Minutes of Discussion
for
The Project for Study on Upgrading and Maintenance Improvement
of
National Power Grid in the Republic of Palau
between
Palau Public Utilities Corporation (PPUC)
and
Japan International Cooperation Agency (JICA)

In the middle of the implementation of the Project for Study on Upgrading and Maintenance Improvement of National Power Grid in the Republic of Palau (hereinafter referred to as "the Project"), Japan International Cooperation Agency (hereinafter referred to as "JICA") with JICA Expert team (hereinafter referred to as "the JICA side") exchanged their opinions and had a series of discussions with Palau Public Utilities Corporation (hereinafter referred to as "PPUC") for pursuing consensus on direction of the Project especially for updating renewable energy roadmap as well as transmission and distribution system expansion plan.

As a result of the discussions, the JICA side and PPUC agreed to the matters referred to in the document attached hereto as a supplement to the original Record of Discussions (hereinafter referred to as "R/D") signed on 21 March, 2017.

Koror, Palau, 1st December, 2017

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ATTACHMENT

I. Scenario Setting of Renewable Energy Road Map and Master Plan

Under the Palau's Nationally Determined Contribution (hereinafter referred to as "NDC") which put the nation on a trajectory to generating 45% of its energy from renewable sources by 2025, both sides confirmed that base scenario of master plan for upgrading and enhancement of power transmission and distribution facilities in consideration of the introduction of further renewable energy (hereinafter referred to as "RE") will be formulated in line with it. In other word, 45% RE scenario (hereinafter referred to as "45% Scenario") will be prepared in the master plan (hereinafter referred to as "MP").

On the other hand, JICA Expert team explained expected challenges to achieve 45% Scenario including high capital and O&M costs, land issues as well as technical side such as RE output forecasting, control and battery management. Then, in order to compare several scenarios from financial and technical view point, the JICA side proposed to prepare alternative scenario with lower RE generation rate through analyzing levelized cost of electricity (hereinafter referred to as "LCOE"). In response, PPUC explained that 45% Scenario is the national target so they requested the JICA side to analyze detailed phasing and sequence of RE road map by 2025, instead of preparation of alternative plan. The JICA side agreed to analyze it, even though they showed concern of realization of 45% Scenario up to 2025.

Then, preliminary analysis by JICA Expert team revealed that introduction of RE which can generate 45% of power would require large amount of energy storage system both for short and long term. To avoid potentially excessive cost that PPUC might incur through the introduction of energy storage system, optimizing operation of the existing power system with battery storage system be examined and studied closely to find out the most reasonable scenario economically and environmentally.

In this way, both sides confirmed that necessary steps for the analysis of updating RE road map are as follows.

Step 1: Improvement of operational practice of Diesel Engine Generators

In order to integrate larger capacity of RE into PPUC grid, the existing operation practice of Diesel Engine Generators (hereinafter referred to as "DEG") should be examined and improved. For example, following items need to be considered:

(1) Low Load Operation of DEG
The allowable minimum power output from each unit is generally different depending on manufacturers and type of engines. Some manufacturers will allow 30% minimum output in one hour, if the output return close to 100% rated capacity after that period. Therefore, specification and actual operational conditions for each unit should be taken into consideration.

(2) Number of DEG in operation
Allowable RE connection capacity from the viewpoint of the long-term restriction is decided by DEG output under the low load operation. However, it will be determined not only by DEG output, but also the number of units of the DEGs in operation. Therefore, in order to make the wide range of analysis, JICA Expert team will add a study case that one (1) unit of DEG shall be deleted from normal operation conditions in day time (when PV system is operational).

(3) Operation with high-speed engines
As the share of variable RE are increasing, introduction of high-speed DEG should be examined, as they are usually more flexible in terms of start-up time and changing rate of power output (kW/second).

(4) Improvement of governor control
Improvement of governor response can be expected by replacing the existing mechanical governor into electronics governor. Also, the possibility of introducing isochronous control should be studied with cost-benefit analysis.

(5) Sequence of RE development
Analyze and discuss in detail the practical phasing sequence up to the year 2025 that will take advantage of the swiftly decreasing costs of PV and battery storage system.

Step 2: Output restriction of RE generation systems

In order to reduce the output/capacity of energy storage, the optimum capacity and duration of restriction mechanism should be proposed. The energy amount (kWh) that need to be restricted can be calculated by reviewing the record of existing PV system and demand forecast.

Step 3: Finalize the output and capacity of energy storage

As a result of the above examination, the required output/capacity of energy storage can be calculated for short- and long-term energy storage, respectively for efficient and safe utilization of existing base load DEG.

The result of above careful analysis for 45% Scenario will be reflected to power system analysis and transmission/distribution system planning.

II. Important Factors of 45% Scenario

Based on the Annex-1, both sides discussed on the important factors for the study of 45% Scenario:

1. Minimum Power Output of DEG

Based on the Annex-1, JICA Expert Team explained possible impact by setting of DEG minimum output and number of DEG for further penetration of RE. In order to realize 45% Scenario, PPUC is expected to set minimum output of DEG as 40% or 50%. However, PPUC explained that 40% operation in a longer period cause to harmful influences on engines such as black smoke generation by abnormal combustion, low fuel consumption rate, etc. Finally, both sides agreed to use 50% of minimum output of DEG on the condition that one (1) DEG will be stopped to accept further RE as well as to keep output level of DEG more than 50%.

2. RE Power Resource

Besides, through the explanation of Annex-1, in order to consider optimal combination of photovoltaic (hereinafter referred to as "PV") and Wind Turbine (hereinafter referred to as "WT"), the JICA Expert Team pointed out negative aspect of WT especially for low capacity factor in other island countries and difficulty of timely supply of spare parts. PPUC agreed to conduct sensibility analysis with lower capacity factor of WT.

3. Power System Analysis and Planning.

In consideration of negative aspect of WT mentioned above, both sides confirmed that

45% Scenario with 100% of PV will be utilized for the core case of transmission/distribution system planning. Then, 45% Scenario with PV and WT could be the reference case of MP.

4. Potential Sites of Renewable Energy

Current potential sites for RE is as shown in Annex-II. However, JICA side explained that additional potential sites for PV with around 20MW including Solar Home System (hereinafter referred to as "SHS") are necessary to achieve 45% Scenario. Then, both sides confirmed that around 10% of additional PV potential site will be calculated as SHS.

JICA side requested PPUC to propose rough location of potential sites for additional PV before 8th December, 2017.

5. Implementation Structure of 45% Scenario

In order for Palau side to realize 45% Scenario by the target year, PPUC request the JICA side to analyze possible measures and necessary implementation structures how to finance or invest RE related projects including inviting Independent Power Producer (hereinafter referred to as "IPP"). The JICA side agreed to consider it.

III. Project Implementation Schedule

1. Approval Process of MP

PPUC explained that MP prepared by the Project will be approved by the board members of PPUC as well as Minister of Public Infrastructure, Industries & Commerce.

2. After 3rd Field Survey
    (1) JICA Expert team explained the tentative project implementation schedule (refer to Annex-3). PPUC agreed with the schedule as a baseline schedule to formulate MP including pre-feasibility study for high-prioritized-projects.
    (2) As a part of the Strategic Environmental Assessment (SEA), comments/opinions from stakeholders on the progress report-2 must be collected prior to the 4th field survey, scheduled in March-April 2018. Therefore, PPUC and the JICA Expert team will collect the comments/opinions from the stakeholders by the end of February 2018 by means not limited to physical conference under the attendance of all stakeholders.

Annex List

Annex-1: Explanation sheets for "Target of introduction of renewable energy capacity against total generating capacity by year 2025"

Annex-2: Expected PV installation Location

Annex-3: Tentative Project Implementation Schedule

Annex-1

Japan International Cooperation Agency

YACHIYO ENGINEERING CO.,LTD.
Consulting Engineers & Architects

Kansai Electric Power

Current Report of Renewable Energy Roadmap Study - Draft for Discussion -

1 December, 2017

Agenda

1. Study Process in this Project
2. RE Roadmap Study Steps
3. Further Study Policy

Study Process in this project

RE Roadmap

45% Scenario (A)
45% Scenario (B)
Another Scenario
: Lower than 45%

→ Power System Analysis → Power System Planning

RE Roadmap Study Steps

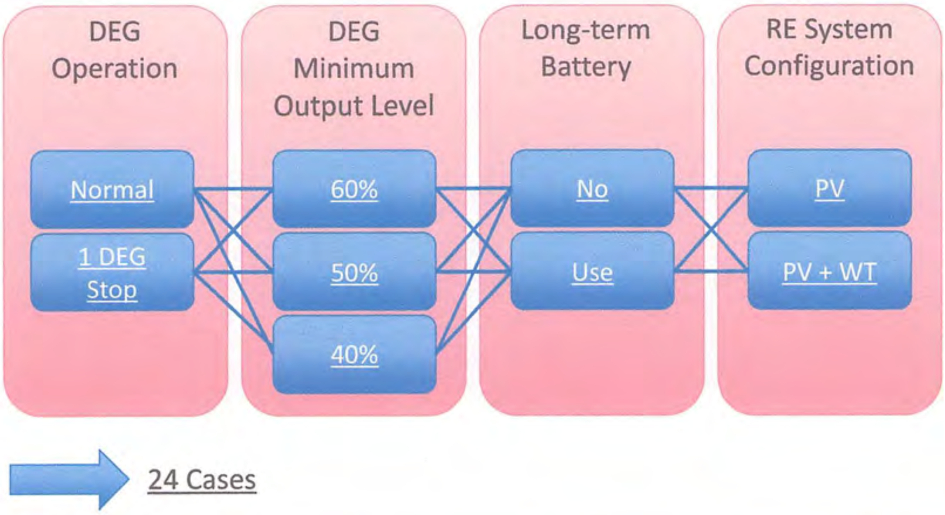
Step1: DEG improvement
- ✓ Operation of DEG
  - Minimum output level
  - No. of unit connected to the grid
  - High speed DEG

Step2: RE output curtailment
- ✓ RE system configuration
  - PV only or PV + WT
- ✓ Location of PV and WT

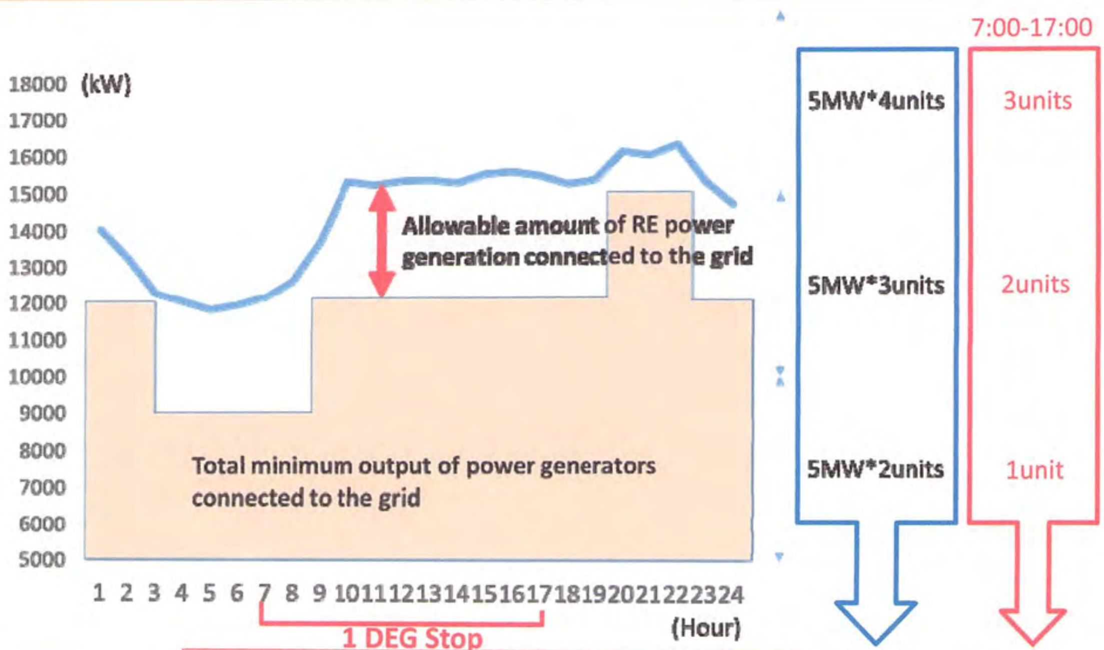
Step3: Long-term battery Introduction

Study Condition: Summary

Demand Data: 2025 Weekday and Weekend



Study Condition: <Step1> DEG Operation



In case of suddenly stopping RE power generation, electric power will be supplied from batteries for a short time until additional DEG starts electric power generation.

Study Condition: <Step1> DEG Load Operation

Generator use	Make	Model	Name	Year installed	Capacity (kW)
Active generation	Nigata	16V28HLX	Unit 14	2011	5,000
	Nigata	16V28HLX	Unit 15	2011	5,000
	Mitsubishi	18KU30A	Unit 6	2013	5,000
	Mitsubishi	18KU30A	Unit 7	2013	5,000
Total active generation capacity					20,000

Minimum Output : 40%, 50% and 60%

Additional maintenance will be required

Generator use	Make	Model	Name	Year installed	Capacity (kW)
Back up	Caterpillar	3516B	Unit 1	2007	2,000
	Caterpillar	3516B	Unit 2	2007	2,000
	Wartsila	SACM 12V200	Wartsila 1	1996	1,200
	Mitsubishi	S6R - PTA	Unit 1	2013	500
	Mitsubishi	S6R - PTA	Unit 2	2013	500
	Mitsubishi	S6R - PTA	Unit 3	2013	500
	Mitsubishi	S6R - PTA	Unit 4	2013	500
Total backup capacity					7,200

Study Condition: <Step2> RE System Configuration

RE power source

PV or WT Location is necessary for Power system analysis.

Study Condition: <Step2> RE System Configuration

No	Location	Capacity	Owner
1	Aimeliik (Next to power plant) This is already planned with PPUC.	5 MW	PPUC
2	Ngatpang (Kokusai)	2-3 MW the capacity is not confirmed for #2 Ngatpang and #3 Ngardmau	PPUC
3	Ngardmau (Terraces of Hill)	2-3 MW	PPUC
4	Commercial roof top by Joint Crediting Mechanism	Total 5 MW	Surangle, WCTC PIDC & PMA
5	Airai airport side by road	3 MW	PPUC
	Koror & Airai (Roof top)	2-5 kw / roof	House owner
Total		19 MW	

<u>More PV installation plans are needed to achieve 45% goal</u>

Study Condition: <Step2> RE System Configuration

- Basically maintenance-free

<u>There are big challenges for deployment of WTs</u>

- Regular maintenance is required
- 30% of output curtailment
  → 1.5 times capacity is required
- Low capacity factor in other Island country
- Bad supply of spare parts
- Output forecast is difficult

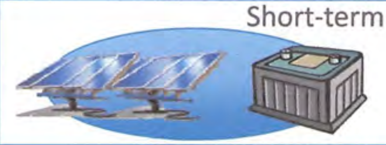
Study Condition: <Step2> RE System Configuration

Long-term Battery Use

45% Scenario

No Long-term Battery

Surplus Power will be curtailed



Another Scenario

Draft of Study :<Step3> Long-Term Battery Use

<Common condition for all cases> A little of RE output curtailment is accepted.
No. of 275kW WT unit is maximum capacity for short-term fluctuation.
PV is installed at maximum capacity in daytime.

System configuration :

Annual Gross Generation at 2025 115,110 MWh
RE deployment goals at 2025 51,800 MWh

	DEG		Maximum Capacity of RE Connected to Electricity Grid (MWh)		RE share (%)	PV (MW)	WT		Batt					
									Long-Term			Short-Term		
	Minimum output ratio	Operation	Gross	Net			275kW WT No. of unit	Capacity (MW)	MW	MWh	Inv.	MW	MWh	Inv.
1-1.PV	60%	Normal	33,241	31,991	28	24	0	0	24	55	11	19.9	8.0	19.9
1-1.PV+WT				31,725	28	13	27	7	13	17	9	11.2	4.5	11.2
1-2.PV		1DEG Stop	44,041	42,607	37	32	0	0	32	57	13	29.1	11.6	29.1
1-2.PV+WT				43,522	38	25	19	5	25	50	11	23.7	9.5	23.7
2-1.PV	50%	Normal	46,931	46,687	41	35	0	0	35	79	16	30.9	12.4	30.9
2-1.PV+WT				46,418	40	24	27	7	24	66	13	22.2	8.9	22.2
2-2.PV		1DEG Stop	55,931	52,107	45	39	0	0	39	72	16	36.1	14.4	36.1
2-2.PV+WT				51,539	41	31	19	5	31	62	14	29.7	11.9	29.7
3-1.PV	40%	Normal	60,621	52,080	45	39	0	0	39	79	17	34.9	14.0	34.9
3-1.PV+WT				51,705	45	27	27	7	27	66	14	25.2	10.1	25.2
3-2.PV		1DEG Stop	67,821	52,166	45	39	0	0	39	64	15	36.1	14.4	36.1
3-2.PV+WT				51,718	45	31	19	5	31	54	13	29.7	11.9	29.7

Draft of Study :<Step3> Long-Term Battery Use

Capital Cost @ 2025

Unit: USD

	PV	WT	Batt				DEG Maintenace	Total
			Long-Term		Short-Term			
			Li-ion	Inverter	Li-ion	Inverter		
1-1.PV	33,000,000	0	19,250,000	1,650,000	2,786,000	2,985,000	0	**59,671,000**
1-1.PV+WT	16,500,000	20,250,000	5,950,000	1,350,000	1,568,000	1,680,000	0	**47,298,000**
1-2.PV	45,000,000	0	19,950,000	1,950,000	4,074,000	4,365,000	0	**75,339,000**
1-2.PV+WT	34,500,000	14,250,000	17,500,000	1,650,000	3,318,000	3,555,000	0	**74,773,000**
2-1.PV	49,500,000	0	27,650,000	2,400,000	4,326,000	4,635,000	0	**88,511,000**
2-1.PV+WT	33,000,000	20,250,000	23,100,000	1,950,000	3,108,000	3,330,000	0	**84,738,000**
2-2.PV	55,500,000	0	25,200,000	2,400,000	5,054,000	5,415,000	0	**93,569,000**
2-2.PV+WT	43,500,000	14,250,000	21,700,000	2,100,000	4,158,000	4,455,000	0	**90,163,000**
3-1.PV	55,500,000	0	27,650,000	2,550,000	4,886,000	5,235,000	1,000,000	**96,821,000**
3-1.PV+WT	37,500,000	20,250,000	23,100,000	2,100,000	3,528,000	3,780,000	1,000,000	**91,258,000**
3-2.PV	55,500,000	0	22,400,000	2,250,000	5,054,000	5,415,000	1,000,000	**91,619,000**
3-2.PV+WT	43,500,000	14,250,000	18,900,000	1,950,000	4,158,000	4,455,000	1,000,000	**88,213,000**

PV = 1,500USD/KW
275kW WT = 750,000USD/Unit
Li-ion Battery = 350USD/KWh
Battery Inverter = 150USD/KW
} **Same as IRENA Roadmap**

DEG Maintenace = 1,000,000USD (For All Generator)

Tentative

Draft of Study :<Step3> Long-Term Battery Use

Capital Cost @ 2025

→ 60% actual capacity factor of WT in other Island country is reflected to costs.

