The Kingdom of Tonga
Tonga Power Limited

PREPARATORY SURVEY REPORT
ON
THE PROJECT FOR INSTALLATION OF
WIND POWER GENERATION SYSTEM

April 2017

Japan International Cooperation Agency (JICA)

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Summary

1. Outline of the Recipient Country

The Kingdom of Tonga (hereinafter referred to as “Tonga”) is located in the South Pacific and consists of 176 islands. The largest island is Tongatapu Island, which is the residence for 73 % of the population of Tonga. The Tonga Trench, which is the continental plate boundary, exists on the east side of Tonga from north to south. Most of the ground of Tongatapu Island is formed from raised limestone.

The temperature is highest between December and March. The monthly average high temperature is about 30 degrees Celsius, and the monthly average low temperature is about 23 degrees Celsius. Generally, from January to March is high precipitation and from July to October is low precipitation.

The wind speed at the airport located in the southeastern part of Tongatapu Island is about 3 to 5 m/s and stable throughout the year. In addition, in Nuutua, the project site of this Project, wind speed is also stable at 6 to 10 m/s throughout the year. The wind direction mostly consists of east-southeast winds (from the direction of the sea), so the wind conditions are favorable.

However, in Tonga, cyclones commonly occur in the summer season (usually from December to April), especially from January to February. The scale of cyclones has increased in recent years, and in February 2016, a cyclone named Winston, with maximum instantaneous wind speed of 84.9 m/s, occurred. After approaching Tonga, cyclone Winston caused serious damage to Fiji.

Due to the geographical conditions of being an "island country", Tonga imports of oil fuel account for about 20 % of total imports, which is equivalent to 10 % of GDP. Major industries are agriculture, fishery and tourism. However, 31 % of GDP is occupied with remittance from overseas since the economy of Tonga largely depends on grant aid assistance from other countries and money transferred from migrant workers.

2. Background and Outline of the Project

(1) Overall Goal

Tonga is greatly affected by global crude oil price fluctuations and is extremely vulnerable from the viewpoint of energy security. In response, the Cabinet of Tonga constituted in 2009 a policy goal of “increasing the proportion of renewable energy to 50% of the entire electricity supply by 2020” to deal with two crucial issues: greenhouse gas emissions reductions and improvement in energy security. On this basis, Tonga had installed 2.3 MW of photovoltaic systems on Tongatapu Island. To further increase the proportion of renewable energy, Tonga expects wind power generation facilities to be developed on Tongatapu Island.

Therefore, this Project aims to contribute to the stable supply of energy in Tonga, by developing a wind power generation system and grid stabilization system on Tongatapu Island, promoting the utilization of renewable energy and diversifying the power supply source.

(2) Current Conditions and Problems

The soaring of the global crude oil prices in 2008 obliged the Tongan authority to raise electricity charges to TOP 1.00/kWh (approx. USD 0.5/kWh), causing serious impact on economic activities and the peoples’ lives in the country. Having learnt from this experience, the government of Tonga formulated a Tonga Energy Road Map 2010-2020 (hereinafter called the “TERM”) as an implementation policy to achieve the policy goal: “increasing the proportion of renewable energy to 50% of the entire electricity supply by 2020”. TERM listed various types of renewable energy, but only photovoltaic and wind power generation are judged to be available renewable energy sources which have abundant potential at the present time and can be connected to the existing grid system on a large scale.

In December 2015, a draft of a commitment voluntarily determined by each country (Intended Nationally Determined Contributions: INDC) was formulated in Tonga to achieve the objectives of the United Nations Framework Convention on Climate Change. In addition to TERM's policy, INDC plans to achieve both emission reduction and investment for climate recovery, such as increasing the proportion of renewable energy to 70 % by 2030 and increasing energy efficiency. Through INDC, Tonga explicitly shows it is taking cost-effective actions and avoids cost increases due to inaction in dealing with to climate change.

Based on the above situation, Tonga has developed a total of 2.3 MW of photovoltaic power output; a 1.0 MW power storage system and a 1.3 MW micro grid control system with the support of New Zealand and Japan.

However, in order to achieve TERM's goal of “increasing the proportion of renewable energy to 50 % of the entire electricity supply by 2020”, in addition to the development of further renewable energy, a stable supply of renewable energy and frequency control of the power system are required. To cope with this, it is imperative for Tonga to further develop renewable energy as well as to stabilize the power supply based on the existing micro grid system and suppress the frequency fluctuation of the power system as much as possible.

(3) Background and Outline of the Project

On Tongatapu Island, the target island of this Project, Tonga Power Limited (hereinafter referred to as “TPL”) supplies electric power by operating eight diesel generators with a total rated capacity of 14.16 MW. The power consumption varies according to the season with the maximum power consumption at about 9.1 MW. Although renewable energy has been developed, most of the power supply is still being covered by these diesel generators. Therefore, from the viewpoint of national energy security, the Tongan government considers the development of renewable energy and reduction of imported fuel consumption through promotion of energy conservation as an important policy challenge. In particular, based on TERM, TPL plans to increase the output power of photovoltaic and wind power generation systems to 9.3 MW and 6.6 MW, respectively.

In Tonga, the installation of photovoltaics as renewable energy has been moving forward, and many independent photovoltaic systems are developed in isolated islands where diesel power generation is non-existent. Since the 1990’s, through the support of Australia, EU and Japan, installation of residential home solar photovoltaic systems has been progressing in each of the remote islands of Tongatapu, Vava‘u, Ha'apai, and Niuas. Regarding the grid connection type of photovoltaic systems, a 1.3 MW photovoltaic system was developed on Tongatapu Island with the support of New Zealand, and a 500 kW photovoltaics system was developed on Vava‘u Island by the UAE. In addition, a photovoltaic system with a maximum output of 1.0 MW, a grid stabilization system with a capacity of 1.0 MW, and a micro grid control system has been installed through Japan's grant aid. In addition to photovoltaics, a feasibility study of wind power generation was carried out under the cooperation of the government of New Zealand and the potential of wind power generation was confirmed. In this way, with the support of Japan and other donors, the introduction of renewable energy is progressing, but in order to attain the targets listed in TERM by 2020, it is necessary to secure more diverse sources of electric power.

Under such circumstances, in 2014, Tonga made a request for the introduction of a wind turbine generator system and grid stabilization system in Tongatapu Island, as a Japanese grant aid project. In response to this request, the government of Japan implemented the preliminary survey. In this Project, it is expected to introduce the wind turbine generator system and grid stabilization system which are suitable for the environment of Tongatapu Island, to diversify energy resources, and to contribute to the improvement of the rate of energy self-sufficiency.

3. Summary of the Survey and Contents of the Project

(1) Summary of the Survey

1) Wind Speed and Cyclone

In Tongatapu Island, a wind condition survey is being conducted at a height of 40 m in Niutoua, the project site, under the support of New Zealand. The wind condition data are shown below.

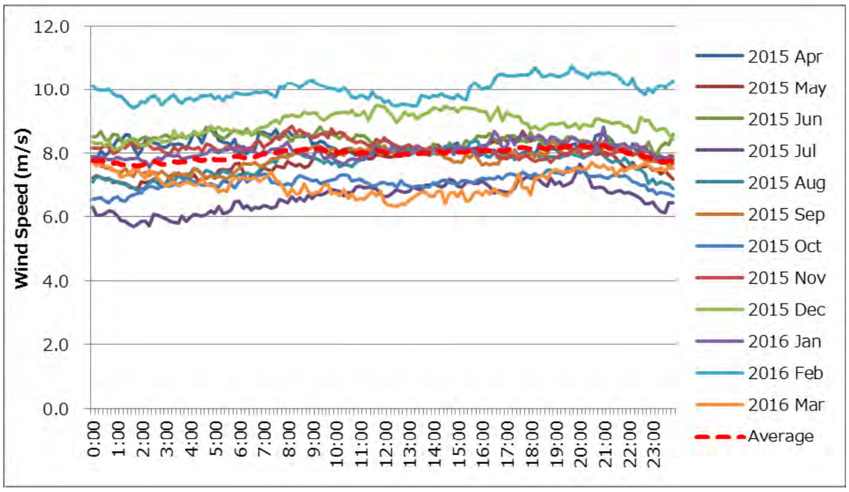


Figure 1 Monthly average wind speed in Niutoua (2015 April – 2016 March)

Wind speed is stable at 6 to 10 m/s throughout the year, and since the Niutoua area faces the ocean, coupled with the high altitude of the observation point, the wind speed conditions are favorable.

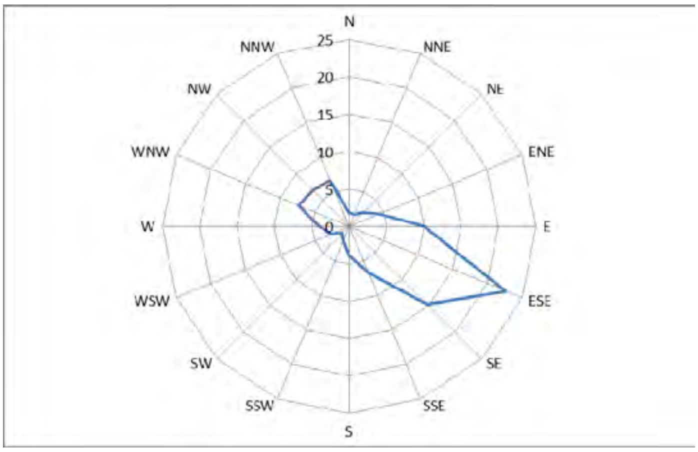


Figure 2 Annual wind rose (2015 April - 2016 March)

The wind direction concentrates from the east-southeast to the southeast, and wind direction is constant throughout the year. Both wind speed and wind direction are very stable, and it can be confirmed that this environment is suitable for wind power generation.

In Tonga, cyclones commonly occur during the summer season (usually from December to April), especially from January to February. About 60% of cyclones are category 2 (30 m/s at 1 minute average wind speed), but category 4 and 5 cyclones (more than 50 m/s at 1 minute average wind speed) also occur. The strength of cyclones has increased in recent years. In the past, category 4 and 5 cyclones had occurred about once in 10 years, but five category 4 and 5 cyclones have already occurred since 2010.

Figure 3 Damage situation by Winston (Fiji)

In February 2016, a cyclone named Winston, with maximum instantaneous wind speed of 84.9 m/s, occurred. After approaching Tonga, cyclone Winston caused serious damage to Fiji.

2) Ground Condition

New Zealand carried out the digging (depth: about 2.5 m) of the test pits at 7 places in 2014 and 17 places in 2015. About 30 cm of the surface layer is covered with silt clay derived from weathered volcanic ash. Up to a depth of 2.3 m from the ground, the limestone gradually changes from weathered to unweathered. From a depth of 2.5 m or more, soil texture becomes an unweathered limestone, which has been confirmed to be bedrock. There was no groundwater. As a result of the infiltration test conducted with some test pits, the penetration of water into the ground was confirmed. However, this seems to have penetrated into the weathered layer of limestone up to a depth of 2.3 m.

In the 2015 survey, point loading tests with a sample of the weathered layer on the bedrock were also conducted. The breaking load is 3,300 to 6,400 kN/m2, and it was confirmed that the strength was sufficient to construct a structure.

Also in 2015, subsurface elastic wave velocities were measured in the target area. The results are shown in Figure 4. The elastic wave velocity (Vs) is about 285 m/s at around a depth between 2.0 to 2.3 m. This is same with N value 45 in the standard penetration test, and Vs becomes 500 m/s or more (converted to N value 244) when the depth exceeds 4.0 m. Therefore, it is confirmed that this bedrock is hard rock of limestone.

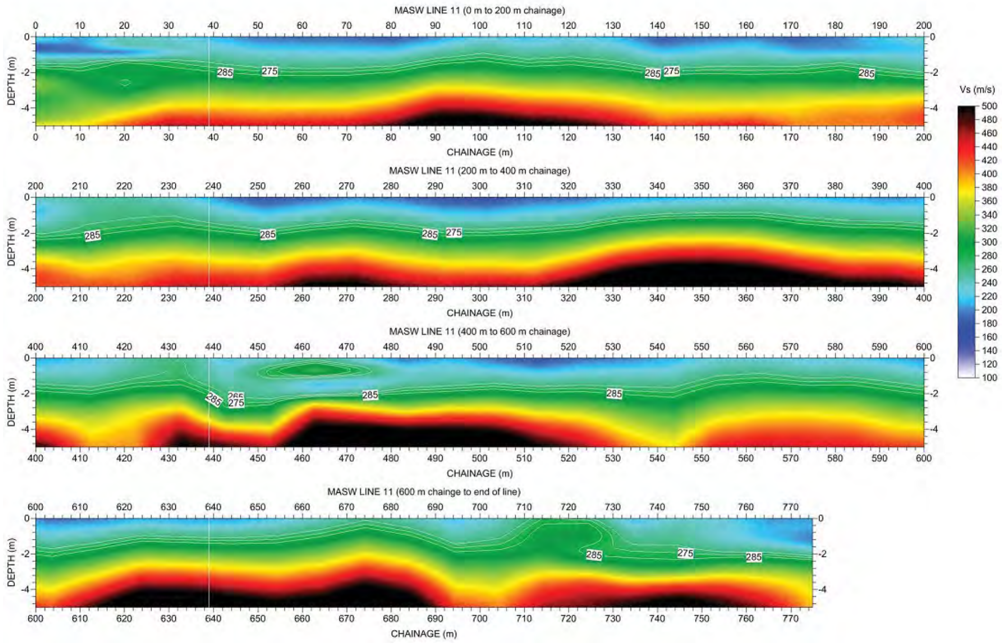


Figure 4 Elastic wave velocity spectrum by MASW conducted by New Zealand (partial deduction)

3) Design horizontal seismic coefficient

Although the design horizontal seismic coefficient in Tonga needs to be considered for each structure, the situation surrounding earthquakes is similar to Japan, and from the design value of the previous Japanese Grant Aid Project, “The Project for Introduction of a Micro-Grid system with Renewable Energy for the Tonga Energy Road Map in the Kingdom of Tonga”, this Project set the design horizontal seismic coefficient as 0.2 (horizontal acceleration: 0.2G) which is generally adopted in Japan.

(2) Contents of the Project

1) Wind Power Generation System

In this Project, based on Tongan building standards and with consideration of recent large-scale cyclones, wind turbines that satisfy the following conditions are candidates for the Project.

Table 1 Condition of wind turbine generator system

Output Power	1.3MW or more by 5 wind turbines
Extreme Wind Speed	Designed by wind turbine class of IEC61400-1 in normal condition, and following value as maximum instantaneous wind speed (cyclone) 10m from the ground: 70.0m/s 40m from the ground: 76.2m/s 45m from the ground: 76.7m/s
Turbulence Intensity	0.12 or more
Design Horizontal Seismic Coefficient	0.2G or more

2) Grid stabilization System

The output of the grid stabilizing system needs to compensate for the short cycle output fluctuation of the wind turbine generator system. As a result of the algebraic method of calculation for the output of the necessary grid stabilizing system, if the output of wind turbine is 1,375 kW, the output of the grid stabilization system becomes 530 kW from the required LFC capacity.

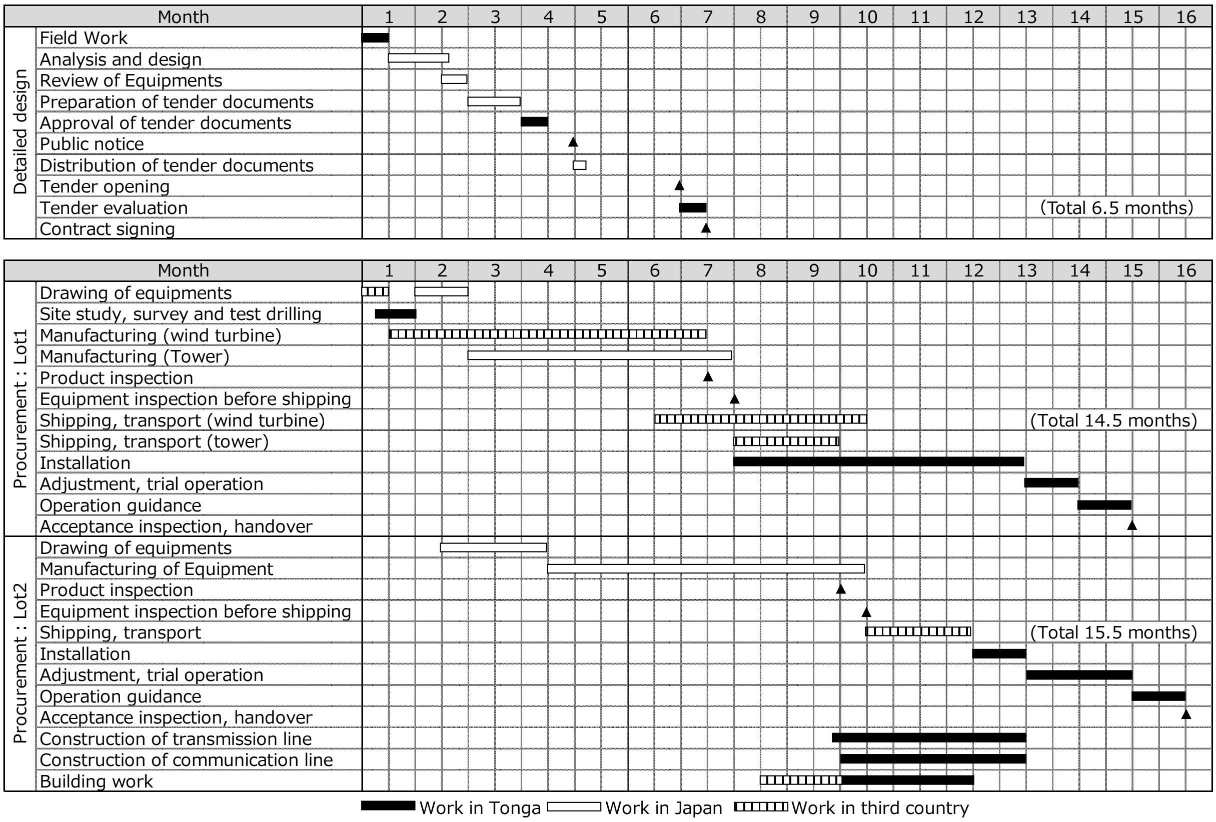
In addition, if the SOC is 50 %, the storage capacity needs to be 12.5 kWh or more. Since the number of charge-discharge cycles is extremely increased in accordance with the output fluctuation of the wind power generator, a lithium-ion capacitor capable of securing 100,000 times or more of the charge-discharge cycles is adopted as the power storage for compensating short cycle fluctuations.

4. Implementation Schedule and Project Cost

(1) Implementation Schedule

The implementation schedule for the Project is shown below.

Table 2: Implementation schedule



(2) Project Cost

In order to implement this Project, the Project cost borne by the Tongan side is around 1,811,100 TOP.

5. Project Evaluation

(1) Relevance

The Project implementation through Grant Aid is evaluated to be reasonable based on the result of this survey for the following reasons.

- The Project is implemented in Tongatapu Island, the largest island in Tonga. With a population of 75,416 people, residents from Tongatapu Island make up approximately 73% of the total population of Tonga, ensuring a considerable number of citizens are beneficiaries of the Project.
- Tonga is an island country and relies on diesel power with imported fuel for the majority of its electricity generation. Through implementation of this Project, Tonga can generate renewable energy itself. Therefore, from the viewpoint of reducing greenhouse gas emissions and improving energy security, this Project will greatly contribute to a stable supply of energy.
- TPL aims for renewable energy to meet 50 % of the demand for electric energy. This Project contributes to achieve this goal.
- TPL has already installed photovoltaic power systems as renewable energy systems and has the experience and technical expertise in repairing, operating and maintaining photovoltaic power systems as well as diesel generators. Although this is the first time for the development of a Megawatt (MW) class of wind power generation in Tonga, this Project designed the grid stabilization system according to the existing system and sustained operation and maintenance by TPL can be expected.
- This Project is the development of an electric power generation system that will play a key role in the life of the Tongan people and is consistent with the framework of grant aid.
- Although environmental impacts including air pollution, waste, land acquisition and accidents are predicted through this Project, it is estimated that the environmental impact can be minimized by implementing mitigation of measures.

(2) Effectiveness

1) Quantitative Impact

The quantitative impact to be expected from implementation of this Project is shown in the following table.

Table 3: Quantitative impact after implementation of this Project

Output indicator	Present value (Actual values in 2016)	Target value (2022) (After three years of project completion)
Wind power generation amount	0 MWh/year	4,296 MWh/year
Capacity factor	0 %	35.7 %
Availability	0 %	90.7 %
Reduction in diesel fuel consumption	0 kL/year 0 TOP/year	1,079 kL/year (IMF) 1,492,810 TOP/year
Proportion of renewable energy	7.42 % (PV) 0 % (Wind power)	6.42 % (PV) 7.32 % (Wind power)
CO_2 emissions reduction	0 t CO_2/year	2,903 t CO_2/year

2) Qualitative Impact

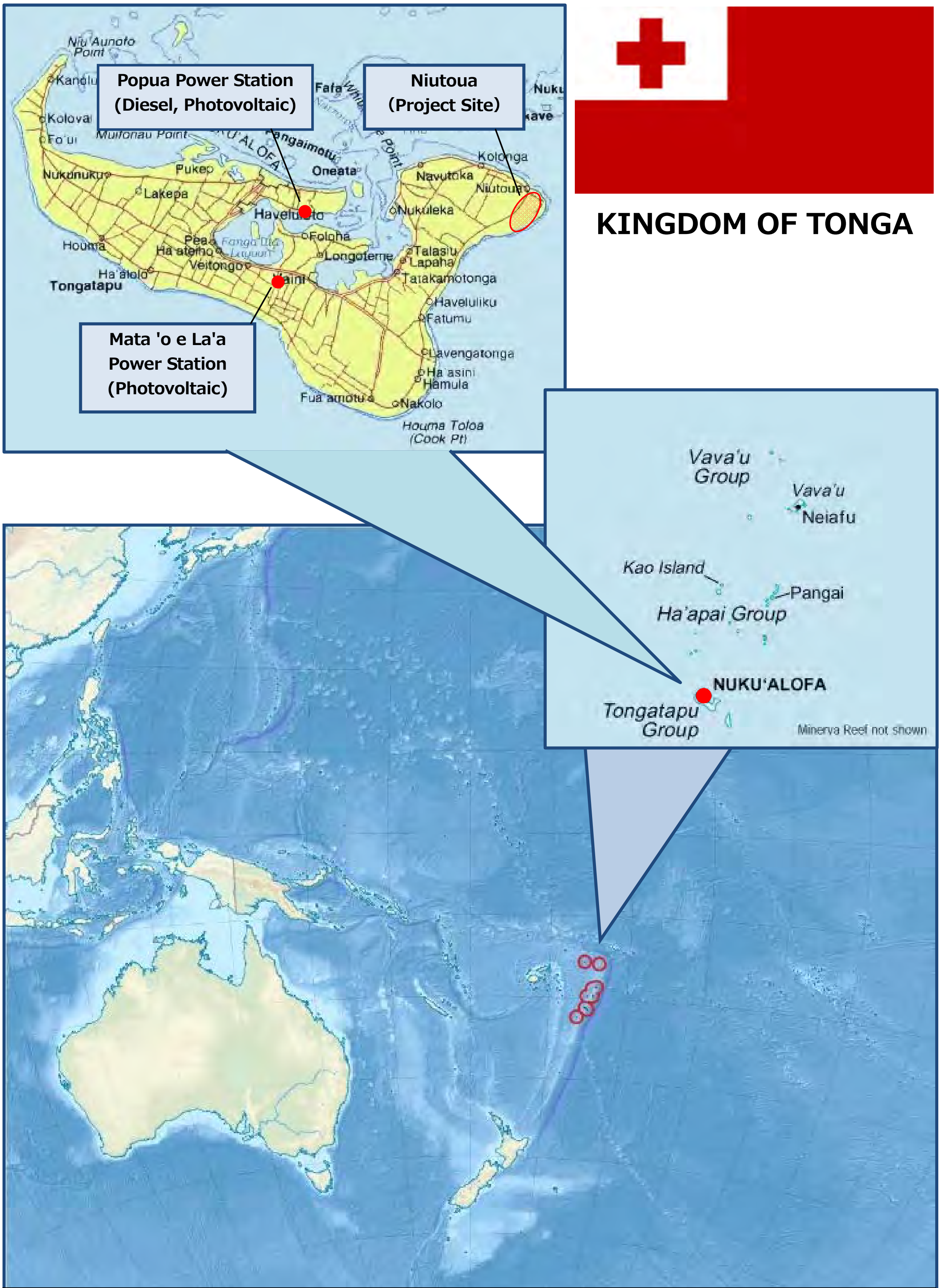
The qualitative impact to be expected from implementation of this Project is mentioned below.

- Diversification of source of electricity supply
- Stable supply of energy

From the above-mentioned contents, implementation of this Project is assessed as reasonable and effective.

Contents

Location Map

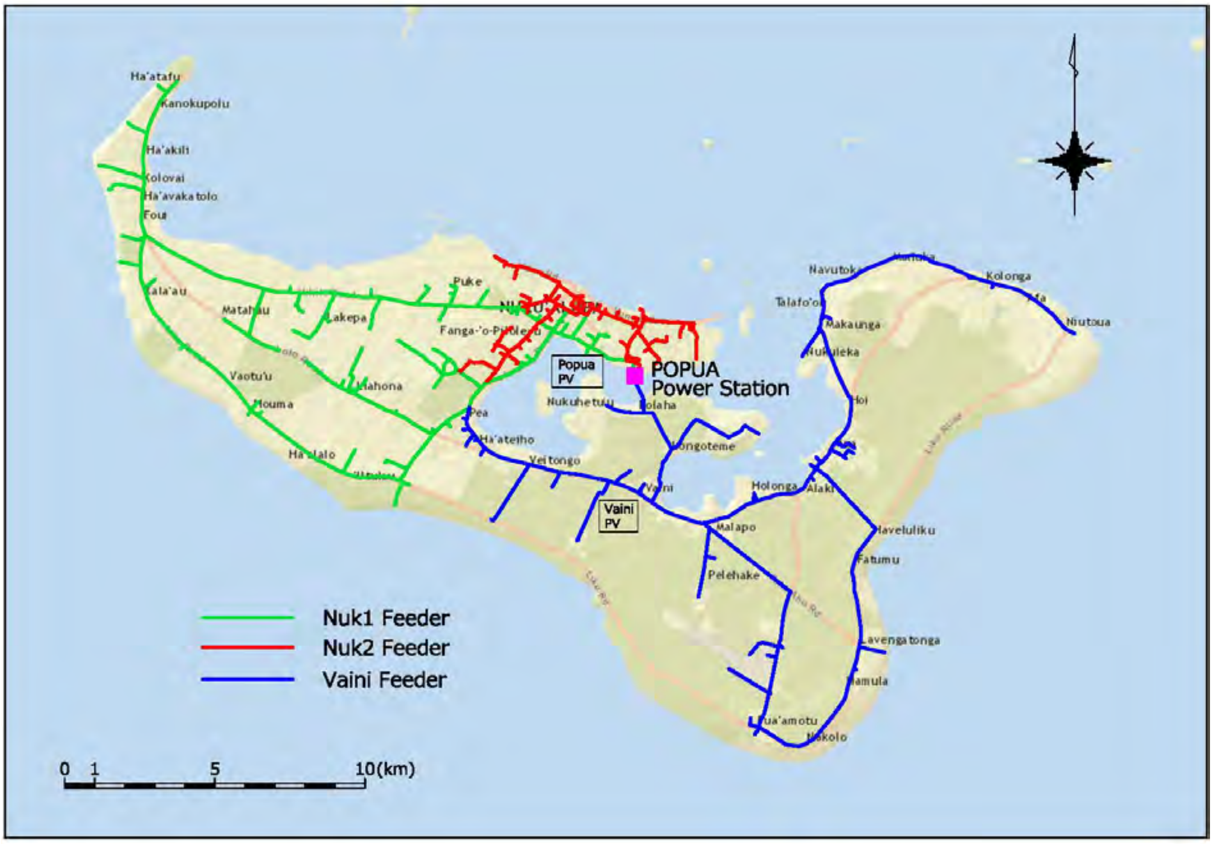


THE PROJECT FOR INSTALLATION OF WIND POWER GENERATION SYSTEM

Perspective

Tiltable type wind turbine (reference)

Fixed type wind turbine (reference)



Tongatapu Island, power system diagram (current)

Tongatapu Island, power system diagram (after June, 2017)

Tongatapu Island system relationship diagram

List of Figures and Tables

Abbreviations

ACI	American Concrete Institute
ASTM	American Society for Testing and Materials
BS	British Standard
CEO	Chief Executive Officer
DAC	Development Assistance Committee
DEC	Department of Environment & Climate Change
DSM	Demand Side Management
E/N	Exchange of Notes
EAC	Environmental Assessment Committee
EIA	Environmental Impact Assessment
EIA	Energy Information Administration
EU	European Union
G/A	Grant Agreement
GDP	Gross Domestic Product
GNI	Gross National Income
GPR	Ground Penetrating Radar
IEA	International Energy Agency
IEC	International Electrotechnical Commission
IMF	International Monetary Fund
IPP	Independent Power Producer
ISO	International Organization for Standardization
JAXA	Japan Aerospace Exploration Agency
JCS	Japanese Cable Makers' Association Standard
JEC	Japanese Electrotechnical Committee
JEM	Japan Electrical Manufactures
JICA	Japan International Cooperation Agency
JIS	Japanese Industrial Standards
JTWC	Joint Typhoon Warning Center
LAN	Local Area Network
LFC	Load Frequency Control
LIC	Lithium Ion Capacitor
MASW	Multi-channel Analysis of Surface Waves
MEIDECC	Ministry of Meteorology, Energy, Information, Disaster Management, Environment Climate Change, and Communications
MFNP	Ministry of Finance and National Planning
MLSNRE	Ministry of Lands Survey and Natural Resources

MoI	Ministry of Infrastructure
NEDO	New Energy and Industrial Technology Development Organization
NOAA	National Oceanic and Atmospheric Administration
NS$	New Zealand dollar
NZAID	New Zealand International Aid and Development Agency
ODA	Official Development Assistance
OJT	On the Job Training
PAT	Ports Authority Tonga
PCS	Power Conditioning System
PEEP	Promoting Energy Efficiency in the Pacific
PV	Photovoltaics
SCADA	Supervisory Control And Data Acquisition
SHS	Solar Home System
SOC	State Of Charge
TERM	Tonga Energy Road Map
TGIF	Tonga Green Incentive Fund
TOP	Tonga pa'anga
TPL	Tonga Power Limited
TSDF	Tonga Strategic Development Framework
TVNUP	Tonga Village Network Upgrade Project
USD	U.S. dollar
WTI	West Texas Intermediate

Chapter 1

Background of the Project

CHAPTER 1 BACKGROUND OF THE PROJECT

1-1 Background of the Project

The energy source of Tonga is mostly imported oil fuel and solar energy. Especially, 93% of the power supply is depending on the small grid system generated by import diesel oil. In Tongatapu Island, the target island of this Project, Tonga Power Limited (hereinafter referred to as “TPL”) is operating eight diesel generators (total output power: 14.16MW) and supply electricity to the whole island. The power consumption varies according to the season, and the maximum power consumption is about 9.1 MW. Although the introduction of renewable energy has begun, the majority of electricity supply is still being covered by these diesel generators. Therefore, from the viewpoint of national energy security, Tongan government positions the reduction of imported fuel consumption as an important policy by introducing renewable energy such as photovoltaics system and promotion of energy conservation. Specifically, TERM was formulated in June 2010, which policy goal is to make 50% of electricity supply renewable energy by 2020. Based on this, TPL plans to increase the capacity of photovoltaics and wind power generation to 9.3 MW and 6.6 MW, respectively.

In Tonga, the installation of photovoltaics as renewable energy is preceded, and many independent photovoltaics systems are developed in isolated islands where diesel power generation is not existing. Residential Solar Home System is installing in remote islands of each islands of Tongatapu, Vava‘u, Ha'apai, Niuas with the support of Australia, EU and Japan since the 1990s. Regarding the grid connection type of photovoltaics systems, 1.3MW photovoltaics system was developed on Tongatapu Island with the support of New Zealand, and a 500kW photovoltaics system was developed to Vava‘u Island by UAE. In addition, 1.0MW of photovoltaics system, 1.0MW of grid stabilization system, and micro grid control system has been installed by Japan's grant aid. In addition to photovoltaics, the potential of wind power generation has also been confirmed, the feasibility study was carried out under the cooperation of the government of New Zealand. In this way, with the support of Japan and other donors, the introduction of renewable energy is progressing, but in order to attain the targets listed in TERM by 2020, it is necessary to secure more diverse electric power sources.

