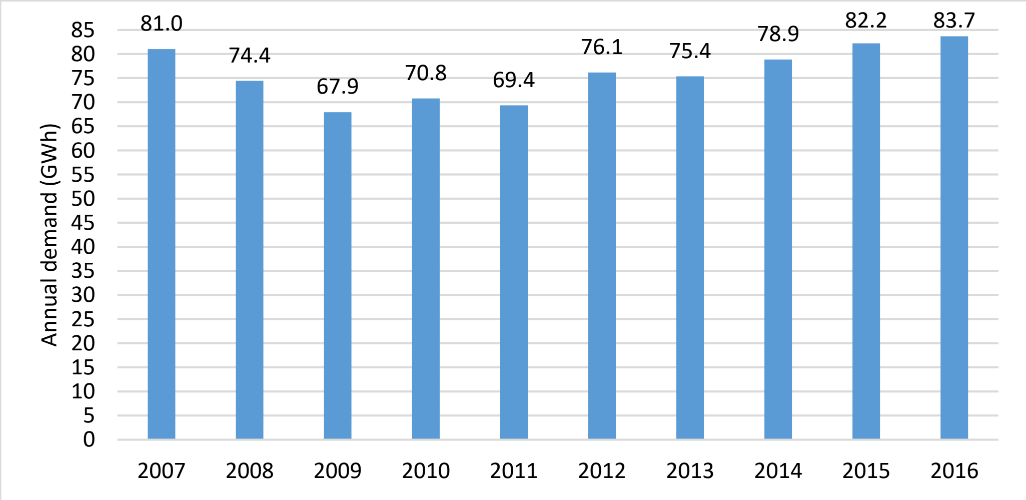
4-1-2 Power Demand in the Palau Energy Roadmap 2017

4-1-2-1 Purposes of the roadmap

The roadmap is plotted out to achieve the Palau Energy Policy and INDCs (Intended Nationally Determined Contributions) of COP21 in cooperation with IRENA (International Renewable Energy Agency). The roadmap proposes the least-cost forms of power generation while meeting the preconditions set for the use of renewable energies. Concretely, renewable energies are to supply a targeted 45% of the total energy consumption in Palau by 2025. Palau has abundant renewable energy resources such as Solar, Wind, and Bio.

4-1-2-2 Power demand forecasts

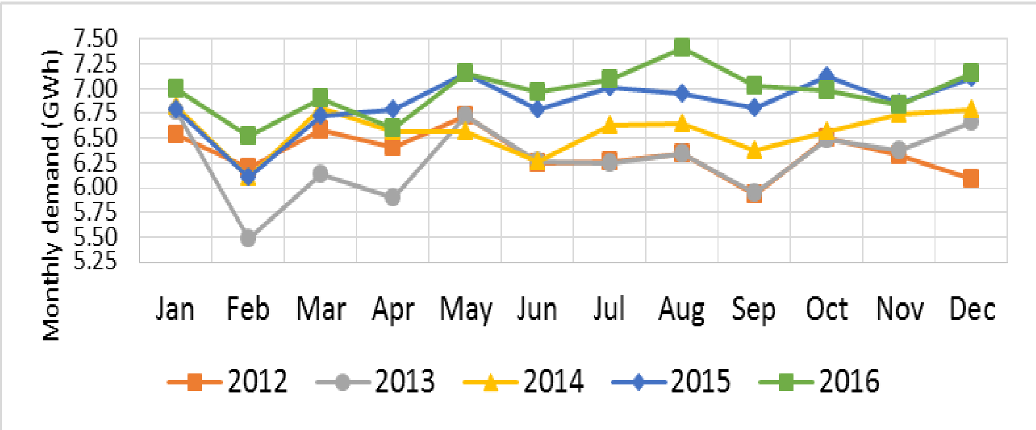
Palau's population is concentrated in Koror, so most of the power demand is in Koror state. Figure 4-1-2-2.1 shows the power demand of the PPUC grid system from 2007 to 2016. The power consumption in 2016 reached 83.7 GWh, exceeding the power demand before the financial crisis of 2008 (81.0 GWh in 2007).



Source: PPUC

Figure 4-1-2-2.1 Power consumption in Koror and Babeldaob

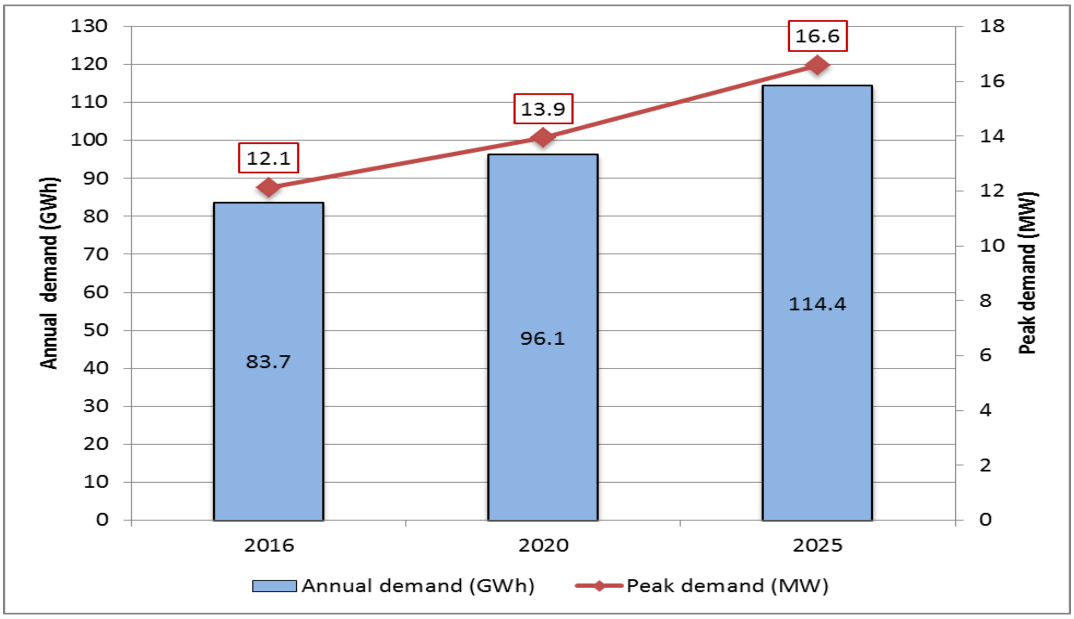
Figure 4-1-2-2.2 plots the monthly power supply curves from 2012 to 2016. The power supply in 2012 and 2013 decreased due to the loss of two power generators in the fire in Aimeliik state. Palau also weathered a long drought emergency in 2016, which had negative impacts on the Tourism sector.



Source: PPUC

Figure 4-1-2-2.2 Monthly power demand (GWh)

In the power demand forecasting under the Palau Energy Roadmap, the actual average growth rate from 2009 to 2016 is applied as the future growth rate in 2020 and 2025 (3.5% growth per year). The power demand (GWh) and peak demand (MW) are shown in Figure 4-1-2-2.3.



Source: Palau Energy Roadmap

Figure 4-1-2-2.3 Power demand (GWh) and peak demand (MW)

4-1-3 Evaluation of the Existing Power Demand Forecasts

The peak demand in 2016 under the Power Sector Improvement Master Plan 2008 was set at 21.8 MW, whereas the actual peak demand hat year was 12.5 MW. The following factors explain why no increase in the power demand was seen from 2007 to 2016.

a) The global financial crisis of 2008

b) Higher prices for crude oil and petroleum products from 2010 to 2014

c) The power generator fire in Aimeliik in 2011

d) Decreased tourism due to the long drought emergency in 2016

The failure in the peak demand forecast is understandable, given that none of the above four factors could have been predicted in advance by any methodologies.

The Palau Energy Roadmap 2017 forecasts the power demand from 2017 to 2025 based on a time series analysis that applies the growth rate in power consumption in the past five years to the future 8 years. The method used is not persuasive.

An auto correlation method is sometimes used for power demand forecasts over a time frame of 3 to 5 years. Population and GDP factors should also be considered, however, for middle- and long-term power demand forecasts. (IRENA forecasts 8 years forward)

4-2 Methodology for Power Demand Forecasts

4-2-1 Required Functions of Power Demand Forecasts

The trends in past power consumption and the current situation should be analyzed for forecasting the future power demand of Palau. The structural factors under the power demand forecasts should also be identified. If the power demand can be assumed to reflect trends in social and economic activities, the structures of power demand model should be designed to meet following conditions.

- Social and economic changes should be linked to the model.
- The impact of power tariff changes should be considered in the model.
- Functions to analyze sectoral power demand should be established in the model.
- Power demand forecast functions by state should be built into the model.
- A function to compare power demand internationally should be available in the model.

4-2-2 Structure of the Power Demand Forecasting Model

First, the power demand forecasting model requires functions to forecast the sector-wise power demand. After that, the peak demand and power generation are calculated and the state-wise power demand is forecasted. The flow chart in Figure 4-2-2.1 below plots the flow of the power demand model.