	PV	WT	Batt				DEG Maintenace	Total
			Long-Term		Short-Term			
			Li-ion	Inverter	Li-ion	Inverter		
1-1.PV	33,000,000	0	19,250,000	1,650,000	2,786,000	2,985,000	0	**59,671,000**
1-1.PV+WT	16,500,000	33,750,000	5,950,000	1,350,000	1,568,000	1,680,000	0	**60,798,000**
1-2.PV	45,000,000	0	19,950,000	1,950,000	4,074,000	4,365,000	0	**75,339,000**
1-2.PV+WT	34,500,000	23,750,000	17,500,000	1,650,000	3,318,000	3,555,000	0	**84,273,000**
2-1.PV	49,500,000	0	27,650,000	2,400,000	4,326,000	4,635,000	0	**88,511,000**
2-1.PV+WT	33,000,000	33,750,000	23,100,000	1,950,000	3,108,000	3,330,000	0	**98,238,000**
2-2.PV	55,500,000	0	25,200,000	2,400,000	5,054,000	5,415,000	0	**93,569,000**
2-2.PV+WT	43,500,000	23,750,000	21,700,000	2,100,000	4,158,000	4,455,000	0	**99,663,000**
3-1.PV	55,500,000	0	27,650,000	2,550,000	4,886,000	5,235,000	1,000,000	**96,821,000**
3-1.PV+WT	37,500,000	33,750,000	23,100,000	2,100,000	3,528,000	3,780,000	1,000,000	**104,758,000**
3-2.PV	55,500,000	0	22,400,000	2,250,000	5,054,000	5,415,000	1,000,000	**91,619,000**
3-2.PV+WT	43,500,000	23,750,000	18,900,000	1,950,000	4,158,000	4,455,000	1,000,000	**97,713,000**

Big Challenges for Achievement 45% Goal

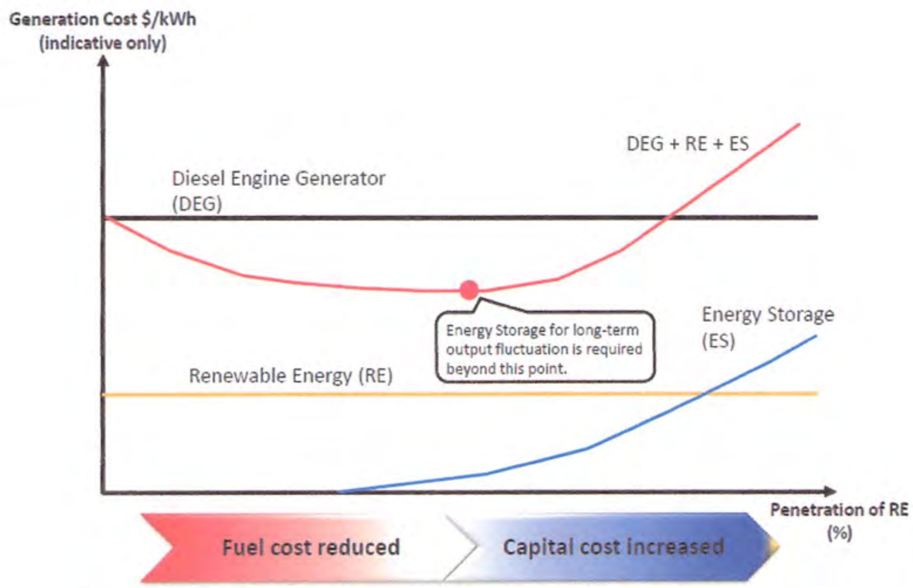
<Finance>

- ☐ High Capital Costs
- ☐ High O&M Costs
- ☐ High Tariff
- ☐ Land Space
- ☐ …

<Technology>

- ☐ DEG and RE operation
  - RE output forecasting and control
  - Battery Management
- ☐ Maintenance
- ☐ …

Further Study Policy



Source : JICA

PV generation system installation plan (As of Oct. 2017)

In the Republic of Palau

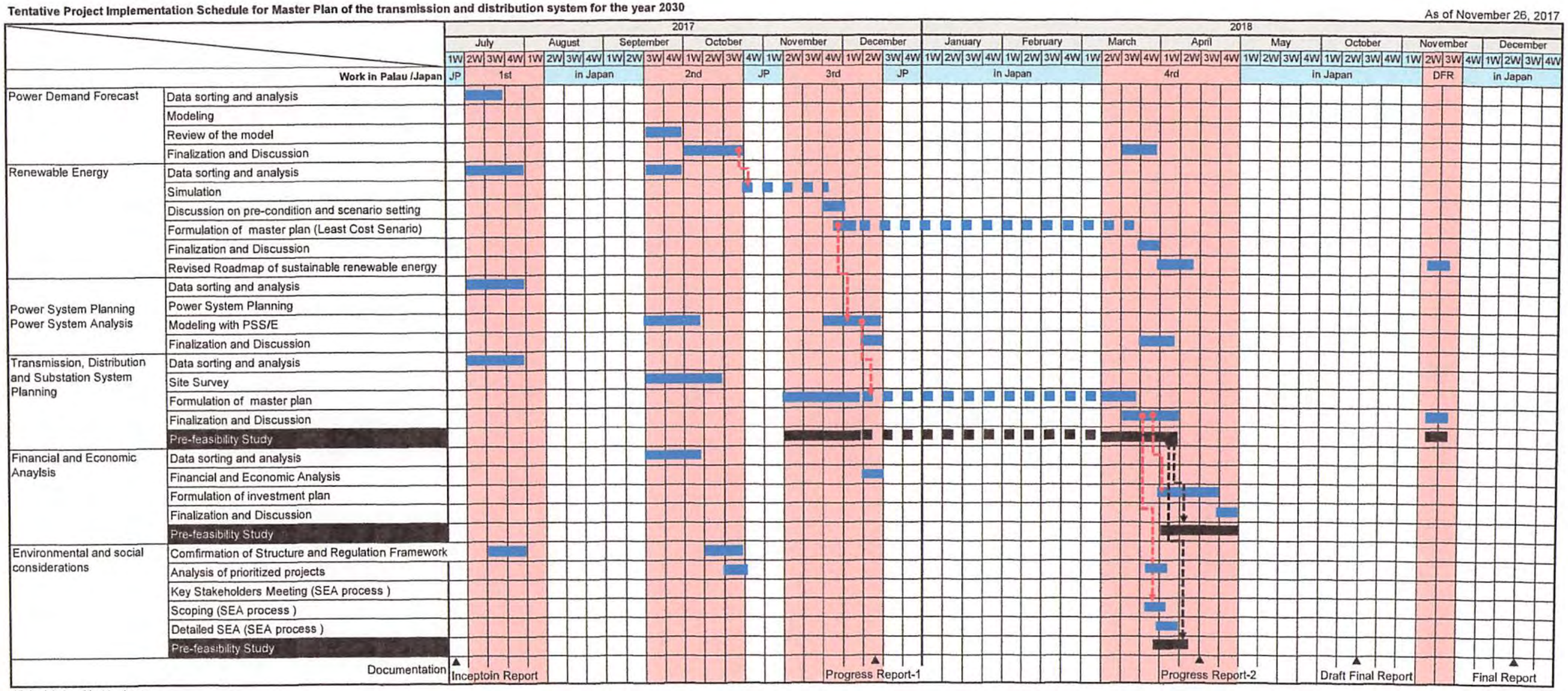
No	Location	Capacity	Owner
1	Aimeliik (Next to power plant) This is already planned with PPUC.	5 MWp	PPUC
2	Ngatpang (Kokusai)	2-3 MWp the capacity is not confirmed for #2 Ngatpang and #3 Ngardmau.	PPUC
3	Ngardmau (Terraces of Hill)	2-3 MWp	PPUC
4	Commercial roof top by Joint Crediting Mechanism(JCM)	Total 5 MWp	Surangle, WCTC PIDC & PMA
5	Airai airport side by road	3 MWp	PPUC
6	Koror & Airai (Roof top)	2-5 kWp / roof	House owners
	Total	19 MWp	

Source: Energy Administration office

Annex-3

Tentative Project Implementation Schedule for Master Plan of the transmission and distribution system for the year 2030

As of November 26, 2017



*Schedule is subject to change

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The 1st Joint Coordination Committee (hereinafter referred to as "JCC") Meeting on Japan Technical Cooperation Project for Study on Upgrading and Maintenance Improvement of National Power Grid in the Republic of Palau (hereinafter referred to as "the Project"), was held on 13th April, 2018. Japan International Cooperation Agency (hereinafter referred to as "JICA") with JICA Expert team (hereinafter referred to as "the JICA side") presented the progress of the Project and had a series of discussions with Palau Public Utilities Corporation (hereinafter referred to as "PPUC") for pursuing consensus on the progress report-2 for the master plan and pre-feasibility study.

As a result of the discussions prior to JCC meeting, the JICA side and PPUC have confirmed the main items described in the attachment.

Koror, 13th April, 2018

Ms. Ritsuko KAWABE Special Advisor Energy and Mining Group Industrial Development and Public Policy Dept. Japan International Cooperation Agency (JICA)	Mr. Kione J. Isechal, P.E. Chief Executive Officer Palau Public Utilities Corporation (PPUC) The Republic of Palau
Mr. Mitsuhisa NISHIKAWA Team Leader JICA Expert Team Japan International Cooperation Agency (JICA)	Mr. Reagan Belechel Member of Board of Directors Palau Public Utilities Corporation (PPUC) The Republic of Palau
Mr. Nobuaki MIYATA Resident Representative JICA Palau Office Japan International Cooperation Agency (JICA)	Mr. Charles I. Obichang Minister of Public Infrastructure, Industries & Commerce (MPIIC) The Republic of Palau

ATTACHMENT

I. Scenario of Renewable Energy Road Map and Master Plan

Under the Palau's Nationally Determined Contribution (hereinafter referred to as "NDC") which put the nation on a trajectory to generating 45% of its energy from renewable sources by 2025, both sides confirmed that the target year of the master plan (hereinafter referred to as "MP") for updating roadmap of 45% of renewable energy (hereinafter referred to as "RE") and for enhancement of power transmission and distribution facilities in consideration of the introduction of further RE would be 2025. However, the said MP was formulated for the target year of 2030 in the progress report-2, and therefore the both sides agreed to revise it in the updated progress report-2. Moreover, replacement of substation facilities, such as existing Malakal and Aimeliik substations and decommissioning of Airai substation by 2030 might be replaced as a recommendation in the updated progress report-2.

On the other hand, PPUC requested the JICA side to delete the scenario of MP in 2030 for only operation of diesel power plant (hereinafter referred to as "DG) in the updated progress report-2.

II. Important Factors of 45% Scenario

Both sides discussed the important factors for the study of 45% Scenario:

1. Change of precondition for the worst condition of power flow analysis during peak time in 2025
   In case batteries discharge continuously for 365 days at peak periods and no renewable energy, PPUC requested that power flow analysis during that time as the peak time condition. JICA side agreed it.

2. Confirmation of battery allocation sites
   PPUC requested that the sites for batteries would be distributed in each PV power stations, and power flow analysis was executed accordingly. However, JICA side explained the advantage and disadvantage of distributed allocation as below. PPUC confirmed the advantages and disadvantages and PPUC would consider the detailed study whether it is profitable or not technically and financially in the future feasibility study.

   Advantages:
   - Reduction of land space by each site
   - Reduction of transmission loss
   - High flexibility operation of power generation

   Disadvantages:
   - Cost impact

3. Power flow analysis of the intermediate section
   PPUC requested JICA side to conduct power flow analysis at each step up to the final step in 2025 in order to anticipate impacts due to delay.

4. Power flow analysis for Wind Turbine
   JICA side implemented load flow analysis for wind turbine as a reference case in progress report-2. PPUC accepted it.

III. Implementation Structure of 45% Scenario

In order for Palau side to realize 45% Scenario by the target year, PPUC requests the JICA side to analyze possible measures and necessary implementation structures how to finance or invest RE related projects including inviting independent power producer (hereinafter referred to as "IPP"). JICA side will recommend it in the updated progress report-2 in order to enhance private investment for IPP. Furthermore, PPUC requested that a sentence, "PPUC should employ technical and financial consultants for IPP introduction" would be added in the updated progress report-2. JICA side confirmed to give recommendations on each step for the analysis of updating RE road map in the view point as below.

- Benefit and disadvantage of introducing IPP
- Regulation of IPP introduction
- Finance of IPP introduction
- IPP contract
- Scope of work of IPP

IV. Additional Activities

JICA side has decided to extend the Project from January 2019 to May 2019 depending on the progress of activities. Accordingly, the JICA Expert team presented the completed and on-going technical transfer items based on the Annex 4.

PPUC requested the JICA side to add technical transfer of "Fault Calculation" so that PPUC can identify the cause of faults, such as fault current and fault voltage against customers and among the related department of PPUC. JICA Expert team, however explained even though the utility company in Japan implements the fault calculation, there are some cases that cause of faults cannot be identified. Therefore, JICA Expert team suggested implementing technical transfer from the point of view of the knowledge and experiences in Japan and PPUC agreed it as a part of technical transfer.

On the other hand, PPUC is concerned some items in connection with the calculation of allowable amount of renewable energy and maintenance of transmission and distribution lines as below. Those 3 items are on-going training in the Project. Therefore, PPUC and JICA Expert team confirmed not to include the following three items PPUC requested.

- Algebraic method of short-term constraint
- Demand-supply balance simulation including how to use HOMER-Pro
- Facility maintenance and management technology

V. Project Implementation Schedule

After 4th Field Survey, JICA side explained the tentative project implementation schedule as of Annex-3. PPUC agreed with the schedule as an extended schedule to implement the project activity.

Both sides agreed that JICA side would revise the report based on the above discussions with PPUC and would submit the updated progress report-2 in the beginning of August, 2018.

Draft final report will be submitted in the middle of February, 2019 and final report will be submitted in May, 2019.

VI. Other relevant information

In the JCC meeting, Mr. Ken Uyehara, governor of Angaur stated that MP should consider to install underground transmission lines, submarine cable and gas turbine instead of battery for renewable energy. JICA Expert team explained why they are not feasible for PPUC to apply such technology, and will include the reasons in the updated progress report-2.

Annex List

Annex-1: Presentation Papers for JCC

Annex-2: List of the JCC Meeting Participants

Annex-3: Tentative Project Implementation Schedule

Annex-4: Technical Transfer Items

TIME TABLE FOR
JOINT COORDINATION COMMITTEE
ON THE PROJECT FOR
STUDY ON UPGRADING AND MAINTENANCE IMPROVEMENT OF NATIONAL POWER GRID
IN THE REPUBLIC OF PALAU

PLACE AND VENUE: PALASIA HOTEL, KOROR, PALAU
DATE: 13TH APRIL, 2018.

Time	Event/ Activity	Action by
09:10-09:15	Opening Remarks	Representative from PPUC
09:15-09:20	Introduction of Members of JICA Study Team	Mr. Mitsuhisa Nishikawa
09:20-09:30	Power Demand Forecast	Mr. Tomoyuki Inoue
09:30-09:55	Renewable Energy Roadmap	Mr. Masaki Kobayashi
09:55-10:10	Network Planning and Analysis	Mr. Nobuyuki Kinoshita
10:10-10:25	Power Transmission and Distribution line	Mr. Tatsuhiro Tamura
10:25-10:40	Substation Planning & Summary of Facility Planning	Mr. Makoto Abe
10:40-10:50	Questions and Answers	All
10:50-11:10	Coffee break	All
11:10-11:20	Environmental and social considerations	Mr. Masaya Sugita
11:20-11:30	Economic Analysis	Mr. Yoshiyuki Choso
11:30-11:40	Target of Pre-feasibility Study	Mr. Makoto Abe
11:40-11:50	Questions and Answers	All
11:50-11:55	Closing Remarks	Representative from JICA

Members of JICA Study Team

Assignment	Name	Belonging to
Team Leader / Power System Planning	Mitsuhisa NISHIKAWA	Yachiyo Engineering Co., Ltd.
Deputy Team Leader / Renewable Energy / System Stabilization Method	Masaki KOBAYASHI	Kansai Electric Power Company, Inc.
Power Demand Forecast	Tomoyuki INOUE	Yachiyo Engineering Co., Ltd.
Power System Analysis (1)	Nobuyuki KINOSHITA	Yachiyo Engineering Co., Ltd.
Power System Analysis (2)	Kazuaki KONDO	Yachiyo Engineering Co., Ltd.
Power Transmission & Distribution System	Tatsuhiro TAMURA	Kansai Electric Power Company, Inc.
Operation & Maintenance of Power Transmission & distribution System	Takamu GENJI	Kansai Electric Power Company, Inc.
Substation System	Makoto ABE	Yachiyo Engineering Co., Ltd.
Operation & Maintenance of Substation System	Kazuki KONISHI	Kansai Electric Power Company, Inc.
Economic & Financial Analysis	Yoshiyuki CYOSO	Yachiyo Engineering Co., Ltd.
Environment & Social Consideration	Masaya SUGITA	Yachiyo Engineering Co., Ltd.
Project Coordinator / Assistant of Power System Planning	Naoya KISHI	Yachiyo Engineering Co., Ltd.