Under such circumstances, in 2014, Tonga made a request for the introduction of the wind turbine generator system and grid stabilization system in Tongatapu Island, as a Japanese grant aid project. In the response to this request, the government of Japan implemented the preliminary survey. In this Project, it is expected to introduce the wind turbine generator system and grid stabilization system, which are suitable for the environment of Tongatapu Island, to diversify energy resources, and to contribute to the improvement of energy self-sufficiency rate.

1-2 Request Contents of Tongan Side

Requests from Tonga are as follows. The contents are the introduction of each facility related to wind turbine generator system and the technical assistance concerning the operation and maintenance of power system accompanying the introduction of wind turbine generator system.

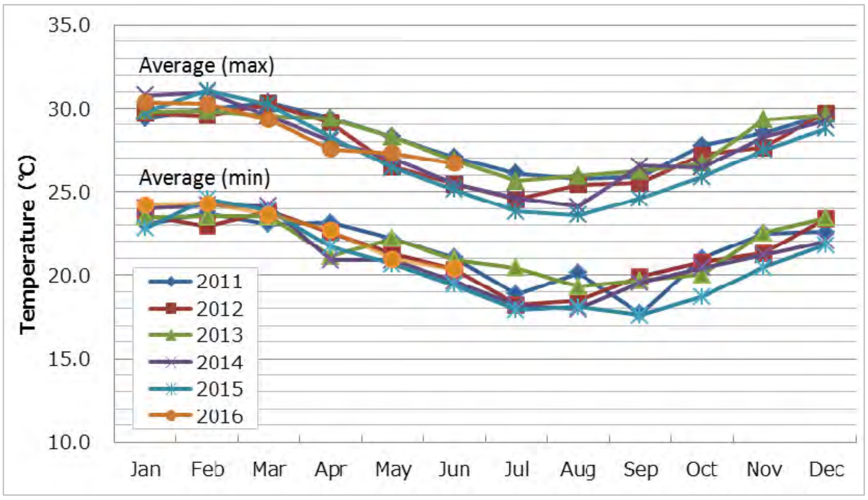
① Procurement and installation of wind turbine (total output power: 1.3MW)
② Procurement and installation of grid stabilization system (accumulator or capacitor)
③ Procurement and installation of interconnected distribution facilities (new and enhancement)
④ Technical assistance concerning the operation and maintenance of wind turbine generator system and grid system control

1-3 Natural Condition

(1) Climate

1) Temperature

The temperature is highest between December and March, the monthly average high temperature is about 30 degrees Celsius, and the monthly average low temperature is about 23 degrees Celsius. After that, the temperature slowly drops, and becomes lower from July to August. Monthly highest temperature is about 25 degrees Celsius, monthly lowest temperature is about 19degrees Celsius (under 20degrees Celsius). The difference between the highest and the lowest temperature is about 6 to 7 degrees Celsius throughout the year and it is stable.

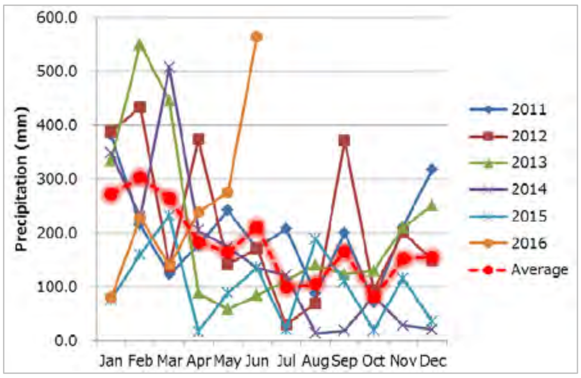


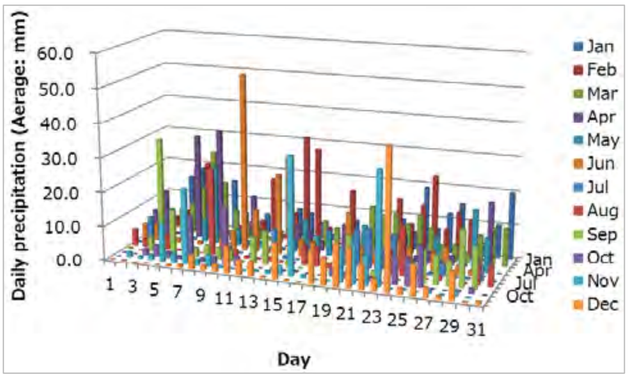
Source: The study team (based on the data from Tonga Meteorological & Coast Radio Services)

Figure 1-1: Monthly average temperature (2011 Jan-2016 Jun)

2) Rainfall

In general, from January to March is the season of much rain, and rainfall tends to be low from July to October. The annual rainfall was about 2,500 mm up to 2013, but the annual rainfall decreased to about 1,800 mm in 2014. Furthermore, the annual rainfall was 1,200 mm in 2015, that is about 50% of the average annual precipitation (about 2,300 mm). This rainfall trend continued until March 2016. However, the precipitation after that exceeded the monthly average, and in June 2016, it was recorded that monthly precipitation is about 560 mm/month, which is about four times the average monthly precipitation of past records. Also, in August 2016, the trend of rainfall was different from the past, such as rain falling continuously every day. In Tonga, August is a low rainfall season of the year, the people of Tonga considered this climate change is the influence of El Niño.



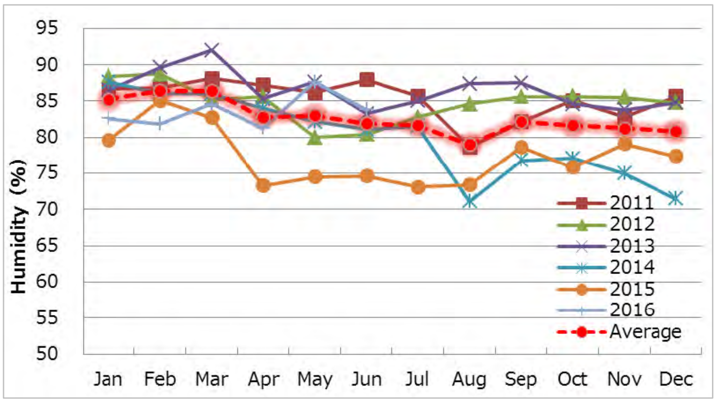


Source: The study team (based on the data from Tonga Meteorological & Coast Radio Services)

Figure 1-2: Monthly precipitation (Left) and average daily precipitation (Right)

3) Humidity

Until the middle of 2014, the average monthly humidity had been around 80 to 90%. However, with the decrease of rainfall between the last half of 2014 and 2015, the average humidity dropped to the 70% level. Since then, due to the recovery and increase in rainfall in 2016, humidity becomes 80 to 90% again.



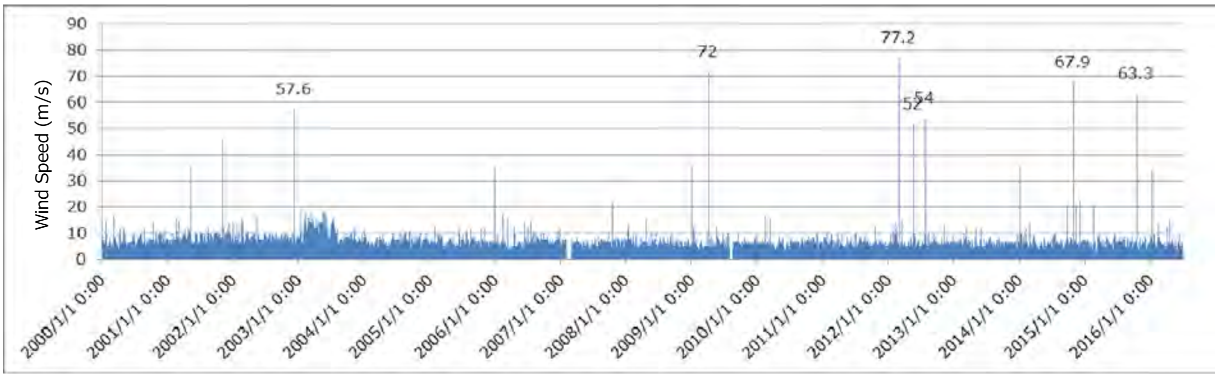
Source: The study team (based on the data from Tonga Meteorological & Coast Radio Services)

Figure 1-3: Monthly average humidity (2011 Jan-2016 Jun)

4) Wind

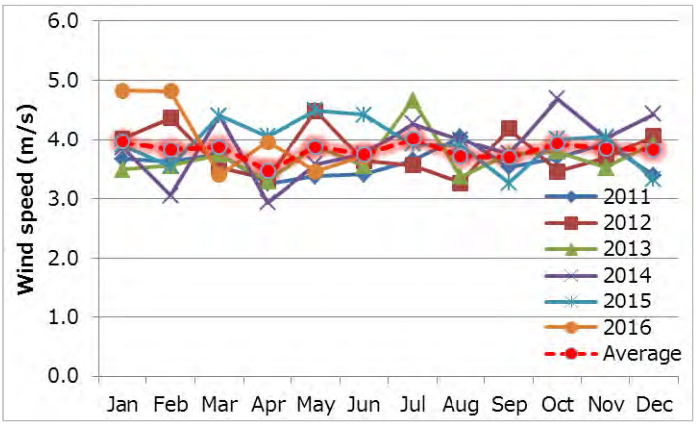
① Tongatapu Island (observatory in the airport)

The following wind speed data are from the observatory in the airport located in the southeastern part of Tongatapu Island. Wind speed data are recorded every three hours from 1 AM to 7 PM, and straight measurement is not done. Therefore, it is difficult to gain the instantaneous wind speed, but the wind speed exceeding 70 m/s has been recorded twice in the past. Apart from strong winds such as cyclones, wind speeds are about 3 to 5 m/s throughout the year and are stable.



Source: The study team (based on the data from Tonga Meteorological & Coast Radio Services)

Figure 1-4: Wind speed at the airport (after 2000)

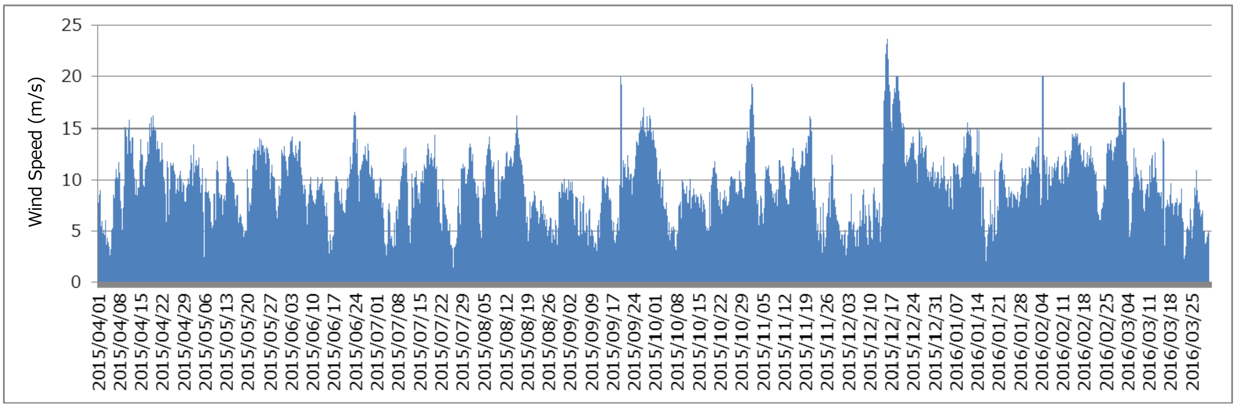


Source: The study team (based on the data from Tonga Meteorological & Coast Radio Services)

Figure 1-5: Monthly average wind speed at the airport (2011 Jan-2016 Jun)

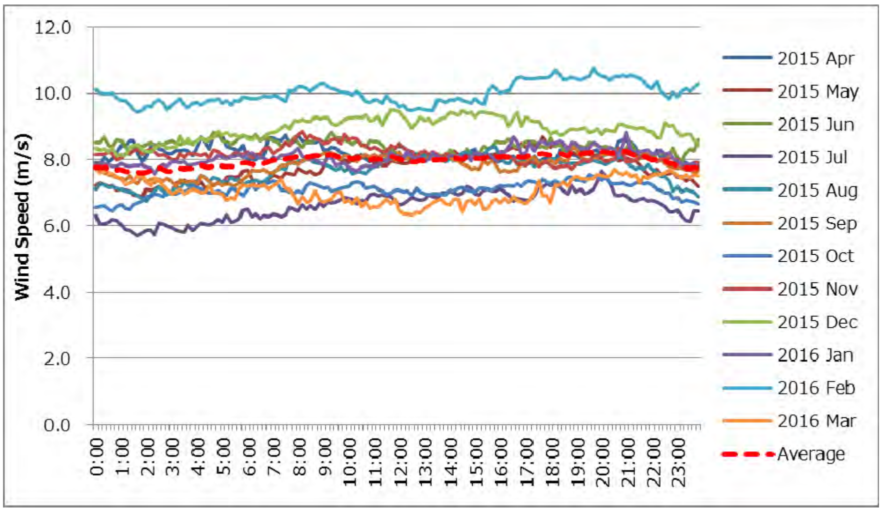
② Tongatapu Island (Niutoua)

In Niutoua, the site of this Project in Tongatapu, the wind condition survey is conducted at 40 m above the ground under the support of New Zealand. The following is the wind condition data of Niutoua.



Source: The study team (based on the data from TPL)

Figure 1-6: Wind speed at Niutoua (10 minute interval)



Source: The study team (based on the data from TPL)

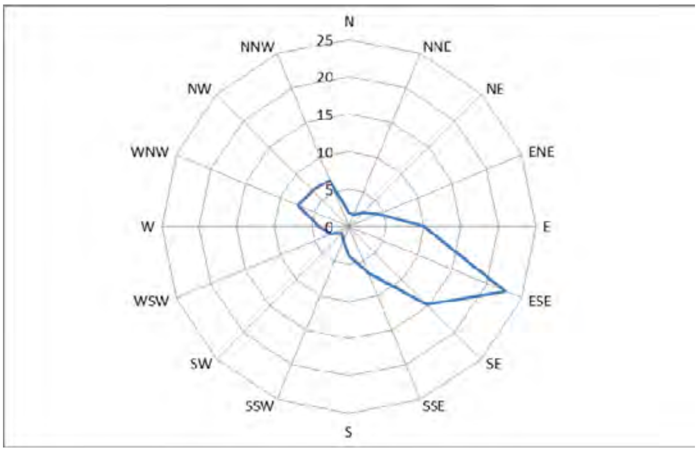
Figure 1-7: Monthly average wind speed at Niutoua (2015 Apr-2016 Mar)

Figure 1-7 shows the hourly wind speed fluctuation by month. Wind speed is stable at 6 to 10 m/s throughout the year, and is about 4 m/s larger than observation record at the airport. This is due to the fact that Niutoua is facing the sea, the majority of the wind direction is from the sea, from east and southeastern. In addition, the height of observation point is also the reason of stable wind, Niutoua is very good condition for wind turbine generated system.

Table 1-1: Frequency of wind direction (monthly)

Month	Direction (%)																	Number of Data
	Calm	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	
Jan	0.54	1.75	3.09	3.09	4.17	16.13	54.30	10.75	1.21	1.34	0.81	0.13	0.00	0.27	0.40	0.94	1.08	744
Feb	0.00	0.72	0.14	0.57	1.15	11.93	52.73	22.27	4.89	1.58	0.43	0.43	1.58	0.29	0.43	0.29	0.57	696
Mar	4.70	0.00	1.61	2.96	10.89	25.40	35.89	10.35	2.82	1.88	0.81	0.94	0.94	0.40	0.40	0.00	0.00	744
Apr	0.28	2.22	1.67	3.89	7.22	9.58	18.19	22.50	17.92	5.56	4.86	1.53	1.67	1.11	0.83	0.28	0.69	720
May	0.00	1.75	2.15	3.36	6.18	7.39	20.56	28.63	15.05	8.47	0.67	0.94	1.21	1.61	0.27	0.81	0.94	744
Jun	0.00	0.14	5.14	4.03	3.47	5.97	22.50	28.61	15.69	9.17	4.31	0.42	0.14	0.14	0.14	0.00	0.14	720
Jul	0.40	0.54	1.21	4.30	6.72	12.23	16.94	15.59	9.68	8.06	10.62	6.72	3.63	1.48	0.94	0.54	0.40	744
Aug	0.13	7.66	1.48	1.21	0.94	4.84	11.16	28.23	12.10	9.95	1.88	0.40	0.40	0.13	0.13	0.67	18.68	744
Sep	0.00	3.75	0.14	0.42	0.14	4.17	2.78	2.78	1.53	0.56	0.56	0.42	2.64	4.17	21.11	21.94	32.92	720
Oct	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.00	1.88	11.02	24.19	28.49	24.73	9.54	744
Nov	0.00	0.00	0.28	3.47	4.58	5.97	2.78	0.00	0.00	0.00	0.00	1.81	7.64	10.83	28.33	24.44	9.86	720
Dec	0.13	3.36	3.49	3.76	6.18	15.46	34.54	7.53	0.13	0.13	0.00	0.00	1.34	4.03	6.59	7.80	5.51	744
Jan-Dec	0.52	1.83	1.71	2.60	4.33	9.95	22.67	14.74	6.74	3.90	2.08	1.31	2.69	4.08	7.32	6.85	6.68	8784

Source: The study team (based on the data from TPL)



Source: The study team (based on the data from TPL)

Figure 1-8: Annual wind rose (2015 April - 2016 March)

The wind direction concentrates from east-southeast to the southeast, and the wind is blowing from the constant direction throughout the year. Both wind speed and wind direction are very stable, and it can be confirmed that Project site is an environment suitable for wind power generation.

(2) Earthquake

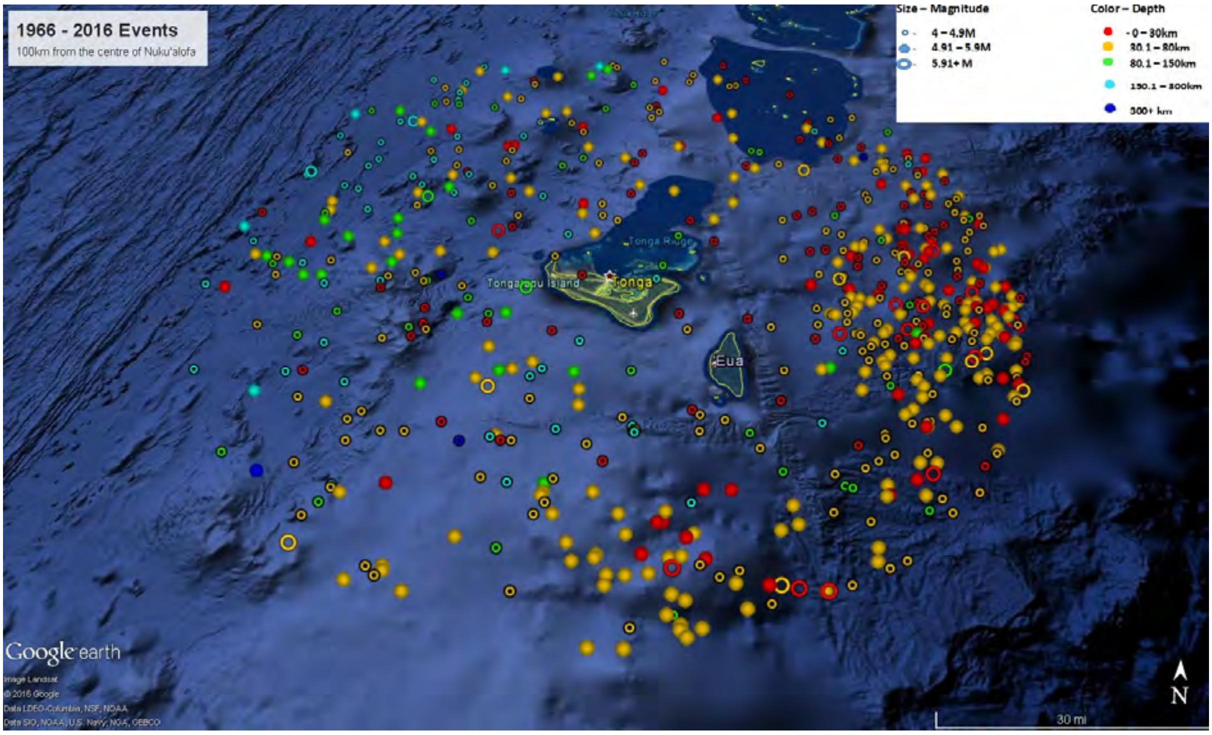
1) Past records

The records of the earthquake that occurred within 100 km from Tongatapu Island in the past fifty years are shown below. Earthquakes of magnitude from four to six account for the majority, but earthquakes of magnitude larger than six occurred every few years. The epicenter is predominant in the east of Tongatapu Island, that is assumed to be the effect of the Tonga Trench which becomes the continental plate boundary.

Table 1-2: Breakdown of earthquakes occurring within 100 km of Tongatapu Island (1966 - 2016)

Year	Magnitude							Total	Maximum seismic intensity
	<3.00	3.00-3.99	4.00-4.99	5.00-5.99	6.00-6.99	7.00-7.99	>=8.00		
1970				1				1	4 Apr, M5.8
1971				1				1	2 Feb, M5.6
1972				3				3	3 Mar, 29 Sep, M5.9
1973			2	2				4	22 Jun, M5.5
1974			2	8				10	6 Aug, M5.7
1975			3	2				5	15 Sep, M5.4
1976			1	5				6	9 Aug, M5.6
1977			3	3				6	6 Feb, M5.7
1978			3	7	1			11	4 Mar, M6.3
1979		1	4	4				9	1 Oct, M5.6
1980			1	4	1			6	19 Dec, M6.1
1981			7	3				10	16 Jun, M5.4
1982				1				1	4 Jun, M5.0
1983			1	7	1			9	21 Mar, M6.7
1984			3	3				6	17 Aug, M5.5
1985			5	2				7	26 Nov, M5.5
1986			8	3				11	29 Jul, M5.4
1987		1	1	4	1			7	26 Mar, M6.1
1988			1	2	1			4	15 Jan, M6.4
1989			4	3				7	15 Aug, M5.1
1990			2	2				4	2 Nov, M5.6
1991			1	4	2			7	3 Mar, M6.2
1992			2	2				4	25 Aug, 24 Sep, 5.6
1993			1	2	1			4	4 Oct, M6.0
1994			5	8				13	20 Oct, M5.5
1995			11	7	2			20	27 Jul, M6.4
1996			11	6				17	28 Jun, 6 Aug, M5.6
1997		1	13	8	1			23	10 Sep, M6.1
1998		2	7	2	1			12	19 Jul, M6.0
1999			9	10	1			20	24 Jan, M6.1
2000			8	3				11	17 Aug, M5.7
2001		1	6	3				10	11 Nov, M5.4
2002			12	3				15	25 May, M5.4
2003			13	8	1			22	3 Jul, M6.0
2004			15	7	1			23	24 Apr, M6.1
2005			6	1				7	20 Sep, M5.0
2006			39	13	1			53	30 Nov, M6.0
2007		3	23	6				32	5 Feb, M5.8
2008			16	5				21	9 Oct, M5.9
2009			11	8				19	17 Jul, M5.7
2010			24	8	1			33	13 Feb, M6.1
2011			10	8	1			19	12 Feb, M6.1
2012			20	14				34	13 Nov, M5.6
2013			9	5	1			15	23 May, M6.3
2014			17	4	1			22	26 Apr, M6.1
2015			15	3				18	6 Jul, M5.8
2016			14		1			15	15 Feb, M6.0
Total	0	9	369	218	21	0	0	617	
Ratio	0.00%	1.46%	59.81%	35.33%	3.40%	0.00%	0.00%	100.00%	

Source: Tonga Meteorological & Coast Radio Services



Source: Tonga Meteorological & Coast Radio Services

Figure 1-9: The epicenter and seismic depth of earthquakes (within 100 km of Tongatapu Island)

2) Tsunami

Due to the frequent occurrence of earthquakes near the Tonga Trench, Tonga has taken the maximum attention to the occurrence of the tsunami caused by the earthquake. The tsunami that reached Tonga in the past was about twenty, most of which was smaller with the height less than one meter. However, due to the "2009 Samoa earthquake and tsunami" that occurred in September 2009, the tsunami, maximum height is 16.8 meters, reached the Niuatoputapu Island located about 600 km north of Tongatapu Island, caused serious damage.

In response to this, Tonga predicted the size of tsunami with the magnitude of 9.0, with the support of Australia. The height of the tsunami reaching Tongatapu Island is 13 to 16 meters at maximum, and 8 to 10 meters at Niutoua.

(3) Cyclone

1) Cyclones passing near Tonga

Cyclone data of Tonga Meteorological & Coast Radio Services with the data of Japan Aerospace Exploration Agency (JAXA) and National Oceanic and Atmospheric Administration (NOAA) are shown as below. In Tonga, the scale of cyclones is recorded according to the cyclone classification defined by Australian standard generally adopted in Oceania. Cyclones are commonly occurring in the summer from December to April, especially from January to February. Around 60 % of cyclone is the category 2 (about 30 m/s: 1 minute average wind speed), however, category 4 or 5 (more than 50 m/s: 1 minute average wind speed) is also occurring. Category 4 or 5 of cyclones were occurring once in the ten years in the past, but 5 cyclones of category 4 or 5 have already occurred after 2010, cyclones tend to be larger.

Table 1-3: Record of cyclone in Tonga (1960 - 2016)

No	NAME	DATE	YEAR	AREA AFFECTED *1	CLASSIFICATION *2-5			MAX SUSTAIN WINDS of Cyclone (1min average) (m/s)	The time the wind speed change	
									10 to 25m/s	25 to 50m/s
1	Unnamed	17-19 Jan	1960	Northern and Central	Storm	C2	48 to 63 knots	---	---	---
2	Unnamed	14-19 Mar	1961	Central and Southern	Severe Hurricane	C4 or 5	>100 knots	---	---	---
3	Unnamed	22-23 Nov	1964	Southern	Gale	C1	34 to 47 knots	33.15	22.8	---
4	Unnamed	25-26 Feb	1969	Central and Southern	Gale	C1	34 to 47 knots	33.15	---	---
5	Unnamed	11-17 Jan	1969	Northern and Central	Gale	C1	34 to 47 knots	---	---	---
6	Dolly	11-25 Feb	1970	Northern	Hurricane	C3 or 4	64 to 100 knots	---	---	---
7	Gillian	08-11 Apr	1970	Central	Hurricane	C3 or 4	64 to 100 knots	---	---	---
8	Helen	13-16 Apr	1970	Northern	Storm	C2	48 to 63 knots	17.85	---	---
9	Bebe	19-28 Oct	1972	Southern	Hurricane	C3 or 4	64 to 100 knots	---	---	---
10	Collete	02-03 Nov	1972	Northern	Storm	C2	48 to 63 knots	---	---	---
11	Eleampr	31-07 Feb	1973	Northern	Hurricane	C3 or 4	64 to 100 knots	---	---	---
12	Juliet	03-04 Apr	1973	Central	Severe Hurricane	C4 or 5	>100 knots	---	---	---
13	Tina	23-28 Apr	1973	Central	Storm	C2	48 to 63 knots	---	---	---
14	Lottie	05-12 Dec	1974	Southern	Hurricane	C3 or 4	64 to 100 knots	---	---	---
15	Val	29-05 Feb	1975	Northern	Hurricane	C3 or 4	64 to 100 knots	---	---	---
16	Pat	15-18 Mar	1977	Central	Storm	C2	48 to 63 knots	---	---	---
17	Anne	25-31 Dec	1977	Central	Storm	C2	48 to 63 knots	---	---	---
18	Ernie	16-23 Feb	1978	Central and Southern	Storm	C2	48 to 63 knots	28.05	105.6	---
19	Leslie	21-23 Feb	1979	Central	Storm	C2	48 to 63 knots	---	---	---
20	Meli	24-23 Mar	1979	Northern and Southern	Hurricane	C3 or 4	64 to 100 knots	---	---	---
21	Ofa	10-15 Dec	1979	Northern`	Storm	C2	48 to 63 knots	---	---	---
22	Tia	21-27 Mar	1980	Central	Storm	C2	48 to 63 knots	---	---	---
23	Peni	01-06 Jan	1980	Southern	Storm	C2	48 to 63 knots	33.15	47.76	---
24	Val	24-29 Mar	1980	Northern	Storm	C2	48 to 63 knots	---	---	---
25	Betsy	30-03 Feb	1981	Central and Southern	Gale	C1	34 to 47 knots	---	---	---
26	Cliff	08-15 Feb	1981	Central	Storm	C2	48 to 63 knots	---	---	---
27	Daman	20-24 Feb	1981	Northern	Storm	C2	48 to 63 knots	---	---	---
28	Isaac	27-05 Mar	1982	Central and Southern	Severe Hurricane	C4 or 5	>100 knots	51	56.4	32.64
29	Lance	03-08 Apr	1984	Northern	Storm	C2	48 to 63 knots	---	---	---
30	Drena	11-14 Jan	1985	Northern	Storm	C2	48 to 63 knots	---	---	---
31	Eric	14-20 Jan	1985	Northern, Central	Hurricane	C3 or 4	64 to 100 knots	51	82.8	58.8
32	Keli	08-12 Feb	1986	Southern	Gale	C1	34 to 47 knots	22.95	---	---
33	Martin	10-14 Apr	1986	Central	Storm	C2	48 to 63 knots	---	---	---
34	Kerry	29-03 Apr	1989	Northern and Southern	Storm	C2	48 to 63 knots	---	---	---
35	Ofa	30-10 Feb	1990	Northern	Severe Hurricane	C4 or 5	>100 knots	---	---	---
36	Sina	24-04 Dec	1990	Central and Southern	Hurricane	C3 or 4	64 to 100 knots	63.75	55.2	21.6
37	Val	04-13 Dec	1991	Northern	Hurricane	C3 or 4	64 to 100 knots	---	---	---
38	Joni	06-13 Dc	1992	Southern	Storm	C2	48 to 63 knots	---	---	---
39	Nina	23-05 Jan	1993	Northern and Central	Hurricane	C3 or 4	64 to 100 knots	---	---	---
40	Kina	26-05 Jan	1993	Southern	Hurricane	C3 or 4	64 to 100 knots	61.2	84	36
41	Mick	05-09 Feb	1993	Central	Storm	C2	48 to 63 knots	---	---	---
42	Hina	12-21 Mar	1997	Southern	Hurricane	C3 or 4	64 to 100 knots	38.25	100.8	---
43	Keli	10-15 Jun	1997	Northern	Hurricane	C3 or 4	64 to 100 knots	---	---	---
44	Ron	01-08 Jan	1998	Northern	Severe Hurricane	C4 or 5	>100 knots	---	---	---
45	Cora	23-30 Dec	1998	Central and Southern	Hurricane	C3 or 4	64 to 100 knots	45.9	74.4	---
46	Mona	08-10 Mar	2000	Central and Southern	Storm	C2	48 to 63 knots	40.8	52.8	---
47	Paula	26-08 Mar	2001	Central and Southern	Storm	C2	48 to 63 knots	53.55	42	---
48	Waka	29-01 Jan	2001	Northern and Central	Severe Hurricane	C4 or 5	>100 knots	51	232	37
49	Yolande	03-05 Dec	2002	Central	Gale	C1	34 to 47 knots	20.4	---	---
50	Ami	10-15 Jan	2003	Southern	Storm	C2	48 to 63 knots	56.1	30	68
51	Cilla	27-28 Jan	2003	Central	Gale	C1	34 to 47 knots	17.85	---	---
52	Eseta	13-14 Mar	2003	Central and Southern	Gale	C1	34 to 47 knots	56.1	77	43
53	Fili	14-15 Apr	2003	Central	Gale	C1	34 to 47 knots	---	52	---
54	Heta	05-06 Jan	2004	Northern	Severe Hurricane	C4 or 5	>100 knots	71.4	---	108
55	Lola	30-01 Feb	2005	Southern	Gale	C1	34 to 47 knots	---	---	---
56	Tam	12-13 Jan	2006	Northern	Gale	C1	34 to 47 knots	17.85	---	---
57	Urmil	14-15 Jan	2006	Northern	Gale	C1	34 to 47 knots	30.6	15	---
58	Vaianu	11-15 Feb	2006	Southern	Gale	C1	34 to 47 knots	38.25	48	---
59	Daman	5-Dec	2007	Vavau Haapai Tongatapu and Eua	Gale	C1	34 to 47 knots	53.55	35	35
60	Cliff	4-6 Apr	2007	Tongatapu and Eua	Gale	C1	34 to 47 knots	28.05	40	---
61	Elisa	12-Jan	2008	Tongatapu and Eua	Gale	C1	34 to 47 knots	25.5	46	---
62	Mick	15-16 Dec	2009	Tongatapu and Eua	Gale	C1	34 to 47 knots	33.15	36	---
63	Lin	3-6 Apr	2009	Tongatapu and Eua	Storm	C2	48 to 63 knots	30.6	97	---
64	Rene	14-16 Feb	2010	All island except Niuafoou	Severe Hurricane	C4 or 5	>100 knots	51	39.84	110
65	Wilma	22-25 Jan	2011	All island except Niuafoou	Severe Hurricane	C4 or 5	>100 knots	58.65	55.2	80.4
66	Cyril	7-Feb	2012	Vava'u	Gale	C1	34 to 47 knots	22.95	---	---
67	Jasmine	14-Feb	2012	Haapai Tongatapu and Eua	Gale	C1	34 to 47 knots	58.65	42	29
68	Ian	6-11 Jan	2014	Haapai	Severe Hurricane	C4 or 5	>100 knots	63.75	54	58
69	Kofi	1-Mar	2014	Tongatapu	Gale	C1	34 to 47 knots	25.5	36	---
70	Tuni	27-29 Nov	2015	Niuas	Gale	C1	34 to 47 knots	20.4	---	---
71	Ula	31-03 Jan	2015	Vavau Haapai Tongatapu and Eua	Severe Hurricane	C4 or 5	>100 knots	28.05	10	32
72	Victor	20-23 Jan	2016	Haapai Tongatapu and Eua	Storm	C2	48 to 63 knots	45.9	10.5	---
73	Winston	15-20 Feb	2016	Vavau Haapai Tongatapu and Eua	Severe Hurricane	C4 or 5	>100 knots	81.6	20	26
74	Zena	7-8 April	2016	Tongatapu and Eua	Storm	C2	48 to 63 knots	45.9	7	---

*1 Northern =Niuafo'ou & Niuatoputapu, Central = Vava'u & Ha'apai, Southrn = Tongatapu & Eua
*2 Gale means average winds of 34 to 47 knots, Category 1
*3 Storm means average winds of 48 to 63 knots, Category 2
*4 Hurricane means average winds of 64 to 100 knots, Category 3 or 4
*5 Severe Hurricane means average winds of >100 knots, category 4 or 5

Source: The study team

Table 1-4: Category of cyclone

Category	10 Minute Average Wind Speed		Maximum Instantaneous Wind Speed (3 sec)	
	km/h	m/s	km/h	m/s
1	62-88	17.2-24.7	90-125	25.0-34.7
2	89-117	24.7-32.8	125-164	34.7-45.8
3	118-157	32.8-43.9	165-224	45.8-62.5
4	158-198	43.9-55.0	225-279	62.5-77.8
5	>198	>55.0	>280	>77.8

Source: Bureau of Meteorology: Australia

2) Cyclones that damaged Tonga

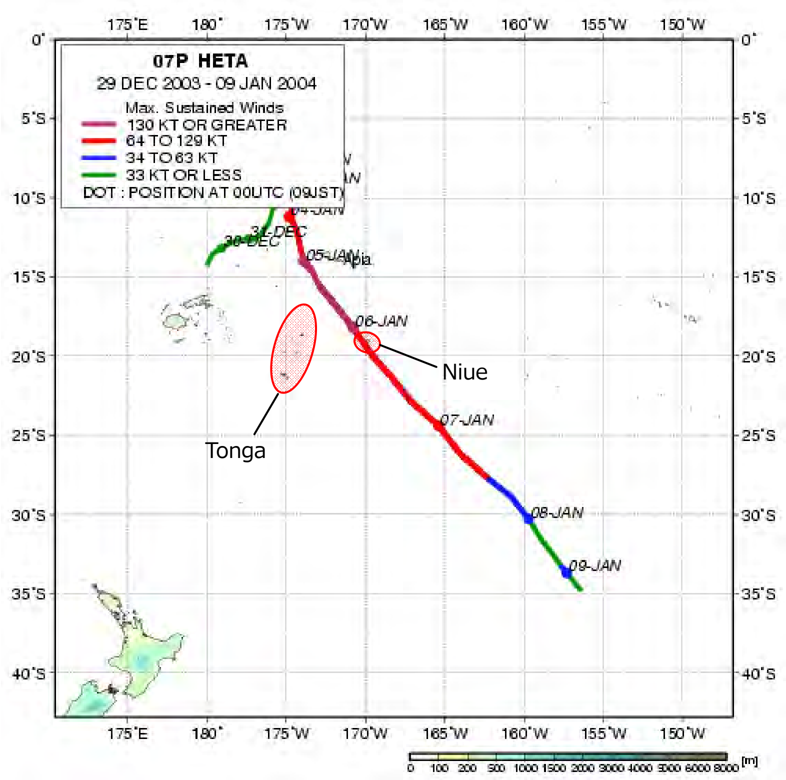
Cyclones based on the data of Tonga Meteorological & Coast Radio Services, caused extensive damage to Tonga and suburb country are explained as below.