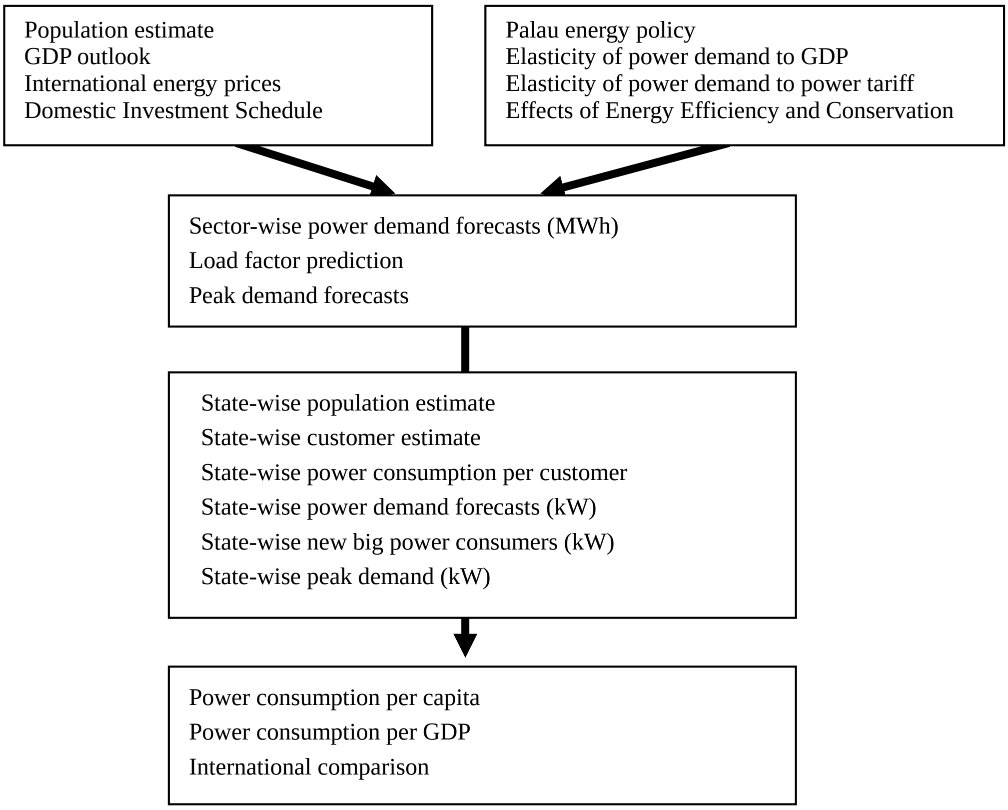


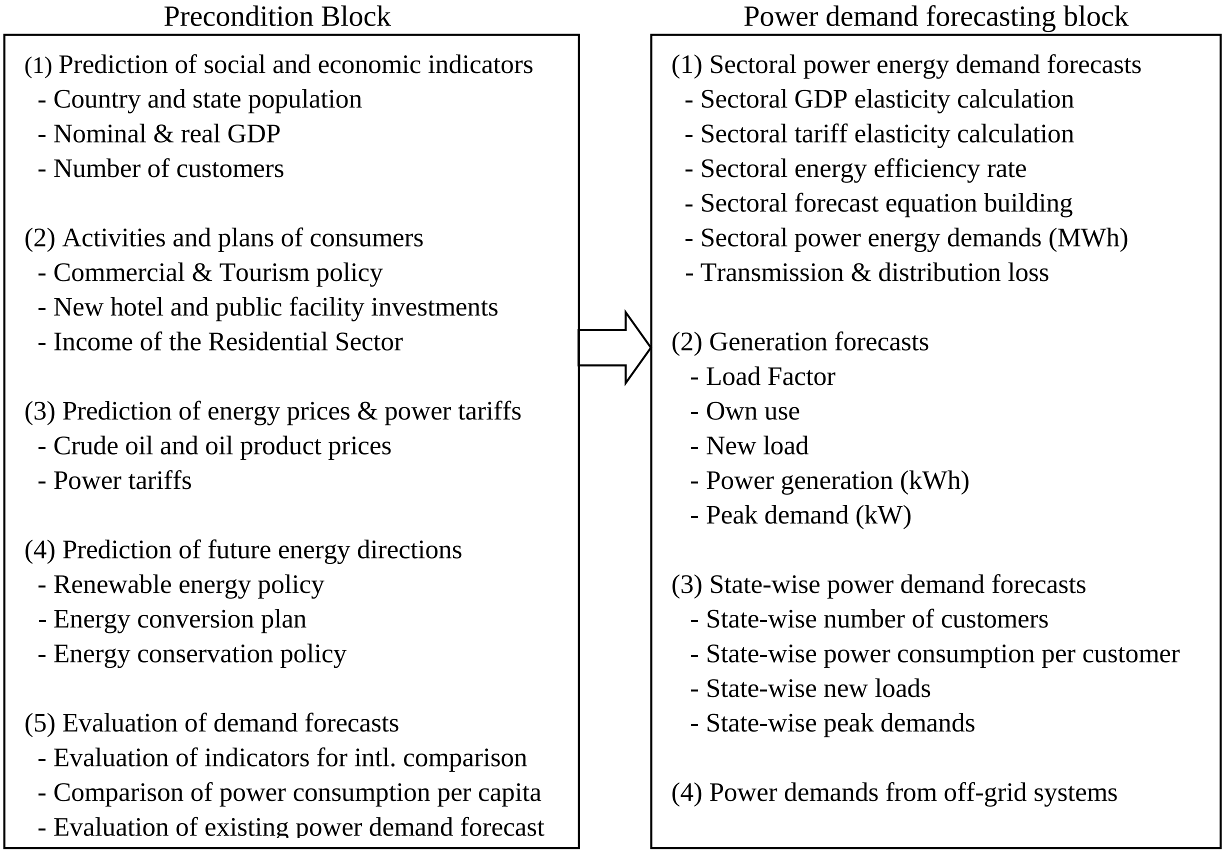
Figure 4-2-2.1 Power demand forecast flow

The power demand model is built up in line with the previous flow (Figure 4-2-2-2.1). The following are technical procedures.

- Future social and economic activities are decided after discussing the existing social and economic strategies and power development plans and policies with counterparts.
- An econometric method is applied to build the model using Simple.E, an MS-EXCEL add-in

application.

- The structural flow of the power demand forecasting model is shown in Figure 4-2-2-2.2 just below. The “Precondition Block” includes social and economic strategies and plans, energy prices, power tariffs, target indicators for power development plans, and so on. The “Power Demand Forecasting Block” includes sectoral power demand forecasts, power supply forecasts, and regional power demand forecasts.



Note: Selected sectors are Commercial, Public, Residential, and Transmission / Distribution loss

Figure 4-2-2.2 Block flow for the power demand forecasting model

4-2-3 Power Demand Forecasting Equations

The calculated power consumer sectors are Commercial, Public, Residential, and T/D loss. The country-wide power demand is calculated by summing up the above sectoral demands. The forecasting procedures are as follows:

4-2-3-1 Calculating elasticities

The elasticities between GDP and sectoral power demands are estimated using past data. The long-term elasticities are calculated using data from 2000 to 2016. The short-term elasticities are calculated using data from 2010 to 2016. The elasticities for power demand forecasting equations are decided after analyzing the above two elasticities. The forecasting equation formations are as follows:

- Commercial and Public sectors

  Ln (Sectoral power demand) = a*Ln (Sectoral GDP) - b*Ln (sectoral tariff) + c

- Residential sector

  Ln (Residential power demand) = a*Ln (Income per capita) - b*Ln (Residential tariff) + c

In the above equations, “Ln” is the natural logarithm, “a” is GDP elasticity, and “b” is tariff elasticity.

4-2-3-2 Setting the forecasting equations

The power demands for the Commercial, Public, and Residential sectors are forecasted by using the above elasticities after evaluating them. The power demand equations are as follows:

[Forecasting equation for the Commercial and Public sectors]

Yt: Power demand of the sectors (t year MWh)

a: Elasticities to sectoral GDP b: Elasticities to tariffs

Energy Efficiency & Conservation rate (EE&C rate): Effects of EE&C activities are defined by “Power energy savings / Power energy demand.”

$$Y_t = Y_{t-1} * (1 + a * \text{Sectoral GDP growth rate}) * (1 - b * \text{Tariff growth rate}) * (1 - \text{EE\&C rate}/100)$$

[Forecasting equation for the Residential sector]

Y_t: Power demand of the sector (t year MWh)

a: Elasticity to income per capita b: Elasticity to Tariff

Energy Efficiency & Conservation rate (EE&C rate): the same as that for Productive sectors

Electrification rate growth rate: Electrification rate (t) / Electrification rate (t - 1) (unit%)

$$Y_t = Y_{t-1} * (1 + a * \text{Income per capita growth rate}) * (1 - b * \text{Tariff growth rate}) * (1 - \text{EE\&C rate}/100)$$

4-3 Preconditions and Outlook for Power Demand Forecasts

4-3-1 Population Outlook

The future population growth rates of Palau are shown in Table 4-3-1.1. The population growth rate estimates are based on the 2015 census by Ministry of Finance, Palau. The following population includes foreign workers. The population is the main factor used to decide the number of customers and Residential power demand.