Power Demand Forecasts and Evaluation

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2. Preconditions for Model Building (page 4)
3. Results of PPUC Power Demand (page 10)
4. Evaluation of Power Demands (page 13)

April 2018

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1. Collection of the data

(1) Information and data from Palau's authorities

No.	Data and Information	Device	From following organization
1	Population estimation up to 2030	EXCEL	MOF
2	Employment and wage estimation up to 2030	EXCEL	MOF
3	GDP outlook up to 2030	EXCEL	MOF
4	Economic Review 2016 by OCI	Document	MOF
5	Palau Energy Policy 2010	PDF	Energy Administration
6	Palau Energy Roadmap - Draft for discussion	Word	Energy Administration, IRENA
7	Power peak and generation data	EXCEL	PPUC - Generation
8	Power demand data by sector and state	EXCEL	PPUC - Generation
9	PV System Connected to Grid	EXCEL	PPUC -RE
10	Intended Nationally Determined Contribution	PDF	PPUC -RE
11	Power sales by sector	EXCEL	PPUC - Finance
12	Power tariff by sector	EXCEL	PPUC - Finance
13	Number of Customers by sector	EXCEL	PPUC - Finance
14	WWO Power consumptions & payment	EXCEL	PPUC - WWO
15	Foreign Investment List	PDF	Foreign Investment Board
16	Public Infrastructure Plan	Hearing	Capital Improvement Program
17	State Investment plans	Hearing	Ngarchelong, Melekeok, Ngchesar, Airai, Koror

(2) Related power and Energy documents from Int. organizations 3

Organization	Reference documents	Published
DOI	Economic Review 2016, Republic of Palau	February 2017
ADB	Private Sector Assessment for Palau	2016
ADB	Country Operation Business Plan	November 2016
ADB	Actions for Palau's Future 2009-2014	2009
World Bank	World/Palau Economic Energy data	2017 version
IMF	Economic outlook of Palau	October 2016
IMF	2014 Article IV Consultation : Staff report	May 2014
United Nations	UN Population Study	2015 version
IEA	World Energy Outlook 2016 and 2017	2016, 2017 version
IRENA	Palau Energy Roadmap 2017 (Draft)	2017 version
EIA	Energy Transition Initiative	2015
IEEJ	Asia/World Energy Outlook	2016 version
IEEJ	IEEJ monthly paper on World Renewable energy	2016 and 2017
BP	BP Statistics	2016
Donors	Donor list for Palau energy sector projects	Past years

IEA: International Energy Agency
BP: British Petroleum (International Oil Company)
PEC: Pacific Energy Conference
SPC : Secretariat of Pacific Community
PEC: PACIFIC ENERGY CONFERENCE
EIA: Energy Information Agency of DOE, USA
IEEJ: The Institute of Energy Economics, Japan
MOF: Ministry of Finance, Palau
PPUC: Palau Public Utilities Corporation
IRENA: International Renewable Energy Agency

2. Preconditions for the model building 4

(1) Number of Population by state

Unit: person

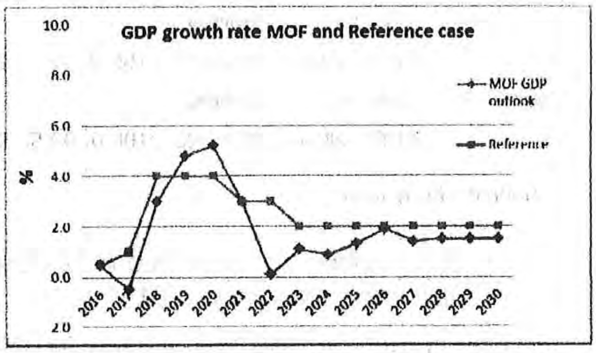
	2005	2010	2015	2020	2025	2030	2035	2040
Aimeliik (アイメリーク)	270	275	334	337	341	344	348	351
Airiai(アイライ)	2,723	2,463	2,455	2,528	2,602	2,681	2,761	2,844
Koror (コロール)	12,776	12,061	11,754	11,907	12,057	12,201	12,345	12,489
Melekeok(メレケオク)	391	396	277	281	287	294	303	312
Ngaraard(ガラルド)	581	499	413	419	426	434	442	449
Ngardmau(ガラスマオ)	166	165	185	187	189	191	193	195
Ngaremlengui(アルモノグイ)	317	300	350	353	357	361	364	368
Ngatpang(ガスパン)	464	302	282	285	288	291	294	297
Ngchesar (チェサール)	254	266	291	295	302	309	318	328
Ngarchelong(アルコロン)	488	435	316	321	326	332	338	344
Ngiwal(オギワール)	223	234	282	285	288	291	294	297
Koror+Babeldaob(バベルダオブ)	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

- The state population are forecasted under considering regional investment schedules.
- Future country population is estimated by MOF. The increase rate is 0.3 % per year.
- The state population are forecasted by elasticity to the increase rate of the country population

(2) GDP growth rate as Reference case

< GDP growth rate forecasted by MOF and Study team>

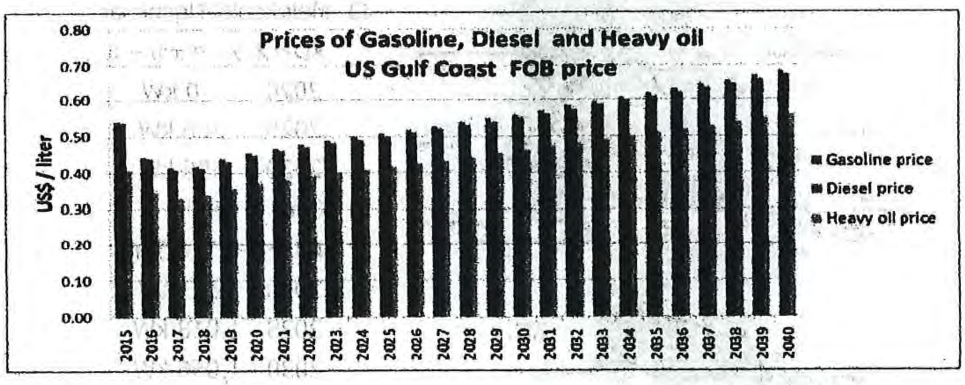
Unit %	MOF outlook	Study team outlook
2016	0.5	0.5
2017	-0.5	1.0
2018	3.0	4.0
2019	4.8	4.0
2020	5.2	4.0
2021	3.0	3.0
2022	0.1	2.0
2023	1.1	2.0
2024	0.9	2.0
2025	1.3	2.0
2026	1.9	2.0
2027	1.4	2.0
2028	1.5	2.0
2029	1.5	2.0
2030	1.5	2.0
2035/30		2.0
2040/35		2.0



(3) Crude oil and Fuel prices for estimating power tariffs

	Unit	2017	2020	2030	2040
WTI	US$ / bbl	50	61	75	91

Source: Study team after referring IEA and IEEJ outlook.



(4) Energy efficiency & Conservation factors

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Sector	Items	Unit	2017	2018	2019	2020	2025	2030	2035	2040
Commercial	EE&C rate	Saving%	0.0	0.5	0.5	0.5	1.0	1.0	1.0	1.0
	EE&C Indicator	2017=100	100.0	99.5	99.0	98.5	96.1	91.4	86.9	82.6
Gov & Public	EE&C rate	Saving%	0.0	0.5	0.5	0.5	1.0	1.0	1.0	1.0
	EE&C Indicator	2017=100	100.0	99.5	99.0	98.5	96.1	91.4	86.9	82.6
Residential	EE&C rate	Saving%	0.0	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	EE&C Indicator	2017=100	100.0	99.5	99.0	98.5	96.1	93.7	91.4	89.1

Source: Study team

- EE&C activities are described in "Intended Nationally Determined Contribution, November 2015"
- The targets of EE&C are reduced to 35% by energy intensity ,energy conversion and energy efficiency to 2015 by 2025.
- EE&C rate with 0.5% in the table is world average from 2013 to 2040 by IEA report in 2016.

(5) Locations of future additional demands

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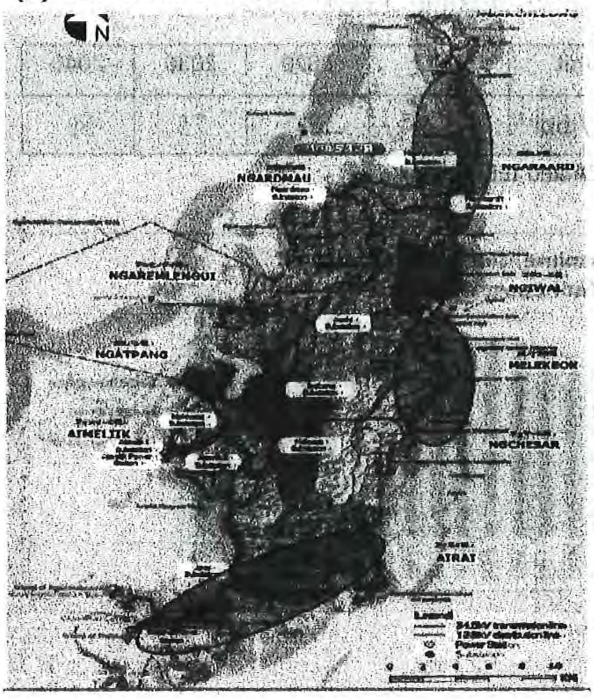


- Ngaraard+ Ngarchelong
  ガラルド+アルコロン
  2020 0 kW
  2025 236 kW
  2030 397 kW
- Melekeok+Ngchesar
  メレケオク+チェサール
  2020 0 kW
  2025 206 kW
  2030 396 kW
- Koror + Airai
  コロール+アイライ
  2020 273 kW
  2025 1,018 kW
  2030 1,056 kW

Source: The forecasted future demand are based on FIB, CIP and State government plans.

(6) Investment plans for future additional demands 9

◆ Koror + Airai

Unit: kW

	2020	2021	2022	2023	2024	2025	2030	2035
a) New hotel for 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	28	28	28	28	28
Total	273	371	518	665	812	1,018	1,056	1,095

◆ Melekeok+Ngchesar

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 hotel				70	70	84	98	98
d) Small hotels				29	39	49	98	98
Total				123	149	206	396	416

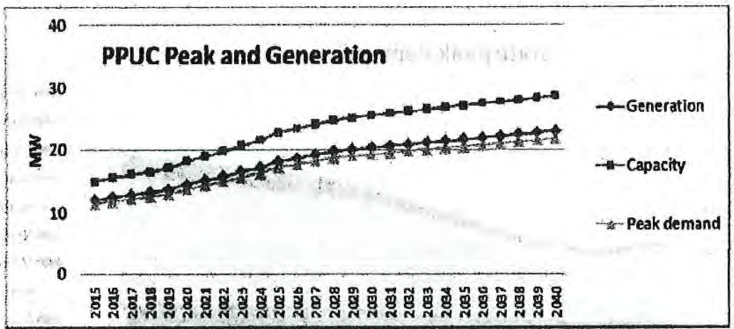
◆ Ngaraard+ Ngarchelong

Unit: kW

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

3. Results of PPUC Power Demand 10

(1) Peak demand of PPUC



Source: Study team

PPUC Peak and Generation

MW

	2016	2017	2019	2020	2025	2030	2035	2040
Peak demand	11.8	12.2	13.0	13.8	17.2	19.3	20.5	21.8
Generation	12.5	12.9	13.7	14.6	18.2	20.3	21.6	23.0
Capacity	15.6	16.1	17.1	18.2	22.7	25.4	27.0	28.7

(2) Annual power and peak demands

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		2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Gross generation	MWh	83,430	84,870	88,020	91,290	96,880	100,210	102,920	106,920	110,040	115,110
Load factor	%	76.3	76.0	76.0	76.0	76.0	75.2	74.5	73.7	73.0	72.3
Reserve margin	%	20	20	20	20	20	20	20	20	20	20
Required capacity	kW	15,610	16,130	16,530	17,140	18,190	19,000	19,720	20,690	21,510	22,730
Net demand(Energy	MWh	79,310	80,460	83,450	86,540	91,840	95,000	97,560	101,360	104,310	109,120
Net peak demand	kW	11,840	12,230	12,530	13,000	13,790	14,410	14,950	15,690	16,310	17,240
Own use	MWh	4,350	4,413	4,577	4,747	5,038	5,211	5,352	5,560	5,722	5,986
Own use rate	%	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2

		2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Gross generation	MWh	116,850	119,140	121,270	123,230	124,960	126,550	128,170	129,730	131,280	132,850
Load factor	%	71.6	70.8	70.1	70.1	70.1	70.1	70.1	70.1	70.1	70.1
Reserve margin	%	20	20	20	20	20	20	20	20	20	20
Required capacity	kW	23,300	24,000	24,680	25,070	25,430	25,750	26,080	26,400	26,710	27,030
Net demand(Energy	MWh	110,770	112,950	114,970	116,820	118,460	119,970	121,500	122,980	124,450	125,940
Net peak demand	kW	17,670	18,200	18,710	19,020	19,280	19,530	19,780	20,020	20,260	20,500
Own use	MWh	6,076	6,196	6,306	6,408	6,498	6,581	6,665	6,746	6,827	6,908
Own use rate	kW	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2

Source: Study team

(3) State wise power demand and capacity

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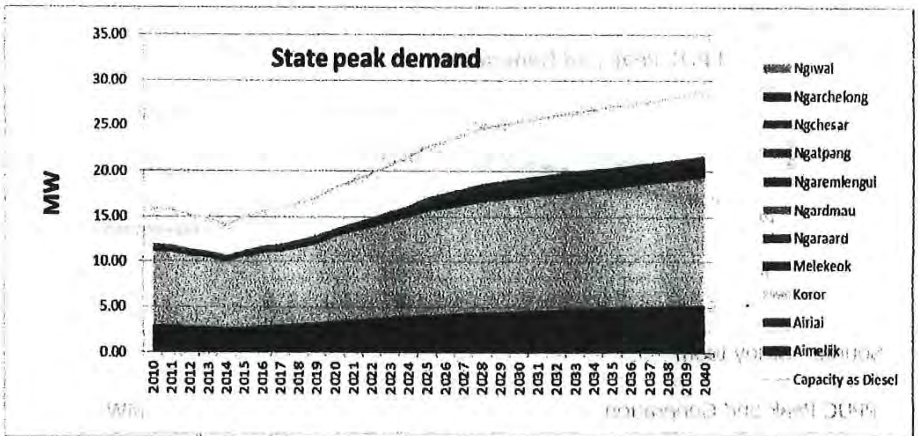

Source: Study team

4. Evaluation of power Demands

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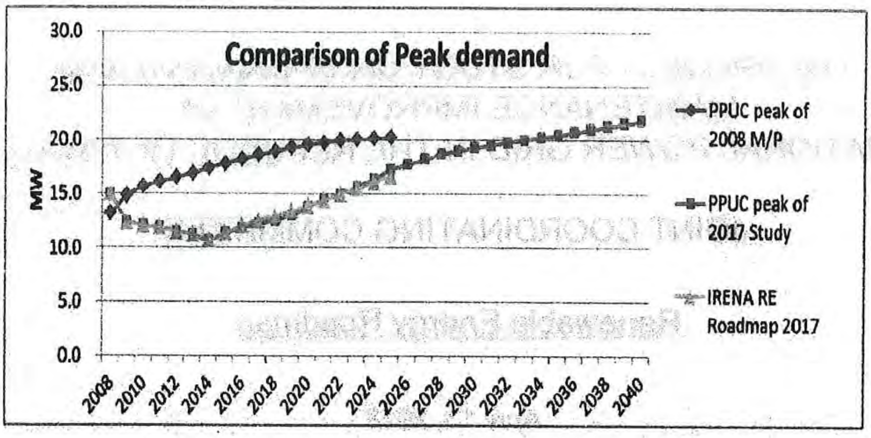
(1) Comparison of IRENA 2017, M/P 2008 and Study team 2017



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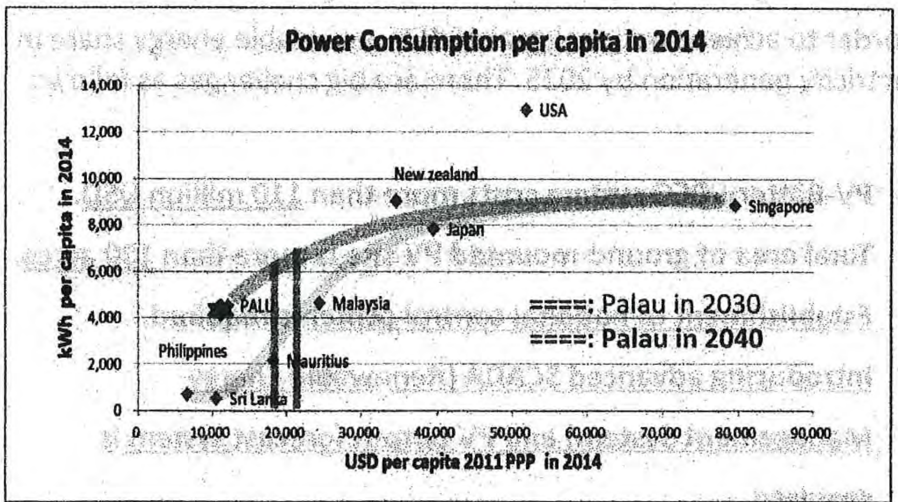
(2) Comparison of power consumption per capita



Source: Countries: World bank database
Palau: Study team

Japan International Cooperation Agency

YACHIYO ENGINEERING CO.,LTD.
Consulting Engineers & Architects

Kansai Electric Power

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

JOINT COORDINATING COMMITTEE

Renewable Energy Roadmap

April 13, 2018

1

Executive Summary

In order to achieve national goal of 45% renewable energy share in electricity generation by 2025. There are big challenges as follows.