① Cyclone Heta (07P, 2004)

Time period : 2004/01/02 - 2004/01/08

Area : Southern Pacific (Pass over Niue)

Maximum wind speed (1 minute) : 140 kt (71.40 m/s, Category 5) (Maximum instantaneous wind speed: 92.82m/s (reference))



Source: JAXA

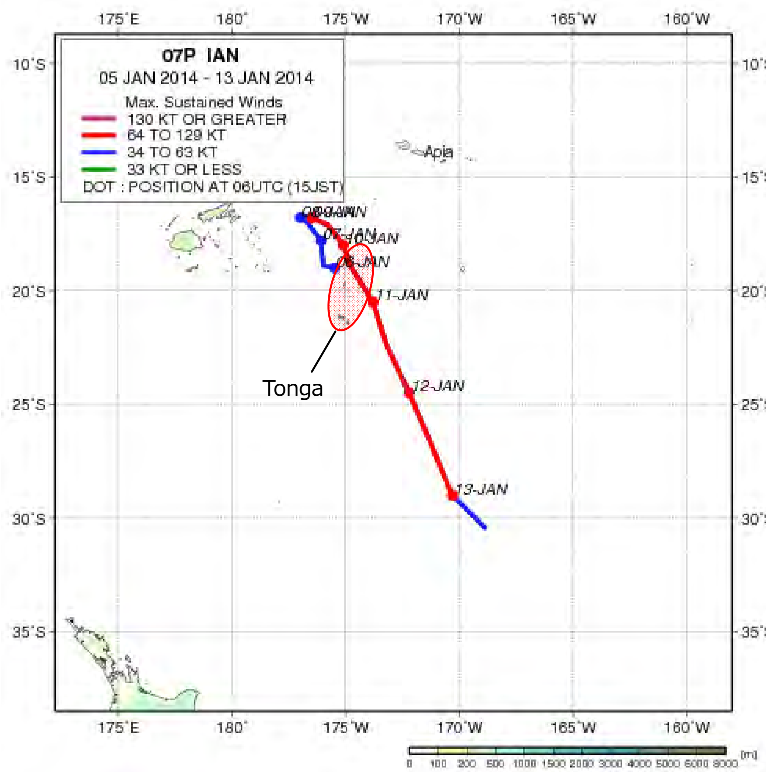
Figure 1-10: Route map of Cyclone Heta

Cyclone Heta moved about 300 km east-northeast of Tonga, keeping its maximum power. Cyclone Heta passed through Niua, 10% of the population lost their houses and became homeless. Cyclone Heta also destroyed the infrastructure, water supply and sewer facilities, hotels and other key infrastructure, and damaged to Niue seriously.

Cyclone Heta did not pass Tonga directly, but more than half houses and buildings were destroyed in the northern Tafahi Island and Niuatoputapu Island.

② Cyclone Ian (07P、2014)

Time period	: 2014/01/05 - 2014/01/13
Area	: Southern Pacific (Pass over Tonga)
Maximum wind speed (1 minute)	: 125 kt (63.75 m/s, Category 4) (Maximum instantaneous wind speed: 82.88m/s (reference))



Source: JAXA

Figure 1-11: Route map of Cyclone Ian

Cyclone Ian occurred in the northern part of Tonga and once went north, then strengthened its power and came down to the south. Ian passed through the northeast of Ha'apai Islands. The Joint Typhoon Warning Center (JTWC) has recorded over 120kt of 1 minute maximum wind speed (61.73 m/s, maximum instantaneous wind speed: 80.25 m/s as reference).

Although there were few victims (one dead, one serious injury), there were huge damage to houses, infrastructure and agricultural crops throughout the Ha'apai Islands, and more than 5,000 people were directly damaged. More than 3,500 people lost their homes and it was estimated that it will cost 56 million TOP (about 3.1 billion yen) for restoration.

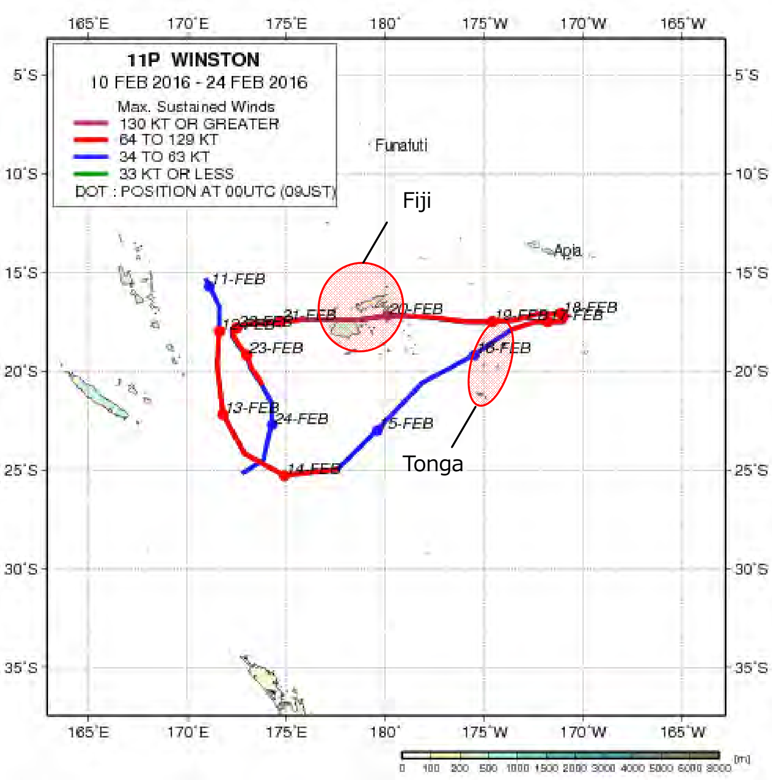
In response to the request from the Tonga government, Japanese government provided emergency assistance to Tonga for humanitarian assistance to victims.

③ Cyclone Winston (11P、2016)

Time period	: 2016/02/10 - 2016/02/24

Area : Southern Pacific (Pass over Fiji)

Maximum wind speed (1 minute) : 160 kt (81.6 m/s, Category 5) (Maximum instantaneous wind speed: 84.9m/s (reference))



Source: JAXA

Figure 1-12: Route map of Cyclone Winston

Cyclone Winston did not pass through the major islands of Tonga, and there was no direct hit to Tonga. However, Winston roundtriped northern part of Tonga with expanding power. After moving 50 km northwest of Babau Island from west southwest to east northeast, Winston reversed direction and passed straight north of Babau Island, heading straight to Fiji in the west. Therefore, damage such as house collapse and power outage occurred in Babau Island.

Figure 1-13: Damage situation by Winston (Fiji)

Fiji is the country that suffered the greatest damage by Winston, and Winston caused enormous damage to Fiji. According to JAXA's record, the maximum wind speed is 81.60 m/s (1 minute) and maximum instantaneous wind speed is 106.08 m/s (reference). Meanwhile, maximum instantaneous wind speed observed by the Fiji weather station is 84.9 m/s (measured value). Although the value of JAXA and Fiji weather station is different, Cyclone Winston was the biggest cyclone among the cyclones that occurred in the Southern Hemisphere in the past. There were 42 dead, 360 houses and 65 school buildings were destroyed, and more than 14,000 people were forced to live in a shelter.

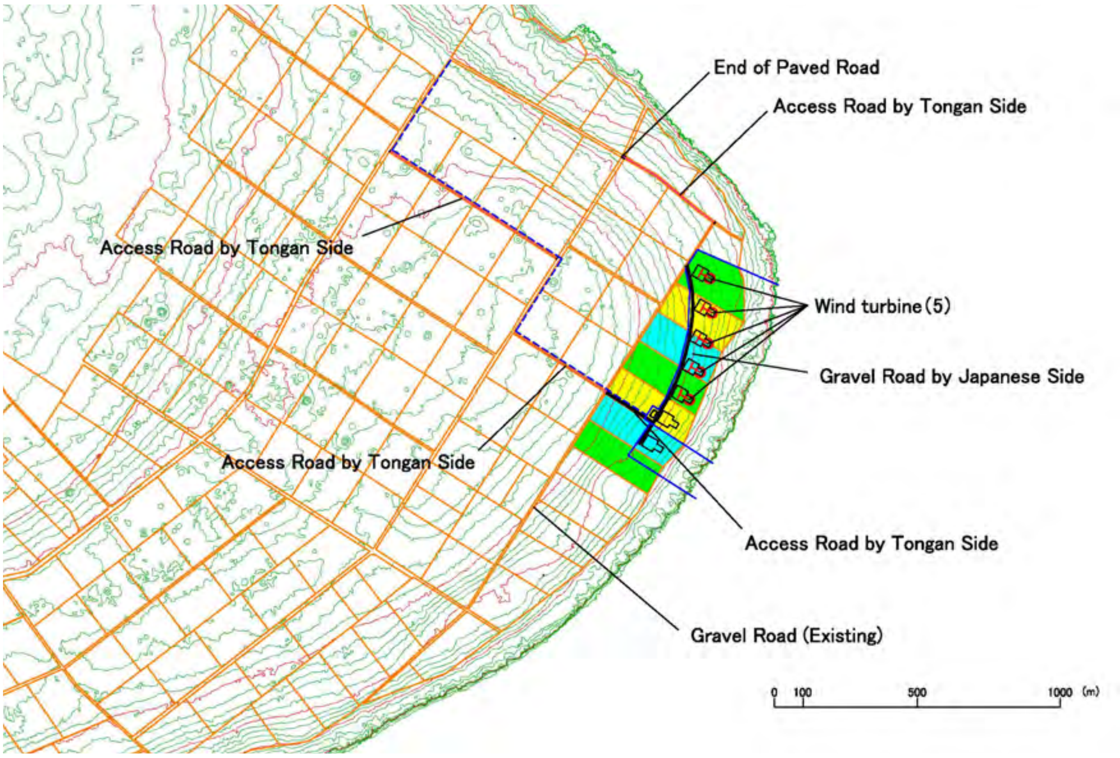
1-4 Social and Environmental Considerations

1-4-1 Environmental Impact Assessment

1-4-1-1 Components of the Project which have a Negative Environmental Impact

The objective of this Project is to install a wind power station. Therefore, the Project also aims to install a storage battery facility which will be connected to the existing power supply grid to secure and stabilize the system of wind power facilities. Tonga is planning a new road which can be used to access to the new wind power station. This Project provides an access road inside the project site. This Project is classified as Category B on "JICA investigation of environmental and social guidelines (April 2010)" because the environmental impact on the project site is not assessed to be significant.

For this reason, the environmental and social considerations survey was conducted on the site, and the contents of monitoring and mitigation measures for the major environmental and social impact items were examined as follows.



Source: The study team

Figure 1-14: Construction Site

1-4-1-2 Environmental and Social Conditions around the Project Site

1-4-1-2-1 Natural Environment

The project site for the construction of the wind power station, Niutoua, is located at the northeast of Tonga's largest island, Tongatapu. The site encompases five blocks of farmland and is 180 m from the eastern coastline. Most of the farmland is covered in weeds; however, some vegetation such as coconut palms and taro plants grow in a part of this area. Moreover, several livestock (cattle) are raised around the project site but not in the construction area as it is located near to the shore. Furthermore, there are no protected flora and fauna in the site. Thus, the impact of the Project on the natural environment of the site is considered to be minimal.

1-4-1-2-2 Social Environment

Most residential areas in Niutoua are in the northeast of Tongatapu, which is 1 km away from the target site. The main industries are fisheries, agriculture, livestock farming, sale of livestock, commerce and tourism. The population of the area is about 750. All of the land is owned by the King of Tonga; however, the residents can lease blocks of land. The Department of Lands and Survey under the Ministry of Lands Survey and Natural Resources (MLSNRE) has registered each land lessee. There are five land lessees (of five blocks of land) at the project site; therefore, monitoring and consulting for compensation of the land acquisition is needed.

1-4-1-2-3 Pollution

There is no water environment to cause water pollution near the project site. Since no air pollution, land contamination, or noise and vibration is reported, baseline data of them is considered to be nearly zero.

1-4-1-3 System and Organization of Social Environmental Considerations in Tonga

1-4-1-3-1 Environmental Legislation and Standards

The Environmental Impact Assessment Act was enacted on December 3rd, 2003. This regulation stipulated that an Environmental Impact Assessment (EIA) must be conducted for all new projects that are likely to have a significant impact on the environment and are related to the 29 categories of development activities – including abattoirs, breweries, airports, farms, chemical plants, power plants, logging of trees and vegetation over 0.5 ha, and tourism – as these could influence the biotope or ecosystem permanently and yield pollutants.

Furthermore, the Ministry of Environment and Climate Change was established by proclamation of the Environmental Management Act (EMA; August 2010) and the ministry administrative environmental field. Environmental Impact Assessment Regulations were also enacted in the same year of the EMA and this regulation depicted the practical details of the EIA. Regarding this Project, the construction of wind power station and laying power lines will be involved in the EIA. However, in accordance with the EIA, construction of roads (paving) inside the target site of the Project will not be investigated.

Table 1-5: Environmental legislation and standards

Standard	Year (revised year)
Environmental Impact Assessment Act	2003
Environmental Impact Assessment Regulations	2010
Environmental Management Act	2010
Environmental Management (Amendment) Act	2015
Waste management Act	2005
Hazardous Wastes and Chemicals Act	2010
Renewal Energy Act	2008 (2010)
Land Act	1927 (1988)

Source: The study team

1-4-1-3-2 Environmental Institutions

The final approval of the environmental impact assessment has been carried out by the Ministry of Meteorology, Energy, Information, Disaster Management, Environment, Climate Change, and Communications (MEIDECC) in Tonga.

In this Project, TPL reported the wind power development plan to the Environmental Assessment Committee, EAC, which is under the Department of Environment & Climate Change (DEC) of MEIDECC. EAC notifies the required EAC and assess the Environmental Study Report submitted by the proponent, and issue a certification of approval. It takes approximately three months for this process.

Afterward, the Environmental Assessment Committee (EAC) assessed, the DEC judged, and MEIDECC approved the plan in accordance with the EIA. Afterwards, the MLSNRE will plan laying the power line and the Ministry of Infrastructure, MoI, will administer the actual operation.

1-4-1-3-3 Environmental policy of TERM

The Government of Tonga (GoT) established ‘Tonga Energy Road Map 2010-2020, TERM’ in June 2010 as a means of combating inflation in the price of oil. Its goal is to change 50 % of the current electricity from imported oil to renewable energy for an economical and sustainable environment by 2020; solar power to 9.3 MW and wind power to 6.6 MW. Currently, the GoT is requiring environmental and social assessments, in accordance with international practice, to mitigate the impact of developments such as the construction of power plants. This Project also helps to cut electricity production costs and contribute to the lives of the people of Tonga.

The following table compares TERM’s policy against environmental issues and JICA Guideline. Both place emphasis on compliance with the international standard on environmental and social considerations. JICA Guideline also places emphasis on respect for fundamental human rights and democratic governance system.

1-4-1-4 Comparative Examination of Alternative Plans

A comparison table of the case of implementing the Project and the zero option (non-implementation) of the construction is as shown in the following table.

By carrying out the Project, environmental impacts, such as land acquisition, air pollution from the exhaust gas, noise and dust during construction, will occur. Also the Project will incur a financial cost. However, the construction of a wind power station will provide sustainable and economical power supply in Tonga.

Furthermore, according to the report of the preliminary investigation for the Project for Introduction of a Micro-Grid System with Renewable Energy for the Tonga Energy Road Map by JICA in 2013, there is no access road to the site, but currently it has been agreed that Tonga will develop the road before the beginning of this Project.

For these reasons, the implementation of this Project is recommended as the most suitable plan, because it was confirmed that the contribution to the residents through this Project is significant.

Table 1-6: Comparison of the case of implementing the Project and the zero option

item		Zero option	implementation of the Project
facility of wind power system		0 point	5 points
installation of electrical line		0m	approximately 2.0km
Environmental and social consideration	Social environment	・Power generation by diesel engine will be main source and against Tonga government policy of saving energy, which prevents reducing the consumption of imported energy. ・If the electrical line is not installed, the facility of wind power system is left unattended.	・For the purpose of installing the facility of wind power system, the acquisition of ROW is necessary, however, on the basis of discussion with landowner and TPL, the compensation will be paid. The agreement between TPL and landowner on this moment prevents the trouble which might happen prior to construction and after starting actual service. ・The construction is not implemented in the residential area, therefore, residents shall not need to move. ・The acquisition of power by renewable energy will enable for residents to reduce the payment of tariff of electricity.
	Natural environment	・Already most lands have been developed as farmland or rangeland, thus neither animals nor plants to be protected inhabit. ・Power is generated by diesel fuel, so the damage for natural environment is not evitable.	・No animals or plants inhabit which needs to be protected. Thus, no bad influence on natural environment. ・No bad influence on natural environment such as trees because the electrical line is planned to be build along the public road.
	Anti-pollution measures	・Exhaust gas or dust is observed from trucks or buses on unpaved roads.	・Exhaust gas or dust is emitted by vehicles for construction, however, the pollution does not exceed over the average because of short period of construction. ・No influence on the residents in terms of noise because the construction site is remote from residential area.
Recommended proposal and reason		**Deprecated**	**Recommended as optimal proposal**
		・On the current condition, the consumption of imported diesel does not change, which is problem in the view of saving energy. ・Against the TERM settled by Tonga government to take measures in high price of imported fuel.	・Applying renewable energy contributes to lower consumption of imported fuel and lower burden of electricity tariff by residents.

Source: The study team

1-4-1-5 Result of the "Eva of TPL and New Zealand on social and environmental Assessment"

As for this Project Tonga produced the report 'Environmental Impact Assessment-Tonga Power Limited Proposed Wind Farm-Niutoua, Hahake Districts, Tongatapu Island' in July 2014, and New Zealand (NZAID) produced the report 'Tongatapu Wind Farm-Environmental Impact Assessment Addendum-Ministry of Foreign Affairs and Trade' on April 20, 2016. The EIA report of TPL was released on the Tonga Environment and Climate Change Portal website after the approval of MEIDECC in August 2014. The results of both reports are shown in the following Table 1-17, but some items (within quotation marks) in Table 1-17 were not clear from the Guidelines for Environmental and Social Consideration of JICA, and the additional assessments shall be carried out in this Project.

Table 1-7: Evaluation contents of EIA by TPL and New Zealand

Category	Number	Impact item	Impact Assessment by TPL and New Zealand
Anti air pollution measures	1	air pollution	Air pollution by emission of dust will occur for short period of time due to traffic increase of construction, however, the amount of traffic on the Project is relatively low, therefore, no excessive SPM (Suspended Particulate Matter) and dust will be emerged. The dust from the construction can be stopped by sprinkle of water on the dry land. Accompanied with operation of wind power facility, no work that causes air pollution is anticipated afterwards.
	2	water pollution	—
	3	wastes	Remaining soil after the construction or wasted material are generated, however, classification of site by fence, regular collection of waste and the education for operators will be its solution. Industrial battery for the purpose of storing surplus power shall be recycled every 15 to 17 years. After starting actual operation, used batteries are exported to New Zealand under the approval of both Tonga and New Zealand government (follow the Basel Treaty). Companies in New Zealand purchase the used batteries to export them to recycle for new materials in Korea. Purchasing price of batteries are more than freight cost to New Zealand. In this regard, Tonga government will not have much expense for the disposal of battery.
	4	soil pollution	—
	5	noise, vibration, electro magnetic effect, low frequency effect	Although some noise or vibration are emitted during the construction, noise level will be around 35 decibels (dB) which can be still acceptable by residents where they live 1km away from the site. According to NZ consul report, Tonga needs to adapt the standard of New Zealand (NZS 6808:2010) because Tonga government does not have any noise standards or requirements. The standard determines that the level of sound from noise-sensitive location such as residences and schools should not exceed the background sound level by more than 5 dB or 40dB. The level of sleep disturbance is set below 30 dB inside of the room based on the WHO guideline. The standard expected of the Project is 40dB outside of the room, which is acceptable as background sound. (Where 500m away from the site indicates 40dB of predicted noise, also is lower than 60dB which is as silent as conversation.) The interference by the rotating blades for electromagnetic communications such as satellite communications, RADAR, aircraft instrument, terrestrial microwave links or television broadcast can be mitigated by the change of location of wind power system and some elements of signals.
	6	ground subsistence	No work is expected which causes subsistence.
	7	offensive odor	No work is expected which causes offensive odor during the construction as well as after the start of operation of the wind power system.
	8	sediment	To avoid bad influence on the soil environment, excavation and falling trees needs to limited with a minimum work.
Natural Environment	9	sanctuary	No sanctuary for wild animal and plants is set within the targeted site.
	10	biota, ecosystem	The reptile fauna was examined over five days in October (12/10/2015-16/10/2015). A total of seven reptile were recorded, including skink(Scincidae) and four species of gecko (Gekkonidae) which inhabit widely Oceania as well as entire area of Tonga. The impact on the reptile fauna by the Project is not anticipated. 10 bird species were recorded during the investigation from 14 to 16 October. The area where they inhabit is mainly at the south-west side of the island, far from the Project site. They normally fly towards the coast from inland. No accident of bird strike was observed by turbines of wind power facility built in Narako two years ago. In these points, there will be little impact on birds. Three inhabitation area of bat in the Tongatapu island was found (Kolovai,Vaini,Hufangalupe Beach), however these area are apart from the Project site. In this regard, there will be minor impact on the fauna of bat. Regarding vegetation, there are 330 species of plant. Around the project site, coconuts and other grass are widely planted as well as Taro (potato). However, there is no essential species of plant to be protected, and thus no big impact on the ecosystem.
	11	underground water	—
	12	geographical features	—
	13	soil erosion	During the construction, the soil at the site is controlled by Erosion and Sediment Control Plan (ESCP). The construction will proceed to avoid damaging the green land on the site. In this regard there is little possibility of soil erosion.
Social Environment	14	land acquisition, resettlement of residents	All lands of Tonga are owned by the King of Tonga, the designated area of the Project site are being utilized as farmland of residents. To acquire TOR of the land, the lease agreement will be made between TPL and land owners, compensating certain amount of cash. (At the prior EIA investigation, discussion with stakeholders was done.)
	15	ethnic minorities, indigenous peoples, regional conflict	At Tongatapu island, there is an unique tribe. There is neither ethnic minorities nor indigenous peoples.
	16	local economy (employment, livelihood)	The construction of facility will last for 8 months, more than 25 number of employment will be borne. Some of them will obtain operation skill of wind power system. The increase of power generation by wind power system can mitigate the fuel consumption of diesel engine, resulting in the decrease of tariff of electricity. Therefore it will be positive impact.
	17	land use and utilization of local resources	—
	18	water usage	No muddy water will be emitted during the construction, therefore no impact on the water usage.
	19	existing social infrastructures and services	No traffic increase by construction nor traffic congestion. Also even after the actual service starts, no increase of traffic will be expected. There are many requests of increasing power supply, no objection to connection with existing grid and new installation of electrical line.
	20	social institutions such as social infrastructure and local decision-making institutions	—
	21	misdistribution of benefits and damages	As the wind power system of the Project is public facility, there is little possibility of causing misdistribution of benefits and damages around the area.
	22	local conflicts of interest	As the purpose of the Project is to supply power for the entire island, there is little possibility of causing local conflicts of interest by construction and service of wind power system. (At the prior stakeholder's meeting, the purpose was agreed between them.)
	23	cultural heritage	At Niutooua, there is heritage of the early 13th century called "Ha'amonga 'a Maui", however, the heritage is located at the opposite side of the Project site, and thus there is little impact on the heritage.
	24	landscape	Shadow flicker of the wind power system will emerge, however the phenomena occur only a short period at a few directions. In this regard there is little impact on the landscape. Moreover, the wind mill is not seen from residential areas, so there is no negative impact on landscape.
	25	the poor	—
	26	gender and children's rights	—
	27	infectious diseases such as HIV / AIDS	The actual work will be done during the day including cleaning at the site before getting dark. This action will prevent for workers from being sick.
	28	working conditions including occupational safety	According to the working standard of TPL, the construction work is done during the day and safety shoes, helmet, jacket and glasses are provided for each worker. Moreover, the construction will be supervised by the person who has enough experience and knowledge of supervising followed by PPE. During the construction, the employment of workers will increase and knowledge and skill of workers will be improved. Even after the start of the operation, TPL will be an enterprise of power supply, creating new employment in the field of construction. In this point, there will be no negative impact on working conditions.
others	29	accident prevent measures	Attending to the safety management at the construction site, accidents need to be avoided in any case to protect all workers who are involved in the Project. First aid kit should be prepared always and obey the safety management standard by TPL.
	30	impact on border crossing and climate change	—

Source: The study team

1-4-1-6 Scoping and Terms of Reference, TOR, with regards to Environmental and Social Considerations

As mentioned above, additional items in accordance with the Guidelines for Environmental and Social Consideration of JICA were examined. All of the 30 items of Table 1-7 are for a scoping study regarding the wind power station. The following 10 items: water pollution, conservation area, ecosystem, topography, resettlement, living cost, cultural heritage, scenery, ethnic minorities, and native tribes and labor environment, are for a scoping study of the storage battery facility. The evaluation items are as follows.

Table 1-8: Evaluation tandard

evaluation grade	evaluation standard
A	Serious impact(s) is (are) expected
B	Less serious impact(s) is (are) expected
C	Impact not known without further research
D	Negligible impacts are expected or no impact is expected

Source: The study team

As a result of the additional evaluation, it is determined that the impact of the land acquisition at the site, and the emissions control of heavy equipment and the safety management during the construction phase are relatively strong, while waste battery treatment (disposal) will also be significant.