Table 4-3-1.1 Population outlook by MOF

	MOF outlook person	Growth rate %
2015	17,661	1.6
2016	17,714	0.3
2017	17,767	0.3
2018	17,820	0.3
2019	17,873	0.3
2020	17,927	0.3
2021	17,981	0.3
2022	18,034	0.3
2023	18,088	0.3
2024	18,142	0.3
2025	18,197	0.3
2026	18,251	0.3
2027	18,306	0.3
2028	18,361	0.3
2029	18,416	0.3
2030	18,471	0.3
2035	18,750	0.3
2040	19,030	0.3
2030/15	0.3%	

Note: The rates of the previous years are applied as the annual growth rates from 2031 onward
Source: Ministry of Finance, Palau

The state-wise population is calculated using the procedures shown Table 4-3-1.2, setting the country population growth rates as a precondition. At first, the initial elasticities between the country growth rate and state growth rate are calculated using the past data. The state population is estimated from the initial elasticity. The initial elasticity, however, changes year by year.

a) When the initial elasticity is larger than 1.0, the future elasticity gradually decreases to 1.0 year by year.

b) When the initial elasticity is smaller than 1.0, the future elasticity gradually increases to 1.0 year by year.

c) When state investments for new hotels and public facilities are expected, the initial elasticity increases from the starting year of the investments.

Table 4-3-1.2 Population forecasts by state

Unit: Person

	2005	2010	2015	2020	2025	2030	2035	2040
Aimeliik	270	275	334	337	341	344	348	351
Airai	2,723	2,463	2,455	2,528	2,602	2,681	2,761	2,844
Koror	12,776	12,061	11,754	11,907	12,057	12,201	12,345	12,489
Melekeok	391	396	277	281	287	294	303	312
Ngaraard	581	499	413	419	426	434	442	449
Ngardmau	166	165	185	187	189	191	193	195
Ngaremlengui	317	300	350	353	357	361	364	368
Ngatpang	464	302	282	285	288	291	294	297
Ngchesar	254	266	291	295	302	309	318	328
Ngarchelong	488	435	316	321	326	332	338	344
Ngiwal	223	234	282	285	288	291	294	297
Koror+Babeldaob	18,653	17,396	16,939	17,198	17,461	17,727	17,998	18,273
Others	1,175	892	722	729	736	744	752	759
Total	19,828	18,288	17,661	17,927	18,197	18,471	18,750	19,033

Note: “Others” include Angaur, Hatohobei, Kayangei, and Peleliu.
Source: Study team

4-3-2 GDP Outlook

In the GDP outlook forecast by MOF shown in Table 4-3-2.1, the GDP growth rate after 2022 is around 1% per year due to termination of COMPACT support. The GDP growth rates almost match those in the “Conservative scenario” in Economic Review 2017 published by Department of Interior USA (DOI, USA), largely because MOF uses the same econometric model as DOI. When the preconditions of MOF match those of DOI, the GDP growth rate estimates are almost the same. In the “Rebound scenario” presented in Economic Review 2017 alongside the “Conservation scenario,” the GDP growth rates increase by 2% per year after 2022. The realization of the “Rebound scenario” can be expected to increase due to the promotion of IoT industry and a large influx of Chinese tourists in the future. The Study Team therefore sets the GDP growth rates higher than the MOF forecasts in consideration of the Rebound scenario from DOI.

Table 4-3-2.1 GDP growth rate outlook

Unit:%

Year	MOF Outlook	Study Team Outlook	Year	MOF Outlook	Study Team Outlook
2016	0.5	0.5	2024	0.9	2.0
2017	-0.5	1.0	2025	1.3	2.0
2018	3.0	4.0	2026	1.9	2.0
2019	4.8	4.0	2027	1.4	2.0
2020	5.2	4.0	2028	1.5	2.0
2021	3.0	3.0	2029	1.5	2.0
2022	0.1	2.0	2030	1.5	2.0
2023	1.1	2.0	2040/30		2.0

Note: The “MOF outlook” is the outlook from the Ministry of Finance, Palau.
Source: MOF and the Study Team

The contents of the COMPACT agreement between Palau and USA governments in 2010 are shown in Table 4-3-2.2 below as supplementary information.

Table 4-3-2.2 COMPACT agreement between Palau and USA in 2010

Unit: million USD

	1	2	3	4	5	Total
	Trust fund *1	maintenance of Infra *2	Maintenance COMPACT road *3	Fund for non-repayment in the past *4	Direct assistance from USA	
FY2010					13.25	13.25
FY2011		2.00		5.00	21.00	28.00
FY2012		2.00		5.00	20.75	27.75
FY2013	3.00	2.00			20.50	25.50
FY2014	3.00	2.00			18.00	23.00
FY2015	3.00	2.00			16.50	21.50
FY2016	3.00	2.00			15.00	20.00
FY2017	3.00	2.00			8.50	13.50
FY2018	3.00	2.00			7.25	12.25
FY2019	3.00	2.00			6.00	11.00
FY2020	3.00	2.00			5.00	10.00
FY2021	3.00	2.00			4.00	9.00
FY2022	3.00	2.00			3.00	8.00
FY2023	0.25	2.00			2.00	4.25
FY2024		2.00				2.00
Total	30.25	28.00	3.00	10.00	160.75	232.00

*1 A trust fund of 70 million USD was provided by the USA government from 1994 to 2009. The subsequent finance comes from the performance of the trust fund.

*2 The finance is applied to the maintenance of infrastructure established by the United States. The Palau government also prepares 0.6 million USD.

*3 The payment years are unclear.

*4 The fund is prepared for an unpaid fund provided by the USA to Palau in the past year.

Source: General Incorporated Association "Kasumigasekikai," an interested organization of the Ministry of Foreign Affairs, Japan.

4-3-3 Crude Oil Price Prediction

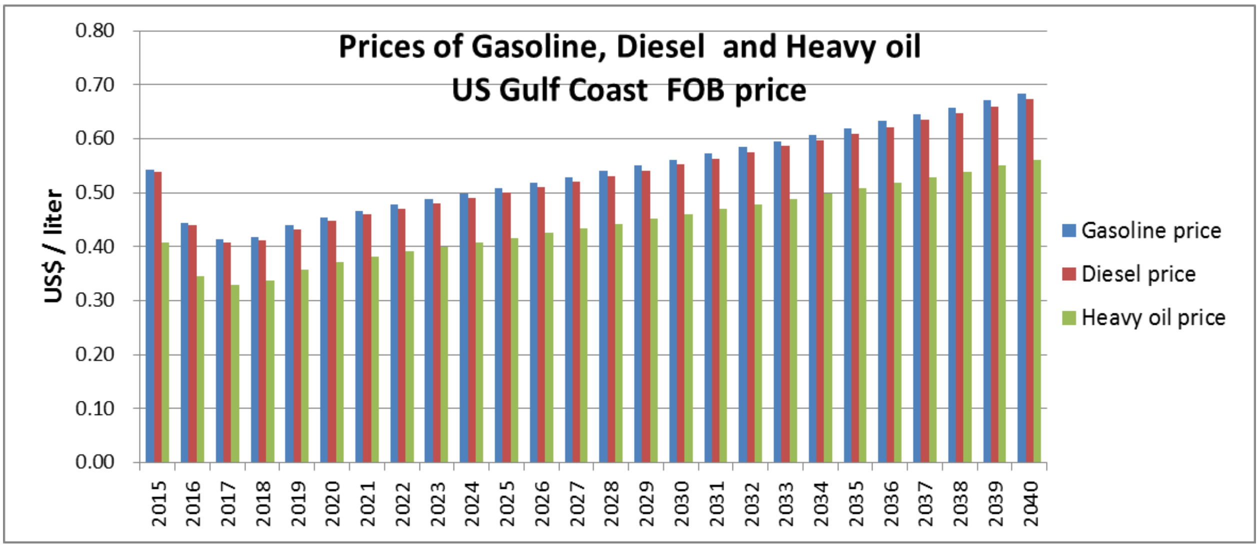
As of April 2018, the WTI (West Texas Intermediate) in the New York market ranged from \$55/bbl to \$65/bbl. Crude oil exporting countries like Saudi Arabia expect to increase crude oil prices to compensate for the benefits from the US dollar devaluation. When inflation in the USA increases 2% per year, the crude oil price increases 2% per year in the future. When looking at the recent energy market, including factors such as shale oil & gas supply and vehicle fuel regulation in the EU, the future crude oil price is not forecast to increase by the level estimated in the International Energy Agency (IEA) outlook. The assumed WTI price shown in Table 4-3-3.1 is based on the above factors in the international oil market.

Table 4-3-3.1 West Texas Intermediate (WTI) price forecasts

Year	US$/bbl.	%
2015	50	
2016	45	-10.0
2017	50	11.1
2018	55	10.0
2019	60	9.1
2020	61	2.0
2021	62	2.0
2022	64	2.0
2023	65	2.0
2024	66	2.0
2025	68	2.0
2026	69	2.0
2027	70	2.0
2028	72	
2029	73	2.0
2030	75	2.0
2031	76	2.0
2032	78	2.0
2033	79	2.0
2034	81	2.0
2035	82	2.0
2036	84	2.0
2037	86	2.0
2038	87	2.0
2039	89	2.0
2040	91	2.0

Note: The crude oil price stays constant at the 2005 level.
Source: Actual data from the British Petroleum Statistics

Figure 4-3-3-1 shows the forecast for the Gulf Coast Exporting Oil Price linked to the WTI crude oil price. The price almost matches the Singapore oil exporting price.