- **PV-Battery-DEG system costs more than 110 million USD.**
- **Total area of ground-mounted PV site is more than 100 acres.**
- **Establishment of national control center is required.**
- **Introducing advanced SCADA (Renewable Energy Management System) and PV output forecast system is required.**

Presentation Outline

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- ➢ RE roadmap objective
- ➢ RE roadmap analysis methodology
- ➢ RE system configuration
- ➢ RE 45% roadmap
- ➢ Recommendation

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RE Roadmap Objective

3

To provide RE development plan in order to achieve national goal of 45% renewable energy share in electricity generation by 2025 <u>under maximum consideration of securing the electric power supply quality and PPUC's O&M capacity.</u>

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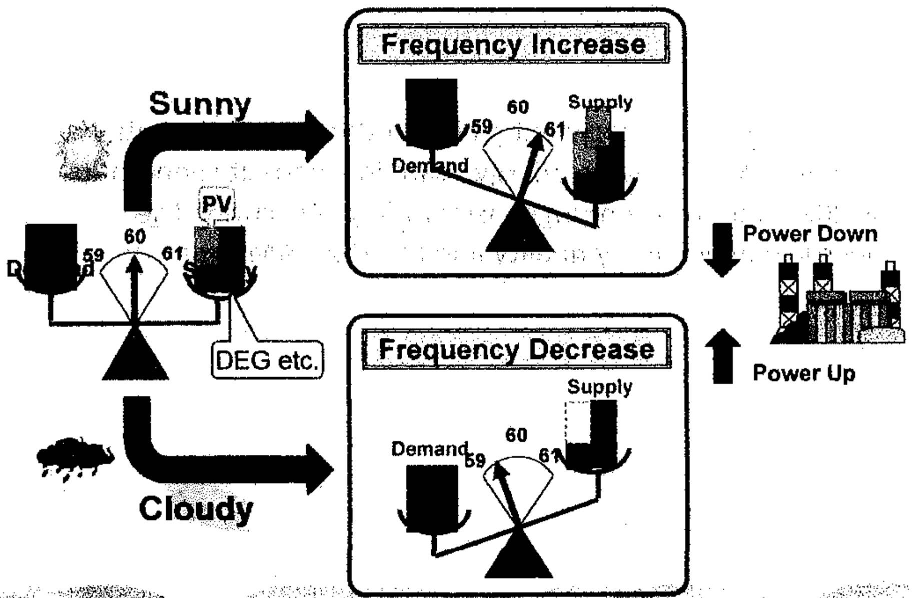
RE Roadmap analysis methodology

	Influence and Issues	Countermeasures
1	Frequency Fluctuation (Short-term constraint)	• LFC/AFC • Generator Improvement • Batteries
2	Surplus Electricity (Long-term constraint)	• Demand creation • Generator Improvement • RE output curtailment • RE output forecast • Batteries
	Take into consideration in RE roadmap analysis	
3	Voltage Rise in Distribution System	• Demand creation • Voltage control equipment
4	Lack of Transmission / Distribution Facilities	• New transmission/distribution facilities
	Take into consideration in power system planning	

Frequency Fluctuation (Short-term constraint)



Surplus Electricity (Long-term constraint)

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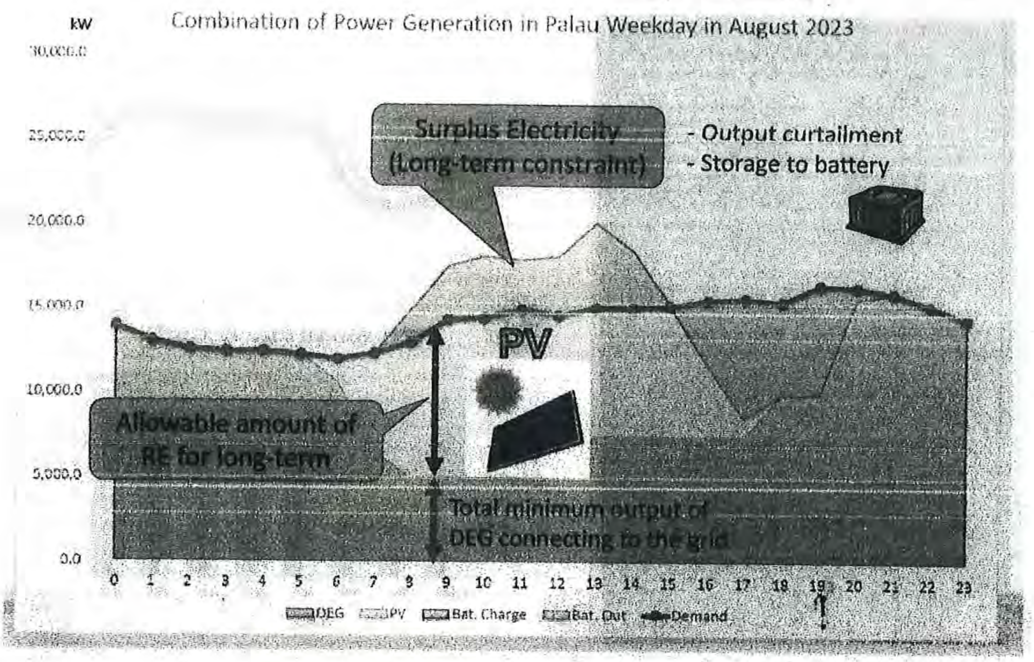

RE Roadmap analysis methodology

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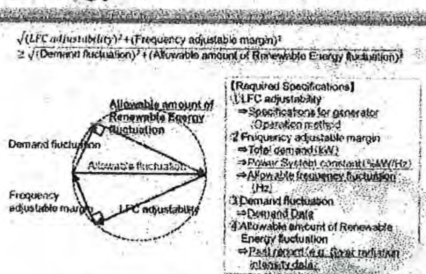
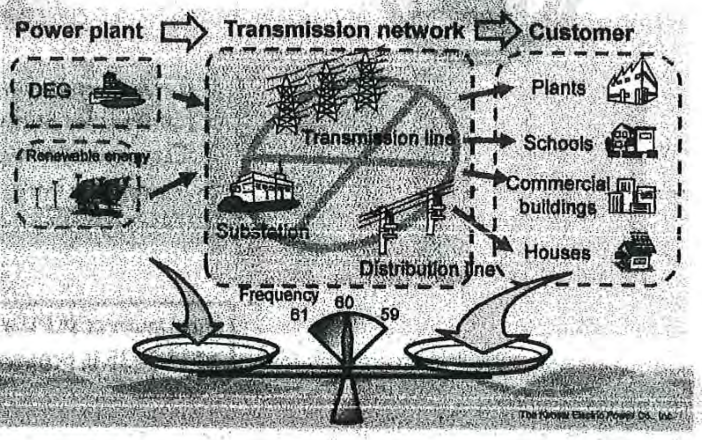


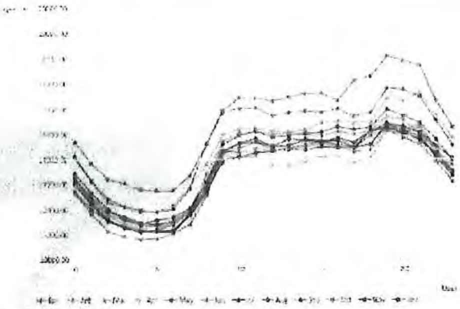
Short-term constraint
⇒ Algebraic method

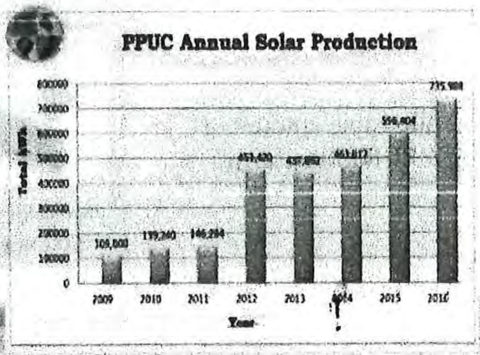
Long-term constraint
⇒ Demand-supply balance simulation



RE Roadmap analysis methodology

Baseline: 2016 power system





RE Roadmap analysis methodology

<Renewable energy source>

- Average of wind speed is little low
- Regular maintenance is required
- Low capacity factor in other Island country
- Bad supply of spare parts

Minimum cost PV +WT system configuration as of 2025 is presented for reference.

RE Roadmap analysis methodology

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Generator use	Make	Model	Name	Year installed	Capacity (kW)
Active generation	Nigata	16V28HLX	Unit 14	2011	5,000
	Nigata	16V28HLX	Unit 15	2011	5,000
	Mitsubishi	18KU30A	Unit 6	2013	5,000
	Mitsubishi	18KU30A	Unit 7	2013	5,000
Total active generation capacity					20,000

Minimum Output : 50 %

Generator use	Make	Model	Name	Year installed	Capacity (kW)
Back up	Caterpillar	3516B	Unit 1	2007	2,000
	Caterpillar	3516B	Unit 2	2007	2,000
	Wartsila	SACM 12V200	Wartsila 1	1996	1,200
	Mitsubishi	S6R - PTA	Unit 1	2013	500
	Mitsubishi	S6R - PTA	Unit 2	2013	500
	Mitsubishi	S6R - PTA	Unit 3	2013	500
	Mitsubishi	S6R - PTA	Unit 4	2013	500
Total backup capacity					7,200

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RE Roadmap analysis methodology

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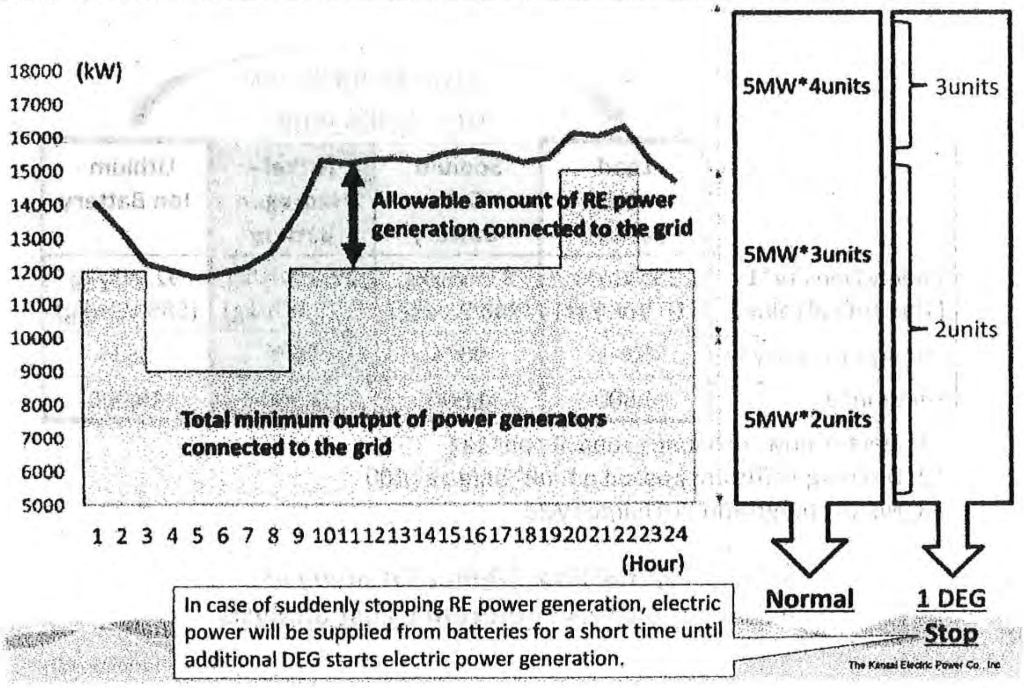

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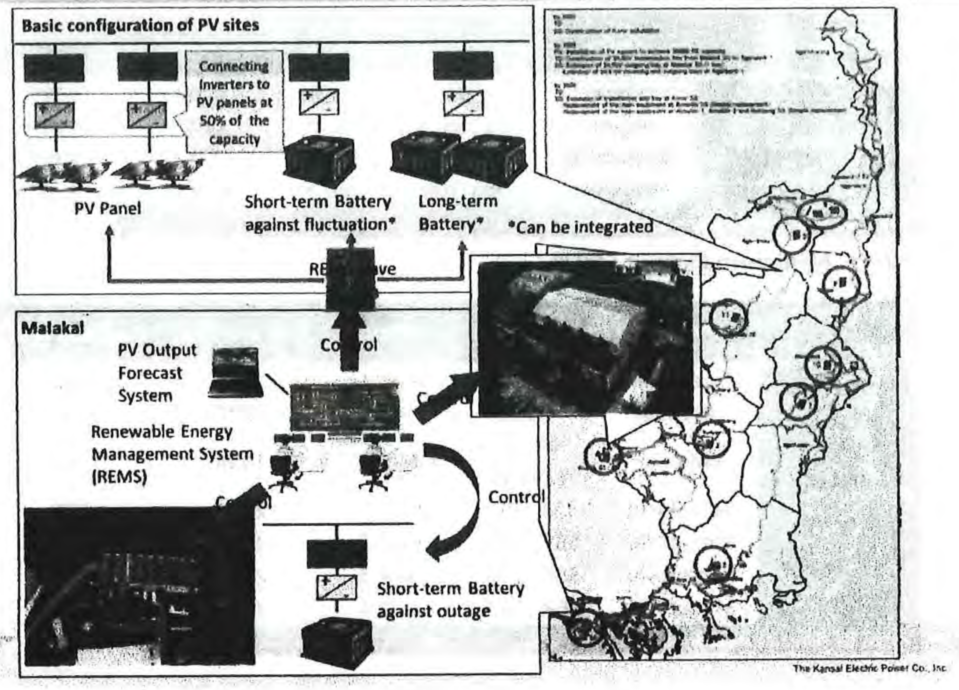
RE System Configuration



RE System Configuration

Cost: 35-65 % low
Size: 150% large

	Lead - Acid Battery	Sodium - Sulfur Battery	Nickel - Hydrogen Battery	Lithium - Ion Battery
Energy Density*1 (Theoretical value)	25 Wh/kg (167 Wh/kg)	87 Wh/kg (786 Wh/kg)	[illegible]	92 Wh/kg (585 Wh/kg)
Energy Efficiency*2	85 %	90 %	[illegible]	95 %
Lifetime*3	4,500	4,500	[illegible]	15,000

*1: Electric power charging capacity per 1kg
*2: Discharge efficiency based on full charge as 100
*3: No. of charge and discharge cycle

Lithium-Ion Battery: Main cost analysis
Lead-Acid Battery: Reference cost analysis

RE 45% Roadmap

		Phase1			Phase2			Phase3	
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PV panel (kW)*	Panel (kW)	6,000	10,000	16,000	16,000	22,000	30,000	40,000	44,000
	Inverter (kW)	3,000	5,000	8,000	8,000	11,000	15,000	20,000	22,000
Short-Term Battery against fluctuation	Battery (kW)	400	2,400	5,400	5,400	8,400	12,400	17,400	21,400
	Battery (kWh)	200	1,200	2,700	2,700	4,200	6,200	8,700	10,700
	Inverter (kW)	400	2,400	5,400	5,400	8,400	12,400	17,400	21,400
Short-Term Battery against power outage	Battery (kW)	0	0	5,000	5,000	5,000	5,000	5,000	5,000
	Battery (kWh)	0	0	2,000	2,000	2,000	2,000	2,000	2,000
	Inverter (kW)	0	0	5,000	5,000	5,000	5,000	5,000	5,000
Long-Term Battery	Battery (kW)	0	0	0	0	0	9,000	17,000	22,000
	Battery (kWh)	0	0	0	0	0	37,800	71,400	92,400
	Inverter (kW)	0	0	0	0	0	9,000	17,000	22,000
Peak Demand (kW)		12,530	13,000	13,790	14,410	14,950	15,690	16,310	17,240
RE Share of Gross Generation (%)		-	-	19	-	-	-	-	45
Gross Generation (kWh)		88,020,000	91,290,000	96,880,000	100,210,000	102,920,000	106,920,000	110,040,000	115,110,000
Rooftop PV (kW)		2,400	2,700	3,000	3,400	3,700	4,000	4,500	5,000

DEG normal operation ↔ 1 DEG stop operation

→ National control center (with REMS and RE forecast system)

The Kansai Electric Power Co., Inc.