Table 1-9: The result for the scoping items of environmental and social considerations

Category	Number	Impact Item	evaluation: Before and During the Construction	evaluation: in Operation	Point of Assessment
Anti air pollution measures	1	air pollution	B^-	D	During the construction: air pollution by emission of dust will occur for short period of time due to traffic increase of construction, however, the amount of traffic on the Project is relatively low, therefore, no excessive SPM (Suspended Particulate Matter) and dust will be emerged. in operation: After the start of operation of wind power facility, no work that causes air pollution will be anticipated.
	2	water pollution	D	D	During the construction: There is no drainage from the construction site (including the telegraph pole), construction vehicle and camping site for workers, therefore no possibility of water pollution. in operation: There is no drainage from wind power system and thus there is no possibility of water pollution.
	3	wastes	B^-	B^-	During the construction: Remaining soil after the construction or wasted material will be borne, however, classification of site by fence, regular collection of waste and education for workers will be its solution. in operation: On the project, industrial battery for the purpose of storing surplus power shall be recycled every 15 to 17 years. Regarding the disposal of used batteries, the sole recycling company in Tonga (Gio recycle) load the batteries onto the containers under the approval of both Tonga and Korea government (follow the Basel Treaty) to export them to recycle for new materials in Korea. The cost of container is covered by Tonga. (the cost at the time of investigation was 2,600 T$ per container). Disposal of capacitor of Lithium-ion needs to be checked.
	4	soil pollution	D	D	During the construction and in operation: There is no possibility of flow of construction oil and soil pollution through the polluted material from construction vehicle.
	5	noise, vibration, electro magnetic effect, low frequency effect	D	D	During the construction: although some noise or vibration are emitted during the construction, noise level will be around 35 decibels (dB) which can be still acceptable by residents where they live 1km away from the site. in operation: According to NZ consul report, Tonga needs to adapt the standard of New Zealand (NZS 6808:2010) because Tonga government does not have any noise standards or requirements. The standard determines that the level of sound from noise-sensitive location such as residences and schools should not exceed the background sound level by more than 5 decibels or 40dB. The level of sleep disturbance is set below 30 dB inside of the room based on the WHO guideline. The predicted noise level of the Project will be less than 40dB outside of the room, which can be acceptable by residents. On the investigation in March 2016 by New Zealand consultant, the level was 40 dB where is 500 away from the targeted site and 35dB at the center of Niutooua, which are smaller than 60dB of normal conversation. The interference by rotating blades for electromagnetic communications such as satellite communications, RADAR, aircraft instrument, terrestrial microwave links or television broadcast can be mitigated by the change of location of wind power system and some elements of signals.
	6	ground subsistence	D	D	During the construction and in operation: No work is expected which causes subsistence.
	7	offensive odor	D	D	During the construction: No work is expected which causes offensive odor in operation: No cause for emitting offensive odor from wind power system
	8	sediment	D	D	During the construction and in operation: To avoid bad influence on the soil environment, excavation and falling trees are limited with a minimum work, therefore no impact on sediment.
Natural Environment	9	sanctuary	D	D	During the construction and in operation: No sanctuary for wild animals and plants is set within the targeted site including the area of electrical line.
	10	biota, ecosystem	D	D	During the construction and in operation: At Environmental Impact Assessment by TPL and New Zealand, investigation was implemented on the animals and plants in the farmland and forests along the road in the targeted area. The result was that the impact on ecosystem, for instance fauna of reptile and bird is relatively low. The main inhabited area of the bird is concentrated on the south east of the island which is remote from the Project site. Moreover, their trajectory is out of the site, north east of the island. No accident of bird strike was observed by turbines of wind power facility built in Narako two years ago. In these points, there will be little impact on birds. Three inhabitation area of bat in the Tongatapu island was found (Kolovai,Vaini,Hufangalupe Beach), however these area is located at southern area of the island and apart from the Project site. In this regard, there will be minor impact on the fauna of bat. Around the project site, coconuts and other grass are widely planted as well as Taro (potato). However, there is no essential species of plant to be protected, and thus no big impact on the vegetation.
	11	underground water	D	D	During the construction and in operation: The construction of wind power system does not have adverse impact on the water quality and flow of underground water
	12	geographical features	D	D	During the construction and in operation: As there is no plan of cutting and filling the ground, there is no adverse impact on topography and geology.
	13	soil erosion	D	D	During the construction and in operation: The construction will proceed to avoid damaging the green land on the site. In this regard there is little possibility of soil erosion.
Social Environment	14	land acquisition, resettlement of residents	B^-	D	Before the construction: No people live in the constructing area, however, the area is currently leased to the people as farmland, therefore the compensation will be paid based on the lease agreement after the discussion of land owner. (At the former stakeholder meeting, the matter was explained to the residents.) The Right of Way of installing electrical line is applied by TPL. in operation: The problem will be solved by compensation before the start of construction.
	15	ethnic minorities, indigenous peoples,	D	D	During the construction and in operation: At Tongatapu island, there is an unique tribe. There is neither ethnic minorities nor indigenous peoples.
	16	local economy (employment, livelihood)	B+	B+	During the construction: Opportunity of employment will get better, Some of workers will obtain operation skill of wind power system. in operation: The increase of power generation by wind power system can mitigate the fuel consumption of diesel engine, resulting in the decrease of tariff of electricity. Therefore it will be positive impact. electrical line will be built along the road and its ROW is applied to the Ministry of social infrastructure by TPL. In this point there is no adverse impact on the residents lives.
	17	land use and utilization of local resources	D	D	During the construction and in operation: The construction and operation of wind power system does not have negative impact on the utilization of surrounding areas and local resources.
	18	water usage	D	D	During the construction: No muddy water will be emitted, therefore there is no adverse impact on the water usage. in operation: No water is used during the operation of the system, therefore there is no adverse impact on the water usage.
	19	existing social infrastructures and services	D	D	During the construction: As the targeted area is farmland, there is little traffic of local vehicles. Only two or three trucks will be operated during the construction. In this regard, no traffic congestion will occur. in operation: Only a few cars of operators of the system will be increased.
	20	social institutions such as social infrastructure and local decision-making institutions	D	D	During the construction and in operation: As the wind power facility is mainly operated by TPL, there are no adverse impact on social institutions social institutions such as social infrastructure and local decision-making institutions.
	21	misdistribution of benefits and damages	D	D	During the construction and in operation: As the wind power system of the Project is public facility, there is little possibility of causing misdistribution of benefits and damages around the area. (at the prior stakeholder meeting, it was explained.)
	22	local conflicts of interest	D	D	During the construction and in operation: As the purpose of the Project is to supply power for the entire island, there is little possibility of causing local conflicts of interest by construction and service of wind power system. (At the prior stakeholder's meeting, the purpose was agreed between them.)
	23	cultural heritage	D	D	During the construction and in operation: At Niutooua, there is ancient Polynesian heritage of the early 13th century called "Ha'amonga 'a Maui" however, the heritage is located at the opposite side of the Project site across the town center, also 1km away from the site, and thus there is no impact on the heritage. The electrical line does not cross the heritage.
	24	landscape	D	D	During the construction: There is no special landscape which needs to consider the targeted area. in operation: Shadow flicker of the wind power system will emerge, however the phenomena occur only a short period at a few directions. In this regard there is little impact on the landscape. Moreover, the wind mill is not seen from residential areas, so there is no negative impact on the landscape.
	25	poor people	D	D	During the construction and in operation: No negative impact is expected on the poor.
	26	gender and children's rights	D	D	During the construction and in operation: No negative impact is expected on gender and children's right.
	27	infectious diseases such as HIV / AIDS	D	D	During the construction: The actual work will be done during the day including cleaning at the site before getting dark. This action will prevent for workers from being sick. in operation: No circumstance is expected which affects health of residents.
	28	working conditions including occupational safety	D	D	During the construction: According to the working standard of TPL, the construction work is done during the day and safety shoes, helmet, jacket and glasses are provided for each worker. Moreover, the construction will be supervised by the person who has enough experience and knowledge of supervising followed by PPE. During the construction, the employment of workers will increase and also knowledge and skill of workers will be improved. in operation: Even after the start of the operation, TPL will be an enterprise of power supply, creating new employment in the field of construction. In this point, there will be no negative impact on working conditions.
others	29	accident prevent measures	B^-	D	During the construction: Taken into consideration the risk of accident, the safety management meeting at the construction site shall be organized regularly in order to prevent accident. in operation: Safety management measures based on the operation manual needs to be obeyed to avoid accident.
	30	impact on border crossing and climate change	D	D	The targeted site is concentrated on the east side of Tongatapu island, therefore there is no negative impact on the border crossing. By increase of power consumption with wind power, the consumption of diesel fuel will decrease, which expects decrease of CO_2 by less consumption of the fuel.

Grade:
A: Serious impact(s) is (are) expected
B: Less serious impact(s) is (are) expected
C: Impact not known without further research
Note: Progress of project itself may reveal the impact (further research is not necessary, in this case)
D: Negligible impacts are expected or no impact is expected

Source: The study team

Through the survey, it was considered appropriate to select the following items of impact assessment:

1. Air pollution
2. Waste Management
3. Land acquisition
4. Accidents

TOR methods are as shown in following table.

Table 1-10: TOR

category of impact	survey item	how to survey
air pollution	・total emission of exhaust gas from construction vehicle which cause air pollution of construction vehicle	・Check the density of NOx or SPM to evaluate the degree of impact on the environment
wastes	・disposal status of construction waste ・way of dispose of used battery	・interview with local workers to check how they dispose the waste ・interview with Waste Authority Limited (WAL) governmental office about waste disposal ・visit waste disposal plant
acquisition of land	・relation of lease on the targeted site ・scale of land to be acquired ・way of compensation in case of land acquisition ・status of utilization of land around the targeted site ・status of household and life of land users at targeted site	・law, scheme and former cases related to land acquisition ・visit targeted site to check the existence of buildings and its type for instance, resident, school, medical center ・interview with locals around the targeted site to check the status of utilization ・interview with lessee at the targeted site
accident	・impact during the construction	・status of the road to the targeted site ・check the safety measure

Source: The study team

1-4-1-7 Result of Preliminary Environmental Impact Study

1-4-1-7-1 Air pollution

In this Project, temporary air deterioration could occur through the use of cranes and concrete mixers during the construction. For this reason the Project Team assumed the operation of using a 70t crane and a concrete mixer with a capacity of 4.4n3 at the same time as the worst-case scenario, and calculated the presumed concentration of the air pollution in Niutoua. The results show NOx is about 0.0023 ppm and PM is about 0.00013mg/m3, which means there would be little impact on air quality. Furthermore, the nearest residential area is 1 km away from Niutoua; therefore, it is expected to have a minimal impact on air quality between the residential area and the site.

1-4-1-7-2 Waste Management

Surplus soil and waste materials are a byproduct of construction. Contractors have to submit an application for permits to MEIDECC through the Waste Authority Ltd.,WAL, in accordance with the Waste Management Act 2005. Construction waste is brought to a designated reclaimed land site in Vaini District as well as general waste. On the other hand, contractors make use of surplus soil for farming or backfilling.

This Project planned the installation of a lithium-ion capacitor (LIC) as a battery facility for security of the system, but it will be necessary to dispose of (or treat) the LIC in approximately 20 years. The TPL has already recognized the importance of ensuring a budget for disposing the LIC; however, there is no regulation regarding LIC disposal in Tonga and there are no applicable incineration facilities in Tonga. Currently, all waste is disposed of directly (open dumping or landfilling) or buried set in concrete.

The practical way is to dispose the LIC in the ground, because when it comes to incinerating the LIC, Tonga has to conclude an agreement with a third country to which Tonga will export the LIC. On the other hand, in the case of burying the LIC in the ground, prior electrical insulation treatment must be carried out and the LIC should be wrapped in a water-proof film to avoid any contact with water. Currently burying the LIC safely is the optimal way under Tongan regulations.

Currently, GIO Recycling Company is the only recycling company that collects and disposes used vehicle batteries in Tongatapu. The company exports the used batteries to Korea by ship and a Korean company actually recycles them.

A New Zealand company previously purchased and exported the used batteries, but Tonga and Korea have an agreement now.

GIO Recycling Company has a permit to export waste directly to Korea. The price to purchase a lead battery by GIO Recycling company is 0.2 TOP/kg and the transport fee is 2,600US$ at the moment.

1-4-1-7-3 Land Acquisition, Resettlement

Currently there are no buildings and unlawful occupants. That is why there is no need to resettle any residents; however, there are some agricultural products such as coconuts, mangos and taros. The land owner is the Tongan King, but each block of land is subdivided to leaseholders, who lease the land from the Tongan King. The TPL has to consult with the land leaseholders and has to pay appropriate compensation for using these lands. Moreover, both sides need to sign a lease contract. Since TPL has experienced similar land acquisition processes many times, the impact on land acquisition is minimal.

1-4-1-7-4 Accidents

It is unlikely that traffic accidents would occur as a result of the construction because there will be few vehicles on the access road to the site. However, it is necessary to consider the safety of the construction work.

1-4-1-8 Impact Assessment

Based on the TOR, the four scoping studies were evaluated. As a result, all impact items were ranked as shown in Table 1-11. B- means positive/negative impact is expected to some extent. Items with B- are highlighted in yellow and impact mitigation measures are required.

Table 1-11: Impact assessment

category	No.	impact item	impact assessment at scoping		impact assessment based on result of survey		result of survey
			during the construction	in operation	during the construction	in operation	
anti pollution measures	1	air pollution	B^-	D	D	D	During the construction: Due to increase of traffic by vehicles for construction, air pollution was anticipated temporarily, however, the construction site is 1km away from residential areas, therefor the concentration of air pollution substance does not have adverse impact on the air, because the figure of NOx is about 0.0023ppm and PM (particulate matters) is about 0.00013mg/m3 respectively. in operation: No air pollution occurs because there is no traffic of construction.
	2	wastes	B^-	B^-	D	B^-	During the construction: Remaining soil or materials are disposed appropriately by constructors. in operation: In the Project, as a facility of storage of electricity, combination usage of lead-acid storage battery and lithium-ion capacitor will be used as storage of electricity. Lead-acid storage battery needs to be disposed 15 to 18 years and lithium-ion capacitor needs 20 years, respectively. Under this condition, the lead-acid storage battery is exported to Korea by the recycling company in Tonga to dismantle and recycle. On the other hand, lithium-ion capacitor cannot be recycled, so needs to be buried based on the waste disposal law of Tonga government.
social environment	3	land acquisition/ resettlement of residents	B^-	D	B^-	D	The construction site is registered as farmland of crop by each landowner. In the field there are trees of mango, coconut or some vegetables but most areas are covered by weeds which is not eatable. Prior to construction: In order to acquire the land as a construction site, TPL needs to discuss with each landowner. After they agree, lease agreement will be contracted. On the contract, TPL will pay compensation fee for landowners to acquire ROW for 50 years. Currently, the negotiation with landowners in the process by TPL. in operation: No problem will occur because the land will be acquired subject to lease agreement. If something happens, a customer center of TPL will handle the problem.
others	4	accident	B^-	D	B^-	D	During the construction: Some accident might occur. Each worker needs to obey attending points of safety management guidance to prevent accident. in operation: TPL controls the safety of operation throughout. Also regular maintenance is important to prevent accident.

Source: The study team

1-4-1-9 Mitigation Measures and Cost for Implementation

Mitigation measures for the items assessed as having a potential environmental impact (of B-) are listed in the following table. All the items assessed as having a potential negative impact are also able to be resolved through the mitigation measures.

Table 1-12: Mitigation measures

No.	impact item	period	measures of mitigation	organization	cost
1	wastes	after the operation	・ The disposal of lead-acid storage batteries as facility of storage electricity is managed by the sole recycling company in Tonga, called "GIO Recycling", which export them to Korea to recycle. TPL will keep the budget for this and execute the disposal of battery. Regarding capacitor of lithium-ion, it needs to be disposed under the approval of Waste Authority Ltd (WAL) which established the regulation of waste disposal management in Tonga.	・ TPL ・ Waste Authority Limited (WAL)	Purchasing price of lead-acid storage battery as of August 2016 is 0.20 TOP / kg and the freight cost to Korea is 2,600 USD / container.
2	land acquisition	prior to construction	・ TPL will explain about the construction well with land owners of targeted site. ・ The payment of compensation of the land will proceed after the discussion between TPL and land owners. ・ After the lease agreement between TPL and land owners, the contract will be submitted to Department of Lands and Survey. ・ On the contract, the duration of lease (usually 50 years), the condition of the use during the construction, customer service center to receive the complaint from customers and other necessary items need to be mentioned.	・ TPL ・ Department of Lands and Survey	TPL officer calculates the compensation based on the area of the leased land, market price of the land and current status of its use. TPL dose not have standard of compensation, therefore the price will be determined after the negotiation with land owners.
			・ In order to settle the electrical line, the plotted map needs to be submitted to Ministry of Lands Survey and Natural Resources and get approval of ROW.	・ TPL ・ Ministry of Lands Survey and Natural Resources	No compensation
3	accident	during the construction	・ Needs to be pay attention to working environment of workers ・ With safety standard and climate of Tonga, safety management guidance needs to be structured. ・ Safety management assembly needs to be executed to enhance self awareness of accident by each worker.	・ companies which take responsibility on construction	including the cost of construction

Source: The study team

1-4-1-10 Monitoring Plan

The monitoring plan before the construction of the wind power station and during its construction is shown below. The impacts and changes of environmental items for the planned mitigation measures will be periodically monitored during construction and during service based on the following monitoring plan.

Table 1-13: Monitoring plan

impact item	monitoring item	target	frequency	responsibility organization
wastes	wastes of construction: interview of leader at the construction site to check the amount of wastes and its final place to be disposed. Lead battery: check the receipt of the wastes by final receiver. Lithium-ion capacitor: check the way of disposal	・construction site ・office of receiver of wastes ・Waste Authority Ltd (WAL)	At the time of disposal	TPL WAL
accident	implementation of safety management assembly status of management of construction material status of accidents	targeted area of the construction	monthly	companies which take responsibility on construction

Source: The study team

1-4-1-11 Consultant Meeting with Stakeholders

Main stakeholders of this Project are: the TPL, which is contracted to the Tonga Government to provide power in accordance with a Concession Agreement (CA); land leaseholders; and residents in Niutoua.

TPL has already consulted with the residents in Niutoua reagarding EIAs. These meetings were conducted by TPL in August 2014, and New Zealand in April 2016. The consultant meeting in 2014 involved a questionnaire sent to 43 households, of which 42 agreed with the project. The fact that the Project will increase the electricity supply, which in turn will lower their power bills, are considered to have contributed to gaining the residents' approval of the questionnaire.

In the 2016 project by New Zealand, the consultant meeting involved 32 participants including land leaseholders of the wind power station, local leaders and pastors; while the NZ consultants and the TPL staff in charge explained the practical plan of the project using a PowerPoint presentation. The residents could actively ask many concrete things including the following: the scale of the plant, construction schedule, the possibility of job development, the influence on the life of the residents, compensation for the residents, non-wind situation, the possibility of the blades falling down, the influence of earthquakes or cyclones, the effects on birds, noise and how much the electricity fee might decrease by.

TPL has already had two consultant meetings; the most recent being four months before this survey. Based on this, the Project Team decided not to hold a consultant meeting again, and the TPL (without the Project Team) will have a final consultant meeting with the concerned stakeholders. The agenda, which the TPL and the Project Team discussed, is shown below.

- TPL will find the leaseholders of the site, and verify their living conditions such as their occupations, income and how they use their land.
- TPL will make sure the leaseholders understand the gist of this Project and the land acquisition.
- Tall trees around the site must be cut for maintaining the necessary amount of wind. The TPL will have to continue explaining to the leaseholders not to plant trees (except plants like taros that will not have an impact on the wind turbine output). This is to be written in an agreement between the TPL and the leaseholders. The final consultant meeting will be held between September and October this year and the minutes will be shared with this Project Team.
- TPL has to negotiate and get approvals regarding the compensation to the leaseholders of the land acquisition before the next survey.
- TPL must be ready to conclude the lease contracts after obtaining the approval of the leasholders (regarding compensation).
- TPL has to obtain the leaseholders' signatures to an agreement explaining to the leaseholders that future complaints about the Project or limits to vegetation height will not be accepted.
- TPL has to arrange the land acquisition before the next investigation because the Tongan Government needs the agreement of the leaseholders and the certification of the EIA to permit construction of the wind power station.

1-4-2 Land Acquisition, Resettlement

1-4-2-1 Necessity of Land Acquisition and Resettlement

Resettlement for this Project is not necessary because the project site is farmland on the northeastern coastline of Tongatapu. On the other hand, rights (consent from the leaseholders) to use the land needs to be obtained and the Project needs to harvest taros and remove the unnecessary trees before starting this Project. As for laying new power lines, it will not have an impact because the line will be located along the public road and there is no impact on any nearby buildings. Furthermore, it is not necessary to acquire land to construct an access road on the site because the Tongan Government already had plans to develop the road before the this Project was conceived.

1. Affected area: seven blocks of farmland in the northeast of Tongatapu, of which five blocks are to be used for the plant.
2. First alternative design plan: relocation of the wind power plant.
3. The best way for land acquisition: calculate the necessary area and conclude the lease agreement to the leaseholders before the Project and plan so that the power lines will not be crossing the road

1-4-2-2 Legal Framework in accordance with the Land Acquisition

Since some of the King of Tonga’s land has been subdivided to people in Tonga, the property rights of the land belongs to the leaseholders of each block. The Constitution of Tonga, revised 1988, banned the trade of the land but allowed land to be leased in accordance with Land Act, 1988 Revised Edition. Therefore, this Project site will be acquired through a lease agreement between the TPL and the leaseholders.

Moreover, the lease agreement was deliberated by Cabinet of Tonga and approved by MLSNRE. The terms of the lease are limited up to 99 years and the agreement is registered to Department of Lands and Survey. Experience shows that this process takes approximately one month from signing lease agreement.

Tongan Government does not set the price of the land legally. For this reason, the TPL has to set the compensation price with the leaseholders. The desirable compensation depends on the leaseholders, so the TPL must calculate the adequate price on the basis of the market price and proceed with the negotiation. The compensation should be paid before the beginning of the Project. However, the TPL does not need to obtain Right of Way (ROW) or pay compensation relating to the overhead lines or underground cables because the use of road is regarded as public use.

1-4-2-3 Scale and Range of Land Acquisition

The necessary area of the wind power plant is seven blocks, as shown in Fig.2-32 below. The actual land acquisition will be five blocks from A to E (Fig.2-32) as this Project plans five wind turbines. However, the compensation for the site is based on whether the TPL is able to acquire the land, and we assumed seven blocks will be necessary in the worst-case scenario.

As mentioned before, the land is currently farmland with some coconut palms, taro plants and weeds. It is confirmed, in a previous survey, that the farmland was not being used much. In this Project, we calculated the area needed for the foundations of the turbines as wells as to conduct necessary future maintenance to confirm the applicable leaseholders. Lease agreements are planned to be concluded with these applicable leasholders. Table 1-14 below demonstrates the area of land acquisition.

Table 1-14: Land acquisition area

lot	land owner (person)	space (m^2)
A	1	3,032.261
B	1	4,345.035
C	1	4,578.846
D	1	3,364.133
E	1	5,826.452
F	1	2,960.644
G	1	3,927.156
total	7	28,034.527

space: the figure includes the area of basement of wind mill, working space for maintenance, and temporary road for

Source: The study team

Source: The study team

Figure 1-15: Land Acquisition Area

1-4-2-4 Concrete Measures of Compensation and Support

All of the seven blocks for the site are farms, but there are few harvestable crops and most land is covered with bush or trees. Accordingly, there will be little economic damage to the leaseholders. The TPL calculates the foundation area for the wind turbines and space needed for maintenance, and calculates the adequate price on the basis of the market price.

The compensation price will be showed to each leaseholder individually, and the TPL will negotiate the price with the leaseholders in view of the estimated loss from this Project, such as the effects on job, family members, earnings and living cost.

This Project will permanently ban planting trees but because of this, it will be easy to plant other crops and they can expect to gain an increase in earnings.

Table 1-15: Entitlement matrix

No.	loss	beneficiaries of compensation	detail of compensation	responsibility organization
1	farm land	land owners (farmers)	Based on the judgement of TPL, compensation will be paid to each land owner.	Tonga energy road map office and TPL
2	crop			

Tonga regulation referred: Constitution of Tonga, Revised 1988
Land Act, 1988 Revised Edition

Source: The study team

1-4-2-5 Mechanism of the Complaints Processing

A residents meeting is to be held regarding the safe management of construction and questions from the residents. Opinions and complaints from residents relating to the wind power station are processed by the TPL through a local leader. If necessary, the TPL will hold a residents meeting at any time to solve the problems early. As for the leaseholders, they will promise not to complain about the Project in the lease agreement. The TPL also has a customer service section to deal with any risks or complaints by means of telephone, e-mail or written correspondence.

1-4-2-6 Executive System

The TPL is proceeding with the land acquisition for the site, and it has experience negotiating for land acquisition. The person in charge of the financial department will consider the necessity and the impact of the land acquisition, scope the target area, explain details to the residents, hold a consultant meeting, and proceed with the compensation on the basis of the scale of assessment of the compensation. The customer service section will deal with complaints during the construction. Incidentally, Fig.2-1 shows TPL's organizational structure regarding land acquisition.

1-4-2-7 Implementation Schedule

All the procedures for the land acquisition should be completed before starting the construction. The schedule of the land acquisition is as follows.

Table 1-16: Implementation schedule

moth	1				2			
week	1	2	3	4	1	2	3	4
confirmation of targeted area of construction								
confirmation of land owners								
confirmation of total cost of compensation								
negotiation of land owner								
explain the outline of construction to residents								
contract of lease agreement								
acquisition of land								

Source: The study team

1-4-2-8 Financial Resources and Cost

The financial resources for the compensation cost of the land acquisition are from TPL's budget and the cost will be paid to the individual leaseholders. The cost is according to the area used for the construction. It will also be taken into account if the land acquisition causes a loss of earnings from crops. Accordingly, if there were no crops at the farm, the TPL would not need to pay any compensation costs to the leaseholders. Table 1-17 below demonstrates the compensation cost in accordance with the market price. There is no standard price of compensation by Land Act of Tonga, so the final decision depends on the present land situation and/or the market price.

Table 1-17: Cost of compensation and financial resources

total space of compensation area	amount of compensation (TOP)	detail	source of budget for resettlement
21,146.73	323,535.682	TPL will determine the compensation based on the total condition of the land such as market price of the land, current status of its use, the crop which is currently cultivated.	TPL

Note: TOP: Tonga dollar (pa'anga)

Source: The study team

Table 1-18: Compensation of farm land

lot	area of compensation for land acquisition	market price of land (TOP/m^2)	amount of compensation (TOP)	
			TOP	JPY
A	3,032.261	9.848	29,860.400	1,375,967.219
B	4,345.035	9.910	43,060.996	1,984,250.693
C	4,578.846	12.328	56,449.080	2,601,173.611
D	3,364.133	12.386	41,666.972	1,920,014.078
E	5,826.452	12.229	71,254.208	3,283,393.924
F	2,960.644	12.242	36,244.026	1,670,124.715
G	3,927.156	11.459	45,000.000	2,073,600.000
total	28,034.527		323,535.682	14,908,524.240

Note: TOP : Tonga dollar (Pa'anga) (Source: TPL)
: exchange rate is based on the rate on cost estimation work (1TOP=46.080JPY)

Source: The study team

In addition to Table 1-18, the compensation cost for the crops could be added; however, it could not be confirmed whether all of the leaseholders actually harvest the crops (for their living). Hence, the compensation cost for crops is based on TPL's site scoping, and it will be determined by a negotiation with the leaseholders.

1-4-2-9 Monitoring System by Implementing Agencies and Monitoring Form

The whole procedure for compensation will be completed before starting construction. The TPL, however will continue to check whether any of the leasholders have any issues or complaints on a regular basis (after the compensation has been settled). Basically TPL is in charge of complaints, but if they have difficulty resolving any issues, the TPL would need to consult with TERM-C (Tonga Energy Road Map Committee). Regarding the height of trees described in agreements, TPL should regularly check for maintaining the necessary amount of wind.

Table 1-19: Monitoring form

Lot	name of land owner	space of land (m^2)	condition around the facility the height of trees	comment (condition / complaint)	responsibility organization
A		3,032.261			TPL
B		4,345.035			TPL
C		4,578.846			TPL
D		3,346.133			TPL
E		5,826.452			TPL
F		2,960.644			TPL
G		3,927.156			TPL

Source: The study team

1-4-2-10 Residents Meeting

TPL has already held a few residents meetings regarding the expansion of the existing power lines and construction of a new solar power station. Therefore, the residents already understand the significance for the land acquisition. Moreover, there have been two resident meetings regarding this wind power site in the past. The most recent meeting was held for 32 residents of Nutoua Village including leaseholders, local leaders and pastors in April 2016 regarding the EIA conducted by New Zealand. No serious objection was raised.

Furthermore, TPL has already consulted with some of the leaseholders of the target site, and they agreed to cooperate with the Project, although there were a few questions. A residents meeting was not held by this

Project Team because the most recent residents meeting was held just four months earlier and the target leaseholders were not present (when the team was in Tonga). The TPL will have an official consultant meeting with residents again after the Project Team returns to Japan. In the meeting, the TPL has to explain the Project to the residents in order to proceed with the compensation fairly and smoothly, and has to collect the proper opinions regarding the plan, and finally has to review the plan.

Chapter 2

Contents of the Project

CHAPTER 2 CONTENTS OF THE PROJECT

2-1 Basic Concept of the Project

2-1-1 Over Goal and Project Goal

In Tonga, fuel imports account for approximately 25 % of all imports, and over 93 % of power supply depends on diesel. Due to this, international variation of oil costs significantly affects Tonga, and therefore Tonga's energy security is very weak. In response to this, Tonga has adopted a policy target in 2009, '50 % of electricity generation from renewable resources by 2020', to tackle CO2 reduction and improve energy security.

Under these conditions, Tonga has already completed the construction of 2.3 MW solar photovoltaic station. Furthermore, Tonga is also expecting to construct a new wind power station in Tongatapu to further increase the renewable energy ratio.

Thus, the Project purpose is to contribute to sustainable growth in Tonga by constructing the wind power station.

2-1-2 Basic Concept of the Project

The Project will construct a 1.3 MW wind power station in Niutoua, including distribution lines and communication cables, to achieve the aforementioned targets. As a result, this will increase the percentage of renewable energy in Tongatapu Island, ensuring the quality of electric power.

2-2 Outline Design of the Japanese Assistance

2-2-1 Design Policy

2-2-1-1 Basic Policy

The introduction of sustainable renewable energy is the main objective of the Project. Therefore, the wind power station, storage batteries, and a facility for the connection to the existing grid shall be installed, and the procurement of materials and equipment related to these shall also be carried out to provide stable electricity supply. Furthermore, the Project will create a system model and perform a simulation for verification of preconditions.

In addition, the target year to achieve the Project is 2020, because the TERM incorporates the target of increasing share of renewable energy of total electricity to 50 % by 2020.

2-2-1-2 Site Selection

Tonga requests the Niutoua to be the construction site of the new wind power station. On the other hand, New Zealand also carried out wind condition investigations in Niutoua and Lapaha, and confirmed that the wind conditions of Niutoua are clearly more adequate than the Lapaha.

Therefore, New Zealand intends to construct a wind power station, with the maximum output of 900 kW, at Niutoua, due to its high power generation efficiency. Furthermore, New Zealand has requested to the Japanese Government to build a wind power station in Lapaha Village, because the Japanese turbines, which are planned to be installed, have small output capacity, and also New Zealand would like to avoid a negative appearance of two different types of turbines at the same location. However, the Project has decided to construct a new station in Niutoua because the New Zealand project is still undecided and the Tonga side wishes to have a new plant in Niutoua. Additionally, even after the construction of a new wind power station by Japan, it will be possible for New Zealand to secure a site in Niutouta Village to build a new wind power station.

2-2-1-3 Transport

2-2-1-3-1 Route

Transport routes from Nuku’alofa Port to the project site are the paved main road to Niutoua, and the non-paved road from Niutoua to the project site. There are two-way-roads around Nuku’alofa Port and Hoi District, and the Project Team has chosen the transport route.

(1) Near Nuku’alofa Port

The VUNA Road and ALAIVAHAMAMA’O Road are considered as routes of Transport. It was learned through interview with the TPL staff in charge that the transportation of electric poles or containers are carried out through the ALAIBAHAMAMA’O Road because the power lines are set high in this road. Therefore, this Project Team has selected the ALAIBAHAMAMA’O Road.

Source: The study team

Figure 2-1: Route plan near Nuku’alofa

Source: The study team

Figure 2-2: Situation of transportation route

(2) Near Hoi area

There are two ways to be considered. One way is along the sea coast and the other is inland. The sea coast way is longer than the inland way, but the road width is 5.5 m, and has two lanes. On the other hand, the road width of the inland way is 3.8 m and it is difficult for construction vehicles to pass oncoming cars. Furthermore, a height of 4.0 m is necessary for construction vehicles to run but the trees along the inland way cover the road and it prevents the vehicles from passing. In the case of the sea coast way, only two trees are along the road and there is 4.5 m of height to the power lines. As a result the Project Team selected the sea coast road.

Source: The study team

Figure 2-3: Two alternative routes near Hoi area

Source: The study team

Figure 2-4: Seashore route (left) and inland route (right)

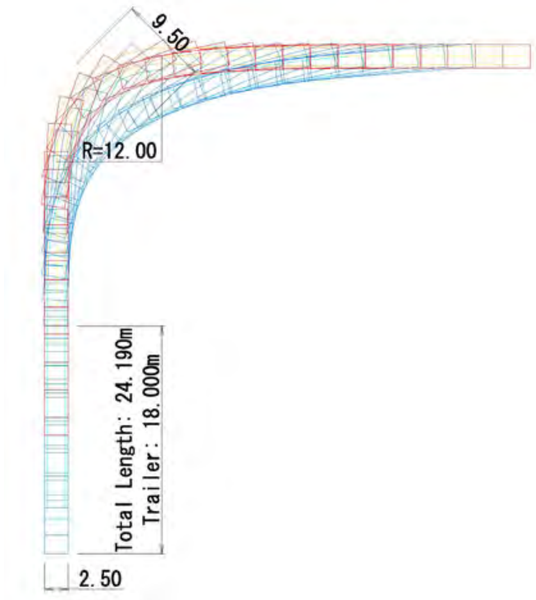
According to the above reasons, the transport route from Nuku'alofa Port to the project site will consist of the paved road, 38.4 km; and the non-paved road, 0.9 km, totaling 39.3 km as is shown in the following image.

Source: The study team

Figure 2-5: Route of transportation

2-2-1-3-2 Expanding road plan

Trailers shall be used for transporting 20 ft containers carrying towers, nacelles, and blades of the fan. One blade is about 16-17 m and the locus chart is as shown below. Where the road consists of two linear lanes there will not be a problem, but road expansion needs to be taken into account at intersections and non-pavement roads in Niutoua.