Source: Study Team

Figure 4-3-3.1 Gulf coast exporting oil price linked to WTI

4-3-4 Power Tariff Prediction

Power tariffs are estimated with an elasticity of 0.2-0.1 to crude oil price. This means that power tariffs are proportional with the crude oil price in the model. Table 4-3-4.1 shows the tariff categories in Residential, Commercial, and Public sectors. The second categories of the sectors are used as representative values of the sectors in the power demand forecasting.

Table 4-3-4.1 Classification of power tariff categories

	Tariff category before 2011	Tariff category after 2012	Abbreviation
Residential	0 – 500 kWh	0-150 k Wh	RA
	501 – 2000 kWh	151-500 k Wh	RB
	2000 kWh over	500 k Wh+	RC
Commercial	0-150,000 kWh	Same as before 2011	CA
	150,001-250,000 kWh		CB
	250,001 kWh over		CC
Government	0-150,000 kWh	Same as before 2011	GA
	150,001-250,000 kWh		GB
	250,001 kWh over		GC

Source: PPUC

The predictions for the second categories of the sectoral nominal and real power tariff are shown in Table 4-3-4.2. The power tariff is not expected to increase steeply in the future, as the world crude oil price will not rise steeply and the LCOE (Levelized Cost of Electricity) of renewable energies will be reduced on a global basis year by year.

Table 4-3-4.2 Forecast of the second categories

Unit: US$ / kWh

	Nominal			Real at 2017p		
	Residential RB	Commercial CB	Government GB	Residential RB	Commercial CB	Government GB
2016	0.25	0.30	0.30	0.25	0.30	0.30
2017	0.25	0.32	0.32	0.25	0.32	0.32
2018	0.25	0.33	0.33	0.25	0.33	0.33
2019	0.26	0.33	0.33	0.25	0.33	0.33
2020	0.26	0.33	0.33	0.25	0.33	0.33
2021	0.26	0.33	0.33	0.25	0.33	0.33
2022	0.26	0.34	0.34	0.25	0.33	0.33
2023	0.26	0.34	0.34	0.25	0.33	0.33
2024	0.26	0.34	0.34	0.25	0.33	0.33
2025	0.26	0.34	0.34	0.25	0.33	0.33
2026	0.26	0.34	0.34	0.25	0.33	0.33
2027	0.26	0.34	0.34	0.25	0.33	0.33
2028	0.26	0.34	0.34	0.25	0.33	0.33
2029	0.26	0.34	0.34	0.25	0.33	0.33
2030	0.26	0.34	0.34	0.25	0.33	0.33
2035	0.26	0.34	0.34	0.25	0.33	0.33
2040	0.26	0.34	0.34	0.25	0.33	0.33

Source: Study Team

4-3-5 Customer Prediction

Table 4-3-5.1 shows the forecast for state-wise customers separated into sectoral customer categories (Commercial, Public, and Residential customers). The sectoral customers in each state are used for the sectoral power demand forecasting in the states.

Table 4-3-5.1 Customer forecasts by state

Unit: Customer

States	2015	2016	2017	2018	2019	2020	2025	2030	2035	2040
Aimeliik	156	177	178	178	178	178	180	182	184	185
Airai	779	821	826	831	836	841	867	894	922	951
Koror	4,673	4,678	4,690	4,702	4,714	4,726	4,785	4,842	4,899	4,956
Melekeok	143	147	147	147	148	148	151	155	160	164
Ngaraard	193	184	184	185	185	186	189	192	195	199
Ngardmau	84	90	91	91	91	91	92	93	94	95
Ngaremlengui	145	139	140	140	140	141	142	143	145	146
Ngatpang	101	100	101	101	101	101	102	103	104	105
Ngchesar	99	94	94	95	95	95	97	99	102	105
Ngarchelong	171	176	177	177	178	178	181	184	187	190
Ngiwal	98	99	99	99	99	99	100	101	102	103
Total	6,642	6,706	6,726	6,746	6,766	6,786	6,887	6,990	7,094	7,201

Source: Study Team

Table 4-3-5.2 Growth rate of customers by state

Unit:%

	2020/15	2025/20	2030/25	2035/30	2035/30	2040/35	2030/17
Aimeliik	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Airai	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Koror	0.3	0.2	0.2	0.2	0.2	0.2	0.2
Melekeok	0.3	0.4	0.5	0.6	0.6	0.6	0.4
Ngaraard	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Ngardmau	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Ngaremlengui	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Ngatpang	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Ngchesar	0.3	0.4	0.5	0.6	0.6	0.6	0.4
Ngarchelong	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Ngiwal	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Total	0.3	0.3	0.3	0.3	0.3	0.3	0.3

Source: Study Team

4-3-6 New Loads Scheduled in 2017

4-3-6-1 Power demand from new loads

The number of the newly built hotels was around 60 projects as of 2017, as presented in Chapter 2. The power demand from new loads by area are as shown in Table 4-3-6-1.1, Table 4-3-6-1.2, and Table 4-3-6-1.3.

Table 4-3-6-1.1 New power demand in Koror and Airai states

Unit: kW

	2020	2021	2022	2023	2024	2025	2030	2035
a) New hotels with 2000 rooms	245	343	490	637	784	980	1,005	1,034
b) Public facility in Airai						10	23	34
c) Prison						28	28	28
Total	245	343	490	637	784	1,018	1,056	1,095

Note: A hotel with more than 50 rooms is defined as large scale and a hotel with fewer than 20 rooms is defined as small scale.

Note: Rooms are operated with 70% occupancy and have a coincidence factor of 70%.

Note a) : 2000 rooms * 70% operation * 1.0 kW /room * CF 70% ＝980 kW

Note b) : 50 rooms＊50% operation * 0.5 kW /room * CF 80% ＝10 kW

Note c) : 100 persons＊70% operation* 0.5 kW/room＊CF80%＝28 kW

CF: coincidence factor, a factor expressing the use of facilities at the same time.

Operation: ratio of "used rooms divided by total rooms"

Source: Study Team

Tale 4-3-6-1.2 New power demand in Melekeok and Ngchesar states

Unit：kW

	2020	2021	2022	2023	2024	2025	2030	2035
a) Government office				24	40	56	88	108
b) Embassy						17	112	112
c) Big hotels				70	70	84	98	98
d) Small hotels				29	39	49	98	98
Total				123	149	206	396	416

Note a) 100 rooms*30% / rooms* CF 80% ＝ 24 kW

Note b) 20 embassies *10 kW / one embassy *870% operation * CF 80%＝ 112 kW

Note c) (50 rooms*2 hotels)* 70% operation * 1.0 kW /room * CF 70%=98 kW

Note d) (20 rooms*10 hotels) * 70% operation*1.0 kW/room* CF 70% ＝ 98 kW

CF: coincidence factor, a factor expressing the use of facilities at the same time.

Operation: ratio of "used rooms divided by total rooms"

Source: Study Team

Table 4-3-6-1.3 New power demand in Ngarchelong and Ngaraard states

Unit: kW

	2020	2021	2022	2023	2024	2025	2030	2035
a) Big hotel with 150 rooms						53	74	74
b) Big hotel with 300 rooms						105	147	147
c) 10 Small hotels				39	59	78	176	196
Total				39	59	236	397	417

Note a): 150 rooms * 70% operation * 1.0 kW/ room * CF 70%＝ 74 kW

Note b： 300 rooms* 70% operation* 1.0 kW / room * CF 70%＝147 kW

Note c): 20 rooms*18 hotels * 70% operation*1.0 kW/room* CF 70%＝ 176 kW

CF: coincidence factor, a factor expressing the use of facilities at the same time.

Operation: ratio of "used rooms divided by total rooms"

Source: Study team

4-3-6-2 New power demand by state

The new power demand from Hotel, Resort, and Public investment plans as of 2017 is shown in Table 4-3-6-2.1 and Table 4-3-6-2.2.

Table 4-3-6-2.1 New power demand by state (1)

Unit: kW

	Aimeliik	Airai	Koror	Melekeok	Ngaraard	Ngardmau	Ngaremlengui	Ngatpang	Ngchesar	Ngarchelong	Ngiwal	Total
2020	0	28	245	0	0	0	0	0	0	0	0	273
2021	0	77	294	0	0	0	0	0	0	0	0	371
2022	0	126	392	0	0	0	0	0	0	0	0	518
2023	0	175	490	123	29	0	0	0	0	10	0	828
2024	0	224	588	149	39	0	0	0	0	20	0	1,020
2025	0	283	735	206	207	0	0	0	0	29	0	1,460
2026	0	288	735	235	216	0	0	0	0	39	0	1,513
2027	0	299	735	295	258	0	0	0	0	49	0	1,635
2028	0	304	735	368	267	0	0	0	0	59	0	1,734
2029	0	313	735	382	309	0	0	0	0	69	0	1,807
2030	0	321	735	396	319	0	0	0	0	78	0	1,849
2031	0	330	735	400	319	0	0	0	0	88	0	1,872
2032	0	339	735	404	319	0	0	0	0	98	0	1,895
2033	0	349	735	408	319	0	0	0	0	98	0	1,908
2034	0	354	735	412	319	0	0	0	0	98	0	1,918
2035	0	360	735	416	319	0	0	0	0	98	0	1,928

Source: Study Team

4-3-7 Energy Efficiency Prediction

An Energy Efficiency Policy is emphasized within Palau’s power sector policy. As of 2017, no systematical energy efficiency activities were implemented in public or commercial facilities. In the near future, however, building codes requiring power-saving lighting and home electric appliances in public and big commercial facilities will be implemented. The following preconditions for energy efficiency are assumed in the model.