RE 45% Roadmap

No.	Location	Capacity	Owner	Distance	Area (Acre)
1	Aimelik (Next to power plant) this is already planned with PPUC.	5 MWp +1MWp	PPUC	0.2 km from the nearest transmission line	15 acres +α
2	Ngatpang (Kokusai)	2-3 MWp +1MWp	PPUC	0.1 km from Kokusai SS	8 acres +α
3	Ngardmau (Terraces of Hill)	2-3 MWp +1MWp	PPUC	0.28 km from the nearest transmission line	7 acres +α
4	Airai Airport side by road	3 MWp +3MWp	PPUC	0.8 km from Airport	8 acres +α
5	Ngchesar	9 MWp +1MWp	PPUC	2.2 km	8 acres +α
6	Ngiwal	3 MWp +1MWp	PPUC	7.7 km	9 acres +α
7	Ngardmau	5 MWp +1MWp	PPUC	.08 km	15 acres +α
8	Melekeok	3 MWp +1MWp	PPUC	.76 km	9 acres +α
9	Ngaremlengui	5 MWp +1MWp	PPUC	.55 km	18 acres +α
Total		33MWp +11MWp			

Area required for 1MW PV is 2.47 acres → 44MW PV is 108 acres

The Kansai Electric Power Co., Inc.

RE 45% Roadmap

< RE system introduction cost by phase (Li-ion Battery) >

USD

		Phase1 (2018-2020)	Phase2 (2021-2023)	Phase3 (2024-2025)	Total	Unit Price
PV	Module, Inverter, etc. (kW)	24,000,000	21,000,000	21,000,000	66,000,000	1,500
Short-term	Battery against fluct. (kWh)	945,000	1,225,000	1,575,000	3,745,000	350
	Inverter against fluct. (kW)	810,000	1,050,000	1,350,000	3,210,000	150
	Battery against outage. (kWh)	700,000	0	0	700,000	350
	Inverter against outage (kW)	750,000	0	0	750,000	150
Long-term	Battery (kWh)	0	13,230,000	19,110,000	32,340,000	350
	Inverter (kW)	0	1,350,000	1,950,000	3,300,000	150
Total		27,205,000	37,855,000	44,985,000	110,045,000	

< RE management system and RE forecast system introduction cost by phase >

USD

		Phase1 (2018-2020)	Phase2 (2021-2023)	Phase3 (2024-2025)	Total	
RE Management System	Meter system	270,000	270,000	270,000	810,000	Install:270kUSD
	Slave system	450,000	450,000	450,000	1,350,000	Slave Addition:90kUSD/Unit Install:150USD/Unit
	Optical Fiber	90,000	90,000	90,000	270,000	4500USD/km
	Subtotal	810,000	810,000	810,000	2,430,000	
RE Forecast	System	160,000	0	0	160,000	
	O&M (Data maintenance, etc.)	45,000	135,000	90,000	270,000	45kUSD/Year
	Subtotal	205,000	135,000	90,000	430,000	
Total		1,015,000	945,000	900,000	2,860,000	

(Unit prices are based on the retail prices at 2017)

RE 45% Roadmap

< For Reference: Lead-acid Battery (50% lower cost of Li-Ion battery) >

USD

		Phase1 (2018-2020)	Phase2 (2021-2023)	Phase3 (2024-2025)	Total	Unit Price
PV	Module, Inverter, etc. (kW)	24,000,000	21,000,000	21,000,000	66,000,000	1,500
Short-term	Battery against fluct. (kWh)	472,500	612,500	787,500	1,872,500	175
	Inverter against fluct. (kW)	810,000	1,050,000	1,350,000	3,210,000	150
	Battery against outage. (kWh)	350,000	0	0	350,000	175
	Inverter against outage (kW)	750,000	0	0	750,000	150
Long-term	Battery (kWh)	0	6,615,000	9,555,000	16,170,000	175
	Inverter (kW)	0	1,350,000	1,950,000	3,300,000	150
Total		26,382,500	30,627,500	34,642,500	91,652,500	

(Reference) PV-WT System Configuration

PV	Module (kW)	36,000	
	Inverter (kW)	18,000	
WT	Turbine(kW)	8,250	
	Inverter (kW)	5,775	
Short-Term Battery against fluctuation	Battery (kW)	36,000	Not require to WTs
	Battery (kWh)	18,000	
	Inverter (kW)	36,000	
Short-Term Battery against power outage	Battery (kW)	5,000	
	Battery (kWh)	2,000	
	Inverter (kW)	5,000	
Long-Term Battery	Battery (kW)	36,000	Not require to WTs
	Battery (kWh)	100,000	
	Inverter (kW)	36,000	

< RE system introduction cost (Li-ion Battery) >

USD

		Total	Unit Price	
PV	Module, Inverter, etc...(kW)	54,000,000	1,500	
WT	Tubine, Inverter, etc...(kW)	22,497,750	2,727	750kUSD/Unit
Short-term	Battery against fluct. (kWh)	6,300,000	350	
	Inverter against fluct. (kW)	5,400,000	150	
	Battery against outage. (kWh)	700,000	350	
	Inverter against outage (kW)	750,000	150	
Long-term	Battery (kWh)	35,000,000	350	
	Inverter (kW)	5,400,000	150	
Total		130,047,750		

1.18 times higher than only PV system

The Kansai Electric Power Co., Inc.

Recommendation

Item		Recommendation
Battery Capacity Reduction	Short-term	Taking high- speed DEG into normal operation
		Improvement of DEG governor function
	Long-term	Introduction of new high- speed DEG which can operate at low load continuously.
		DEG operation planning agree perfectly with the demand
		Demand shifting / creation
Battery Introduction Cost Reduction		Concentration of long-term battery

The Kansai Electric Power Co., Inc.

Recommendation

<Capacity reduction of Short-term battery>

High-speed DEG

1	Total Demand	10.7	MW
2	System Constant	10	%/Hz
3	Allowable Frequency Fluctuation Range	2	Hz
4	Adjustable Frequency Margin	2.14	MW
5	LFC Adjustability	0	MW
6	Allowable Fluctuation	2.14	MW
7	Demand Change Rate	0.2354	MW
8	Total Fluctuation of PV+Wind	2.13	MW
9	PV Output Fluctuation	2.13	MW
11	PV Change Rate	0.338	–
10	Allowable Amount of PV	6.29	MW

1	Total Demand	10.7	MW
2	System Constant	11	%/Hz
3	Allowable Frequency Fluctuation Range	2	Hz
4	Adjustable Frequency Margin	2.354	MW
5	LFC Adjustability	0	MW
6	Allowable Fluctuation	2.354	MW
7	Demand Change Rate	0.2354	MW
8	Total Fluctuation of PV+Wind	2.34	MW
9	PV Output Fluctuation	2.34	MW
11	PV Change Rate	0.338	–
10	Allowable Amount of PV	6.93	MW

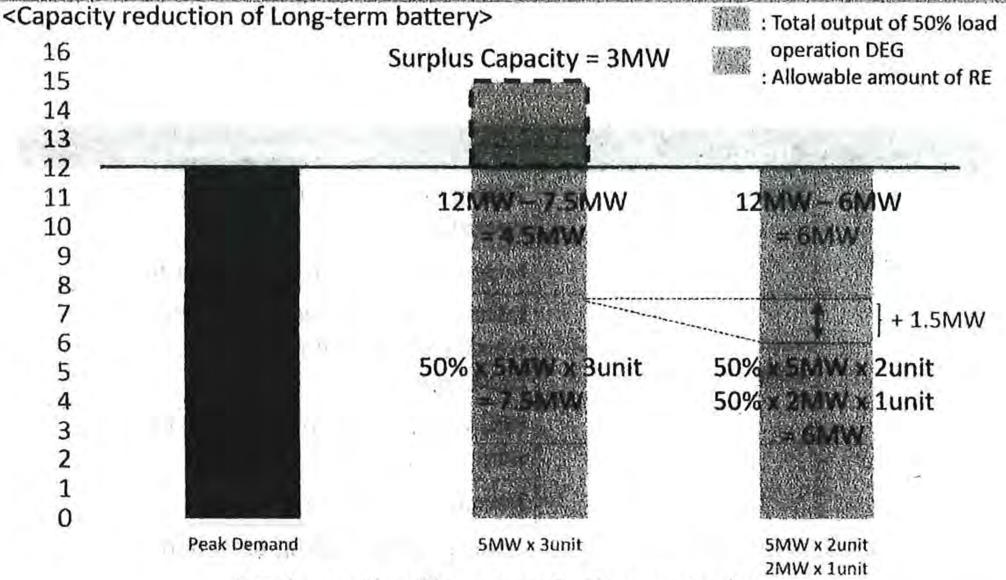
+ 0.6MW

<u>Total capacity of short-term battery can reduce</u>

<u>To improve governor function of DEGs will contribute reducing total capacity of short-term battery as well.</u>

Recommendation

<Capacity reduction of Long-term battery>



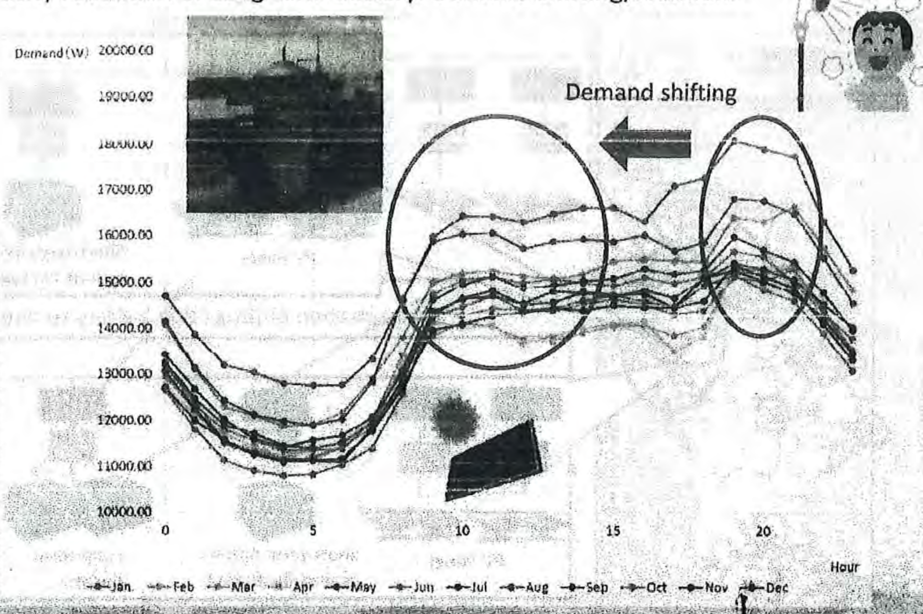
<u>Total capacity of long-term battery can reduce</u>

Introduction of <u>new DEG which can continuously operate at low load</u> contribute to drastically reduce total capacity of long-term battery as well.

Recommendation

22

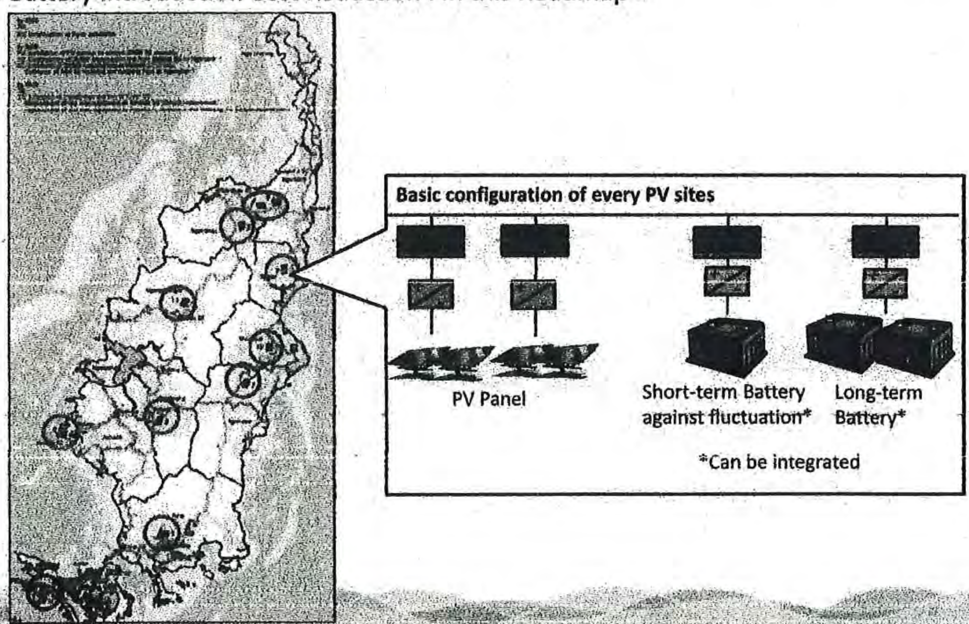
< Capacity reduction of Long-term battery: Demand shifting/creation>



Recommendation

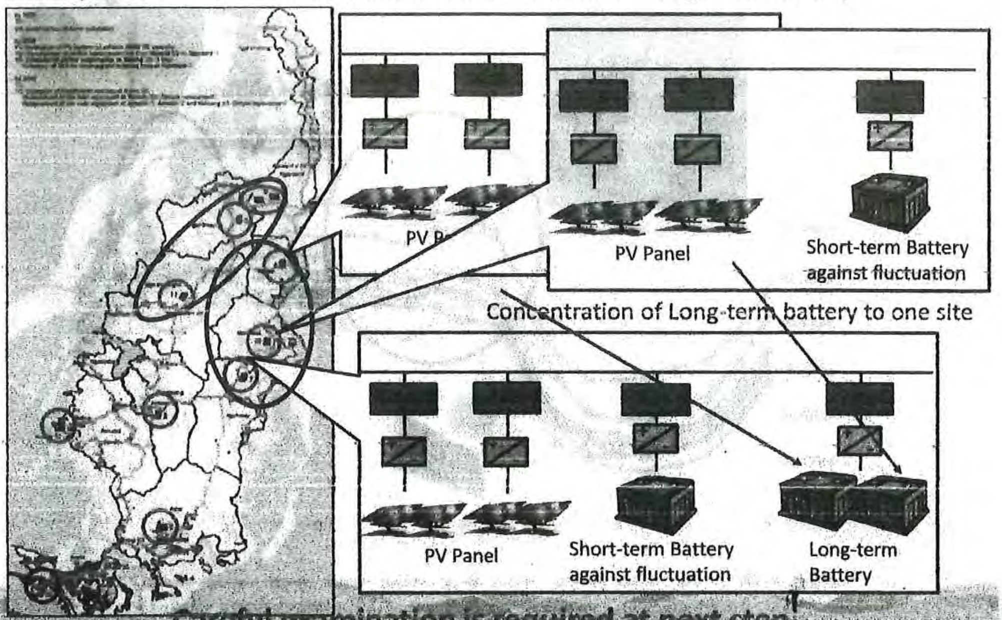
23

< Battery Introduction Cost Reduction : In this Roadmap >



Recommendation

< Battery Introduction Cost Reduction : Concentration of Long-term battery>



Careful examination is required at next step.

The Kansai Electric Power Co., Inc.

Network Planning and Analysis

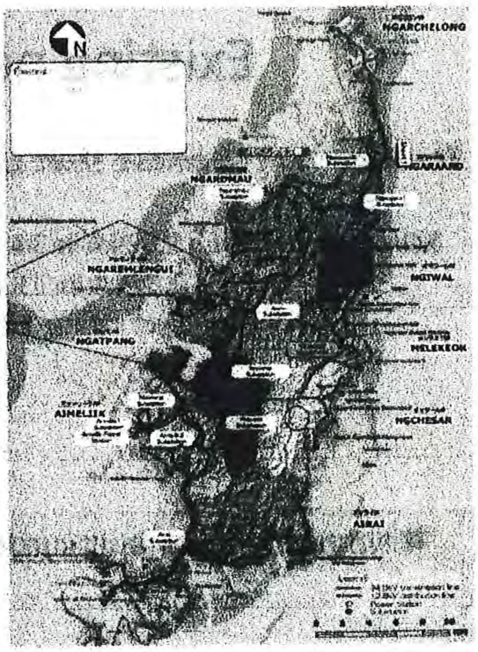
JICA Project Team

Nobuyuki KINOSHITA

Existing network system

Present status of Koror-Babeldaob network

Item	Quantity	Remarks
Peak demand	12.29MW	13th Aug. 2016
Power plant output	36.45MW	Malakal, Aimeliik
Transmission line	79.7km	34.5kV
Substation	59.95MVA	12 stations

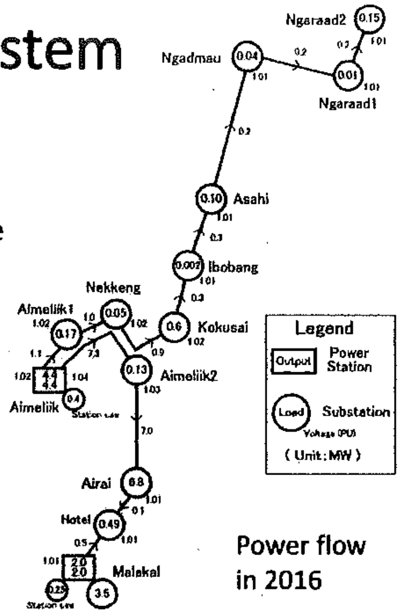


Existing network system

Power flow and voltage

- Max power flow: 7.3MW in Aimeliik-Aimeliik2 line (transmitting capacity 21.5MW)
- Voltage : 101-104% (desired range 95-105%)

■ No problem on power flow nor voltage



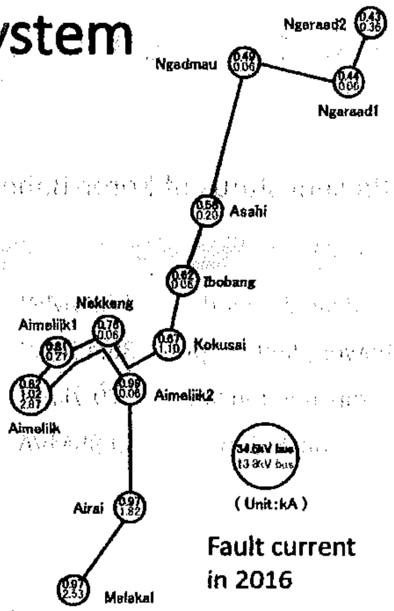
Power flow in 2016

Existing network system

Fault current (3 phase shirt circuit)