Source: The study team

Figure 2-6: Trajectory of trailer transporting for Blades

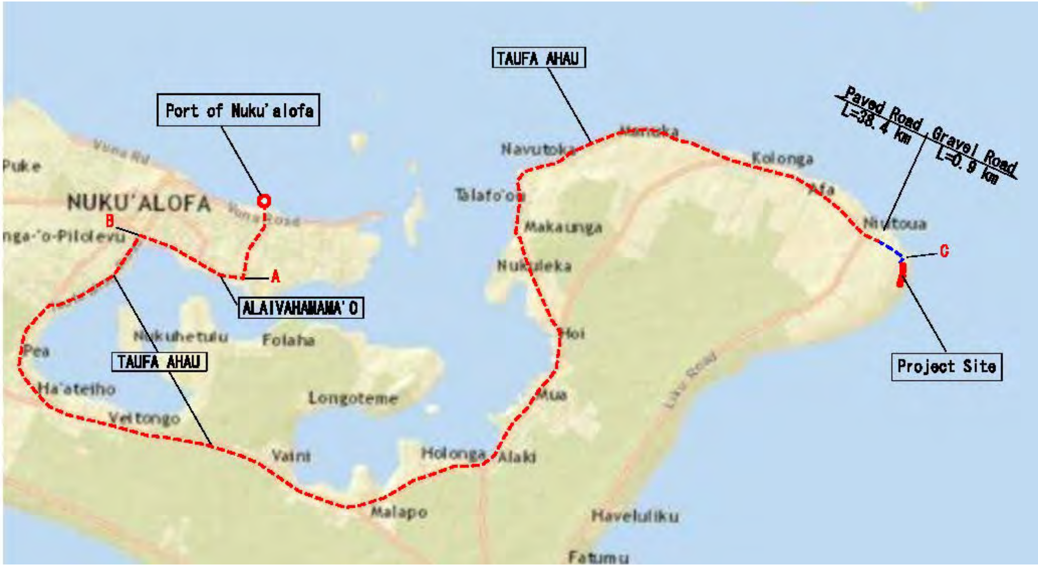
In the transportation route, there are three intersections, A, B and C, where construction vehicles have to turn right or left. The current status of each intersection is shown in the images below.

Intersection A: When transporting the blades, the construction vehicles have to run on the opposite lane and need traffic regulation since the width of the opposite side is 3.6 m and the 0.9 m of median strip will be a hindrance.

Intersection B: There is a roundabout in intersection B and it is possible for cars to get on the roundabout if necessary.

Intersection C: Intersection C is close to the project site and it is unpaved with a width of 2.7 m. Widening is necessary not only for intersection C but also for the linear sections because the Project will use these as access roads. The widening plan is illustrated in Source: The study team

Figure 2-7.



Source: The study team

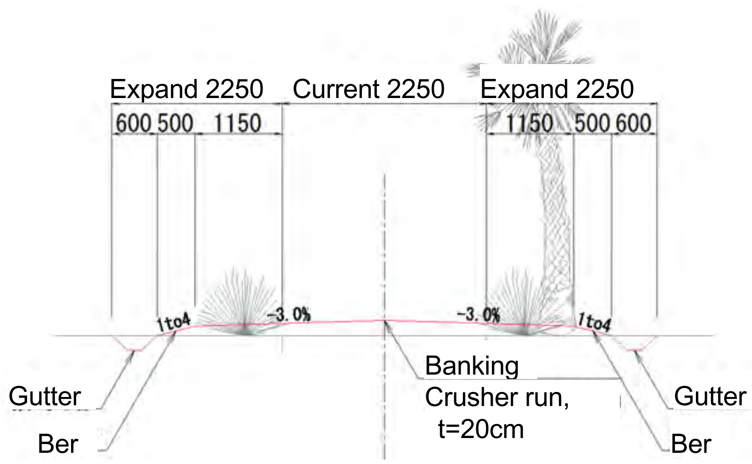
Figure 2-7: Location of intersections

Source: The study team

Figure 2-8: Intersection A

Source: The study team

Figure 2-9: Intersection B (left) and intersection C (right)



Source: The study team

Figure 2-10: Cross-section drawing of the expansion plan

2-2-1-4 Policy of Natural Conditions

2-2-1-4-1 Policy on Temperature and Humidity Conditions

Tonga is a marine tropical climate and monthly average temperatures are constantly between 22 ℃ to 27 ℃ throughout the year. Humidity is between roughly 79 % and 86 % throughout the year. In this plan, the storage batteries, instrumentation devices and circuit breaker consoles are set to be inside buildings so there is no need take special measures against outside temperatures. However, as for the ventilation of the equipment's heat, when considering temperatures for effective operation, the inside temperature should be set to 35 ℃ or lower and the outside facilities should not reach over 40 ℃.

2-2-1-4-2 Policy on Design Wind Speed

(1) Class of Wind Turbine

Many of the wind turbines spinning around the world are designed and manufactured under the International Electrotechnical Commission (IEC) standards. Among these, wind turbines in particular are set to the IEC61400-1 standard. The planned wind power station in Tonga also complies with the IEC. In the IEC61400-1 standard, the wind turbine class is set to enable calculation of design strength, which is confirmed in accordance with design conditions (wind speed and turbulence intensity).

Table 2-1: Class of wind turbine

Wind turbine class	I	II	III	S
V_{ref} (m/s)	50	42.5	37.5	Values specified by the designer
A I_{ref} (-)	0.16			
B I_{ref} (-)	0.14			
C I_{ref} (-)	0.12			
This table applies at hub height V_{ref}: maximum extreme 10 min average with 50 year recurrence period A: applied to high turbulence B: applied to mid turbulence C: applied to low turbulence I_{ref}: reference turbulence intensity at 15m/s of wid speed.				

Source: IEC standard

Class IA to IIIC are the standard wind turbine classes and are designed for 20 years of service life. However, in specific wind and external conditions or if in some cases a special safety class is required, Class S is selected and individual design values are set.

(2) Extreme Wind Speed

Normally, the wind speed is expressed by the value of the observation height of 10 meters above the ground. In order to set the extreme wind speed at 10 meters above the ground, the reference value of the maximum instantaneous wind speed is as follows.

Table 2-2: Maximum instantaneous wind speed

Reference item	Maximum instantaneous wind speed (m/s)	Remarks
Tonga building code	70	Minimum value of design wind speed that needs to be secured as structure
Weather center	78.0	Design wind speed of structure (weather station) built by Tonga Meteorological & Coast Radio Services concerned by MEIDECC. Minimum wind speed of category 5 for cyclone
Meteorological data (airport)	77.2	Maximum observation record of wind speed every 3 hours by Tonga Meteorological & Coast Radio Services
Cyclone (observed value)	84.9	Wind speed of Cyclone Winston (the measurement place is Fiji) which recorded the maximum value as measured value

Source: The study team

In Tonga, the building code will be revised after 2017, and design wind speed will be 70 m/s.

Meanwhile, the Tongan government plans to construct the weather station under MEIDECC in the airport of Eua Island, located about 20 km east of Tongatapu Island. The design wind speed of this weather station is set to 78.0 m/s, the minimum value of the wind speed in category 5, which is the maximum category of classification of cyclone. This shows that the Tongan government is very wary about the threat of cyclones. In addition, it is necessary that the design wind speed prescribed by the Tongan building code is secured at a minimum. However, it shows that it is possible to set the wind speed flexibly and individually to a value higher than the building code for important structures (as shown by the weather center example in Table 2-2 above).

Although the Tongan government adopts design wind speed of 78 m/s (for weather center), which is the minimum wind speed of a category 5 cyclone, there are no records in the past that a cyclone exceeding 70 m/s passed through the target site. Meanwhile, TPL is requesting the wind turbine at extreme wind speed which can withstand cyclones that have been increasing in strength in recent years, and TPL requested Japan to design wind turbine as category S. Therefore, this Project sets extreme wind speed based on the Tongan building code. Concretely, the extreme wind speed at 10 meters above the ground is set to 70 m/s according to Tongan building code. Then, by defining the vertical distribution of the wind speed, the extreme wind speed more than 10 meters above ground is set.

(3) Extreme Wind Speed (vertical wind speed distribution)

The vertical distribution of wind speed is usually defined by the following Wind Shear Law, and the wind speed increases as the altitude increases.

$$V(z) = V(z_r) \times \frac{\ln\left(\frac{z}{z_0}\right)}{\ln\left(\frac{z_r}{z_0}\right)} \cdots\cdots (1)$$

$$V(z) = V(z_r) \times \left(\frac{z}{z_r}\right)^{\alpha} \cdots\cdots (2)$$

Figure 2-11: Wind Shear Law

The index α in the formula is a factor generally used in calculating the vertical distribution of the wind speed according to Wind Shear Law. However, these values of index α can be applied when the wind is stable, and cannot be applied for cyclone. Therefore, in case of cyclone, it is necessary to consider α separately.

Regarding the setting of the index α in case of cyclone, a research paper has been published in 2012 and are described as follows.

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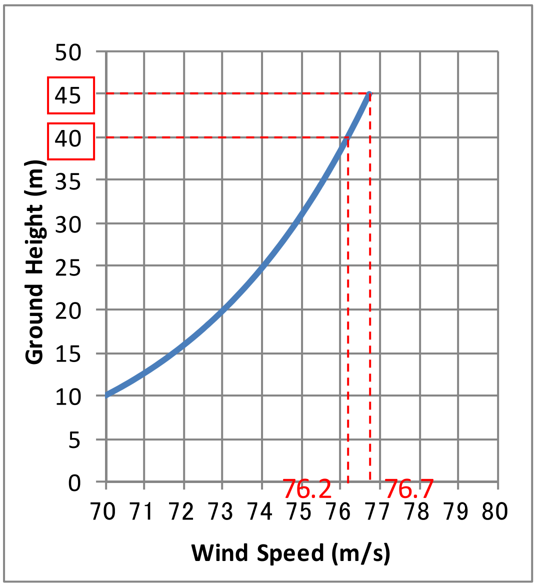
Table 2. Results of log and power law least-squares fits for a 20 – 160 m surface layer.

MBL group (ms^{-1})	Surface layer depth (m)	25 m bin sample size	R^2-Log	R^2-Power	α
35-39.999	20-160	236	0.996	0.993	0.086
40-44.999	20-160	210	0.994	0.991	0.093
45-49.999	20-160	166	0.993	0.992	0.083
50-54.999	20-160	103	0.989	0.952	0.098
54-59.999	20-160	105	0.989	0.968	0.081
60-64.999	20-160	54	0.992	0.975	0.058
65-69.999	20-160	64	0.992	0.991	0.089
70-74.999	20-160	53	0.962	0.941	0.061

Source: Observed characteristics of tropical cyclone vertical wind profiles

Figure 2-12: Index α in case of cyclone

In this research paper, the index α is calculated for each range of wind speed from the investigated data of cyclones. The wind speed distribution in the vertical direction covers 20 to 160 m above the ground, and the index α is calculated for each range of the wind speed. The index α for the extreme wind speed of 70 m/s at 10 meters above the ground is α = 0.061, and the vertical distribution of the wind speed in the sky is calculated as follows.



Source: The study team

Figure 2-13: Vertical distribution of wind speed

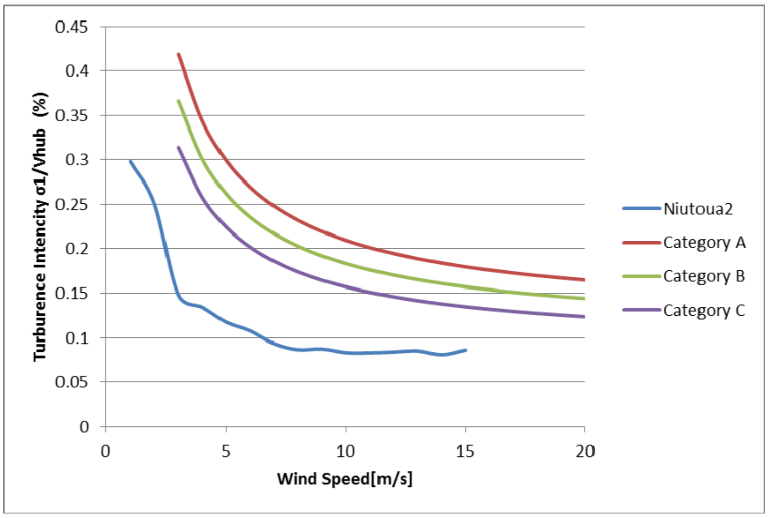
As shown in Figure 2-13, if the extreme wind speed at 10 meters above the ground is 70 m/s, the extreme wind speed at 40 meters above ground is 76.2 m/s and extreme wind speed at 45 meters above ground is 76.7 m/s.

Therefore, this project sets Ve_{50} (extreme wind speed of 50 year return period) to 70.0 m/s at 10 meters above the ground. In addition, extreme wind speeds at 40 meters and 45 meters above the ground are set to Ve_{50} = 76.2 m/s and Ve_{50} = 76.7 m/s. As a result, the extreme wind speed exceeds Class I, so this Project adopts Class S as extreme wind speed.

In Japan, the revision of JIS concerning the Class of wind turbine was conducted in January 2017. Class T was newly established considering the strong winds such as typhoons. 10 minute average wind speed of Class T is 57 m/s, and the extreme wind speed is Ve_{50} = 79.8 m/s. Compared with Class T, Ve_{50} = 76.2 m/s and 76.7 m/s are somewhat small, but it is reasonable because of the calculation based on Tongan building code and the class more than Class I.

(4) Turbulence Intensity

Turbulence Intensity is the standard deviation of wind speed and indicates the degree of wind turbulence. This intensity is used as a design condition for ensuring fatigue strength in normal wind conditions. The following diagram shows turbulence intensity by each wind turbine class and actual observation in Niutoua.



Source: The study team

Figure 2-14: Standard turbulence intensity of each class in Niutoua

The turbulence intensity in Niutoua obtained from wind condition data was not so large, and it was lower than Class C in the entire observed area, and the turbulence was confirmed to be small. Therefore, the turbulence intensity is not less than 0.12 (Class C).

2-2-1-4-3 Policy on Earthquakes

The design horizontal seismic coefficient should be considered by each building in Tonga. However, the design horizontal seismic coefficient of 0.2 G, which is generally applicable for Japan, will be applied in this Project, as Tonga resembles similar circumstances to Japan in earthquake-related situations. And also because this precedent was established in the case of ‘The Project for Introduction of a Micro-Grid System with Renewable Energy for the Tonga Energy Road Map’, which was conducted in advance of this Project.

2-2-1-4-4 Policy on Thunder

As a lightning countermeasure, the Project selects a receptor at the tip of the blade and wind turbine with a lightning rod on the nacelle. Also, by setting the grounding resistance to 10 Ω or less, it becomes easy to ground the lightning. Regarding lightning protection, it follows AS / NZS 1768 which is the same standard as lightning protection in Japan. However, there is no overhead line as a lightning countermeasure on the electricity distribution lines in Tonga. This is an approach taken in areas (including in such areas in Japan) where thunder and lightning is rare.

2-2-1-4-5 Policy on Allowable Bearing Capacity of Ground

In Niutoua, the project site of the wind power station, has roughly 30 cm of the surface of the ground soil, which consists of silty clay derived from weathered volcanic ash. The weathered limestones show up to a depth of 2.3 m, and there is limestone under the depth of 2.5 m, which are not weathered. These limestones are the bedrock of Niutoua. The subsurface exploration test of New Zealand determined that N value was 50 at a depth of 2.5 m (converted N value was more than 200 under 4.0 m). There are no cavities underground and this subsurface would not cause differential-settlement. Therefore, in this Project, bearing capacity of the ground (subsurface) at the Project site is considered sufficient to support the proposed wind turbines using a spread footing foundation.

2-2-1-5 Policy of Wind Turbines Selection

One of the problems for installing a wind turbine generator system in remote islands such as Tonga is procuring use of construction heavy equipment. The New Energy and Industrial Technology Development Organization (NEDO) of Japan encourages the use of less than 20 t-class cranes, and suggests carrying out the installation with a 16 t-class crane using a gin pole pulley system. However, wind turbines less than 300 kW are suitable for Tonga, as the heavy equipment that can be procured in Tonga is limited.

There are two types of wind turbine with class 300 kW, tiltable type and fixed type. Each type has their own advantages. The wind turbine of tiltable type can withstand the strong wind like cyclone by tilting, and be maintained by tilting, so maintenance is easy. On the other hand, since fixed type does not need to be tilted, therefore it is possible to restart power generation immediately after the strong wind has ceased.

It is possible to introduce both the tiltable type and fixed type to an island nation, such as Tonga. It is necessary to operate and maintain the wind turbine generator system according to the type.

2-2-1-6 Policy of Power System Stabilization

Diesel generators supply the main power in Tongatapu Island, and the load-frequency control is carried out by a governor of diesel generator in the power system. If renewable energy is installed, the diesel governor will be required to control the load from output of renewable energy in addition to the load from demand of power.

In the case of this Project, the load from renewable energy exceeds the ability of governor of the existing diesel generator because the output of new power station plus the output of the existing solar photovoltaic power stations (2.3MW) will burden the power system of the governor. Therefore when it comes to installing a wind power station, variation of the load should be considered and measures using energy storage equipment to stabilize the power system should be taken.

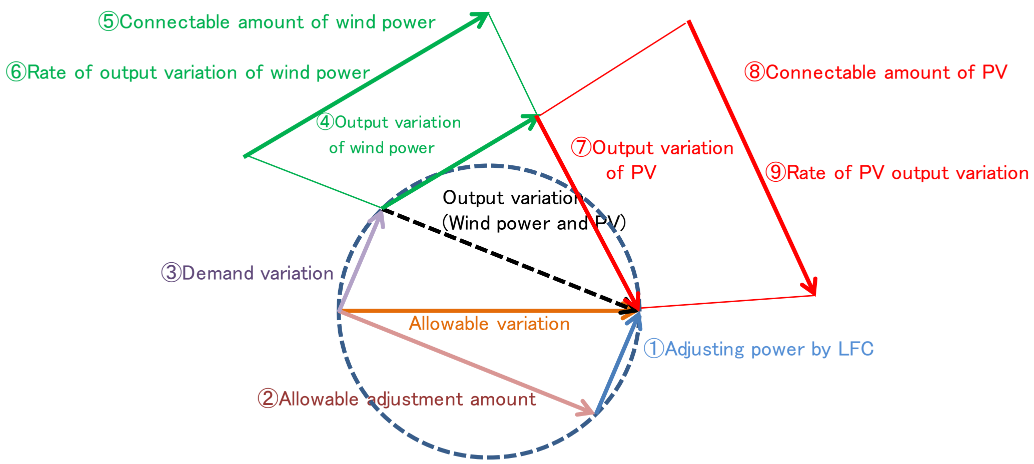
Installation of renewable energy with storage batteries is effective for both increasing domestic energy and becoming independent from fossil fuels. However, although there will be a reduction in cost of diesel fuel with the introduction of wind power system, storage batteries are expensive. Therefore, the renewal cost of storage batteries should be planned, so that Tonga can ensure its energy security.

Type and capacity of storage system is selected based on the existing power generation capacity by renewable energy, frequency variation, and load following capacity of the existing diesel power generators. The basic policy is as described below to compensate for variation of power generation for both short and mid cycles.

2-2-1-6-1 Compensation for short cycle fluctuation

(1) Review method

Compensation for short cycle fluctuation for power system stabilization is considered using algebraic approach, which is used in Japan for calculation of wind turbine capacity allowable for system connectivity based on input parameters.



Source: The study team

Figure 2-15: Concept of Algebraic Approach

System capacity (minimum power demand) and demand variation are obtained from observed data system through 15 minute sampling in TPL's SCADA. A system constant is generally between 8 and 10 %. Since electricity is supplied by diesel generators in an isolated island, a system constant of 10 % is applied. TPL complies with EN50160 as the electricity quality management criterion; therefore an allowable frequency fluctuation ratio is set at +/- 0.5Hz based on its management criterion by EN50160.

Power adjustement using load frequency control (LFC) is under consideration as necessary capacity of storage battery to adjust short term power fluctuation. In Tongatapu, there is a 1.3 MW solar photovoltaic power plant in Popua district and a 1.0 MW solar PV power plant in Vaini. Both are equipped with a 500 kW storage battery to adjust short term power variations and are connected to system. Therefore, the Project does not need to consider power fluctuation by the solar PV power plants when examining necessary storage capacity.

Short term wind power variation shall be calculated based on ever-changing wind condition data. Wind condition data from 2015 to 2016 is avaialable from the wind condition observatory (40 m above the ground) in Niutoua built by New Zealand. Power variation by wind speed is calculated based on 10 minute average wind speed, average wind direction and standard deviation and the power variation per second by wind speed is calculated using aeroelastic analysis called FAST. A wind turbine model used in FAST is developed based on publicly available data by wind turbine manufacturers such as power curve, control approach, blade shape and blade weight, etc. By using input data such as the wind turbine model and turbulence wind speed by wind, FAST calculates cumulative power variation by wind power generation.

In this way, algebraic approach can calculate output power capacity of storage battery.

(2) Selection of System Stabilization Equipment

Output fluctuations of wind turbine generators occur regularly. In the Project, it is necessary to minimize the voltage fluctuation around the connection point because the electricity power is supplied by connecting to the end of transmission / distribution line at the Niutoua.

In Japan, when connecting power generation facilities such as a wind turbine generator to the grid of electric power company, if fluctuation compensation of medium period is required according to the technical requirement relating to connection, wind turbine generator system with output fluctuation relaxation type equipped with an accumulator is installed. Considerable amount of accumulator cpacity is required when medium-period fluctuation compensation is targeted, so the lead accumulator, which is relatively inexpensive, is used. However, the purpose of the Project is to compensate for short period fluctuation. Therefore, it cannot be satisfied by a lead accumulator which has a low charge / discharge cycle.

In order to increase the charge / discharge cycle in short-period fluctuation compensation, it is also considered to set the charge / discharge depth to be shallow. However, in that case, a power accumulator facility is required to have a huge capacity. The accumulator with huge capacity is expensive, so the cost of the whole system will also be high. Moreover, detailed data showing charge and discharge cycles with respect to its capacity and charge / discharge depth are not disclosed. For these reasons, it is difficult to adopt a lead accumulator as a power storage device corresponding to short cycle fluctuation compensation because in the Project an accumulator system is needed which is able to set deeply the charge / discharge depth and capable of over 100,000 times of charge / discharge cycles.

The performance of lithium-ion batteries has improved in recent years. Although the charge / discharge cycle of the lithium-ion battery called output type used for a hybrid car has reached 100,000 times, the number of charge / discharge cycles of a large capacity type lithium-ion batteries used as a system stabilizing power accumulator device is only 10,000 times. In order to stabilize output fluctuation of unstable wind turbine generation, it is assumed that the charge / discharge depth becomes deep and the number of charge / discharge will increase. The charge / discharge cycle of a lithium-ion battery varies depending on the depth of charge and discharge, and there is a possibility to increase the number of life cycles by increasing the battery capacity. However, experimental data proving about life cycles has not so far been disclosed, so it is difficult to adopt a lithium-ion battery for the project because the lithium-ion battery still remains uncertain elements at the moment.

On the other hand, the number of charge / discharge cycles of the lithium-ion capacitor, which is a physical battery, is more than 100,000 cycles, and it can be expected from the viewpoint of expected lifetime as short-period compensation of wind turbine generation. Lithium-ion capacitor aiming at short-period fluctuation compensation is also used for fluctuation compensation of existing photovoltaics equipment which is already installed.

2-2-1-6-2 Compensation for mid cycle fluctuation

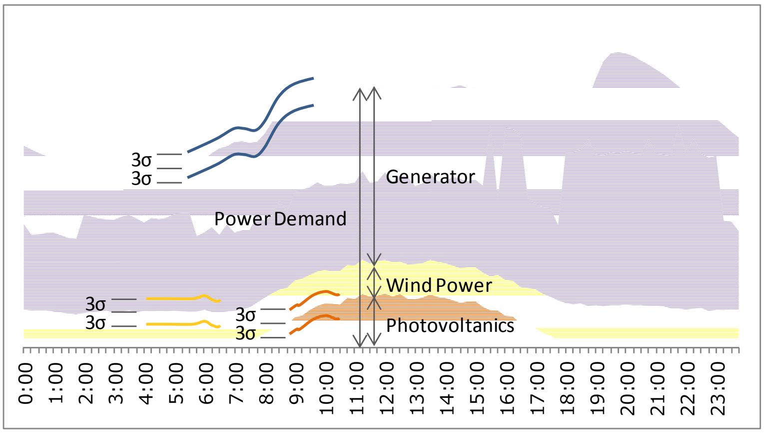
(1) Basic value setting

The compensation for mid cycle fluctuation is examined based on the past records of power demand and solar PV power output, and estimated wind power output based on wind conditions.

Using the 15 minute average data from June 2013 to June 2016, standard deviations σ of monthly averages and annual averages are calculated to set three cases, these averages, the averages + 2σas maximum power output and the average -2σ as minimum power output, as the base for power demand. Since power demands on weekdays and weekends are different, both power demands are calculated for every case. The 3σ of the monthly average power demand is used as load fluctuation.

To examine the available capacity of the current storage batteries, the 15 minute average PV power output data from June 2013 to June 2016 is calculated. At the same time, the standard deviation of the variation of the same data is calculated to set the 3σ as the variation of solar PV power output.

Wind power output is calculated based on wind condition data observed in Niutoua from April 1, 2015 to March 31, 2016. Since wind condition does not change much throughout the year, the maximum 15 minute power output per month is set as the monthly power output for modelling. In the same way, the standard deviation of the monthly variation of 15 minute power output is calculated and the maximum 3σ among them is set as the variation of wind power output.



Source: The study team

Figure 2-16: Generation balance

Table 2-3: Definition of Values

Item	Setting value	Each month, 15minute interval from AM0:00 to PM11:59						Remarks
		Weekday			Holiday			
Power demand	Electric power	Average+2σ	Average	Average-2σ	Average+2σ	Average	Average-2σ	TPL's data
	Load variation	3σ for the variation of power demand in every 15minutes			3σ for the variation of power demand in every 15minutes			
Photovoltaics	Power output	Average of power output in every 15 minutes						TPL's data
	Output variation	3σ for the variation of power output in every 15minutes						
Wind power	Power output	Average of power output in every 15 minutes						Calculated power output by wind condition data
	Output variation	3σ for the variation of power output in every 15minutes						
Diesel power	Power output	Power demand － power output (photovoltaics＋wind power)						---

Source: The study team

The necessary capacity of the diesel power generators is examinied to supply the demand not satisfied by the solar PV and wind power generation based on each of the values calculated above.

(2) Output power and control of the operation number of diesel generator

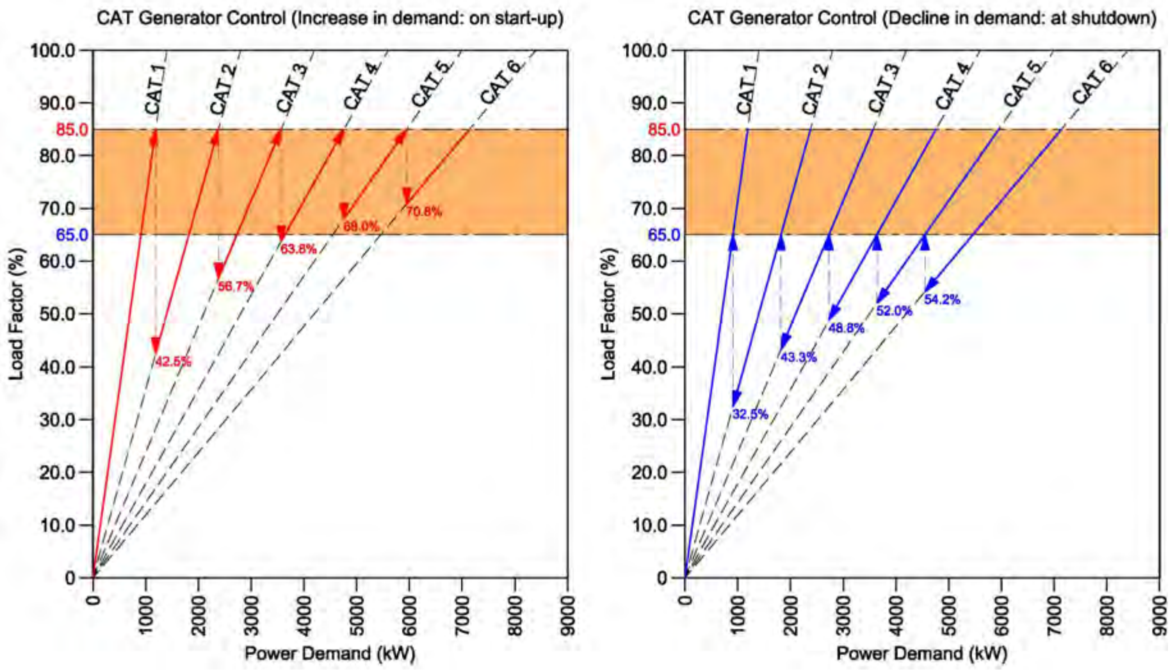
① Number of generators in normal operation

To control operation of CAT diesel power generators, another CAT generator starts operation when the load of operating generators exceeds 85% and a CAT generator stops operation when the load of operating generators decrease under 65%. The total loads when signals are sent to stop or start a generator is as shown below.

Table 2-4: Total Load to Increase or Decrease the Number of Generators

Number of active generators	When redundant generators are stopped		When standby generators are started	
	Load factor	Total output power of diesel generators	Load factor	Total output power of diesel generators
1	0.0%	kW	85.0%	1,190 kW
2	32.5%	910 kW	85.0%	2,380 kW
3	43.3%	1,820 kW	85.0%	3,570 kW
4	48.8%	2,730 kW	85.0%	4,760 kW
5	52.0%	3,640 kW	85.0%	5,950 kW
6	54.2%	4,550 kW	85.0%	---

Source: The study team



Source: The study team

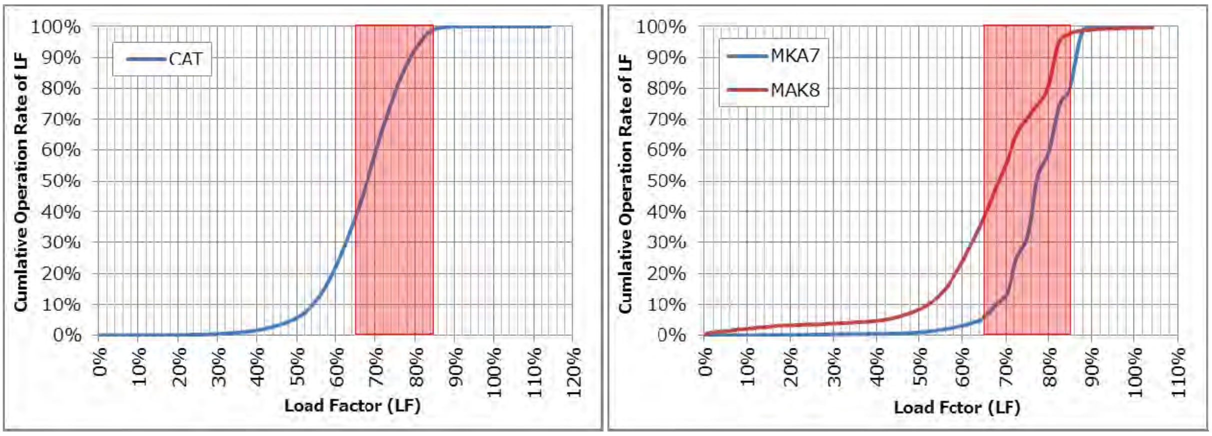
Figure 2-17: CAT generator control by the operation number

In order to examine a necessary reaction to the variation of mid term power output, monthly 15 minute output by diesel power generators is calculated using the maximum (average +2σ), average, and minium (average -2σ). The basic diesel power operation model is developed by necessary numbers and output of MAK and CAT generators for economically optimal operation.

② Reaction to load variation (demand variation), variations of solar PV and wind power output

All six CAT generators react to change in load. To keep the optimal efficiency (load between 65 % and 85 %) of MAK generators, staff in the central control room manually calculate a load factor of MAK generators every 15 minutes and control the number of CAT in operation according to the change in power demand by maintaining the optimal load of MAK. CAT can react to a change in load of 5 % of its rating capacity per second (70 kW/second), whereas MAK takes 500 kW/15 minutes. As a result, the existing CAT and MAK can react to the change in load within an optimal range.

The cumulative operation rates of CAT and MAK generators are illustrated, respectively. CAT is mostly operated within the optimal range of the load factor between 65 % and 85 %, whereas MAK7 and MAK8 are operated over 85 % in 15 % and 5 %, respectively. Since MAK7 is used on a priority basis as a base load battery, this implies that load factor of MAK7 exceeds 85 % more frequently. Therefore, CAT is considered to more effectively control the load factor.