Precondition 1: According to IEA, the world energy efficiency is improving at a rate of 0.5% per year globally. In Palau, Energy efficiency is improving at the same rate in Palau’s Residential sector..

Precondition 2: The energy efficiency in facilities of Public and Commercial sectors is improving at a rate of 1.0% per year.

Table 4-3-7.1 shows the indicators for the above preconditions.

Table 4-3-7.1 Indicators of energy efficiency improvement

	Commercial		Government & Public		Residential	
	EEC rate	EE&C Indicator	EEC rate	EE&C Indicator	EEC rate	EE&C Indicator
	Saving%	2015 = 100	Saving%	2015 = 100	Saving%	2015 = 100
2017	0.0	100.0	0.0	100.0	0.0	100.0
2018	0.5	99.5	0.5	99.5	0.5	99.5
2019	0.5	99.0	0.5	99.0	0.5	99.0
2020	0.5	98.5	0.5	98.5	0.5	98.5
2021	0.5	98.0	0.5	98.0	0.5	98.0
2022	0.5	97.5	0.5	97.5	0.5	97.5
2023	0.5	97.0	0.5	97.0	0.5	97.0
2024	0.5	96.6	0.5	96.6	0.5	96.6
2025	0.5	96.1	0.5	96.1	0.5	96.1
2026	1.0	95.1	1.0	95.1	0.5	95.6
2027	1.0	94.2	1.0	94.2	0.5	95.1
2028	1.0	93.2	1.0	93.2	0.5	94.6
2029	1.0	92.3	1.0	92.3	0.5	94.2
2030	1.0	91.4	1.0	91.4	0.5	93.7
2031	1.0	90.4	1.0	90.4	0.5	93.2
2032	1.0	89.5	1.0	89.5	0.5	92.8
2033	1.0	88.6	1.0	88.6	0.5	92.3
2034	1.0	87.8	1.0	87.8	0.5	91.8
2035	1.0	86.9	1.0	86.9	0.5	91.4
2036	1.0	86.0	1.0	86.0	0.5	90.9
2037	1.0	85.2	1.0	85.2	0.5	90.5
2038	1.0	84.3	1.0	84.3	0.5	90.0
2039	1.0	83.5	1.0	83.5	0.5	89.6
2040	1.0	82.6	1.0	82.6	0.5	89.1

Source: Study Team

4-4 Results of Power Demand Forecasts

4-4-1 Power Demand by Sector

The power demand (MWh) of the Palauan Commercial, Pubic, and Residential sectors and T/D-loss are shown Table 4-4-1.1. The average growth rate of power demand (MWh) from 2016 to 2030 is projected to be 2.9% per year. Over five-year periods, the rate is estimated to be 3.7% per year from 2016 to 2020, 3.5% per year from 2020 to 2025, and 1.7% per year from 2025 to 2030.

Table 4-4-1.1 Power demand forecasts by sector

Unit: MWh

Year	Residential	Commercial	Public use	T/D loss	Total
2016	25,877	25,205	19,846	8,382	79,311
2017	26,040	25,590	19,979	8,851	80,459
2018	26,728	27,111	20,429	9,179	83,447
2019	27,440	28,692	20,889	9,519	86,541
2020	28,209	31,984	21,543	10,102	91,839
2021	28,747	33,924	21,876	10,450	94,997
2022	29,041	35,729	22,062	10,732	97,565
2023	29,337	38,464	22,408	11,149	101,359
2024	29,636	40,500	22,703	11,475	104,314
2025	29,937	44,005	23,175	12,003	109,121
2026	30,243	44,966	23,381	12,185	110,775
2027	30,550	46,239	23,736	12,424	112,949
2028	30,861	47,225	24,237	12,647	114,969
2029	31,175	48,430	24,366	12,850	116,822
2030	31,493	49,442	24,495	13,031	118,461
2031	31,813	50,338	24,625	13,197	119,973
2032	32,137	51,246	24,756	13,365	121,504
2033	32,464	52,104	24,886	13,528	122,982
2034	32,795	52,975	24,994	13,690	124,453
2035	33,128	53,860	25,102	13,854	125,944
2040	34,849	58,491	25,646	14,706	133,692
2020/16	2.2%	6.1%	2.1%	4.8%	3.7%
2025/20	1.2%	6.6%	1.5%	3.5%	3.5%
2030/25	1.0%	2.4%	1.1%	1.7%	1.7%
2035/30	1.0%	1.7%	0.5%	1.2%	1.2%
2040/35	1.0%	1.7%	0.4%	1.2%	1.2%
2030/16	2.1%	4.8%	1.6%	1.7%	2.9%

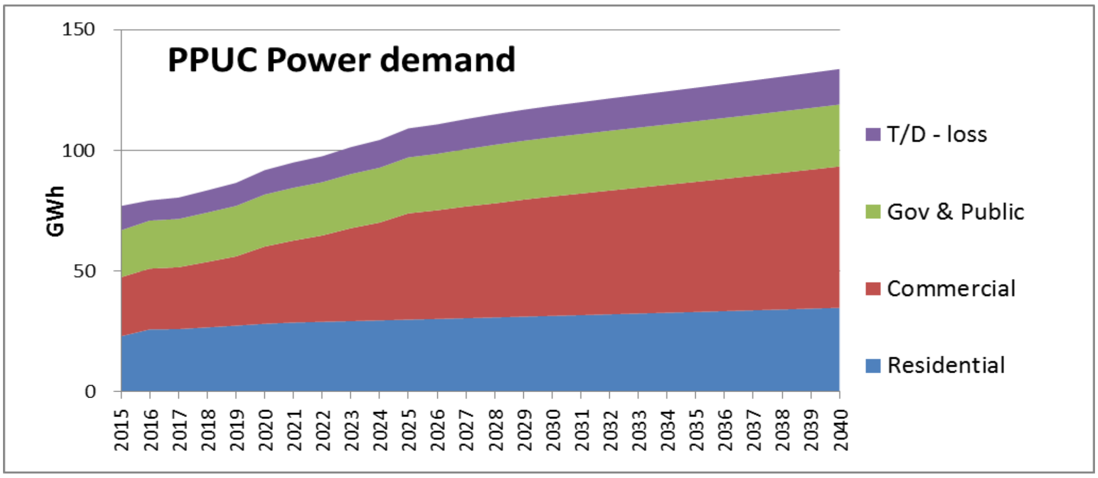
Source: Study Team

Table 4-4-1.2 Contribution of sectoral power demand

Unit:%

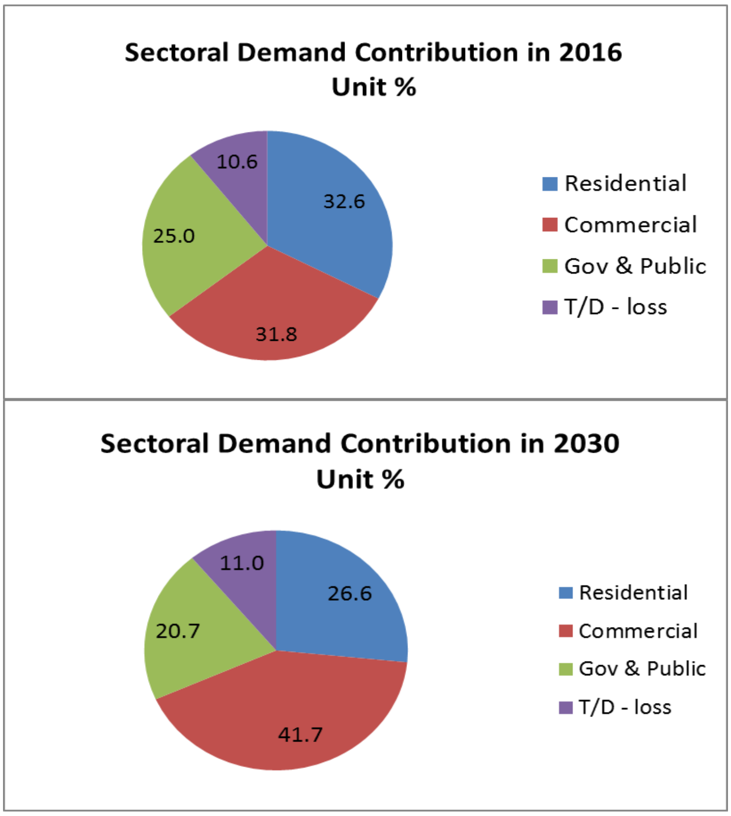
	2016	2020	2025	2030	2035	2040
Residential sector	32	31	27	26	26	26
Commercial sector	32	35	41	42	43	44
Public & Government sector	25	23	21	21	20	19
T/D-loss	11	11	11	11	11	11
Total	100	100	100	100	100	100