- Max fault current : 1.02kA in 34.5kV at Aimeliik
  2.87kA in 13.8kV at Aimeliik
  (circuit breaker rating 12.5kA)

■ No problem on fault current



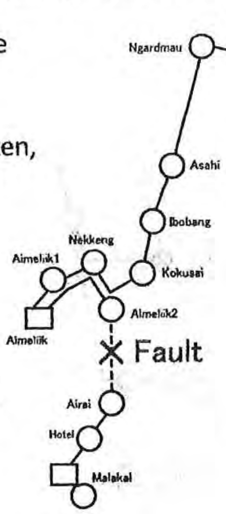
Fault current in 2016

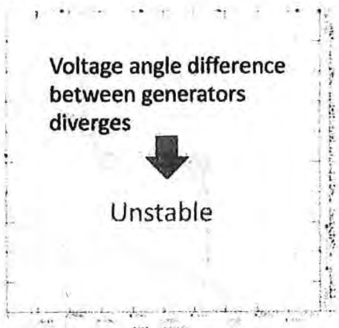
Existing network system

Stability : after fault occurrence and fault cleared, network must be in operation without blackout

- In case of fault occurrence on 34.5kV line between Aimeliik and Malakal power station and opening faulted line, since interconnection of both PSs is broken, network stability can not be maintained and large scale blackout causes

- 2 routes of transmission line connecting Malakal and Aimeliik Power station are necessary





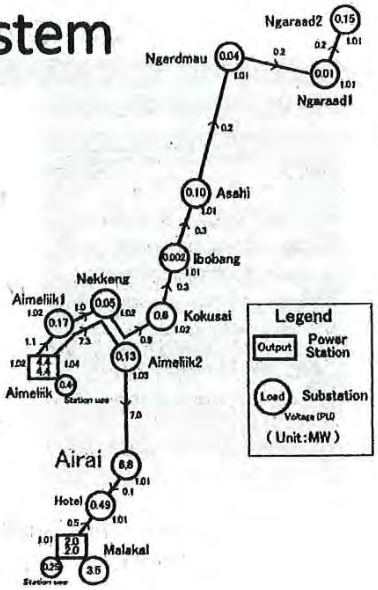
Generator voltage angle fluctuation

Existing network system

Aging Airai substation

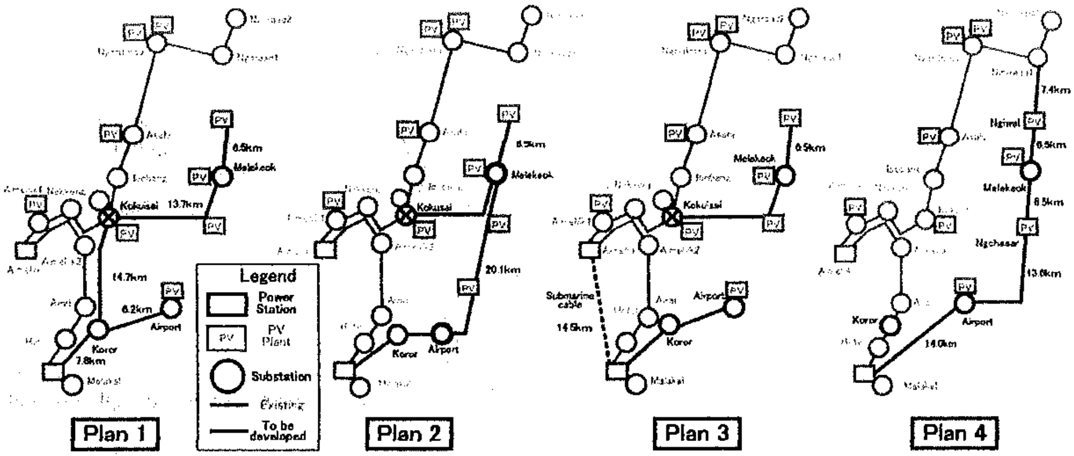
- 34.5/13.8kV Airai Substation most important to supply power to Koror area is aged (constructed in 1985)

- Construction of new substation in Koror Island is necessary



Countermeasures against instability and aging substation

- Taking account of 9 sites of PV, 4 plans of countermeasures can be considered

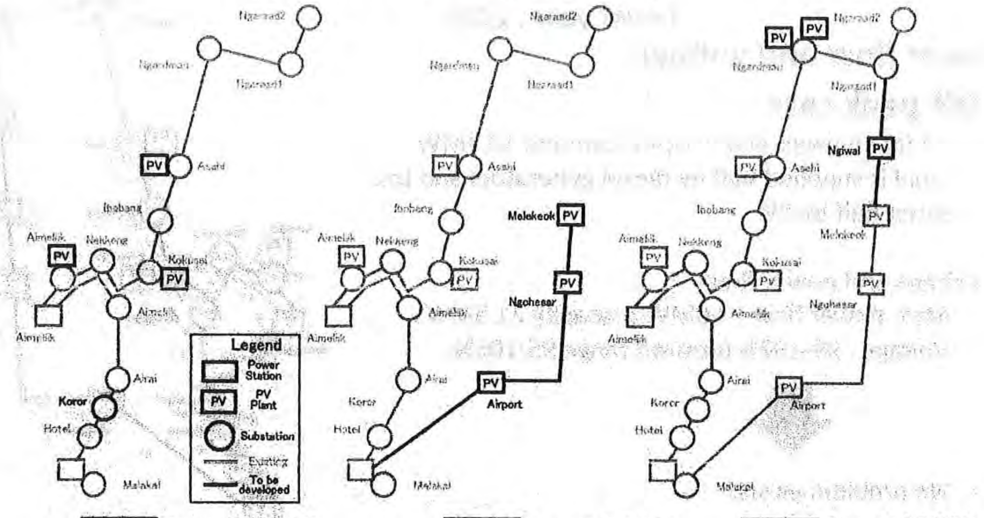


Comparison of countermeasures

	Plan 1	Plan 2	Plan 3	Plan 4
Volume of new overhead line	48.9 km	54.3 km	34.2 km	48.0 km
Submarine cable	-	-	14.5 km	-
Construction cost (US$)	14.7 million	16.3 million	26.4 million	14.4 million
Power supply reliability (Substations which undergo power outage due to transmission line fault)	Low (7 substations)	Medium (5 substations)	Low (11 substations)	High (1 substation)
Environmental impact	Low	Low	High Excavation to coral reefs	Low
Overall evaluation rank	3	2	4	1

- Plan 4, which shall form one round of 34.5 kV transmission line throughout Babeldaob Island is superior to other plans.

Network developing step



Result of power system analysis

Target year : 2025

Power flow and voltage

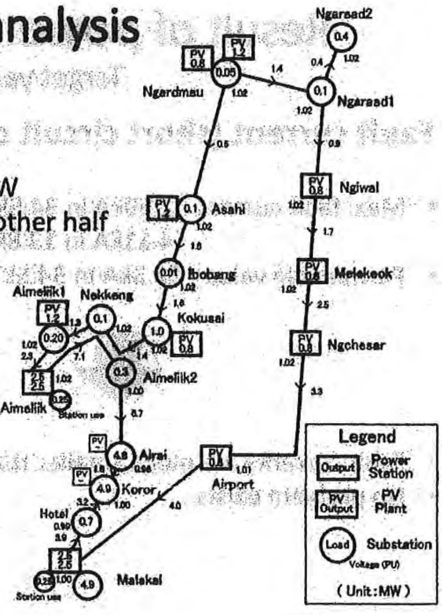
Peak case

- 19:00 on week day in August, max demand 18.1MW
- Load is supplied half by diesel generators and the other half by batteries charged by PV in daytime.

Voltage and power flow

- Max. power flow : 7.1MW (capacity 21.5MW)
- Voltage : 98-103% (desired range 95-105%)

- Through the completion of 34.5kV loop network, the balance of power flows at the east route and the west route will be sustained.
- No problem exists.



Result of power system analysis

Target year : 2025

Power flow and voltage

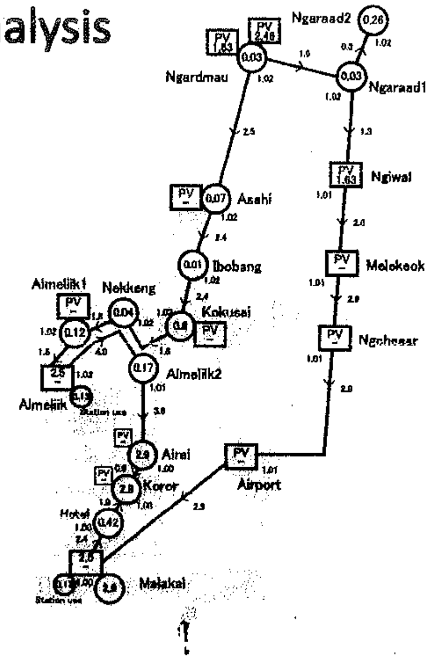
Off-peak case

- 14:00 on week-end in April, demand 10.7MW
- Load is supplied half by diesel generators and the other half by PV.

Voltage and power flow

- Max. power flow : 4.0MW (capacity 21.5MW)
- Voltage : 99-102% (desired range 95-105%)

- No problem exists.



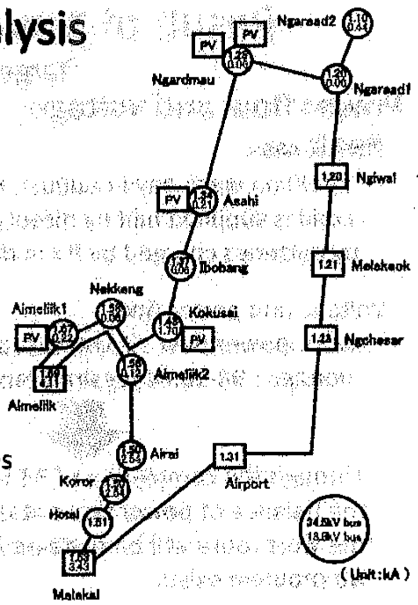
Result of power system analysis

Target year : 2025

Fault current (short circuit current)

- Max. fault current : 1.69kA in 34.5kV network
  4.11kA in 13.8kV network
- Permissible value : 12.5kA in 34.5kV and 13.8kV

- Fault currents are much smaller than permissible values
- No problem exists



Result of power system analysis

Target year : 2025

Stability

- By completion of loop system of 34.5kV transmission line, fluctuation of generator caused by fault shall be damped in the both cases of peak and off-peak conditions. Even if the severe fault happens, the system is maintained to be stable.

[redacted]

Peak case

[redacted]

Off-peak case

Conclusion

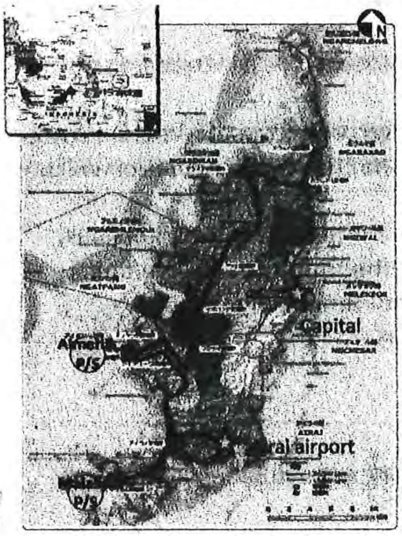
- No problem about voltage and power flow will exist by looped 34.5kV transmission network.
- Regardless of location of transmission line fault, the interconnection of Aimeliik Power Station and Malakal Power Station will be maintained and the stable operation will be maintained even under single contingency condition.
- In addition, almost all of substations shall have the two routes of transmission lines, the power supply to substations will be realized during the transmission line faults and thus the reliability of power supply will be improved remarkably.
- Fault currents are much smaller than permissible values

JICA Project Team recommends to configure loop network around Babeldaob Island

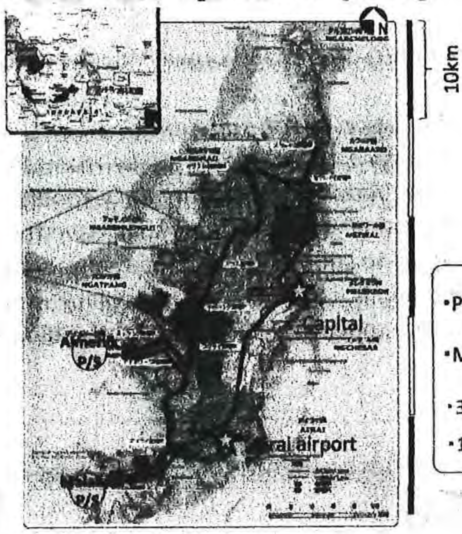
Power Transmission and Distribution line

Outline form of the T/L and D/L in PPUC

Existing form



Final form(Master plan)



- Power station: (P/S)
- Major Substation: ■
- 34.5kV line
- 13.8kV line

Power Equipment planning

3

(1) Transmission line

・Construction of the T/L to form the network in the system master plan. (The network can transmit the forecasted power demand and assumed RE power source.)

・Option : Measures for the improvement of existing T/L on the old road along the COMPACT.

(2) Distribution line

・Construction of the D/L to meet the forecasted power demand.

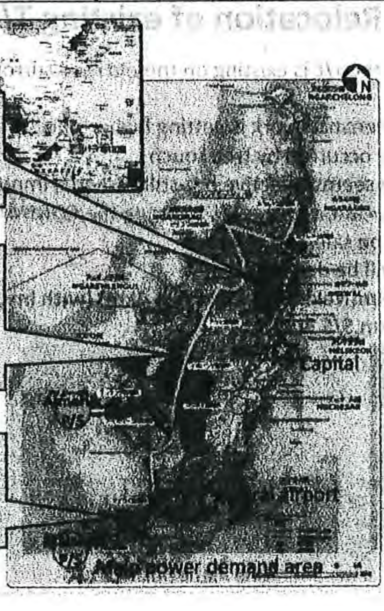
Power equipment planning(Outline of the result)

4

【1】 Construction of New T/L (T/L 50km)

【2】 Relocation of existing T/L (near COMPACT road) (T/L 40km,D/L 5km,S/S 3unit)

【3】 Construction of New D/L from Koror S/S (D/L 1km)



・Power station:
・Major Substation:
・34.5kV line(Existing)
・34.5kV line(New)
・34.5kV line(Relocate)
・13.8kV line

【1】 Construction of new T/L

5

The network in the master plan can meet the following points.

1.Assureance of the power transmission capacity for the future demand
2.Power transmission from new RE power source
3.Upgrade of the supply reliability(making double route of network)

→ to realize the network form, construction of new T/L is planned **(total length=50km)**

・Route Malakal P/S - Melekeok - Ngarraard1 S/S

Koror Island

KB bridge

COMPACT road

【2】 Relocation of existing T/L

6

・Present Situation: Major part of the T/L is existing on the old road surrounded by trees

・Problem :

・Safety risk on the maintenance work is getting higher since the old roads are deteriorated
・Frequent power outage occurred by tree touch
(Intensive tree trimming seems effective but still essential improvement is expected)

→ to address the situation, relocation of the T/L to along the COMPACT road is planned

・Maintenance work will be safe and effective
・Outage by tree touch will be decreased

・Construction volume: T/L 40km(Nekken36 km + A-A 4km) (with insulated conductor), D/L 5km,S/S 3units

The old road where land slipped

Line in the bush

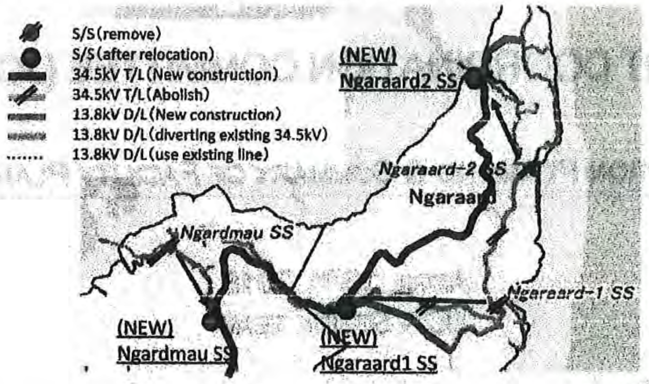
Line on the hill

【2】 Relocation of T/L

7

Accompanied with the relocation of transmission line, existing three substation needs to be replaced to near along the COMPACT road

Nekken T/L (North area)



【3】 Construction of New D/L from Koror S/S

8

Necessity of Construction of new feeder to address the estimated future power demand was examined.
As a result,

1) For **Koror substation**

- Construction of One new D/L feeder is planned to secure the capacity for back up supply when one of two distribution feeders for Koror downtown area is broken.

The planned construction year is in 2020.

- **Construction length: D/L 1km**

2) For other substations

No need to add feeders since the existing lines have enough capacity to meet the estimated future power demand.