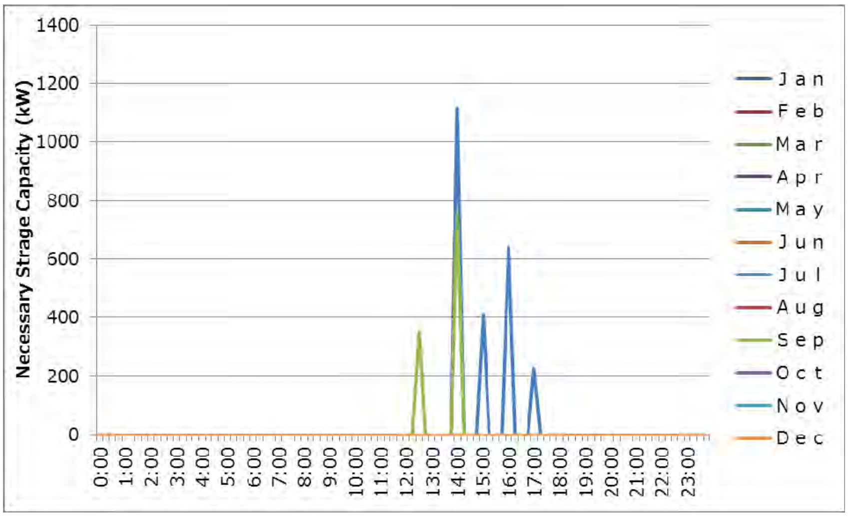
Source: The study team

Figure 2-18: Cumulative operation rate of load factor (Left: CAT, Right: MAK)

Operation control by CAT and MAK generators are considered in 15 minute intervals. The needs of storage battery in mid term cycle is examined as a condition of reacting by changing the number of CAT generators in operation in case the load factor exceeds the optimal range. Although an installed signal automatically notifies the necessity of reaction, switching operation is manually done by TPL staff. Therefore, considering the capacity of TPL staff, if a variation is too large to control by adjusting the operation of a generator(s), the Project shall consider additional storage battery to control a mid term output variation.

③ Needs of additional storage battery to control mid term output variation

Based on the aforementioned conditions, the needs of additional storage battery will be evaluated when considering variation of solar PV power output and 3σ wind power generation.



Source: The study team

Figure 2-19: Necessary storage capacity to store surplus power over the minimum power demand on holidays

The largest capacity of storage battery is required when power demand is low and few diesel power generators are in operation. In Tonga, the power demand is the lowest on holidays between June and October. This is when storage battery use is high, as illustrated in

Source: The study team

Figure 2-19. On weekdays, variation of load and power output by solar PV and wind turbine can be controlled by changing the number of CAT generators and storage battery is not used.

Therefore, installation of storage battery is not considered to react to mid term power variation. Although storage battery is used on holidays when power demand is low, it is rare, only 0.07 %, and control by the number of operating wind turbines can accommodate these needs.

Unlike solar PV power generation, output power by wind power generation often changes drastically by 100 % due to a drastic change in wind speed. Even such drastic changes can be controlled by controlling the number of operating wind turbines.

2-2-1-7 Policy on Connection to the Existing Grid

Output wind power shall be connected to an existing 11kV transmission line, which is planned to be expanded to a ring. Since New Zealand plans to install a wind power-generation facility, it is included in our transmission line plan.

The existing 11kV transmission line in Niutoua is an aluminum conductor called APHIS in Conductor Code with a cross-section area of 26mm2. The allowable current carrying capacity of the transmission line is 199A in standard state, 195A in ambient state, and 124A when it is hot.

The expected current when a 275kW or 300kW wind turbine is connected, is calculated using the following formula.

$$I=P/(\sqrt{3}V\cos\theta)$$

Whereas, I: Current (A), P: Ourput power (W), V: Voltage (V), cos θ : Power factor

Table 2-5: Maximum current by wind power generators

Rated Power (kW)	275	300
Number of Wind Turbine	5	5
Grid Voltage (kV)	11	11
Power Factor	1	1
Maximum Current (A)	72.3	78.8

Source: The study team

With regard to the assumed wind turbines, the generator specification of the 275 kW wind turbine is a two-stage induction generator and soft starter, and the generator specification of the 300 kW wind turbine is an induction generator and an inverter. Neither the soft starter nor the inverter generates enough current to greatly affect the system.

In conclusion, the current value of both the 275 kW and 300 kW wind turbines are below 124 A, which is the allowable current at high temperature of the APHIS conductor, and it was confirmed that it is possible to connect to the grid without strengthening the transmission line. In addition, the maximum current value of seven 300kW wind turbines is 110 A. Even in this case it is not necessary to strengthen the transmission line (as this value, 110 A, is below the minimum (when hot) allowable current of 124 A).

However, if further introduction of wind turbines is promoted, the connectable capacity of the Niutoua area will be insufficient and it will be necessary to strengthen the transmission line up to that of the Lapaha area. The 11 kV transmission line of Lapaha area is aluminum conductor, called FLY, and its sectional area is 64 mm2. The allowable current of this conductor is 333 A, under 20 degree Celsius of wind temperature. The allowable current in natural heat dissipation condition is 326 A, and the allowable current at high temperature is 215 A.

Assuming the transmission line from Niutoua area to Lapaha area is strengthened to the allowable current carrying capacity of the Lapaha transmission line, the maximum connectable capacity of the wind turbines in Niutoua and/or Lapaha is 4,091 kW (11 kV×215 A×1.73 = 4,091 kW).

On the other hand, the sectional area necessary for electric cables to the allowable current during short circuit, as determined by the Japanese Cable Makers' Association Standard (JCS 0168), is 53.8 mm2 (short circuit current: I = 12,500 A, short circuit current duration: t = 0.15 sec, $I\sqrt{t} / 90 = 12{,}500\sqrt{0.15} / 90 = 53.8$ mm2).

The 11 kV transmission line at the end of Niutoua is APHIS and sectional area is 26 mm2. This is smaller than the abovementioned minimum sectional area to cope with short circuits of 53.8 mm2, therefore it will not be able to withstand the instantaneous current generated at the time of short circuit. Therefore, in order to limit the short-circuit current, it is necessary to install an LBS having a power fuse at the connection point between the 11 kV transmission line and the cable newly installed in this Project.

In case of LBS having a fuse corresponding to 12 kV, the operation time of the fuse at the short circuit current 10,000 A or more is less than 0.01 sec. In this case, the sectional area of the electric cable is $I\sqrt{t} / 90 = 12{,}500\sqrt{0.01} / 90 = 13.9$ mm2, which is smaller than the sectional area of the existing transmission line. Therefore, by installing LBS using a power fuse, it is possible to prevent the negative impact of a short circuit on the existing transmission line.

As well, the power transmission line planned to be newly installed in the Project is designed as the aluminum conductor, FLY. This has an allowable current carrying capacity equal to or larger than the APHIS.

Moreover, since the voltage fluctuation by the wind turbine generator system can be dealt with by fully utilizing the compensating function of reactive power by the grid stabilization system, it is unnecessary to consider reducing the system impedance such as by thickening the transmission line.

Furthermore, regarding protection coordination, it is only necessary to set the constant number for controlling wind turbine generator system and grid stabilization system to less than the set value specified by TPL and less than the set value of the existing power generation systems. Moreover, it is not necessary to change the setting at the existing power plants.

Therefore, in this Project, regarding the connection to the existing grid, it is planned that the power transmission line is connected to the end of transmission line in Niutoua. In particular, enhancement of existing transmission and distribution lines shall not be carried out.

Source: TPL

Figure 2-20: Transmission Lines after Expected Enhancement by TPL

2-2-1-8 Policy of Social Economic Conditions

Most people of Tonga are Christian and there are no social customs which affect the construction schedule except Christmas holidays.

A residents meetings were held regarding the general concept of this Project, during the survey of the Environmental Impact Assessment (EIA) by the TPL and by the New Zealand Aid Programme. The meetings were attended by the residents in Niutoua and farmers in the project site. However, it is necessary to hold another residents meeting in order to deeply raise the residents understanding of this Project when installing solar PV modules, storage batteries and distribution lines.

A fence shall be set around the construction site so that outsiders cannot enter the site when it is under construction, even though the project site is a farm and there are few buildings, residents and livestock.

2-2-1-9 Policy of Construction Conditions

2-2-1-9-1 Permits and Licenses

(1) Land-ownership and Concession

The Land Act Revised Edition 1988, which was originally enacted in 1903, states that all lands of Tonga are owned by the King of Tonga; however, a previous king subdivided a part of the lands to residents in Tonga, and the lands are administered by a village chief or by the Department of Lands and Survey under Ministry of Lands Survey and Natural Resources (MLSNRE).

On the other hand, lands of aristocrats which were given to them with hereditary rights by the king are called ‘Tofia’. When citizens lease these lands they sign a lease agreement with the aristocrats. These agreements are deliberated by the Cabinet of Tonga and approved by MLSNRE and registered by Department of Lands and Survey.

This Project uses the blocks of land which are owned by leaseholders. Through the discussion with TPL and leaseholders, the terms of compensation and the lease will be determined, and this will conclude lease agreements. The terms of the lease are limited up to 99 years. TPL will apply for the agreements with MLSNRE.

Afterwards, TPL will obtain the right of using land. TPL does not need to pay any compensation relating to overhead line and underground cable which are set within 1.5 m of both sides of the public road because the use of road is regarded as public use.

(2) Building permission

In constructing buildings – except simple huts made of timber – a building permit request should be submitted to the Ministry of Infrastructure. In this Project, a building permit is required because the construction includes 40 m high turbines and a total floor area of about 200 m2 of storage battery facilities.

The Ministry of Infrastructure officially says that twenty one business days at most are required from submission of the application to get the building permit. However, normally about 10 business days are needed to acquire the permits. During this term, the applications are verified through the Ministry of Infrastructure, Ministry of Health, Ministry of Police (Fire Service), and the Environment Department and Ministry of Land & Survey.

(3) Import Clearance and Tax Exemption

This Grant Aid Project will be carried out in accordance with Exchange of Notes and tax exemption will be applied. Contractors of this Project have to submit an application with the necessary documentation such as a copy of Bill of Lading and the list of materials to the Aid Management Division under Ministry of Finance and National Planning through a Procurement Officer of TPL for acquiring tax exemption, when the contractor’s materials arrive at Nuku’alofa Port.

At the same time, the copy of the documentation should be submitted to the Ministry of Revenue and the contractors have to acquire an agreement from both the Ministry of Revenue and the Ministry of Finance and National Planning before the documentation is signed. After the signed documentation with the list of materials is submitted to customs, the contractors can get a refund on import taxes paid.

(4) Application for Power Supply Facilities

Normally, when a dispersed power system over 10 kW, such as diesel, wind power, and solar power, will be connected to the existing power system, applications for permits are required and should be submitted to the TPL, meeting the standard of AS/NZS 3000 (Electrical Installations). Moreover, in constructing power facilities, the application of permits in advance to the Electricity Commission (EC), which is a regulator of the system basis, are required.

In addition, EC will give a license to electrical power contractors and deliberate the standards for electrical construction.

2-2-1-9-2 Procurement Conditions of Engineers and Workers

It is possible to recruit engineers or technicians, such as carpenters, plasterers, laborers and skilled workers, for the construction work in Tonga. However, the number of experienced experts is limited and multiple contractors need such experts. Thus, it is difficult to secure workers for this Project when the construction market is booming; otherwise the cost of employment may soar. Day laborers can be procured in Niutoua and Nuku'alofa City through a pick-up service.

2-2-1-9-3 Working Conditions

Daily working time is normally eight hours in Tonga. In addition, Saturdays and Sundays are also public holidays, and Sunday is especially regulated as a non-working holiday. Therefore, this Project plans in principal that two days a week will be days-off.

2-2-1-10 Policy of Local Contractors and Materials

2-2-1-10-1 Local Contractors

In principal, the Project actively let the local contractors provide heavy equipment and laborers in the construction of the facility in this Project. However, Japanese experts shall be dispatched, for the quality management, construction schedule control, safety management, and equipment test and adjustment.

2-2-1-10-2 Local Materials

It is possible to procure construction materials, such as stones, aggregates for concrete, cement and reinforced bars, in Tonga. However, the material cost is expensive due to most of the materials are imports, except stones and aggregates. Limestones are a kind of aggregate, and are used for concrete. Each concrete manufacturer uses their own quarry; therefore, verification of concrete strength before construction is necessary.

Regarding cements, Portland cements made in Fiji and New Zealand are distributed and their quality is guaranteed. In Tonga, contractors generally use ready-mixed-concrete. The concrete manufacturers collects 6 test pieces every 5 m2 and confirm the concrete strength after 7 days and then after 28 days in compliance with the Concrete Structures Standard of New Zealand. The manufacturers pay attention to ensure the quality of concrete, for example using cements that are wrapped and stored. Therefore, there is no issue using these manufacturers.

Additionally, some materials, such as steel beams, roofs or walls, distribution pipes and electric cables, are imported from New Zealand but this is insufficient. Therefore, the construction materials for storage batteries facility shall be procured from Japan considering the endurance, airtightness and construction accuracy.

2-2-1-10-3 Procurement from Third Countries

When it comes to procurement from a third country, careful consideration should be given to costs, quality, delivery date, after-sales service and whether it is easy for spare parts to be procured and if they are consistent with the existing facilities.

All of the existing materials for facilities and electricity are imports, most of which came from Australia and New Zealand.

Therefore, a thorough examination will be given for the materials in this Project that can be procured from third countries. However, some instrumentation materials for wind power and storage batteries should be purchased from Japan because the level of after-sales service and the existing level of operation and maintenance skills. In addition, Tonga also wishes to use Japanese products.

2-2-1-10-4 Policy of Dispatch of Engineers

In Tonga, construction laborers, cars for transport, and heavy equipment are relatively easy to be locally procured because there are some contractors and electrical construction companies with foreign capital. In this Project, a steel beam structure will be applied. Therefore, experts from Japan or overseas should be dispatched to carry out quality management, skill instruction and site supervision, as there are few experienced technicians in the local area.

2-2-1-11 Policy of Operation and Maintenance

After the start of service for this Project, the TPL will carry out maintenance of the wind power station as well as the existing facility. The TPL has general operation and maintenance skills of renewable energy and its system because the TPL has carried out operation and maintenance for a solar power system (output 2.3 MW) and a compact type of wind power station (output 11 kW).

However, the micro-grid system, which consists of wind power and solar power, is a pioneering technology in Japan, and is currently undergoing demonstration testing. Therefore, the Japanese contractor of this Project has to transfer the operation skills to the TPL through on the job training (OJT) and the consultant should also transfer the skills through the soft component. Likewise, the TPL maintenance contract should be concluded with establishment of a mid-long term maintenance system.

Moreover, the staff in charge of operation and maintenance of TPL may not have the adequate theoretical knowledge about prevention security and daily-checks as well as operation skills of wind power stations. Therefore, short-term-intensive-lectures will be held by Japanese engineers as part of OJT for the staff during construction. A lecturer will teach basic theory of machinery and the electric system of the wind power station. In addition, prevention security after starting operation shall be proposed with the lecturer taking into consideration effective and efficient operations of the equipment.

2-2-1-12 Policy of Skill level and Range of Facility and Materials

Considering the conditions outlined above, the basic policy for the range of procurement and the skill level will be as follows.

2-2-1-12-1 Policy of Range of Facility and Materials

Basically the wind power station and storage batteries (Lithium-ion capacitor (LIC)) and micro-grid controller should retain the same electric voltage and variation of frequency as 2016, and be composed of effective and economical operations and maintenance facilities. In particular, the power system stabilizer for security of storage batteries shall have necessary and sufficient ability to treat the variation of output. Moreover, the LIC has to be able to handle short frequency of electricity and ensure the adequate operational performance of existing micro-grid system.

2-2-1-12-2 Policy of Skill Level

The TPL has already installed micro-grid system including solar power station and storage batteries and tiltable turbines of 11 kW, which is operational without any problems. Therefore, the wind power station and the power system stabilizer of this Project can be well operated through the OJT and the soft component for improving skill. Considering this situation, the skill level for handling the wind power station should not be beyond the TPL's skill level.

2-2-1-12-3 Policy of Facility Design

The turbines, the foundation and the storage batteries facility should be chosen by long term weather resistance and durability qualities. The Tonga market is small and the materials come from various countries, and there is no guarantee of the quality of the materials. Therefore, most materials for structures in this Project – excluding concrete – shall, in general, be procured from Japan.

The Japanese Standards and International Standards such as JIS, BS, ACI and ASTM shall be applied as much as possible to provide a technically and economically appropriate design. Moreover, the kind of procurement material should be minimized to construct an easy structure.

2-2-1-13 Policy of Construction and Procurement Measures and Time schedule

This Project is based on the scheme of Japanese Grant Aid. After concluding the Grant Agreement, the procurement and the construction shall be completed during the necessary term. In order to achieve expectations and complete the Project within the timeline, cooperation between division of work between Japan and Tonga should be carried out and it is necessary to consider transport route, transport measures and various procedures to formulate a process plan.

There is no special construction work, except the construction of wind turbines. In addition, a Tongan construction company has already experienced building a storage batteries facility in the previous project of Japan, ’The Project for Introduction of a Micro-Grid System with Renewable Energy for the Tonga Energy Road Map’, in which the construction company received instructions from Japanese engineers.

The main transport measure for materials is marine transport from Japan or third countries to Tonga, and the route from Nuku’alofa Port to the project site is about 35 km by land route. The road from the port to Niutoua consists of two lanes which are relatively well maintained and in good condition. In addition, there are no weight limits. However, there is traffic congestion in the mornings and evenings so the time for transporting should be discussed with the police to prevent accidents from occurring through large vehicles running on the road, etc.

The road from Niutoua Village to the project site, some parts of the road are narrow or not well maintained, and TPL needs to construct an access road in accordance with the plan of future subdivision around the project site.

2-2-1-14 Policy of Maintenance

Optimal capacity of wind power station based on the future power demand, and the plan for expansion of the power station are considered. As the capacity of output from the wind power increases, the capacity of the storage batteries is required to be larger. This increases the possibility that the total power generation cost including the future maintenance cost and renewal cost will increase. Therefore, it is necessary to consider the optimal size of the wind power station based on an economical point of view.

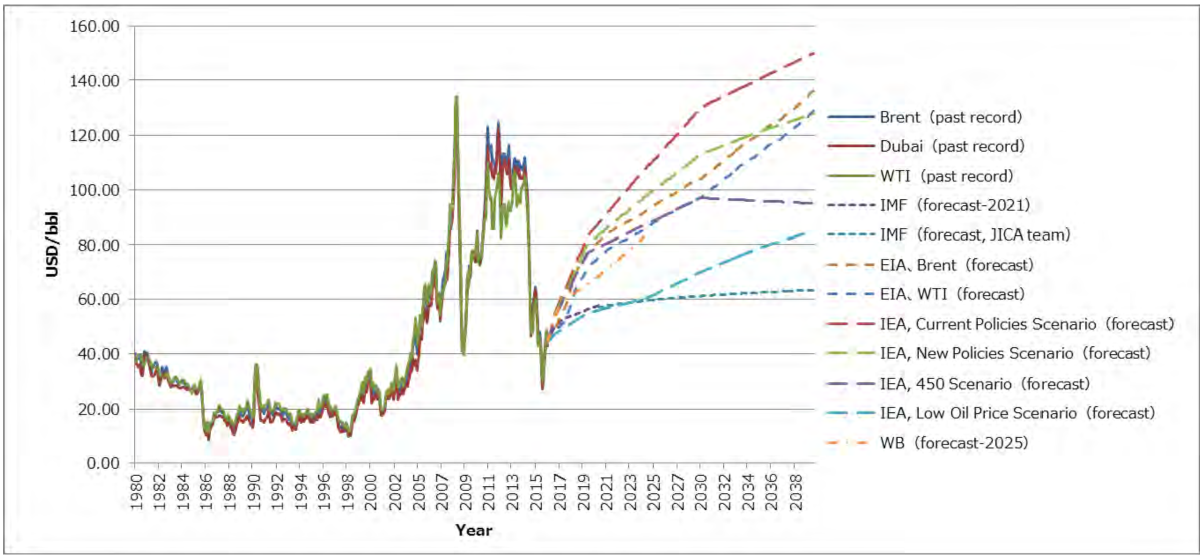
In view of the recent drop in fuel price, the future power generation cost is predicted by the change of fuel price, and the validity of introducing wind power station is verified. It is not assumed by any institution that the fuel price will decline at present, and in the future forecast, various patterns are set for cases where the fuel price stays at the present level or rises. Moreover, the plan of Tonga, which 50 % of the power supply will change to renewable energy by 2020, will be also verified.

2-2-1-14-1 Estimation of Diesel Oil Prices

Among operating expenses, it is necessary to estimate the future price of diesel used for generator operations. Based on the fact that the diesel price is linked to the crude oil price, the diesel price will be estimated from past records of crude oil price and future estimates calculated by individual agency.

(1) Future estimate of Crude Oil Price

The following graph shows the past crude oil prices of Brent, Dubai and WTI and prospects of long-term crude oil price by International Monetary Fund (IMF), Energy Information Administration (EIA: USA), International Energy Agency (IEA), and World Bank (WB). The IMF estimates go up to 2021, so the estimates after that up to 2040 are from the Project Team.



Source: The study team

Figure 2-21: Transition and expected oil price

The IMF expects an oil price rise of about 56 % between 2016 and 2017. After that, the forecasts are about 7% in 2018, 3% in 2020 and 2% in 2021. A convergence tendency is predicted after that. As a result, the Project Team estimated the crude oil price will rise up to about 63 US$ in 2040.

EIA estimates US GDP will grow by 2.4% annually on average, and the brent price will be about 136 US$ and the WTI price will be 129 US$ in 2040. IEA assumed the following four scenarios:

1) ‘Business-as-usual scenario’ which is a continuation of current conditions;

2) 'New policies scenario' which is the current standard case;

3) '450 scenario' which should be actively introduced to various countries that aims to stabilize greenhouse gas concentration at 450 ppm; and

4) 'Low oil price scenario' which assumes that the situation when crude oil prices continued to stagnate over the fifteen years that followed the decline in crude oil prices in the 1980s will occur again.

All of these scenarios estimate the crude oil cost will rise up in comparison with current cost, but in the case of 'low oil price scenario' the crude oil will slightly drop after 2030.

As for WB, although it is forecast until 2025, it is said that crude oil price will rise more than the present situation. The prospects of long-term crude oil prices vary by individual institution, but in all scenarios the price is expected to rise as the demand for oil increases.

(2) Future estimate of diesel price

In estimating the future price of diesel oil, in this Project the diesel price is forecasted to follow the crude oil price movements. The following four cases were considered for estimates:

1) Crude oil prices continue as of July 2016.

2) Crude oil prices gradually rise in accordance with the IMF estimates.

3) Constant economic growth in accordance with the EIA (Brent) estimates.

4) Energy saving scenario, such as IEA will be achieved by aiming to reduce global warming.

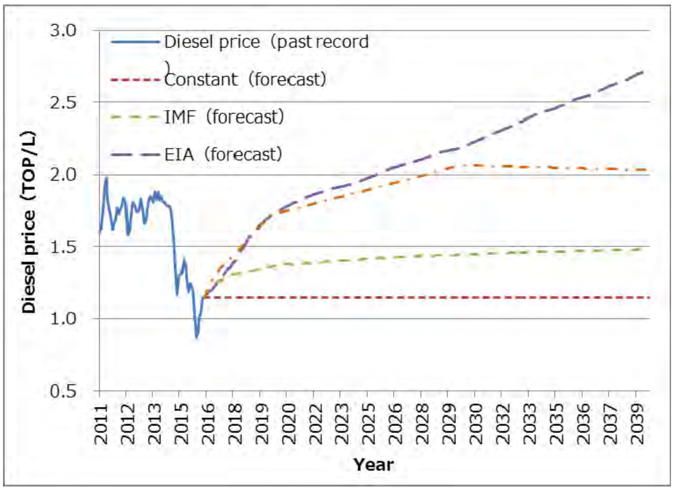
With regard to drop of diesel prices, there are no institutions that are forecasting that the crude oil will decline; therefore, this case is excluded from the subjects of consideration. The results of estimation are shown below.

Table 2-6: Estimated diesel price

Unit : TOP/L

	2016	2017	2018	2019	2020	2025	2030	2035	2040
Constant	1.1496	1.1496	1.1496	1.1496	1.1496	1.1496	1.1496	1.1496	1.1496
IMF	1.1496	1.2405	1.3028	1.3261	1.3580	1.4117	1.4427	1.4644	1.4813
EIA	1.1496	1.2163	1.3706	1.5970	1.7085	1.9681	2.1824	2.4528	2.7391
IEA	1.1496	1.2912	1.4328	1.5744	1.7160	1.8888	2.0616	2.0443	2.0270

Source: The study team



Source: The study team

Figure 2-22: Estimated diesel price

2-2-1-14-2 Evaluation of Appropriateness of Installation and Maintenance of wind power station

The assumed reduction cost of diesel was calculated, based on the transition of the diesel price set in the previous section, and the verification of the cost-effectiveness and appropriateness for installing wind power station is carried out in the later chapter.

2-2-2 Basic Plan (Construction Plan)

2-2-2-1 Precondition of the Project

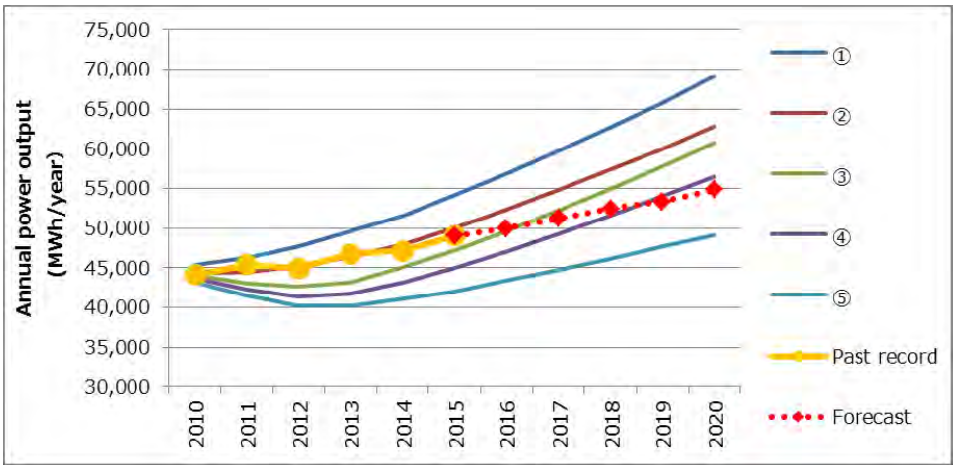
2-2-2-1-1 Annual Power Output and Power Demand

(1) Annual Power Output

With regard to the power demand forecast, which is fundamental to the power development plan, prediction of annual power generation amount (MWh) and peak electric power demand (MW) for 11 years from 2010 to 2020 was implemented by the World Bank. The estimation is classified into the following five cases by the extent of efficiency of power supply and measures to save electric power of consumers (DSM)）.

① There is no improvement of efficiency of power supply nor measures against DSM, medium growth.
② There is improvement of efficiency of power supply but no measures against DSM, medium growth.
③ There is improvement of efficiency of power supply and measures against DSM, high growth.
④ There is improvement of efficiency of power supply and measures against DSM, medium growth.
⑤ There is improvement of efficiency of power supply and measures against DSM, slow growth.

In addition to the estimation of World Bank, the actual value of annual power generation amount from 2010 to 2015 was used as the basis for the estimated value until 2020. This is presented in the following figure below.



Source: The study team (based on World Bank)

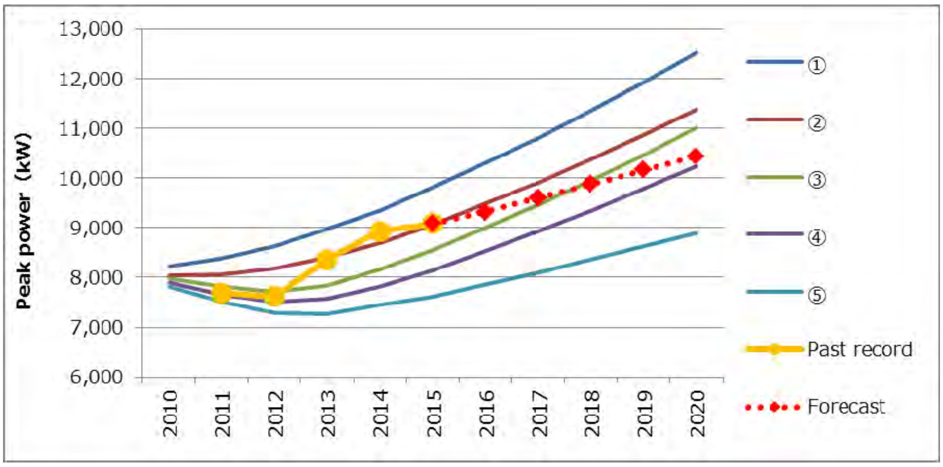
Figure 2-23: Actual and estimated annual power output

So far, Tonga has carried out renovation of transmission for the sake of high efficiency of transmission lines through New Zealand and the project of reducing the consumption of power generation by Asian

Development Bank, investing in the efficiency of power supply and DSM. There is a discrepancy between the actual and estimated value of World Bank. However, the estimated value from 2016 onward by the investigating team is similar to the rate of change of case 5 ‘There is improvement of efficiency of power supply and measures against DSM, slow growth.’ Therefore, the estimated value is an appropriate value. In this context, the estimated value by the investigation team is regarded as the planned value of annual power generation in the Project.

(2) Power Demand (peak power)

The five cases of maximum electric power estimated by the World Bank, the past record of electric power and the estimated value by the investigation team of the Project are presented. Like electrical energy demand, the rate of change is similar to the World Bank estimated value, case 5 “There is improvement of efficiency of power supply and measures against DSM, slow growth.” Therefore, the estimated value by the investigation team is regarded as the planned value of maximum power in the Project.



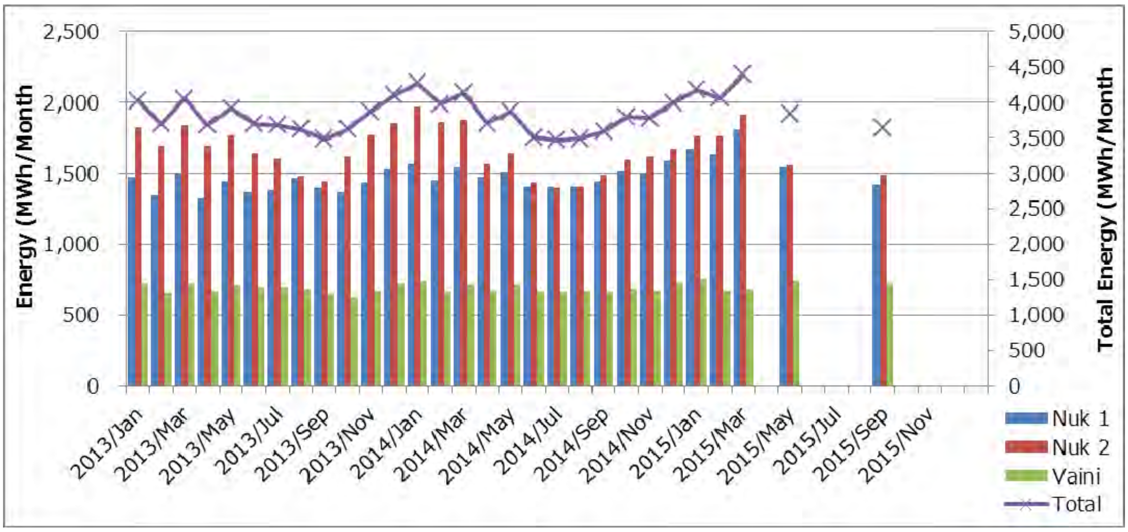
Source: The study team (based on World Bank)

Figure 2-24: Actual and estimated peak power output

2-2-2-1-2 Power Supply by Power System

Power demand increases in summer when daytime temperature is high and decreases in winter when the temperature is low. Source: The study team

Figure 2-25 shows the monthly power supply of three power systems on Tongatapu by SCADA installed in 2013. Because of a mechanical trouble on SCADA in 2015, some data are missing, but it still shows a seasonal trend.