Source: Study Team



Source: Study Team

Figure 4-4-1.1 Trends of sectoral power demand



Source: Study Team

Figure 4-4-1.2 Contribution of power demand in 2016 and 2030

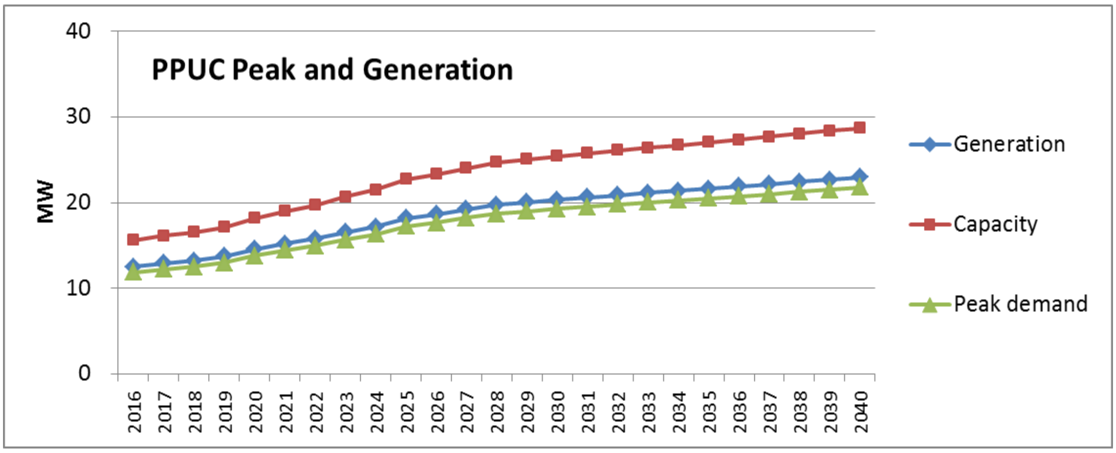
4-4-2 Power Demand of PPUC

Table 4-4-2.1 shows the forecasts of power demand, peak generation, gross generation, load factor, and own use at PPUC from 2016 to 2030. The average growth rate of peak demand is expected to reach 3.5% per year from 2016 to 2030. The power demand (MWh) is expected to grow by 2.9% per year over the same period.

Table 4-4-2.1 Power demand forecasts of PPUC

	Power demand	Peak demand	Gross generation	Gross peak generation	Load factor	Own use	Own use rate
	MWh	kW	MWh	kW	%	MWh	%
2016	79,310	11,840	83,430	12,490	76.3	4,350	5.2
2017	80,460	12,230	84,870	12,900	76.0	4,413	5.2
2018	83,450	12,530	88,020	13,220	76.0	4,577	5.2
2019	86,540	13,000	91,290	13,710	76.0	4,747	5.2
2020	91,840	13,790	96,880	14,550	76.0	5,038	5.2
2021	95,000	14,410	100,210	15,200	75.2	5,211	5.2
2022	97,560	14,950	102,920	15,770	74.5	5,352	5.2
2023	101,360	15,690	106,920	16,550	73.7	5,560	5.2
2024	104,310	16,310	110,040	17,210	73.0	5,722	5.2
2025	109,120	17,240	115,110	18,180	72.3	5,986	5.2
2026	110,770	17,670	116,850	18,640	71.6	6,076	5.2
2027	112,950	18,200	119,140	19,200	70.8	6,196	5.2
2028	114,970	18,710	121,270	19,740	70.1	6,306	5.2
2029	116,820	19,020	123,230	20,060	70.1	6,408	5.2
2030	118,460	19,280	124,960	20,340	70.1	6,498	5.2
2031	119,970	19,530	126,550	20,600	70.1	6,581	5.2
2032	121,500	19,780	128,170	20,860	70.1	6,665	5.2
2033	122,980	20,020	129,730	21,120	70.1	6,746	5.2
2034	124,450	20,260	131,280	21,370	70.1	6,827	5.2
2035	125,940	20,500	132,850	21,630	70.1	6,908	5.2
2036	127,450	20,750	134,440	21,880	70.1	6,991	5.2
2037	128,980	21,000	136,060	22,150	70.1	7,075	5.2
2038	130,530	21,250	137,690	22,410	70.1	7,160	5.2
2039	132,100	21,500	139,350	22,680	70.1	7,246	5.2
2040	133,690	21,760	141,030	22,960	70.1	7,333	5.2
2020/16	3.7%	3.9%	3.8%	3.9%	-0.1%	3.6%	
2025/20	3.5%	4.6%	3.5%	4.6%	-1.0%	3.5%	
2030/25	1.7%	2.3%	1.7%	2.3%	-0.6%	1.7%	
2035/30	1.2%	1.2%	1.2%	1.2%	0.0%	1.2%	
2040/35	1.2%	1.2%	1.2%	1.2%	0.0%	1.2%	
2030/15	2.9%	3.5%	2.9%	3.5%	-0.6%	2.9%	

Source: Study Team



Source: Study Team

Figure 4-4-2.1 Generation, peak demand, and required capacity of PPUC

4-4-3 Power Demand by State

4-4-3-1 Sectoral power demand by state (MWh)

The state-wise power demand (MWh) from 2016 to 2030 is shown in Table 4-4-3-1 to Table 4-4-3-1.5. The state demand is forecasted based on the country-wide sectoral power demand, state-wise population, state-wise customers, and state-wise new power demand.

Table 4-4-3-1.1 State power demand of the Commercial sector

Unit: MWh

	2016	2017	2018	2019	2020	2025	2030	2035
Aimeliik	97	99	105	110	117	134	148	162
Airai	3,570	3,642	3,878	4,124	4,387	6,808	7,687	8,661
Koror	20,716	21,016	22,246	23,525	26,493	33,495	36,439	39,594
Melekeok	438	444	471	498	527	1,487	1,974	2,059
Ngaraard	189	192	203	215	227	1,620	2,385	2,416
Ngardmau	51	52	55	58	61	70	77	85
Ngaremlengui	79	80	84	89	94	108	119	130
Ngatpang	23	23	25	26	27	31	35	38
Ngchesar	4	4	4	4	4	5	6	6
Ngarchelong	10	10	11	12	12	208	531	662
Ngiwal	28	28	30	32	34	38	42	46
Koror+Babeldaob	25,205	25,590	27,111	28,692	31,984	44,005	49,442	53,860

Note: The elasticity of the existing Commercial power demand is 0.4 to the GDP growth rate.

Note: The new demand of the Commercial sector is calculated by investment in the sector as of September 2017.

Note: The total power demand of the states meets the country-wide power demand of the Commercial sector.

Source: Study Team

Table 4-4-3-1.2 State power demand (MWh) of the Public sector

Unit: MWh

	2016	2017	2018	2019	2020	2025	2030	2035
Aimeliik	1,789	1,797	1,834	1,872	1,910	1,988	2,003	2,018
Airai	7,194	7,263	7,448	7,638	8,017	8,600	8,959	9,309
Koror	9,296	9,343	9,538	9,737	9,939	10,358	10,446	10,532
Melekeok	852	857	875	893	912	1,433	2,282	2,431
Ngaraard	90	90	92	94	96	100	101	102
Ngardmau	27	27	28	28	29	30	30	30
Ngaremlengui	207	208	213	217	222	231	232	234
Ngatpang	124	124	127	130	132	138	139	140
Ngchesar	61	61	62	64	65	68	69	70
Ngarchelong	134	135	138	140	143	150	151	153
Ngiwal	73	74	75	77	78	81	82	83
Koror+Babeldaob	19,846	19,979	20,429	20,889	21,543	23,175	24,495	25,102

Note: The elasticity of the existing Public power demand is 0.3 to the GDP growth rate.

Note: The new demand of the Public sector is calculated by investment in the sector as of September 2017.

Note: The total power demand of the states meets the country-wide power demand of the Public sector.

Source: Study Team

Table 4-4-3-1.3 State power demand of the Residential sector

Unit: MWh

	2016	2017	2018	2019	2020	2025	2030	2035
Aimeliik	820	824	845	866	890	938	982	1,027
Airai	4,383	4,423	4,552	4,686	4,830	5,194	5,541	5,909
Koror	17,692	17,793	18,254	18,730	19,244	20,356	21,331	22,343
Melekeok	1,329	1,337	1,372	1,408	1,447	1,544	1,638	1,746
Ngaraard	247	248	255	261	269	286	301	317
Ngardmau	143	143	147	151	155	163	171	179
Ngaremlengui	314	315	323	332	341	359	376	393
Ngatpang	218	220	225	231	237	250	262	274
Ngchesar	209	210	216	222	228	243	258	275
Ngarchelong	329	331	339	348	358	380	401	423
Ngiwal	195	196	201	206	211	223	233	244
Koror+Babeldaob	25,877	26,040	26,728	27,440	28,209	29,937	31,493	33,128

Note: The elasticity of the existing Residential demand is 0.5 to the GDP growth rate.

Note: The total power demand of the states meets the country-wide power demand of the Residential sector.

Source: Study Team

Table 4-4-3-1.4 Transmission and distribution loss by each state

Unit: MWh

	2016	2017	2018	2019	2020	2025	2030	2035
Aimeliik	320	336	344	352	360	378	387	396
Airai	1,790	1,894	1,962	2,033	2,130	2,546	2,742	2,951
Koror	5,637	5,951	6,184	6,426	6,881	7,936	8,431	8,957
Melekeok	309	326	336	346	357	552	728	771
Ngaraard	62	65	68	70	73	248	344	350
Ngardmau	26	27	28	29	30	33	34	36
Ngaremlengui	71	75	77	79	81	86	90	94
Ngatpang	43	45	47	48	49	52	54	56
Ngchesar	32	34	35	36	37	39	41	43
Ngarchelong	56	59	60	62	64	91	134	153
Ngiwal	35	37	38	39	40	42	44	46
Koror+Babeldaob	8,382	8,851	9,179	9,519	10,102	12,003	13,031	13,854

Note: Country-wide T/D loss is divided into state T/D loss in proportion with the state power demand.