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

JOINT COORDINATION COMMITTEE (JCC)

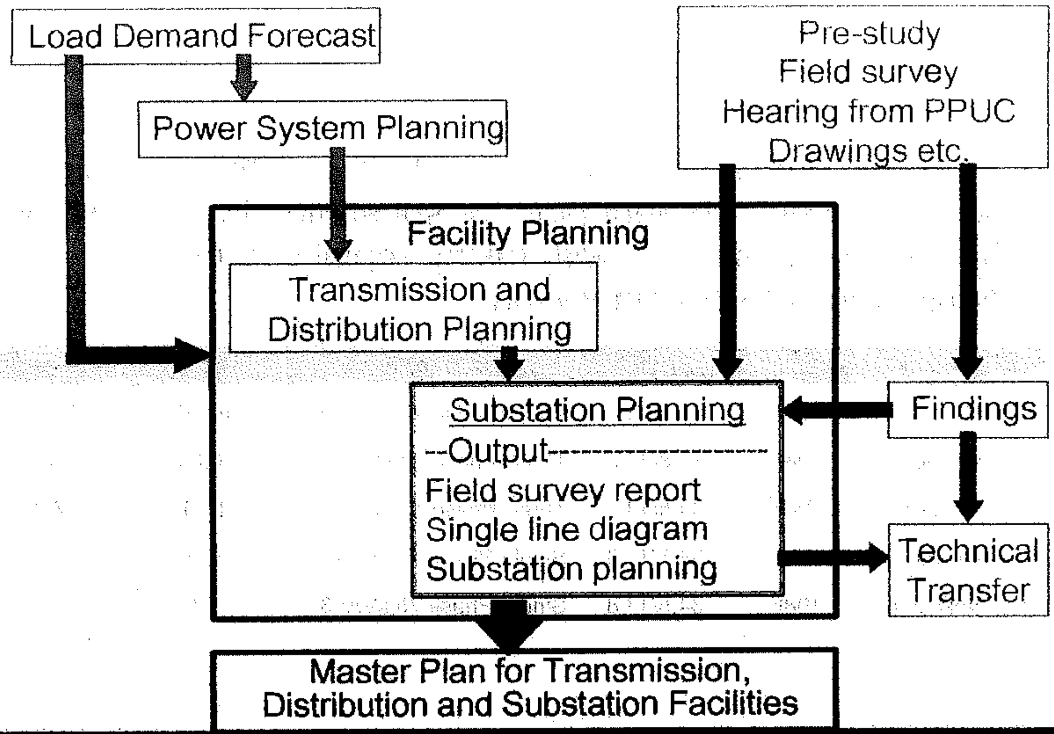
SUBSTATION PLANNING & SUMMARY OF FACILITY PLANNING

APRIL 13TH, 2018
JICA STUDY TEAM

Contents

1. Review of the Work Flow
2. Concept for Substation Facility Planning
3. Countermeasures (Aging Substation Facilities)
4. Countermeasures (Improvement of Power Supply Reliability)
5. Considerations (Improvement of Power Supply Reliability)
6. Considerations (Detailed)
7. Candidates site (Koror Substation)
8. Master Plan of T&D and Substation Facility (Stepping)
9. Master Plan of T&D and Substation Facility (Step1)
10. Master Plan of T&D and Substation Facility (Step2)
11. Master Plan of T&D and Substation Facility (Step3)
12. Master Plan of T&D and Substation Facility (Step4)
13. Summary of Facility Plan and Tentative Rough Cost Estimation

1. Review of the Work Flow



2. Concept for Substation Facility Planning

- ■ Result of Load Demand Forecast
- ➤ Not necessary of countermeasures for Load Demand in the period of Master Plan
- ■ Main Objectives for Substation Facility Planning
- ➤ Improvement of Power Supply Reliability
- ➤ Improvement of Maintenance Manageability
- ➤ Countermeasures for Aging Substation Facilities
- ➤ Countermeasures for Grid connected PV System
- ➤ Countermeasures for Future Load Demand

3. Countermeasures (Aging Substation Facilities)

- Result of Field Survey (Refer to the Field Survey Report for more details of the condition of substation facilities)

> Since old substations which had built in 1986 are aging severely, improvement plan for substation facilities shown below are considered with taking replacement of equipment into consideration.

1	Airai	1986	34.5/13.8	Three-Phase 10 MVA×1	10,000	Y-Y-Δ
2	Aimeliik	1986	13.8/34.5	Three-Phase 10 MVA×2	20,000	Δ-Y
3	Aimeliik-1	1986	34.5/13.8	Three-Phase 1000 kVA×1	1,000	Δ-Y
4	Aimeliik-2	1986	34.5/13.8	Single-Phase 75 kVA×3	225	Δ-Y
5	Nekkeng	1986	34.5/13.8	Single-Phase 75 kVA×3	225	Δ-Y

4. Countermeasures (Improvement of Power Supply Reliability)

- Focus

> In addition to the countermeasures against aging Airai substation facilities, three ideas are considered to determine more reliable power supply for the load center (Koror state).

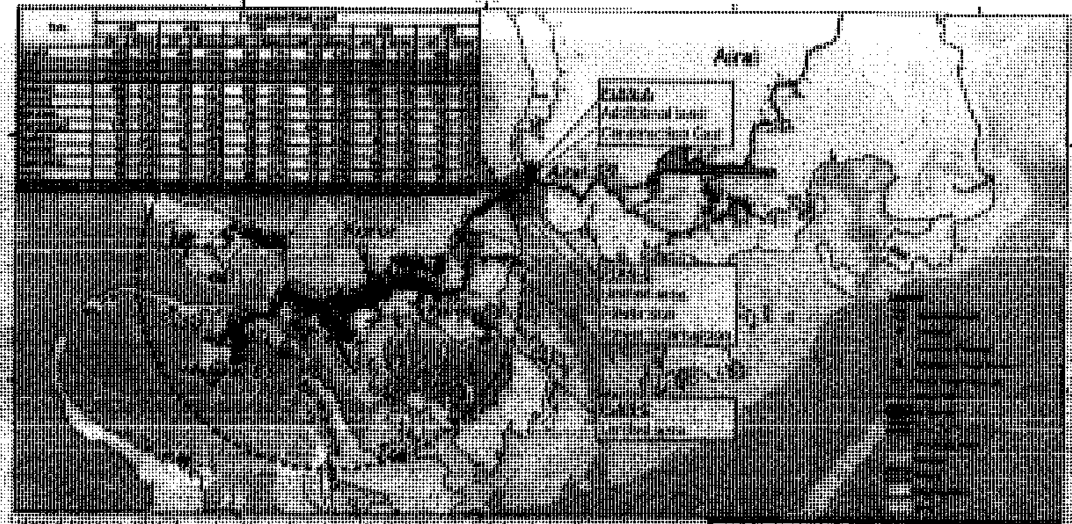
- Ideas (See Considerations (Summary))

> PLAN-A Improvement of existing Airai substation

> PLAN-B Renewal of the Airai substation

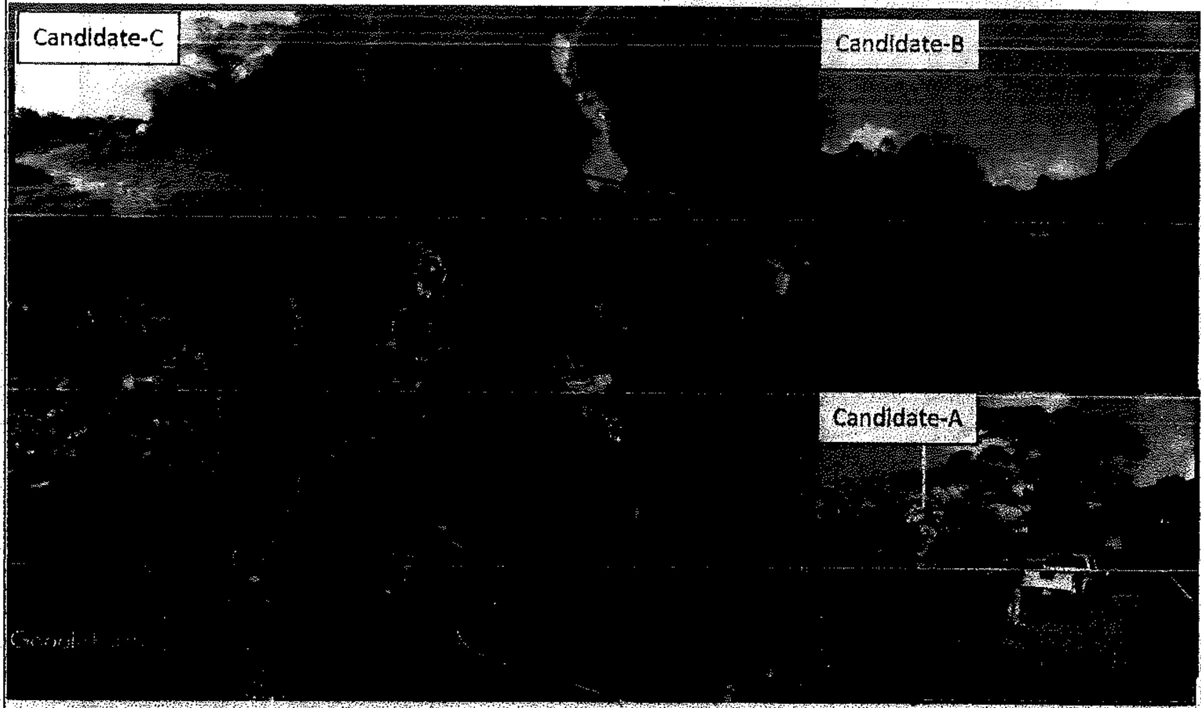
> PLAN-C Construction of New Koror substation

5. Considerations (Summary)



6. Considerations (Detailed)

7. Candidates site (Koror Substation)



8. Master Plan of T&D and Substation Facility (Stepping)

- Target Year
  - Master Plan: 2030
  - Keep in Step with RE roadmap

1	by 2020	Phase1
2	From 2021 to 2023	Phase2
3	From 2024 to 2025	Phase3
4	by 2030	-

9. Master Plan of T&D and Substation Facility (Step1)

■ Step1 Target Year (by 2020) (Refer to the Location Map)

1-1	2020	T&D	Improvement of Maintenance Manageability	■ Relocation of existing 34.5kV Transmission Line ・ Airai – Ngaraard 2
1-2	2020	SS	Improvement of Maintenance Manageability	■ Relocation of existing substations ・ Ngardmau ・ Ngaraard 1 ・ Ngaraard 2
1-3	2020	SS	Improvement of power supply reliability	■ Construction of Koror substation ・ 34.5/13.8kV 1 bank x 10MVA
1-4	2020	D	Improvement of power supply reliability	■ Construction of 13.8kV distribution line ・ 1 feeder x 13.8kV distribution line
1-5	Within the period	SS	For grid protection and maintenance	■ Installation of circuit breaker panel ・ Grid connected PV system (Aimelik) ・ Grid connected PV system (Ngatpang (Kokusai)) ・ Grid connected PV system (Ngaremlengui)

Remarks: T&D: Transmission and Distribution facilities, T: Transmission facilities, D: Distribution facilities, SS: Substation facilities

10. Master Plan of T&D and Substation Facility (Step2)

■ Step2 Target Year (2021-2023) (Refer to the Location Map)

2-1	2023	T	For grid connected PV system and improvement of power supply reliability	■ Construction of 34.5kV transmission line ・ Malakal – Melekeok PV site
2-2	2023	SS	Improvement of Maintenance Manageability	■ Expansion of Malakal substation ・ Expansion of Malakal outgoing feeder bay ・ 34.5/13.8kV 1 bank x 10MVA (Option)
2-3	Within the period	SS	For grid protection and maintenance	■ Installation of circuit breaker panel ・ Grid connected PV system (Airai Airport) ・ Grid connected PV system (Ngchesar) ・ Grid connected PV system (Melekeok)

Remarks: T&D: Transmission and Distribution facilities, T: Transmission facilities, D: Distribution facilities, SS: Substation facilities

11. Master Plan of T&D and Substation Facility (Step3)

■ Step3 Target Year (2024-2025) (Refer to the Location Map)

3-1	2025	T&D	For grid connected PV system and improvement of power supply reliability	■ Construction of 34.5kV transmission line ・ Melekeok PV site - Ngaraard 1 ・ Expansion of outgoing feeder at Ngaraard 1
3-2	Within the period	SS	For grid protection and maintenance	■ Installation of circuit breaker panel ・ Grid connected PV system (Ngiwal) ・ Grid connected PV system(Ngardmau(Terraces of Hill)) ・ Grid connected PV system (Ngardmau)

Remarks: T&D: Transmission and Distribution facilities, T: Transmission facilities, D: Distribution facilities, SS: Substation facilities

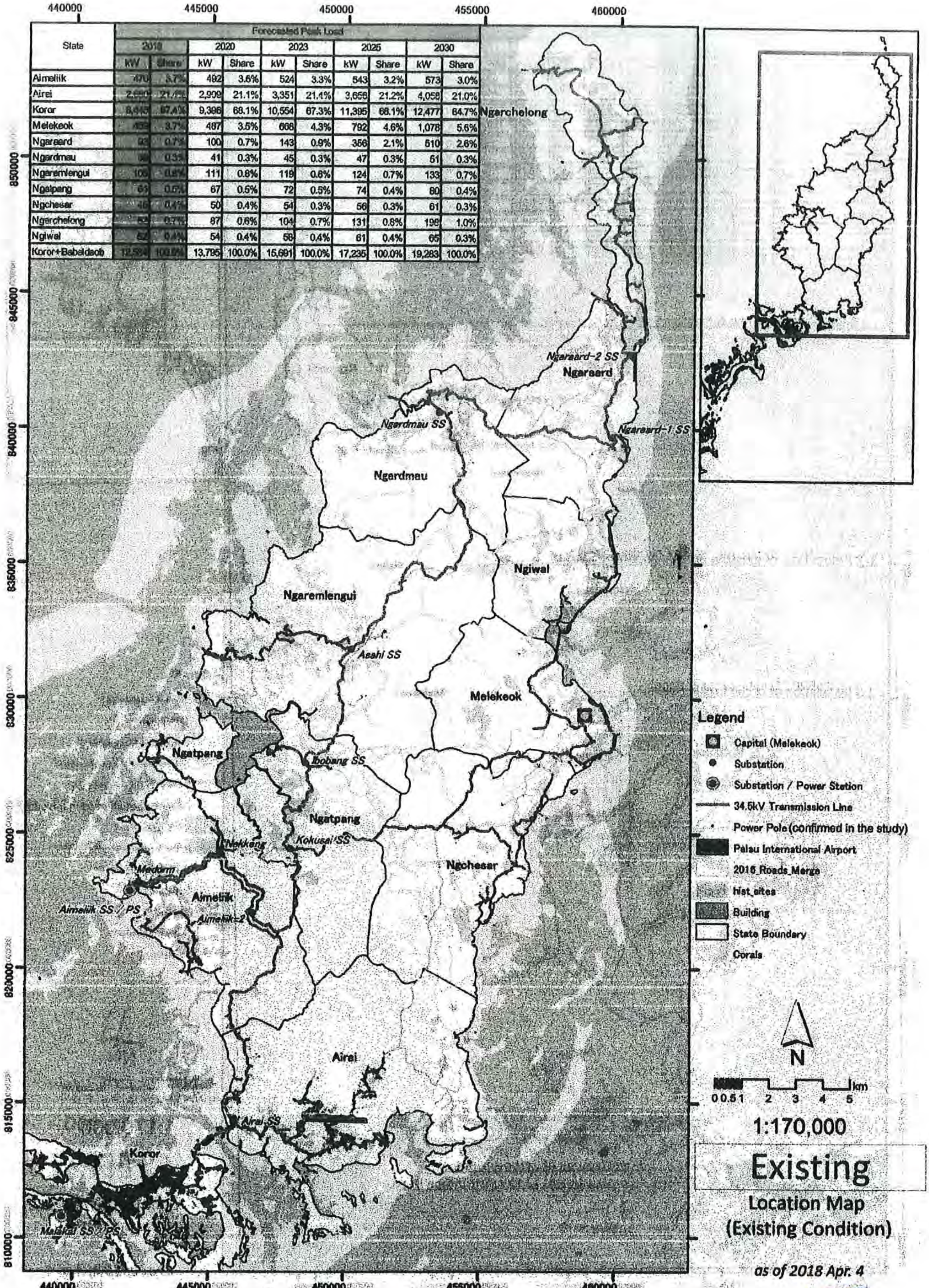
12. Master Plan of T&D and Substation Facility (Step4)

■ Step4 Target Year (2025-2030) (Refer to the Location Map)

4-1	2030	SS	Countermeasure for aged equipment	■ Simple replacement work for existing substations ・ [illegible] ・ [illegible] 1 ・ [illegible] ・ [illegible] 2
4-2	2030	SS	Countermeasure for future load and improvement of Maintenance Manageability	■ Expansion of Koror substation ・ 34.5/13.8kV 1 bank x 10MVA

Remarks: T&D: Transmission and Distribution facilities, T: Transmission facilities, D: Distribution facilities, SS: Substation facilities

State	Forecasted Peak Load									
	2018		2020		2023		2025		2030	
	kW	Share	kW	Share	kW	Share	kW	Share	kW	Share
Aimeliik	470	3.7%	492	3.6%	524	3.3%	543	3.2%	573	3.0%
Airai	[illegible]	21.4%	2,909	21.1%	3,351	21.4%	3,656	21.2%	4,058	21.0%
Koror	8,445	67.4%	9,396	68.1%	10,554	67.3%	11,395	66.1%	12,477	64.7%
Melekeok	[illegible]	3.7%	487	3.5%	668	4.3%	792	4.6%	1,078	5.6%
Ngaraard	93	0.7%	100	0.7%	143	0.9%	356	2.1%	510	2.6%
Ngardmau	[illegible]	0.3%	41	0.3%	45	0.3%	47	0.3%	51	0.3%
Ngaremlengui	105	0.8%	111	0.8%	119	0.8%	124	0.7%	133	0.7%
Ngatpang	61	0.5%	67	0.5%	72	0.5%	74	0.4%	80	0.4%
Ngchesar	46	0.4%	50	0.4%	54	0.3%	56	0.3%	61	0.3%
Ngarchelong	[illegible]	0.7%	87	0.6%	104	0.7%	131	0.8%	198	1.0%
Ngiwal	52	0.4%	54	0.4%	58	0.4%	61	0.4%	65	0.3%
Koror+Babeldaob	12,584	100.0%	13,795	100.0%	15,691	100.0%	17,235	100.0%	19,283	100.0%