Source: The study team

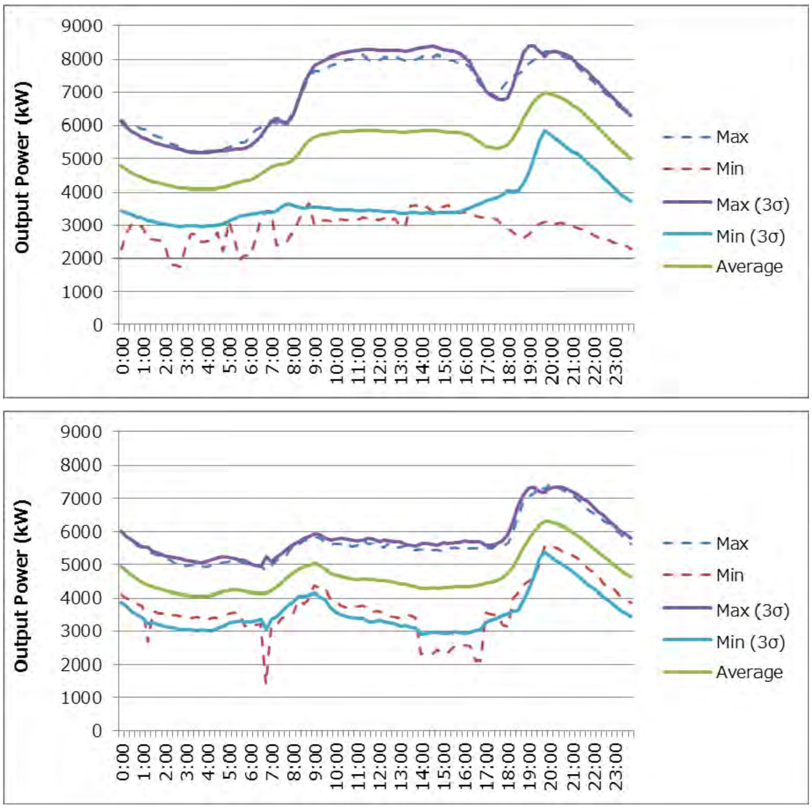
Figure 2-25: Monthly amount of power supply by power system

There are three system networks, Nuk 1 on the west side of Tongatapu, Nuk 2 in the center of Tongatapu, Nuku’aloha, and Vaini on the south and east area around Vaini. Since Nuku’aloha has a large population and public and commercial facilities, power demand and supply on Nuk 2 is large and fluctuates seasonally. Power supply on Nuk 1 was below 1,500MWh/month until September 2014. However, it increased since then as much as that of Nuk 2, which implies that a large power demand occured there. Since small villages are scattered in Vaini, power supply on Vaini is relatively small without a large seasonal fluctuation.

2-2-2-1-3 Daily Load Curve

Tonga is a religious country and prohibits commercial activities on Sundays; therefore power supply is high on weekdays and low on weekends. Seasonally daytime power demand is high during the hot summer and low in the cool winter.

In addition to the existing 1.3 MW and 1.0 MW PV power generating facilities, the Project plans a 1.3 MW wind power generating facility. Renewable energy can contribute to power supply in daytime and its variation of power output affects the entire power system.



Source: The study team

Figure 2-26: Daytime load curve (top: weekdays, bottom: holidays)

Figure 2-26 shows daytime load curves on weekdays and holidays obtained from SCADA data and maximum and minimum power supply by adding three times the standard deviation 3σ on the average between January 2013 and June 2016. The dotted line shows the actual maximum and minimum power supply of each time during the same period. Although the maximum power supplies coincide with the 3σ curve, the minimum is sometimes lower than the 3σ curve because the power supply on March 2, 2016 was extremely low and the power supply temporally decreases when a diesel generator is switched off to control the total power supply. Considering those reasons, we found a trend of change in minimum power supply during the day in the 3σ curve both on weekdays and holidays.

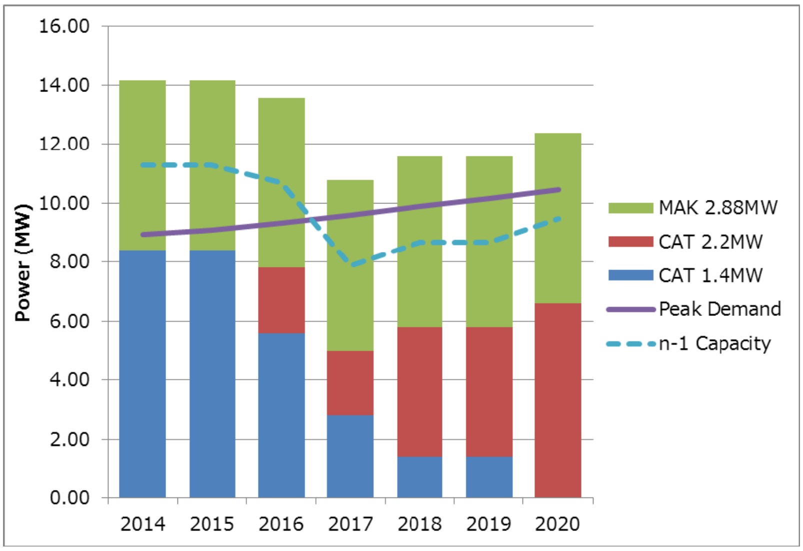
2-2-2-1-4 Power Supply Development Plan

According to the TPL Business Plan 2017-2020, high speed diesel generators (Caterpillar 3516B) with a single unit output of 1,400 kW will be abolished from 2016 onward. Other high speed diesel generator (Caterpillar C175-16) with a single unit capacity of 2,200 kW will be substituted and installed in 2016, 2018 and 2020. The balance of demand and supply of power until 2020, including the power supply development plan, abolishment plan and electric power demand are presented in Table 2-7 and Figure 2-27. 'n-1 capacity' shown in the following figure and the chart means the deducted value of total capacity of one of the single largest generators from the total capacity of generators. In other words, 'n-1' shows the supply amount when one of the largest capacity generators stops operation due to an accident or maintenance.

Table 2-7: Power demand and supply balance of Tongatapu electricity network

Diesel Generator		Installed Year	Installed Capacity (kW)	Year						
				2014	2015	2016	2017	2018	2019	2020
1. Peak Demand (MW)				8.93	9.09	9.32	9.60	9.88	10.16	10.44
1-1. Growth Rate					1.79%	2.54%	3.02%	2.93%	2.85%	2.77%
2. Power Generation Capacity				15.46	16.46	15.86	15.06	15.86	17.23	18.03
2-1. Diesel Generator				14.16	14.16	13.56	10.76	11.56	11.56	12.36
CAT 1	Caterpillar (3516B)-1	1998	1.40	1.40	1.40	Retire				
CAT 2	Caterpillar (3516B)-2	1998	1.40	1.40	1.40	Retire				
CAT 3	Caterpillar (3516B)-3	1998	1.40	1.40	1.40	1.40	Retire			
CAT 4	Caterpillar (3516B)-4	1998	1.40	1.40	1.40	1.40	Retire			
CAT 5	Caterpillar (3516B)-5	1998	1.40	1.40	1.40	1.40	1.40	Retire		
CAT 6	Caterpillar (3516B)-6	1999	1.40	1.40	1.40	1.40	1.40	1.40	1.40	Retire
MAK 7	MaK (6CM32C)-1	2005	2.88	2.88	2.88	2.88	2.88	2.88	2.88	2.88
MAK 8	MaK (6CM32C)-2	2014	2.88	2.88	2.88	2.88	2.88	2.88	2.88	2.88
---	Caterpillar (C175)-1	2016(Plan)	2.20			2.20	2.20	2.20	2.20	2.20
---	Caterpillar (C175)-2	2018(Plan)	2.20					2.20	2.20	2.20
---	Caterpillar (C175)-3	2020(Plan)	2.20							2.20
2-2. Renewable Energy				1.30	2.30	2.30	4.30	4.30	5.67	5.67
	Popua Solar	2012	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30
	Vaini Solar	2015	1.00		1.00	1.00	1.00	1.00	1.00	1.00
	Singyes Solar	2017(Plan)	2.00				2.00	2.00	2.00	2.00
	Niutoua wind Power	2019(Plan)	1.37						1.37	1.37
3. Firm Generation Capacity (MW)(2.－2.2)				14.16	14.16	13.56	10.76	11.56	11.56	12.36
4. Power Balance (MW)(3.－1.)				5.23	5.07	4.24	1.16	1.68	1.40	1.92
5. Capacity of the largest generator (MW)				2.88	2.88	2.88	2.88	2.88	2.88	2.88
6. n-1 capacity (MW)(3.－5.)				11.28	11.28	10.68	7.88	8.68	8.68	9.48
7. Reserve margin (MW)(6.－1.)				2.35	2.19	1.36	-1.72	-1.20	-1.48	-0.96

Source: The study team



Source: The study team

Figure 2-27: Power demand and supply balance of Tongatapu electricity network

Tonga has a plan for introduction of renewable energy and energy reduction. However, the source of capital and feasibility is uncertain; therefore, aside from the wind power system of the Project, renewable energy targeted in the Project is limited to only the following two facilities: the existing solar photovoltaic facility of 1.3 MW and 1.0 MW output installed in the area of Popua Power Station and Vaini Station and the other one is the solar photovoltaic facility planned by China with 2.0 MW output. Nevertheless, the TPL is planning to install a capacitor with 3 MW output and 18 MWh capacity in addition to renewable energy power, such as a solar power system and wind power system with output fluctuation for the Tongatapu power system. When the plan becomes concrete, the TPL will carry out the analysis of power system independently and will need to make a new plan for installation of capacitor which is necessary to maintain the power quality.

2-2-2-1-5 Power Quality Standard

TPL has adopted the European standard, EN 50160, as the quality control standard for power until the end of the year 2013. EN50160 defines the management standard of frequency and power fluctuation as follows.

Table 2-8: Frequency and voltage specified in EN50160

Item	Standards for Quality Control
Frequency fluctuation	For low/medium voltage of interconnected supply systems over time intervals of 10 seconds: 50 Hz ± 1% (49.5－50.5 Hz) for 95% of the time, and 50 Hz + 4 - 6% for 100% of the time.
Voltage fluctuation	For low/medium voltage of interconnected supply systems: ±10% for 95% of the time.

Source: The study team

TPL has not had any specific system requirements until May 2015. However, from now on more renewable energy supported by countries like Japan will be installed and IPPs (independent power producers) will enter into the business. Currently, among system requirements, power quality standard, FRT (fault ride through) requirement[1], consideration for requirement item of power supply facility and installation requirement for IPP are now maintained. The standards of power quality under consideration are presented in the following chart.

[1] Operation continuation requirement at accident; when voltage and frequency fluctuation occur, the requirement to prevent the drop of power quality control connected to transmission line.

Table 2-9: Power quality standard

Item	Set Value	Condition
Frequency		
UF1	47.5Hz, within 5 seconds	UF trip conditions of G7-G8（MAK）and Maama Mai photovoltaic station
UF2	45Hz, within 4.5 seconds	UF trip conditions of Maama Mai photovoltaic station
OF1	52.5Hz, within 5 seconds	OF trip conditions of G1-G6（CAT）, G7-G8（MAK）and Maama Mai photovoltaic station
OF2	55Hz, within 3 seconds	OF trip conditions of G1-G6（CAT）
Normal operation frequency range	49.25-50.75Hz	TPL （25th July, 2008）
Voltage		
11kV OV	1.1 pu, within 3 seconds	OV trip conditions of G1-G6（CAT）
11kV UV	0.85 pu, within 5 seconds	UV trip conditions of G1-G6（CAT）
11kV Continuous UV	0.9 less than pu	TPL （25th July, 2008）
240V OV	1.1 pu	TPL （25th July, 2008）
240V UV（suburb）	0.85 pu, 15 minutes	
240V UV（urban）	0.9 pu	TPL （25th July, 2008）
11kV transient OV	2 pu	AS/NZS61000.2.14: 2009
240V transient OV	1kV	AS/NZS61000.2.14: 2009
11kV Maximum voltage flicker	More than 4 times a day of 3% or more instantaneous voltage fluctuation, or more than 1 time an hour of 1.5% instantaneous voltage fluctuation	AS/NZS61000.3.7: 2012
11kV Maximum voltage imbalance	3%	IEC61000-2-12
Stability		
11kV oscillation stability	The amplitude of vibration should be halved every 5 Hz.	
11kV voltage stability	In case of accidental voltage drop, the voltage is restored to 0.8 pu in 1 second and 0.9 pu in 7 seconds.	
Harmonic		
11kV	AS/NZS61000.-.6: 2012, table 2	

Source: The study team

The installation requirement of IPP is scheduled as shown below. The requirement has already been approved by the TPL power association on September 2016.

① Installation requirement

・Power plant facility shall be installed by qualified electrician.

・Inverter shall have FRT function and generate power up to 190 V.

・Inverter shall respond to system voltage.

・Generation system more than 4 kW shall take a three phase balance.

・Peak voltage shall be within 10 % of official voltage of 240 V.

・Whether relay protection for reverse power is installed or not is determined by TPL.

・Electric installation (rule of electric distribution) shall be based on AS/NZS 3000

・Installation and safety requirement of solar power system (PV) shall be based on AS/NZS 5033

・Standard of structure design (wind requirement) shall be based on AS/NZS 1170.2

・Secondary battery installed inside the facility shall be based on AS 3011

・Installation, maintenance and inspection of secondary battery inside the facility shall be based on AS 2676.

② System requirement

・System connection of generation installation via inverter shall be based on AS4777.

・Protection against lightning shall be based on AS / NZS 1769.

・Standard voltage shall be based on AS 60038.

・EMC requirement shall be based on AS / NZS 61000.

・Installation of substation above 1 kV AC and high voltage facility shall be based on AS 2067.

③ Solar PV module requirement

・Safety eligibility confirmation of solar battery module shall be based on IEC 61730.

・Confirmation of corrosion of solar battery module by brine spray shall be based on IEC 61701.

④ Wind turbines requirement

・Design requirement of small wind turbines (below 65 kW) shall be based on IEC61400-2.

・Requirement of normal wind turbines (above 65 kW) shall be based on IEC 61400-1.

In the Project, wind power system of more than 1.3 MW and system stabilized facility will be installed. To follow the standards of power quality management and to maintain the current power quality shall be preconditions for considering the system.

2-2-2-1-6 The type and capacity of wind power system and capacitor introduced in the Project

(1) The condition of wind power system

As a condition of the wind turbine generator system, following conditions shall be satisfied for the wind turbine.

Table 2-10: Condition of wind power generator system

Output Power	1.3MW or more by 5 wind turbines
Extreme Wind Speed	Designed by wind turbine class of IEC61400-1 in normal condition, and following value as maximum instantaneous wind speed (cyclone) 10m from the ground: 70.0m/s 40m from the ground: 76.2m/s 45m from the ground: 76.7m/s
Turbulence Intensity	0.12 or more
Design Horizontal Seismic Coefficient	0.2G or more

Source: The study team

1) Specifications and performance of candidate wind turbines

Among the candidate wind turbines, the tiltable-type is manufactured by a Japanese manufacturing company which adopts the wind turbine (nacelle and blade) of Vergnet, a French wind turbine manufacturer. The same wind turbine was introduced in Okinawa, and Japanese manufacturers can deal with minor failures. The extreme wind speed is 85 m/s at the time of tilting. Preparations for tilting the tiltable wind turbine need to start when the wind speed reaches 15 m/s after the announcement of the cyclone. The tilting work needs to be finished by they time the wind speed reaches 25 m/s. In the past record of cyclones, it took 7 hours for the wind speed to change from 15 m/s to 25 m/s, therefore it is required to organize a work system that completes tilting work within 7 hours. Periodical maintenance is done about twice a year. This maintenance is conducted when the turbine is in a tilted position. This means large heavy equipment is unnecessary and maintenance can be easily carried out. In case of serious failure requiring replacement of large parts, a crane of about 25 tons is required for replacement after tilting, but in some cases it may be possible to replace by preparing multiple trucks with built-in cranes.

Regarding the fixed-type wind turbine, a wind turbine that exceeds extreme wind speed is under development. If the development of this fixed-type wind turbine is completed by the implementation stage of this Project and if it is confirmed that this wind turbine satisfies the required specifications (Table 2-10 above), the Project shall adopt this fixed-type wind turbine as a candidate. The extreme wind speed of fixed-type wind turbine, which is under development, is 91.26 m/s. This wind turbine will be manufactured by a Japanese wind turbine manufacturing company, and designed by a German company. If this wind turbine fulfills the predetermined functions, and if development is completed, there will be no problem adopting it as a candidate of this Project. Periodical maintenance is done about twice a year, large heavy equipment is unnecessary and maintenance can be easily carried out. In case of serious failure requiring replacement of large parts, and when the wind turbine is being constructed, a crane about 60 tons is required. It is difficult to prepare the large size of crane in Tonga, that is why in case of serious failure, it is necessary to procure a large crane (from overseas) together with replacement parts, and costs for preparation and transportation of heavy machinery should be consider against the maintenance of tiltable-type wind tuirbine.

(2) Comparison of power generation capacity between tiltable and fixed turbines

The results of the simulated amount of electricity generated by the wind turbine of tiltable and fixed type based on the wind condition surveyed from April 2015 to March 2016 are shown below. In the simulation, the availability is calculated from the rate which the wind turbine stop annually, and the wind power generation amount is calculated with consideration of the availability.

Table 2-11: Availability of wind turbine

Tiltable-type wind turbine

Item	Down period		Total downtime	Annual stop ratio	Remarks
	Times	Days			
Meintenance	2	9	432	4.9%	
Operation adjustment	---	4	24	0.3%	Working time per day: 6 hours
Cyclone	3	5	360	4.1%	
Total			816	9.3%	Availability: 100%-9.3%=90.7%

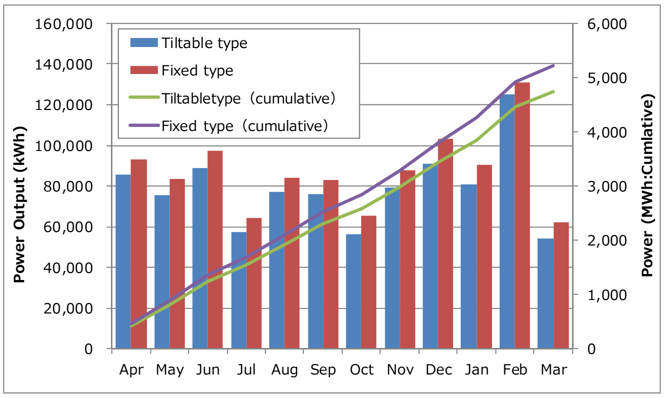
Fixed-type wind turbine

Item	Down period		Total downtime	Annual stop ratio	Remarks
	Times	Days			
Meintenance	2	9	432	4.9%	
Operation adjustment	---	4	24	0.3%	Working time per day: 6 hours
Cyclone	3		18	0.2%	Down time per one cyclone: 6 hours
Total			474	5.4%	Availability: 100%-5.4%=94.6%

Source: The study team

Due to the difference in the capacity of the wind turbine and the cut-in, cut-out wind speed, fixed-type wind turbines generate larger electricity than tiltable-type. This project plans to introduce wind turbines of 1.3 MW or more with five wind turbines. The maximum output is 1.375 MW for tiltable-type (output 275 kW/unit), 1.5 MW for fixed-type (output 300 kW/unit). Therefore, the maximum output of the fixed-type wind turbine is larger than tiltable-type.

Year/month		Power Output（kWh/month/unit）	
		Tiltable type (275kW)	Fixed type (300kW)
2015	Apr	85,808	93,086
	May	75,383	83,542
	Jun	88,963	97,171
	Jul	57,232	64,242
	Aug	77,240	83,763
	Sep	76,259	83,108
	Oct	56,292	65,213
	Nov	79,306	87,674
	Dec	90,683	103,256
2016	Jan	80,854	90,250
	Feb	125,100	130,694
	Mar	54,057	61,962
Total（kWh/year/unit）		947,177	1,043,962
5 wind turbines（kWh/year）		4,735,885	5,219,811



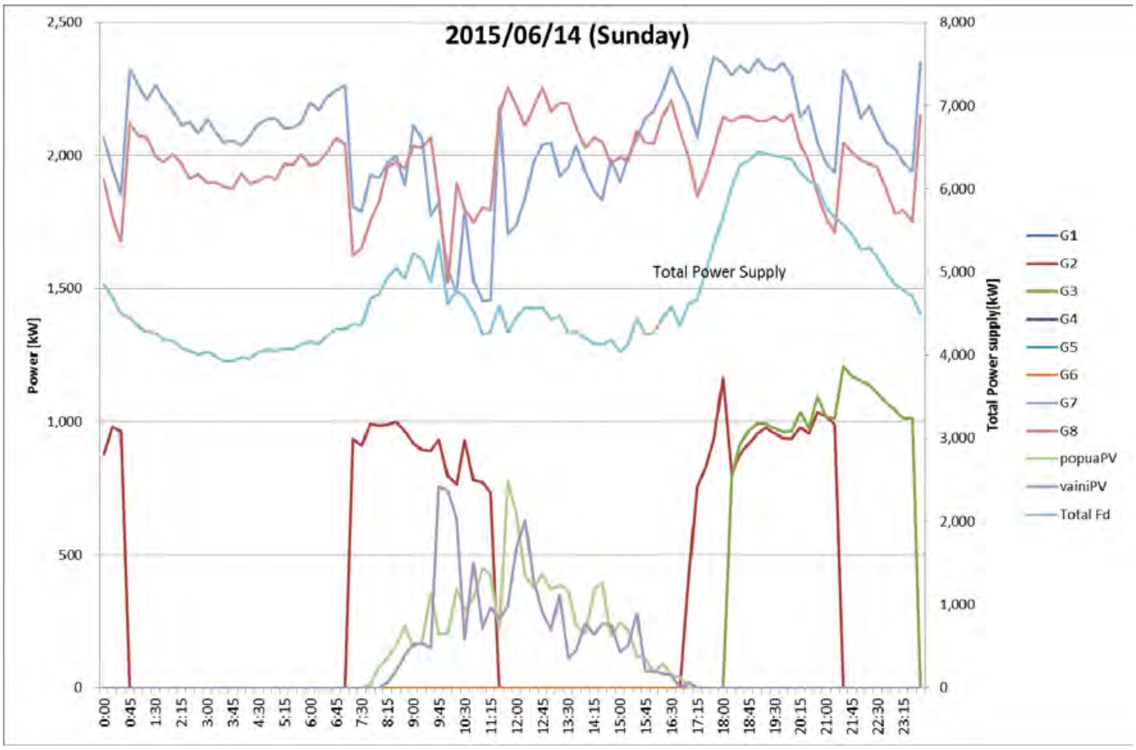
Source: The study team

Figure 2-28: Comparison of wind power generation by wind turbines (each and 5 turbines total)

Also, due to the difference in the availability of the wind turbines, the fixed-type wind turbines generate more electricity per year, and the annual power generation per 1 kW of fixed-type wind turbine is larger than the annual power generation per 1 kW of tiltable-type.

(3) Conditions of power system stabilization equipment (storage battery)

As described before, power system stabilization is considered using algebraic approach.



Source: TPL

Figure 2-29: Power supply on holidays

Change in demand (system capacity) is set at around 4,000 kW based on the minimum demand at 3:00 AM and 3:00 PM on June 14, 2015 (Sunday in winter). Around 3:00 PM, power is also supplied from the solar PV power plant, and the total power generation output is adjusted by only diesel power generation of two MAKs. Shortage of power supply in a slhort period from the solar PV power plant is controlled by lithium ion capacitors. Therefore, the Project does not need to take fluctuation of solar PV power generation in a short period into consideration.

A system constant is generally between 8 and 10 %. Since electricity is supplied by diesel generators in an isolated island, a system constant of 10 % is applied. TPL complies with EN50160 as the electricity quality management criterion; therefore an allowable frequency fluctuation ratio is set at +/- 0.5Hz based on management criterion by EN50160.

Residual allowable adjustment is calculated using a system capacity, system constant and allowable frequency fluctuation ratio. As for power variation by wind turbines in a short period, a 10 minute average turbulence intensity and every minute power variation of a tiltable turbine are calculated. A wind turbine model used in FAST is developed based on publicly available data by wind turbine manufacturers such as power curve, control approach, blade shape and blade weight, etc. Kaimal model is used for turbulence flow model in IEC61400-1 Ed.3 and analysis time interval is set as 5 m/s.

A simulation by FAST showed that power variation per wind turbine is 105 kW at maximum in a wind speed of 11 m/s, which means that wind power variation ratio is 38%.

Cumulative power variation is calculated using the LFC adjusting power, residual allowable adjustment and demand variation. Then, a connectable wind turbine capacity is calculated using the above power variation ratio and the above cumulative power variation.

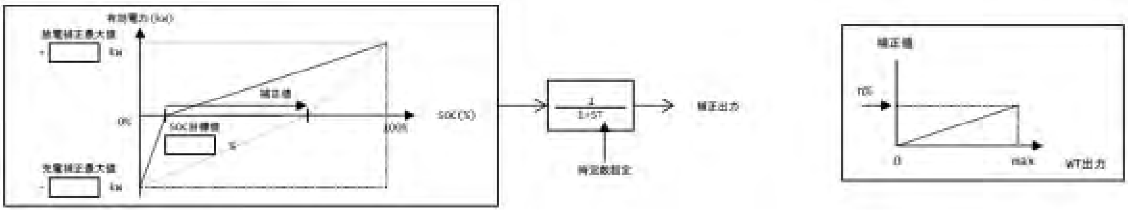
In this case, the planned wind turbine capacity is 1,375 kW and as a result, the required adjusting power by LFC (in this case capacity of PCS in the power system stabilization) to achieve this capacity is calculated as 530 kW.

Table 2-12: Short cycle LFC adjusting power by algebraic approach

System Capacity	P	2500	kW
System Constant	γ	10	%
Rate of Allowable Frequency Variation	ΔF	0.5	Hz
①Adjusting Power by LFC		530	kW
②Allowable Adjustment Amount	R	125	kW
Rate of Demand Variation		5.7	%
③Demand Variation		142.5	kW
⑦Output Variation of PV		0	kW
PV rated power		2300	kW
⑨Rate of PV Output Variation		0	%
Wind Power Vriation per Unit		105	kW
Wind Turbine Rated Power		275	kW
④Output Variation of Wind Power		526	kW
⑥Rate of Output Variation of Wind Power		38	%
⑤Connectable Amount of Wind Power		1376	kW

Source: The study team

On the other hand, wind power fluctuation for a short period is adjusted by changing the state of charge (SOC) of storage batteries. When stored electricity decreases after discharge, the storage batteries shall be recharged little by little so as not to affect the entire system. Since the wind power fluctuation always varies and electricity storage equipment can be dischargeable and rechargeable anytime, the capacity of storage equipment is initially expected to be SOC 50%. The following figure shows this concept.



Source: The study team

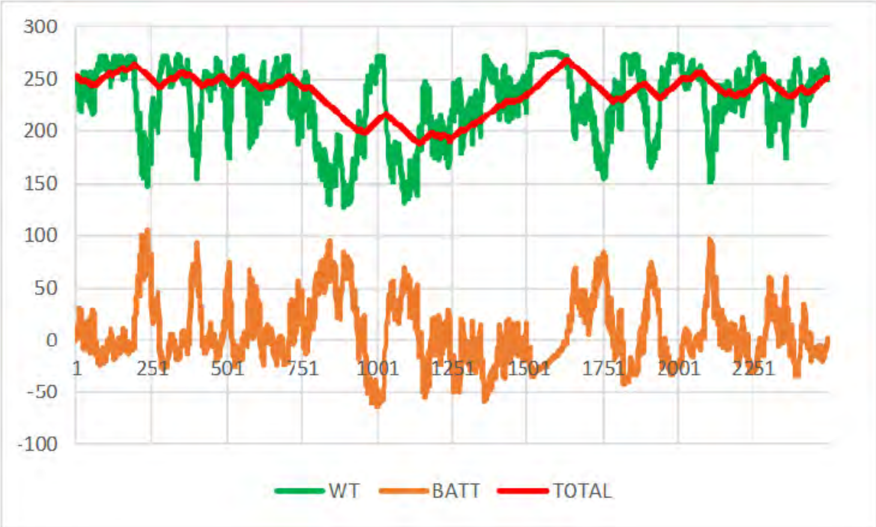
Figure 2-30: Outline of SOC control logic

Table 2-13 shows the following requirements: a storage battery to compensate for a short term variation for each wind turbine, a maximum discharge output of 105 kW and capacity of 1.24 kWh with a wind speed of 11 m/s. This means that the required capacity of PCS for five wind turbines is 525 kW, which is almost equivalent to 530 kW calculated by an algebraic approach. The capacity required for storage batteries is 12.5 kWh with an SOC of 50 %. In accordance with the variation of power output by wind turbines, the recharge and discharge cycle is extremely large.

Table 2-13: Capacity of PCS and storage battery required for a wind turbine

Wind speed (m/s)	Power (kW)		Energy Capacity (kWh)	
	Max Discharge	Max Charge	Max Discharge	Max Charge
3	0.52	-1.11	0.0001	-0.0003
4	8.45	-8.09	0.0048	-0.0153
5	15.87	-13.36	0.0545	-0.0183
6	27.37	-29.57	0.1013	-0.0567
7	36.91	-50.42	0.1187	-0.2306
8	59.82	-65.03	0.4327	-0.1745
9	81.94	-85.09	0.6326	-0.1708
10	98.48	-81.71	0.8388	-0.0719
11	105.14	-62.03	1.2425	-0.0337
12	85.57	-42.89	0.7961	0.0000
13	59.36	-21.86	0.2649	0.0000
14	22.57	-7.14	0.0391	0.0000
15	7.30	-3.01	0.0032	0.0000
16	1.39	-0.71	0.0004	0.0000
17	0.00	0.00	0.0000	0.0000
18	0.00	0.00	0.0000	0.0000
19	0.00	0.00	0.0000	0.0000
20	0.00	0.00	0.0000	0.0000
21	0.00	0.00	0.0000	0.0000
22	0.00	0.00	0.0000	0.0000
23	0.00	0.00	0.0000	0.0000
24	0.00	0.00	0.0000	0.0000
25	0.00	0.00	0.0000	0.0000

Source: The study team



Source: The study team

Figure 2-31: Power output variation of a wind turbine and recharge and discharge output of a storage battery at wind speed of 11m/s

As a result, lithium ion capacitor, with a recharge and discharge cycle of more than one hundred thousand is selected for storage batteries to compensate for a short term output variation.

2-2-2-1-7 Operation of diesel power generators after wind power generators start operation

(1) Operation of the existing diesel power generators

Power accumulator facilities as mid-cycle fluctuation compensation are not installed in the Project Therefore, variation amount of power demand in the middle period, existing photovoltaic, and power fluctuation power amount by wind turbine generation to be installed by the Project depend on the load following capability of the existing diesel generator.

As already mentioned, it has been found that the load following capability of the governor of the existing diesel generator is sufficiently high. As a response to the output fluctuation, in principle, it relies on the load following capability of the diesel generator in operation. If it is not enough, one additional CAT is activated to ensure load following capability.

In consideration of the above-mentioned 3-2-1-4 (2), even under this condition, it will be overloaded in the afternoon of the holiday in winter season (July, September), and it is necessary to take measures to reduce the load. As a countermeasure against this issue, it is certain to install power accumulator facility for mid-cycle fluctuation compensation. However, taking into consideration that the overloading frequency is extremely low in the year, it is expected that the cost effectiveness of the installation of accumulator will not be effective. Therefore, it can not be adopted in the Project. On the other hand, TPL plans to install 18 MWh power accumulator which is for efficient operation in the long cycle. This facility aims to maintain the load of the diesel generator in order to avoid the diesel generator becoming excessively light load during the daytime of holidays when the demand power is low, and it is expected to increase in output of solar photovoltaic. It is also a facility planned to be installed in order to secure the reserve power and to improve the power generation efficiency of the diesel generator due to the increase of the load factor by securing the number of diesel generators. In addition, the electricity accumulated during the day is planned to adopt the time shift method that discharges from the evening to the night when the electric power demand increases. If power accumulator corresponding to long cycles is installed, accumulator facility for the middle cycle is not necessary. In the project, the accumulator should be developed considering only compensation for short period fluctuations.

Therefore, under the circumstances that the overload occurs in the middle cycle, the super-load is to be reduced by reducing the output fluctuation of wind turbine generation by operating the diesel generator(s) and limiting the number of the wind turbine generators being operated to temporarily reduce the output.