Note: The total T/D loss of the states meets the country-wide T/D loss.

Source: Study Team

Table 4-4-3-1.5 State power demand

Unit: MWh

	2016	2017	2018	2019	2020	2025	2030	2035
Aimeliik	3,026	3,056	3,127	3,201	3,277	3,438	3,519	3,603
Airai	16,937	17,222	17,840	18,481	19,365	23,149	24,929	26,830
Koror	53,341	54,103	56,222	58,417	62,558	72,145	76,648	81,425
Melekeok	2,928	2,964	3,053	3,145	3,242	5,016	6,623	7,007
Ngaraard	587	595	617	640	665	2,253	3,131	3,186
Ngardmau	247	250	258	266	275	296	313	331
Ngaremlengui	671	678	697	717	737	784	817	851
Ngatpang	408	413	423	434	446	471	489	507
Ngchesar	306	309	317	325	334	355	374	395
Ngarchelong	529	535	548	562	577	829	1,218	1,390
Ngiwal	331	334	343	353	363	385	401	419
Koror+Babeldaob	79,311	80,459	83,447	86,541	91,839	109,121	118,461	125,944

Note: The above table includes the power demand of the Commercial, Public, and Residential sectors and T/D loss.
Source: Study Team

4-4-3-2 State Peak demand (kW)

The state peak demand is calculated based on the state power demand (MWh) and country-wide load factor. The results are shown in Table 4-4-3-2.1. The upper and lower rows of the table show the peak demand and contribution of the peak demand, respectively.

Table 4-4-3-2.1 State peak demand

Unit: kW

	2016	2017	2018	2019	2020	2021	2022	2023	2024
Aimeliik	453	459	470	481	492	505	514	524	533
Airai	2,535	2,587	2,680	2,776	2,909	3,071	3,209	3,351	3,496
Koror	7,985	8,127	8,445	8,775	9,396	9,807	10,176	10,554	10,941
Melekeok	438	445	459	472	487	503	515	668	712
Ngaraard	88	89	93	96	100	104	106	143	157
Ngardmau	37	38	39	40	41	43	44	45	46
Ngaremlengui	100	102	105	108	111	114	116	119	121
Ngatpang	61	62	64	65	67	69	70	72	73
Ngchesar	46	46	48	49	50	52	53	54	55
Ngarchelong	79	80	82	84	87	89	91	104	117
Ngiwal	49	50	52	53	54	56	57	58	60
Total	11,870	12,090	12,530	13,000	13,790	14,410	14,950	15,690	16,310

	2025	2026	2027	2028	2029	2030	2031	2032	2035
Aimeliik	543	551	559	568	570	573	576	578	586
Airiai	3,656	3,745	3,844	3,937	3,997	4,058	4,120	4,182	4,367
Koror	11,395	11,650	11,911	12,178	12,327	12,477	12,628	12,782	13,254
Melekeok	792	841	927	1,031	1,054	1,078	1,090	1,103	1,141
Ngaraard	356	373	427	445	496	510	511	513	519
Ngardmau	47	48	49	50	50	51	52	52	54
Ngaremlengui	124	126	128	131	132	133	134	135	139
Ngatpang	74	76	77	78	79	80	80	81	83
Ngchesar	56	57	58	60	60	61	61	62	64
Ngarchelong	131	145	159	173	186	198	211	224	226
Ngiwal	61	62	63	64	65	65	66	66	68
Total	17,240	17,670	18,200	18,710	19,020	19,280	19,529	19,778	20,501

Source: Study Team

Table 4-4-3-2.2 Contribution of peak demand

Unit:%

	2016	2017	2018	2019	2020	2025	2030	2035
Aimeliik	3.8	3.8	3.7	3.7	3.6	3.2	3.0	2.9
Airai	21.4	21.4	21.4	21.4	21.1	21.2	21.0	21.3
Koror	67.3	67.2	67.4	67.5	68.1	66.1	64.7	64.7
Melekeok	3.7	3.7	3.7	3.6	3.5	4.6	5.6	5.6
Ngaraard	0.7	0.7	0.7	0.7	0.7	2.1	2.6	2.5
Ngardmau	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Ngaremlengui	0.8	0.8	0.8	0.8	0.8	0.7	0.7	0.7
Ngatpang	0.5	0.5	0.5	0.5	0.5	0.4	0.4	0.4
Ngchesar	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.3
Ngarchelong	0.7	0.7	0.7	0.6	0.6	0.8	1.0	1.1
Ngiwal	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.3
Koror+Babeldaob	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

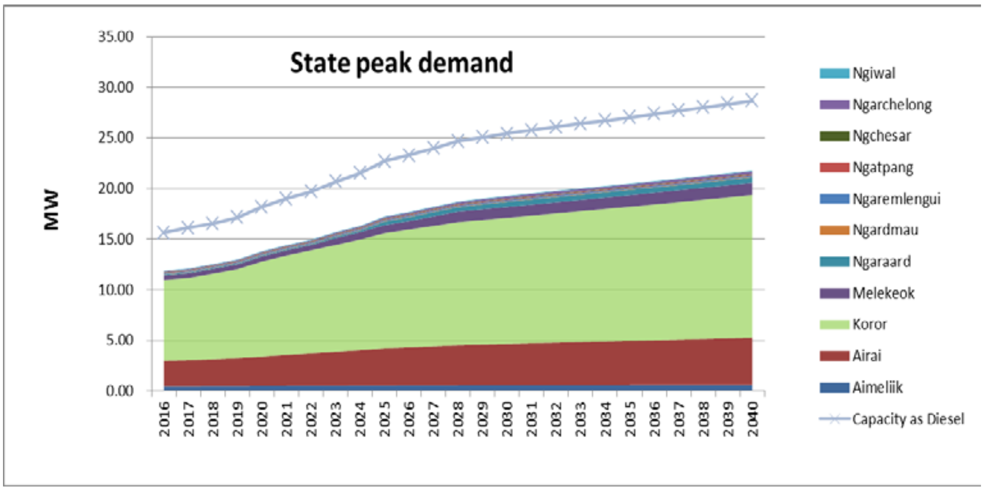
Source: Study Team

Table 4-4-3-2.3 Growth rate of peak demand by state

Unit:%

	2020/16	2025/20	2030/25	2035/30	2040/35	2030/16
Aimeliik	2.1	2.0	1.1	0.5	0.5	2.5
Airai	3.5	4.7	2.1	1.5	1.4	3.6
Koror	4.2	3.9	1.8	1.2	1.2	3.2
Melekeok	2.7	10.2	6.4	1.1	1.1	6.6
Ngaraard	3.2	28.9	7.4	0.3	0.4	12.3
Ngardmau	2.8	2.5	1.7	1.1	1.1	3.0
Ngaremlengui	2.5	2.3	1.4	0.8	0.8	1.8
Ngatpang	2.3	2.1	1.4	0.7	0.7	2.0
Ngchesar	2.3	2.3	1.6	1.1	1.1	2.0
Ngarchelong	2.3	8.6	8.6	2.7	0.4	6.9
Ngiwal	2.4	2.2	1.5	0.8	0.9	2.2
Koror+Babeldaob	3.8	4.6	2.3	1.2	1.2	3.6

Source: Study Team



Source: Study Team

Figure 4-4-3-2.1 Peak demand and required capacity by state

4-4-4 Case Study

The new power demand is expected in Koror, Airai, Melekeok, Ngaraard, and Ngarchelong. When the new power demand of the previous scenario is defined as the Base Case, the new power demand in the High Case and Low Case is defined as double that in the Base Case and zero new demand, respectively. The new power demand in the High Case, Base Case, and Low Case is shown in Table 4-4-4.1. The peak demand in the three cases is shown in Table 4-4-4.2.