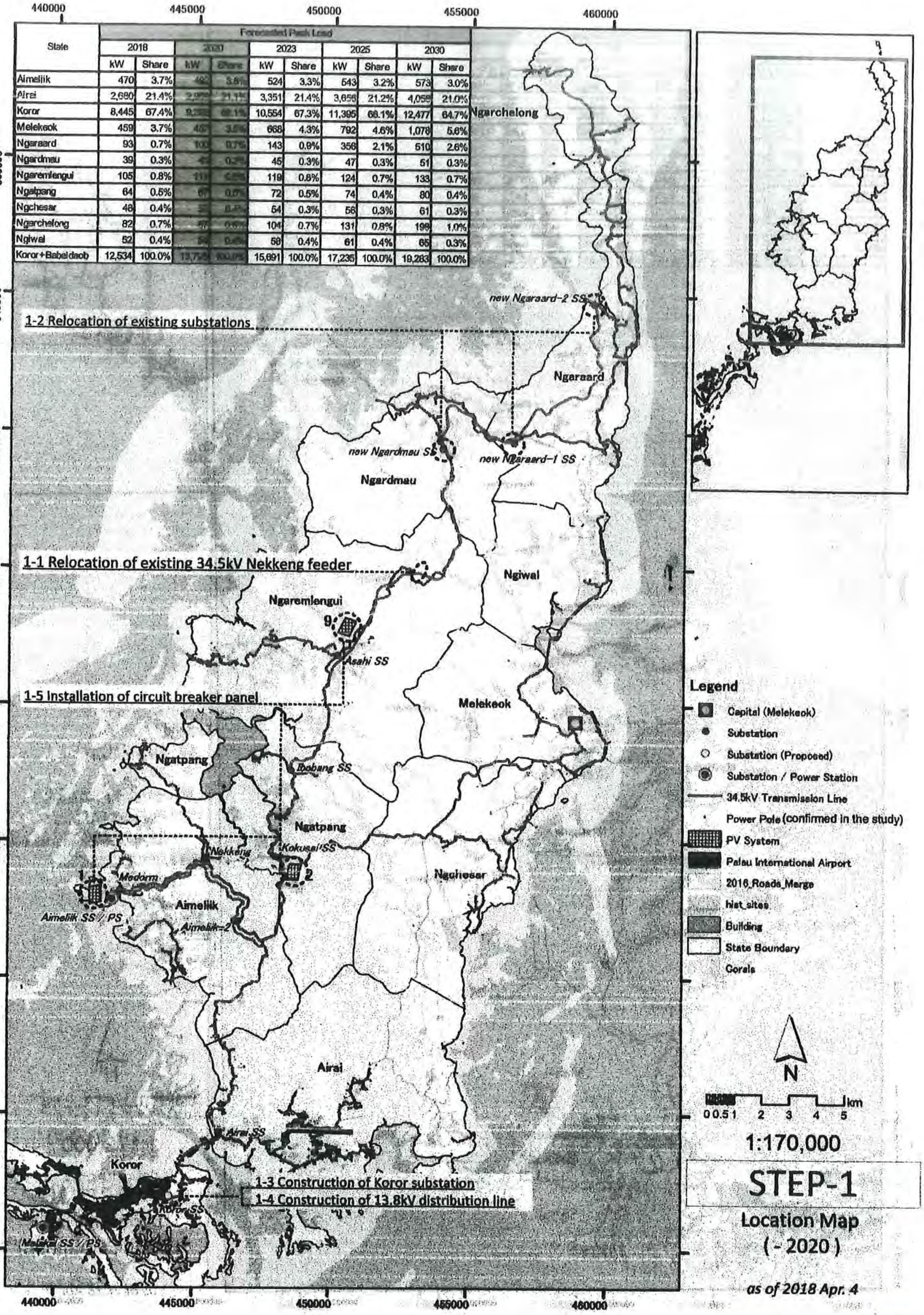


Existing

Location Map
(Existing Condition)

as of 2018 Apr. 4

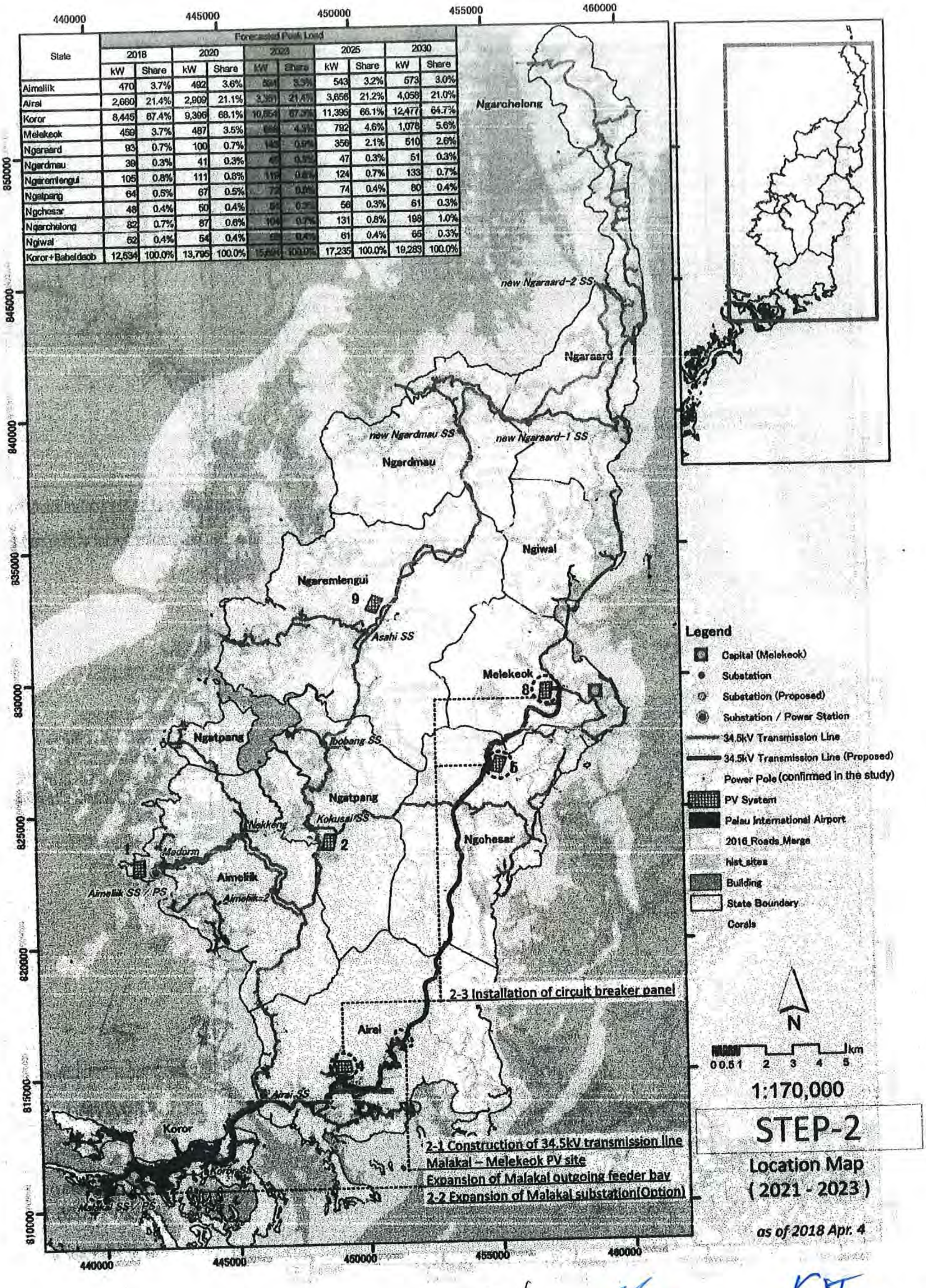
State	Forecasted Peak Load									
	2018		2020		2023		2025		2030	
	kW	Share	kW	Share	kW	Share	kW	Share	kW	Share
Aimeliik	470	3.7%	[illegible]	[illegible]	524	3.3%	543	3.2%	573	3.0%
Airai	2,680	21.4%	[illegible]	[illegible]	3,351	21.4%	3,656	21.2%	4,058	21.0%
Koror	8,445	67.4%	[illegible]	[illegible]	10,554	67.3%	11,395	66.1%	12,477	64.7%
Melekeok	459	3.7%	[illegible]	[illegible]	668	4.3%	792	4.6%	1,078	5.6%
Ngaraard	93	0.7%	100	[illegible]	143	0.9%	356	2.1%	510	2.6%
Ngardmau	39	0.3%	[illegible]	[illegible]	45	0.3%	47	0.3%	51	0.3%
Ngaremlengui	105	0.8%	[illegible]	[illegible]	119	0.8%	124	0.7%	133	0.7%
Ngatpang	64	0.5%	[illegible]	[illegible]	72	0.5%	74	0.4%	80	0.4%
Ngchesar	46	0.4%	[illegible]	[illegible]	54	0.3%	56	0.3%	61	0.3%
Ngarchelong	82	0.7%	[illegible]	[illegible]	104	0.7%	131	0.8%	199	1.0%
Ngiwal	52	0.4%	[illegible]	[illegible]	58	0.4%	61	0.4%	65	0.3%
Koror+Babeldaob	12,534	100.0%	[illegible]	[illegible]	15,691	100.0%	17,235	100.0%	19,283	100.0%



STEP-1

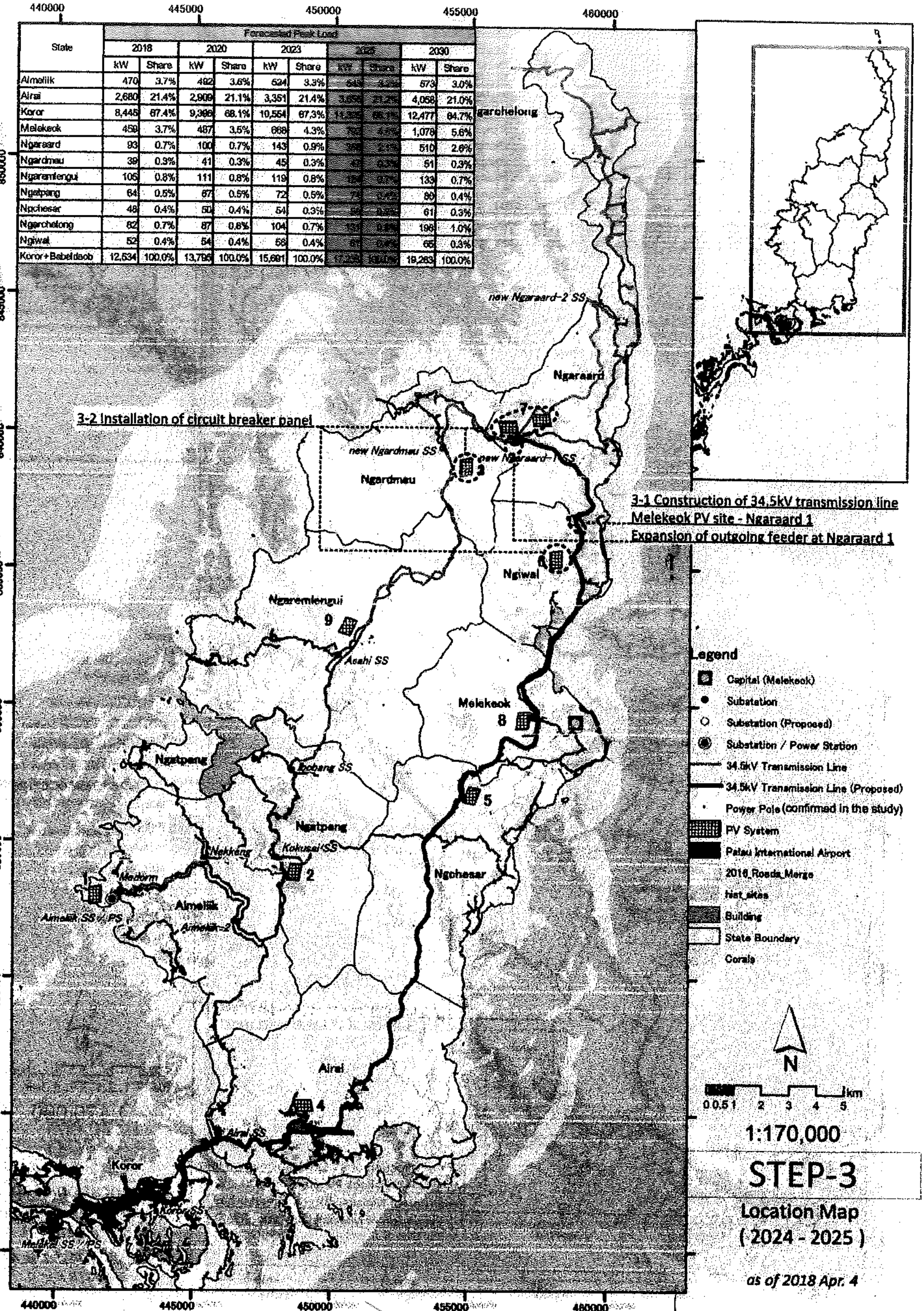
Location Map
(- 2020)

as of 2018 Apr. 4



State	Forecasted Peak Load									
	2018		2020		2023		2025		2030	
	kW	Share	kW	Share	kW	Share	kW	Share	kW	Share
Aimeliik	470	3.7%	492	3.6%	[illegible]	3.3%	543	3.2%	573	3.0%
Airai	2,660	21.4%	2,909	21.1%	3,351	21.6%	3,656	21.2%	4,058	21.0%
Koror	8,445	67.4%	9,396	68.1%	10,554	67.3%	11,395	66.1%	12,477	64.7%
Melekeok	459	3.7%	487	3.5%	[illegible]	4.3%	792	4.6%	1,078	5.6%
Ngaraard	93	0.7%	100	0.7%	[illegible]	0.9%	356	2.1%	510	2.6%
Ngardmau	39	0.3%	41	0.3%	[illegible]	[illegible]	47	0.3%	51	0.3%
Ngaremlengui	105	0.8%	111	0.8%	[illegible]	[illegible]	124	0.7%	133	0.7%
Ngatpang	64	0.5%	67	0.5%	72	[illegible]	74	0.4%	80	0.4%
Ngchesar	48	0.4%	50	0.4%	[illegible]	[illegible]	56	0.3%	61	0.3%
Ngarchelong	82	0.7%	87	0.6%	104	0.7%	131	0.8%	198	1.0%
Ngiwal	52	0.4%	54	0.4%	[illegible]	0.4%	61	0.4%	65	0.3%
Koror+Babeldaob	12,534	100.0%	13,795	100.0%	[illegible]	100.0%	17,235	100.0%	19,283	100.0%

State	Forecasted Peak Load									
	2018		2020		2023		2025		2030	
	kW	Share	kW	Share	kW	Share	kW	Share	kW	Share
Almeliik	470	3.7%	492	3.6%	524	3.3%	[illegible]	[illegible]	573	3.0%
Airai	2,680	21.4%	2,909	21.1%	3,351	21.4%	[illegible]	[illegible]	4,058	21.0%
Koror	8,445	67.4%	9,386	68.1%	10,554	67.3%	[illegible]	[illegible]	12,477	64.7%
Melekeok	459	3.7%	487	3.5%	668	4.3%	[illegible]	[illegible]	1,078	5.6%
Ngaraard	93	0.7%	100	0.7%	143	0.9%	[illegible]	[illegible]	510	2.6%
Ngardmau	39	0.3%	41	0.3%	45	0.3%	[illegible]	[illegible]	51	0.3%
Ngaremlengui	105	0.8%	111	0.8%	119	0.8%	[illegible]	[illegible]	133	0.7%
Ngatpang	64	0.5%	67	0.5%	72	0.5%	[illegible]	[illegible]	80	0.4%
Ngchesar	48	0.4%	50	0.4%	54	0.3%	[illegible]	[illegible]	61	0.3%
Ngarchelong	82	0.7%	87	0.6%	104	0.7%	[illegible]	[illegible]	196	1.0%
Ngiwal	52	0.4%	54	0.4%	58	0.4%	[illegible]	[illegible]	65	0.3%
Koror+Babeldaob	12,534	100.0%	13,796	100.0%	15,691	100.0%	[illegible]	[illegible]	19,283	100.0%



State	Forecasted Peak Load									
	2018		2020		2023		2025		2030	
	kW	Share	kW	Share	kW	Share	kW	Share	kW	Share
Aimeliik	470	3.7%	492	3.6%	524	3.3%	543	3.2%	573	3.0%
Airai	2,680	21.4%	2,909	21.1%	3,351	21.4%	3,656	21.2%	4,058	21.0%
Koror	8,445	67.4%	9,396	68.1%	10,554	67.3%	11,395	66.1%	12,477	64.7%
Melekeok	459	3.7%	487	3.5%	668	4.3%	792	4.6%	1,078	5.6%
Ngaraard	93	0.7%	100	0.7%	143	0.9%	356	2.1%	510	2.6%
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Ngaremlengui	105	0.8%	111	0.8%	119	0.8%	124	0.7%	133	0.7%
Ngatpang	64	0.5%	67	0.5%	72	0.5%	74	0.4%	80	0.4%
Ngchesar	48	0.4%	50	0.4%	54	0.3%	56	0.3%	61	0.3%
Ngarchelong	82	0.7%	87	0.6%	104	0.7%	131	0.8%	198	1.0%
Ngiwal	52	0.4%	54	0.4%	58	0.4%	61	0.4%	65	0.3%
Koror+Babeldaob	12,534	100.0%	13,795	100.0%	15,691	100.0%	17,235	100.0%	19,283	100.0%