Table 4-4-4.1 New power demand in the High, Base, and Low Cases

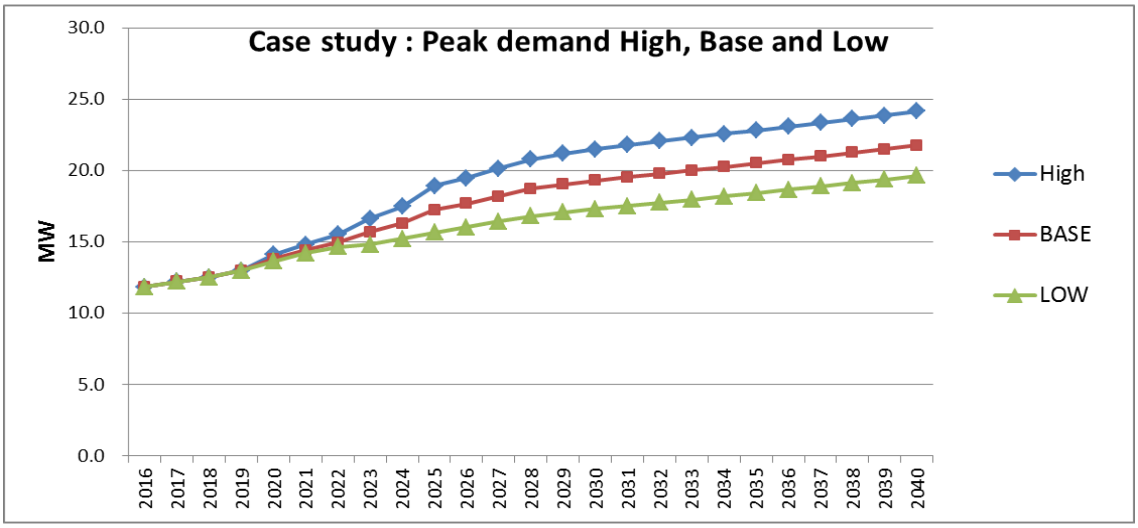
	Unit	2019	2020	2025	2030	2035
High Case	kW	0	546	2,920	3,698	3,856
Base Case	kW	0	273	1,460	1,849	1,928
Low Case	kW	0	0	0	0	0

Table 4-4-4.2 Peak demand in the High, Base, and Low Cases

Unit: MW

	High	Base	Low
2019	13.0	13.0	13.0
2020	14.1	13.8	13.6
2021	14.8	14.4	14.2
2022	15.5	15.0	14.7
2023	16.6	15.7	14.8
2024	17.5	16.3	15.2
2025	18.9	17.2	15.6
2026	19.5	17.7	16.0
2027	20.1	18.2	16.4
2028	20.8	18.7	16.8
2029	21.2	19.0	17.1
2030	21.5	19.3	17.3
2035	22.8	20.5	18.4
2040	24.1	21.8	19.6

Source: Study Team

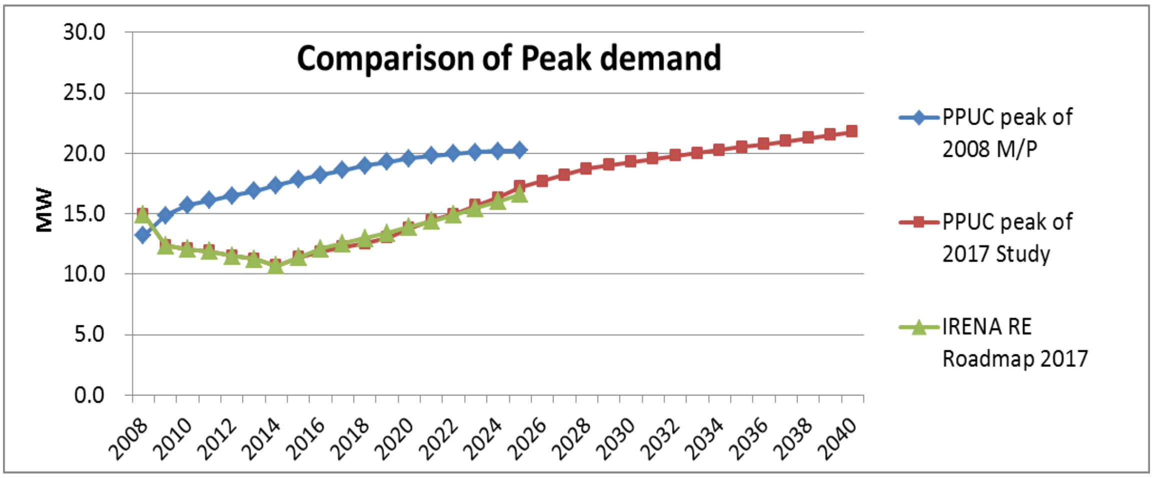


Source: Study Team

Figure 4-4-4.1 Peak demand in the High, Base, and Low Cases

4-4-5 Comparison of Power Demand to that in the Existing Plan

Figure 4-4-5.1 shows the trends found by comparing the peak demand of this project to the estimates under the “Power System Supply Master Plan 2008” by JICA and the “Palau Energy Roadmap 2017” by IRENA. The power demand levels estimated in the three studies almost meet at 20 MW in 2030.

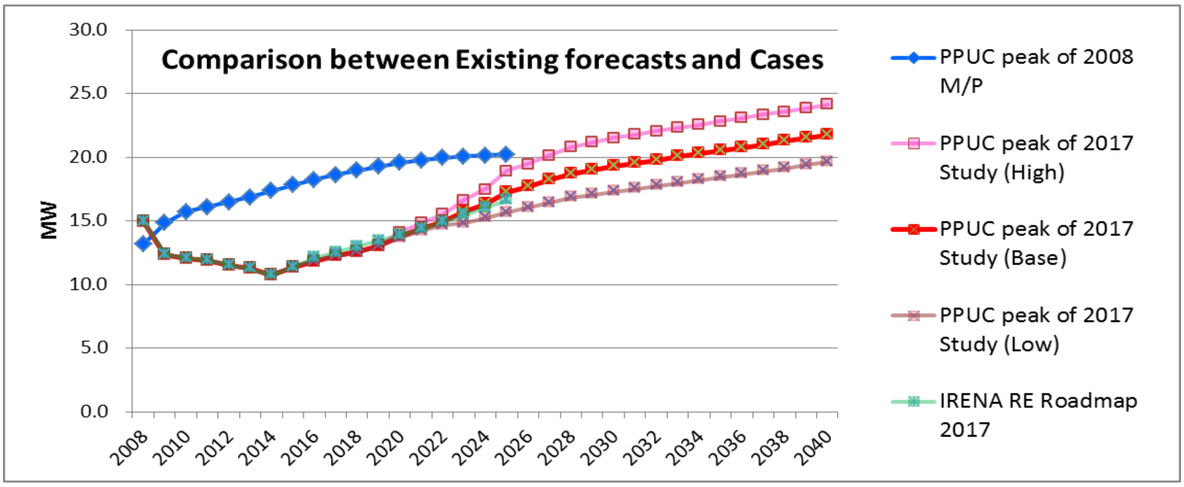


Source: Power System Supply Master Plan 2008" by JICA and "Palau Energy Roadmap 2017"

PPUC peak demand 2017 was studied by the Study Team,

Figure 4-4-5.1 Comparison to existing power demand estimates.

The trends found when plotting the High, Base, and Low Cases in the above figure are shown in Figure 4-4-5.2. The power demand in 2030 is 21.2 MW in the High Case, 19.3 MW in the Base Case, and 17.1 MW in the Low Case.



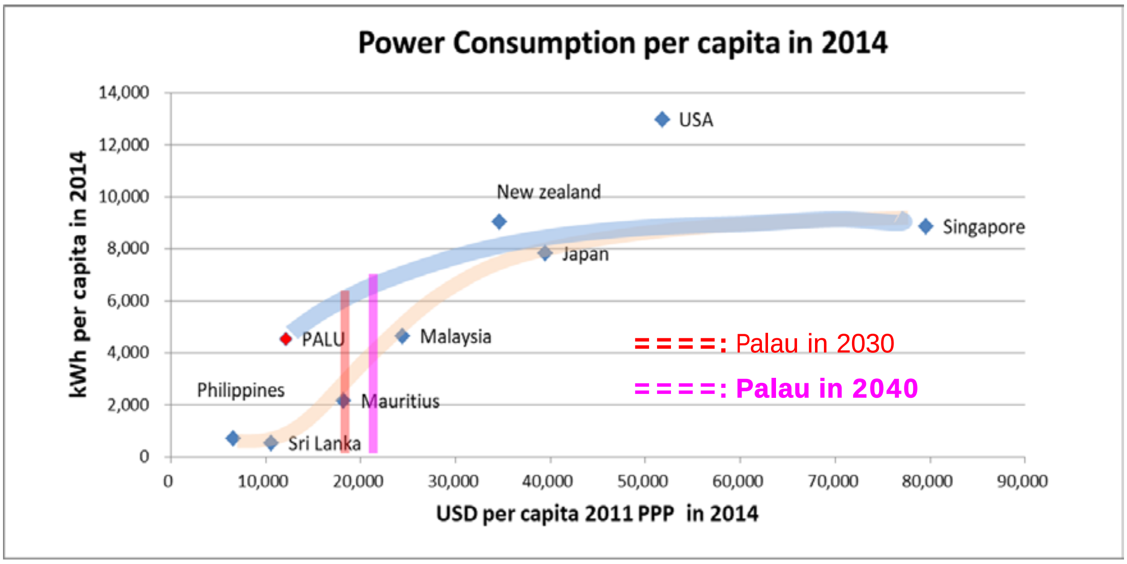
Source: Power System Supply Master Plan 2008" by JICA and "Palau Energy Roadmap 2017"

PPUC peak demand in 2017 was studied by the Study Team.

Figure 4-4-5.2 Comparison of the High, Base, Low Cases and existing plans

4-4-6 International Comparison

Figure 4-4-6.1 plots the per capita power demand of Palau from 2030 and 2040 alongside the forecasts for the USA, Japan, Singapore, New Zealand, Malaysia, Philippines, Mauritius and Sri Lanka. The horizontal scale is GDP per capita and the vertical scale is power consumption per capita.



Source: Forecasts for the compared countries from the World Bank database; Palau forecasts from the Study Team.

Figure 4-4-6.1 International comparison of power consumption