Table 2-14: Output by operation control of diesel generator (CAT, MAK)

Number of generator	Load factor of diesel generator (×100 %, upper: min, lower: max)								Output power: CAT (kW)	Output power: MAK (kW)	Output power: Total (kW)
	CAT						MAK				
	CAT1	CAT2	CAT3	CAT4	CAT5	CAT6	MAK1	MAK2			
CAT: 1	0.65								910		910
	0.85								1260		1260
CAT: 2	0.65	0.65							1680		1680
	0.85	0.85							2520		2520
CAT: 3	0.65	0.65	0.65						2520		2520
	0.85	0.85	0.85						3696		3696
CAT: 2	0.65	0.65					0.65		1820	1872	3692
MAK: 1	0.84	0.84					0.78		2352	2252	4604
CAT: 3	0.65	0.65	0.65				0.65		2730	1872	4602
MAK: 1	0.78	0.78	0.78				0.78		3276	2238	5514
CAT: 4	0.65	0.65	0.65	0.65			0.65		3640	1872	5512
MAK: 1	0.77	0.77	0.77	0.77			0.75		4315	2160	6475
CAT: 3	0.65	0.65	0.65				0.65	0.65	2730	3744	6474
MAK: 2	0.75	0.74	0.7				0.75	0.75	3066	4320	7386
CAT: 4	0.65	0.65	0.65	0.65			0.65	0.65	3640	3744	7384
MAK: 2	0.7	0.71	0.71	0.72			0.75	0.75	3974	4320	8294
CAT: 5	0.65	0.65	0.65	0.65	0.65		0.65	0.65	4550	3744	8294
MAK: 2	0.7	0.7	0.7	0.7	0.7		0.75	0.75	4900	4306	9206
CAT: 6	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	5460	3744	9204
MAK: 2	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	7140	4896	12036

Source: The study team

The above table shows the output ranges based on the number of CAT and MAK, which are diesel generators, and the load factor. In case of output is less than 3.692 kW, considering the MAK output range (1.872 kW: load factor 65%, 2.448 kW: load factor 85%), it is possible to cope with a wide range of output fluctuation by running multiple CATs. If it is assumed that the output of the diesel generator is less than 3.692 kW for several hours, it corresponds to output fluctuation of wind turbine generation by driving only CAT.

The cause of the large fluctuation range of the output power of the wind turbine generation is the case of the cutout occurring at the wind speed exceeding the maximum wind speed that the wind turbine can generate, and it is when all of them occur all at once. In the case of a tiltable-type wind turbine, the wind speed to become the cut out is 20 m / s, and when the cut out occurs, the output of 1.375 kW becomes zero. Therefore, in order to compensate for the missing output, the diesel generator needs to raise the output of 1.375 kW in a short time. Moreover, it is necessary to improve the load following capability of the diesel generator in operation, or to additionally activate one CAT. However, since it takes about 5 minutes to prepare for restarting CAT, it is necessary to predict in advance that wind turbine will cut out all at once. It is difficult to predict the wind condition and judge whether it is within the range that can be handled by the operation of the diesel generator or not in a short time, so it is managed by controlling the output of wind turbine generation.

2-2-2-2 Overall Plan

2-2-2-2-1 Design Condition

The design condition is set as follows considering the Project size and specification.

(1) Natural Conditions

① Design temperature: 40 degrees Celsius
② Design relative humidity: 85% at maximum
③ Extreme wind speed: 70 m/s (10 m above the ground), 76.2 m/s (40 m), 76.7 m/s (45 m)
④ Rainfall: annual average 2,300mm
⑤ Salt deposit density: 0.5 mg/cm2
⑥ Seismic force: horizontal direction 0.2 G
⑦ Soil bearing capacity: 100 kN/m2 (Niutoua)

(2) Applicable Standard

① Japanese Industrial Standards (JIS): applied to all industrial products
② The institute of Electical Engineers of Japan (JEC): applied to all electrical products
③ The Japan Electrical Manufacturers' s Association (JEM): applied to all electrical products
④ The Japanese Electric Wire & Cable Makers' Association (JCS): applied to wire and cable
⑤ Technical criterion on electric equipment: applied to electric work
⑥ International Electrotechcnical Commission (IEC): applied to all electronic products, especially wind turbines
⑦ International Organization for Standardization (ISO): applied to electric and mechanical products

(3) Unit

Basically SI unit is applied.

2-2-2-2-2 Layout Plan

1.3 MW wind power generation facilities and the 530 kW system stabilization equipment are equipped at Niiutoua, northeast of Tongatapu. TPL is under negotiation with the land owners of the candidate site for a re-lease contract. Routes for logistics and installation of transmission line are planned using the existing roads.

TPL is responsible for cutting trees to make way for the new facilities. After drilling survey necessary for foundation work and installation of anchors, wind power generation facilities are built.

A new building for special electric equipment is built in the project site in Niutoua to equip system stabilization equipment such as micro grid control equipment, power storage equipment and PCS, and electric facilities such as high-voltage breaker from the wind turbine facilities. General equipment such as high-voltage transformer is installed outside.

To secure expected life of power storage equipment such as lithum ion capacitor, it is important to control the indoor temperature. Therefore, air-conditioning system is installed in the new building for special electric equipment.

The new SCADA is installed to control wind power generation facilities. Its main system is installed in the new building for special electric equipment and its sub system is installed in the existing manned central control room in Popua power plant to continuously monitor the conditions. Data management systems are also installed in both locations.

2-2-2-3 Project Outline

Based on the above policies and plans, the Project outline is designed as follows.

2-2-2-3-1 Specification of Wind Power Facilities

(1) Extreme Wind Speed

The wind turbine adopted in this Project shall be categorized S in consideration of the recent increase in size of the cyclone scale. Extreme wind speed is set for each height from the ground based on Tonga building code. As a result, the extreme wind speed of 10 meters above the ground is 70.0 m/s, of 40 meters above the ground is 76.2 m/s and of 45 meters above the ground is 76.7 m/s, respectively.

(2) Power Output

Only the 275kW tiltable wind turbine can satisfy the Ve_{50} among currently available wind turbines. In order to meet the request of 1.3MW in rated output, there needs at least five wind turbines. With five tiltable turbines the power output is expected to be 275kW×5=1.375MW.

(3) Type of Towers

Tiltable wind turbines are laid down in case of a cyclone to tolerate the extreme wind speeds up to 85 m/s. It meets the Project requirements.

On the other hand, another fixed type wind turbine is under development and could be used as both tower types are acceptable. Since the turbulence intensity recorded at a height of 40 m is below the design turbulence intensities of both types, the tower height shall be designed according to its manufacturer's standard specification.

2-2-2-3-2 Specification of System Stabilization Equipment (Storage Battery)

(1) Specification of Storage Battery

Type and capacity of storage battery affect its operation and maintenance cost borne by TPL.

Lithium ion battery is used for electric vehicles and hybrid vehicles, whereas for electricity supply requiring large capacity, lithium ion capacitor, electric double layer capacitor, lead battery, and NaS battery are cost effective.

The Project requires a large capacity to ensure instant recharge and discharge to compensate for the short term wind power output variation. Physical cells such as lithium ion capacitor and electric double layer capacitor meets this requirement with a large instant output and expected life of more than one hundred thousand cycles and the replacement cost is lower than chemical batteries such as lead battery and NaS battery.

The Project selects lithium ion capacitor, which is used for and proven by the solar PV power generators.

(2) Power Output by Storage Battery and PCS Capacity

The algebraic approach calculates the output of lithium ion capacitor to be 530 kW. For unit capacity of PCS and reactive power, two 500 kVA PCS shall be installed.

3) Capacity of Storage Battery Equipment

In order to ensure needs for both recharge and discharge to keep the variation of frequency, the default capacity of storage battery is set at SOC 50 %, which means 12.5 kWh to stabilize the wind power output. Considering the connection with two PCSs, the 14 kWh storage battery is installed as 7kWh×2.

2-2-2-3-3 Storage Battery Building

(1) Layout Plan

Lithium ion battery can be stored with instrumentation equipment. For maintenance purposes, every piece of equipment shall be kept a certain distance from other equipment.

(2) Section Plan

It shall be high enough to install equipment such as storage battery and instrumentation equipment. Doors shall be high enough for installation and replacement of equipment in the future.

(3) Structure Plan

Considering the ease of work and efficient work schedule, the building is steel structure, which is also applied for ‘the Project for Introduction of a Micro-Grid System with Renewable Energy for the Tonga Energy Road Map’.

(4) Equipment Plan

① **Electricity Planning**

The primary source is the house transformer in the switch gear and the Project will install the secondary equipment from there. Emergency power system is not included.

② **Lighting Fixture**

The Project shall ensure the same illumination levels as the existing facilities. The Project shall principally plan to install fluorescent lights because thery are generally used in TPL’s existing facilities

③ **Telephone System**

Mobile telephone is the main communication tool and no telephone line is installed in the project site.

④ **Air Conditioning Machine**

In order to avoid performance degradation of lithium ion capacitor, the air-conditioning equipment is installed in the capacitor area.

⑤ **Water Supply System and Sewage Teratment**

Neither water supply or sewage treatment system shall be installed.

⑥ **Fire Protection Equipment**

The Project shall install commonly used dry chemical fire extinguishers.

(5) Finishing Plan

The following table shows the finishing plan of the Storage Battery Building.

Table 2-15: Finishing plan of storage battery building

Element	Finishing
External Finishing	
Roof	Galvanized steel plate, t=0.8mm
Exterior Wall	Galvanized steel plate, t=0.5mm
Doors and Windows	Steel, t=1.6mm or more
Foundation	Reinforced concrete, mortar brush finish
Watershoot	Galvanized steel product or PVC pipe
Internal Finishing	
Floor	Coating by epoxy resin
Wall	Galvanized steel plate, t=0.5mm
Ceiling	Glass wool with nonflammable sheet, t=50mm

Source: The study team

2-2-2-3-4 Grid Connection to High Voltage Distribution Network

(1) Connection points to existing high voltage distribution line

The connection points with existing high-voltage transmission and distribution network is Niutoua area nearest to the wind turbine generator system.

(2) Outline of electric network

In the section from the wind power station to the Liku Road, tall trees grow in a narrow street. To prevent power distribution line accidents caused by contact between high-tension distribution lines and trees, the underground wiring system is adopted in which the power distribution lines are wired in the underground pipeline. The burying method of electric line is to bury it within the pipeline buried in the road to be constructed, by the government of Tonga, for the purpose of transporting in Project materials and for maintenance of the wind turbines. Rising pole shall be set up at the arrival point of Liku Road. In the Project, a wooden support is built around the southeastern side along the Liku Road every 45 m and it is assumed to be an overhead wiring system until the intersection with Taufa'ahau Road in the Niutoua area, which is a connection point with existing transmission lines. Liku Road is a wide road, both sides of the road are open, so there is a low possibility of a contact accident between the high-tension distribution line and trees. Therefore, the construction cost is low and maintenance and inspection is easier than in the buried section.

(3) Connection point with existing high-tension transmission and distribution line

The connection point with the existing high-tension transmission and distribution line shall be support pole for existing high-tension transmission and distribution line near the intersection of Liku Road and Taufa 'aau Road in the Niutoua area. It is planned to set LBS with power fuse (100 A) at connection point to connect new line as a countermeasure to the short-circuit current.

(4) Communication line

1) Selection of communication line

A new communication line will be installed, and high-speed LAN (Ethernet) environment will be established for monitoring and controlling wind turbine generator since there is no effective communication line between Popua power generation station to Niutoua's wind turbine generator. The distance from Popua power station to Niutoua's wind power generator is about 39 km. In order to construct a stable network in this long distance section, optical fiber cable will be adopted as a communication line. It also has the advantage of ensuring stable communication because the optical fiber cable is less susceptible to electromagnetic waves and noise.

2) Line type of optical fiber cable

The line type of the optical fiber cable used for long distance transmission includes multi mode and single mode. The maximum transmission distance of multimode optical fiber cable (core diameter 50 μm) is as short as 550 m. When single mode optical fiber cable (core diameter 8 μm) is used, it will be possible to transmit up to 50 km, so it is selected single mode optical fiber cable in the Project.

3) Number of core of optical fiber cable

It is planned to adopt a full duplex communication using 2 cores in total; one for uplink and one for downlink. The number of lines required is six lines including spare lines, and the number of fibers of the optical fiber cable is twelve in order to accommodate six lines.

4) Overhead line system

There are self-supporting type and messenger wire hanging type for optical fiber cable wiring method. The self-supporting type optical fiber cable requires a lot of exclusive extension material and equipment to extend over long distances, and multiple diameters for wiring work. Spiral hanger type, which is a type of messenger wire suspended type, is adopted in the Project because it can be constructed with relatively few equipment, maintainability after it has been set up as an overhead wire is high, and it is adopted also for the existing microgrid.

5) Selection of underground protecting tube

If it is necessary to wire the optical fiber cable under the ground, it is needed to set a protecting tube. It is necessary to set the protecting tube to more than 1.5 times the outer diameter of the cable. It is adopted a 30 mm FEP pipe which is the size when the diameter of the optical fiber cable is about 10 mm.

2-2-2-3-5 Specification of Major Equipment

The following table shows the specification of major equipment procured by the Project.

Table 2-16: Specification of the major equipment

No	Name of major equipment	Rough specifications	Quantity
0.	Wind turbine generator system		
(1)	Wind turbine	Cut-in wind speed: 3.6m/s or less Cut-out wind speed: 20.0m/s or more	5

No	Name of major equipment	Rough specifications	Quantity
		Wind turbine class: S Turbulence intensity: A or B Low output voltage – frequency: 400V-50Hz High output voltage – frequency 11kV-50Hz Nacelle height: 38m or more	
(2)	SCADA for wind turbine control	Monitoring and operation of wind turbines	2
1.	System stabilization for 1.3MW WTGS		
1.1	Micro-grid controller		
(1)	Micro-grid controlling panel	Stabilize the wind power output in tandem with the generator. Display status and alarm. Drive instruction and various settings. Shape: metal enclosed switchboard for indoor application	1
(2)	Micro-grid controlling panel (Popua power station) and measuring equipment	Acquisition of various measurements and monitoring results at Popua power station. Information display at Popua power station, driving instruction and various settings.	1
(3)	Data management system	Record and display measurement data at 1 second interval.	1
(4)	Weather measurement equipment (anemometer, weathervane)	Observe wind speed and wind direction of Niutoua site (10 m above ground).	1
1.2	System stabilization system		
(1)	Power storage system	Type : lithium-ion capacitor (Lic) Use: for cycle use Capacity: 14 kWh or more (7 kWh×2) Internal resistance: 19 mΩ or less	1
(2)	Storage panel for power storage system	Type: metal enclosed switchboard for indoor application	1
(3)	Connecting panel for power storage system	Connect PCS and Lic. Type: metal enclosed switchboard for indoor application Switchboard: MCCB	2
(4)	Interactive PCS	Based on the instruction of the control device, charge to and discharge from the storage battery. Also, reactive power control is performed within the capacity range. Total capacity: 500 kVA or more Type: metal enclosed switchboard for indoor application Main circuit system: high-frequency PWM Insulation system: commercial frequency insulation transformation Cooling system: forced air cooling Rated power conversion efficiency: 93% or higher Control functions: Automatic start/stop, soft start, automatic voltage adjustment, input/output over-current adjustment, and output adjustment Grid-connected protective functions: over voltage (OVR), under voltage (UVR), over frequency (OFR) and under frequency (UFR) Islanding operation detection function: active and passive type	2

No	Name of major equipment	Rough specifications	Quantity
(5)	Grid-connected transformer	Type: outdoor, oil immersed, self-cooled Capacity: AC 500 kVA, three-phase, 50 Hz Voltage: 11 kV/PCS, AC	2
(6)	DC power-system	Supply power to 11 kV switchboard, PCS, others. Input: AC 210 V, three-phase Output: DC 110 V Type: metal enclosed switchboard for indoor application Power storage system: Sealed- lead acid battery Battery capacity: durable for outage of 12 hours or longer	1
1.3	House electric facility panel	Built in the transformers and switches etc. to ensure the capacity necessary for the internal load. Type: metal enclosed switchboard for indoor application (install a transformer outside) Switchboard: MCCB or ACB Input: AC 11 kV, three-phase Output: AC 210 V three-phase, AC 100 V single phase	1
1.4	Switch gear for 11kV system	Type: metal enclosed switchboard for indoor application Number of feeders: 9 Switchboard: vacuum circuit breaker (VCB) Rated voltage: 11 kV or more Include the protection relay, measuring device, watt hour meter, etc.	1
2.	Grid-connected switch gear for 11kV system		
(1)	Switch gear for grid connection	Rated voltage: 11 kV three-phase Switchboard: PAS or LBS Set up on an electric pole.	1
3.	Optical cable communication system		
(1)	Optical cable communication system	Acquire Popua power station information on Niutoua site and build optical network to display information on Popua power station. In addition, build LAN system for SCADA of wind turbine control / monitoring at Niutoua site and Popua power station.	1

Source: The study team

2-2-3 Outline Design Drawing

Outline design drawings of the Project are mentioned below.

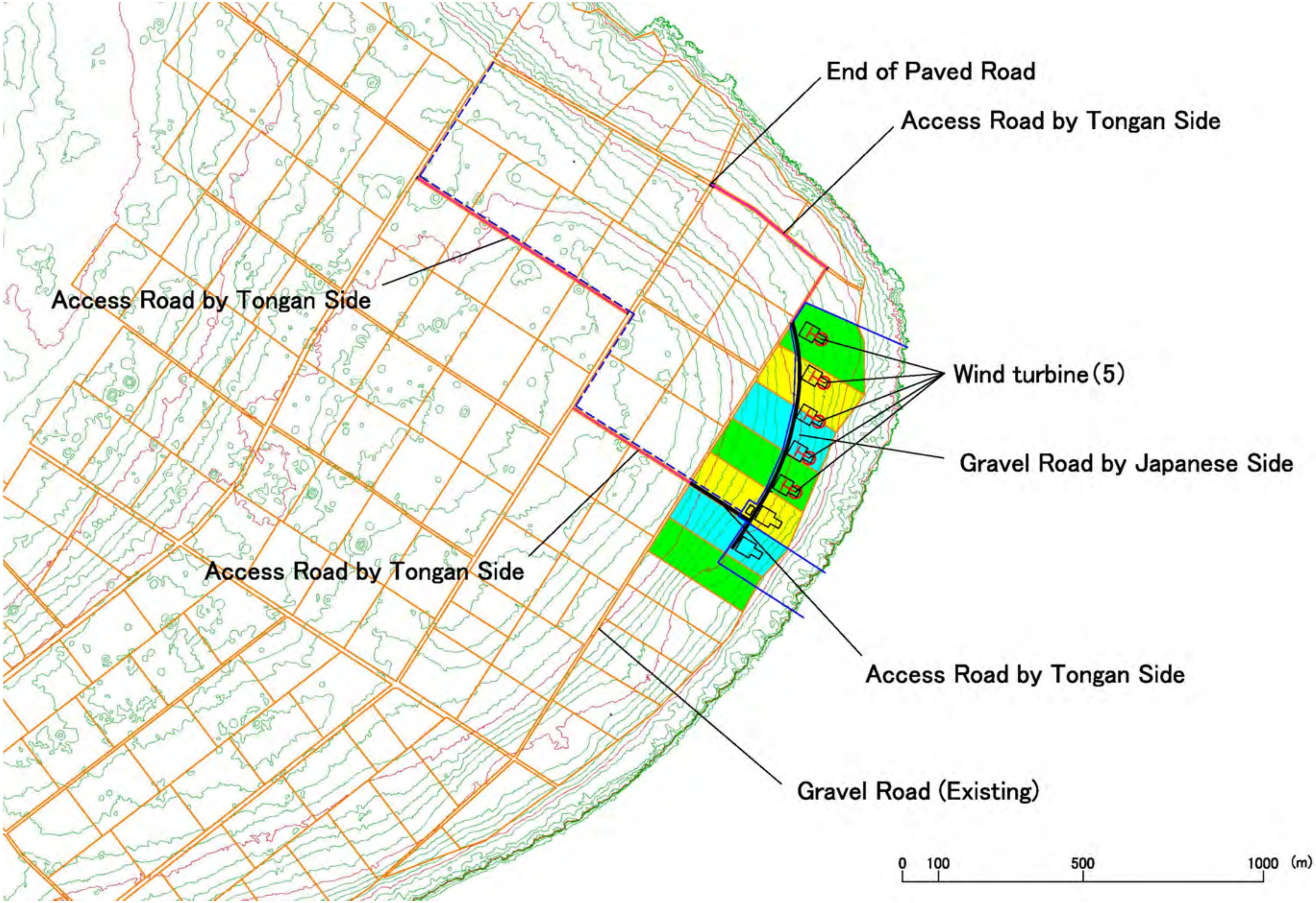


Figure 2-32: Whole Plan of Project Site

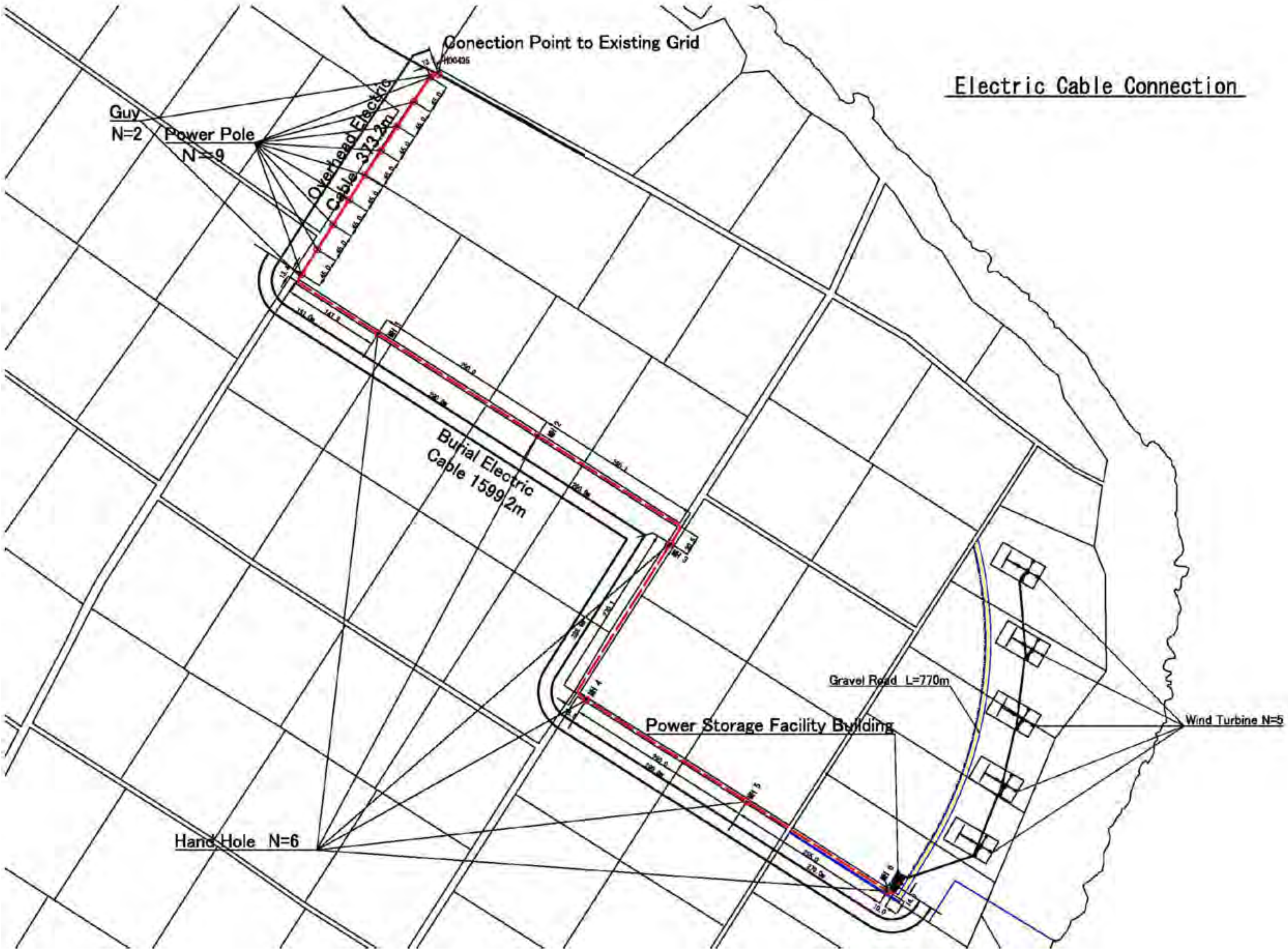
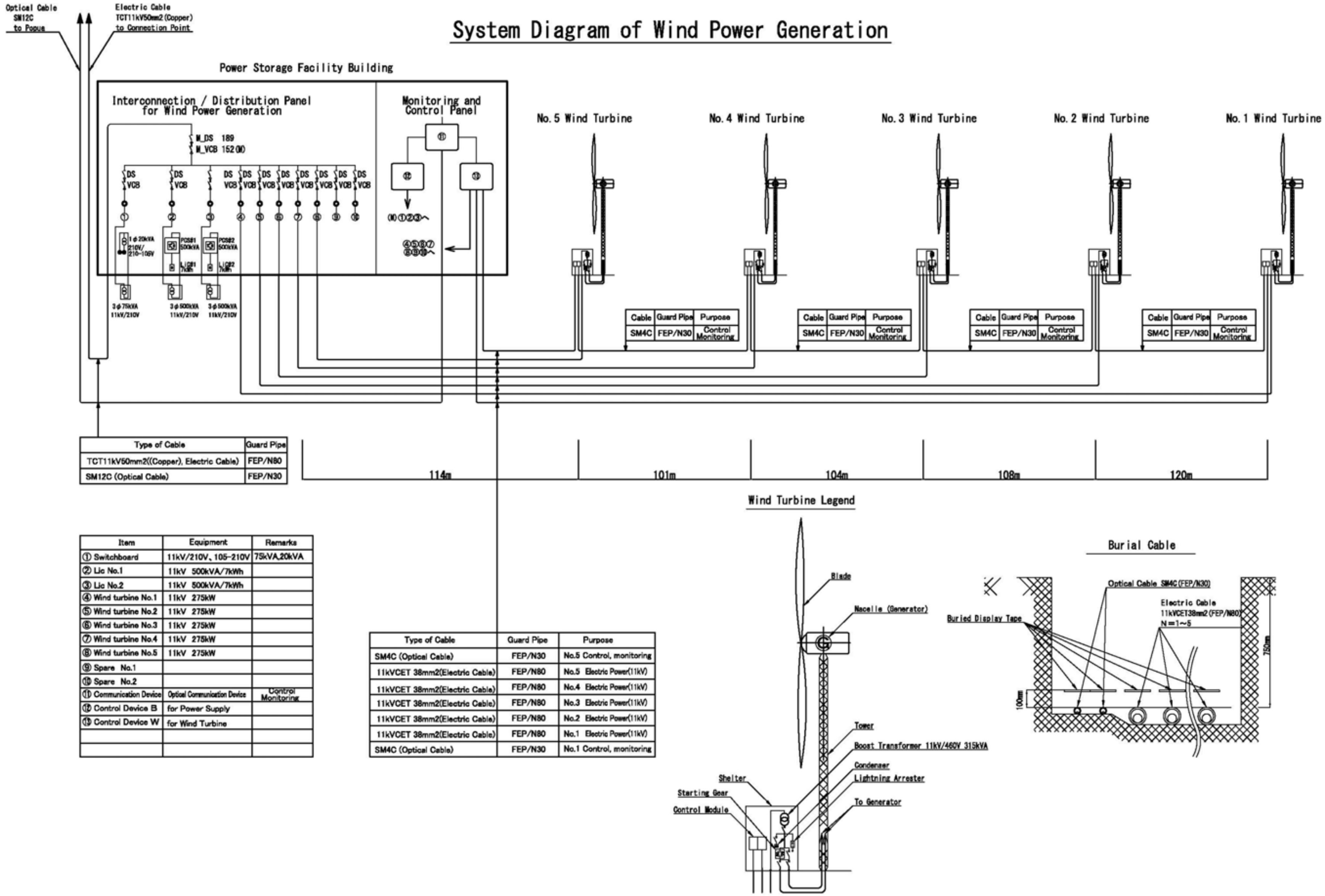


Figure 2-33: Whole System Plan

System Diagram of Wind Power Generation



Type of Cable	Guard Pipe
TCT11kV50mm2((Copper), Electric Cable)	FEP/N80
SM12C (Optical Cable)	FEP/N30

Item	Equipment	Remarks
① Switchboard	11kV/210V、105-210V	75kVA,20kVA
② Lic No.1	11kV 500kVA/7kWh	
③ Lic No.2	11kV 500kVA/7kWh	
④ Wind turbine No.1	11kV 275kW	
⑤ Wind turbine No.2	11kV 275kW	
⑥ Wind turbine No.3	11kV 275kW	
⑦ Wind turbine No.4	11kV 275kW	
⑧ Wind turbine No.5	11kV 275kW	
⑨ Spare No.1		
⑩ Spare No.2		
⑪ Communication Device	Optical Communication Device	Control Monitoring
⑫ Control Device B	for Power Supply	
⑬ Control Device W	for Wind Turbine	

Type of Cable	Guard Pipe	Purpose
SM4C (Optical Cable)	FEP/N30	No.5 Control, monitoring
11kVCET 38mm2(Electric Cable)	FEP/N80	No.5 Electric Power(11kV)
11kVCET 38mm2(Electric Cable)	FEP/N80	No.4 Electric Power(11kV)
11kVCET 38mm2(Electric Cable)	FEP/N80	No.3 Electric Power(11kV)
11kVCET 38mm2(Electric Cable)	FEP/N80	No.2 Electric Power(11kV)
11kVCET 38mm2(Electric Cable)	FEP/N80	No.1 Electric Power(11kV)
SM4C (Optical Cable)	FEP/N30	No.1 Control, monitoring

Figure 2-34: System Diagram of the Project

Wind Power Generation Single-line Diagram

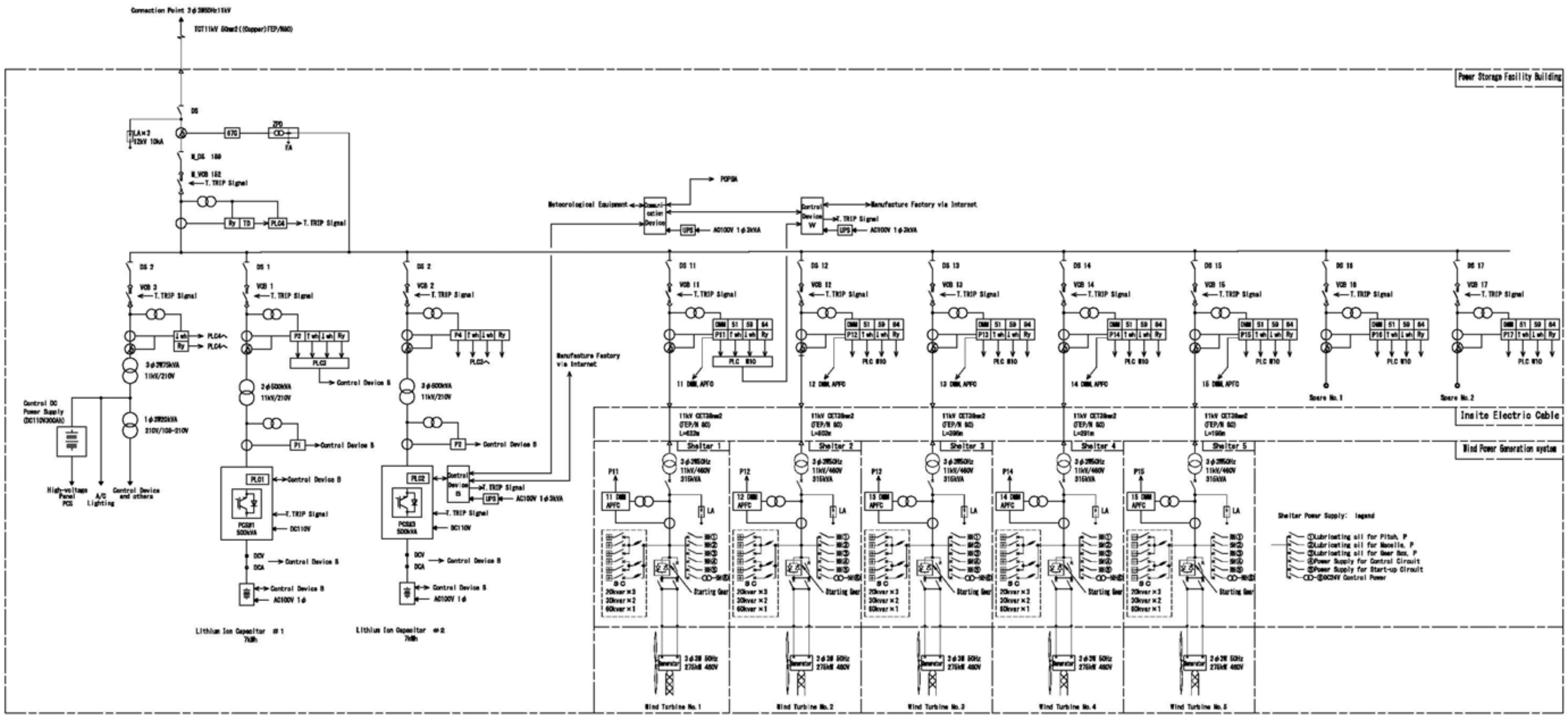


Figure 2-35: Single Line Diagram

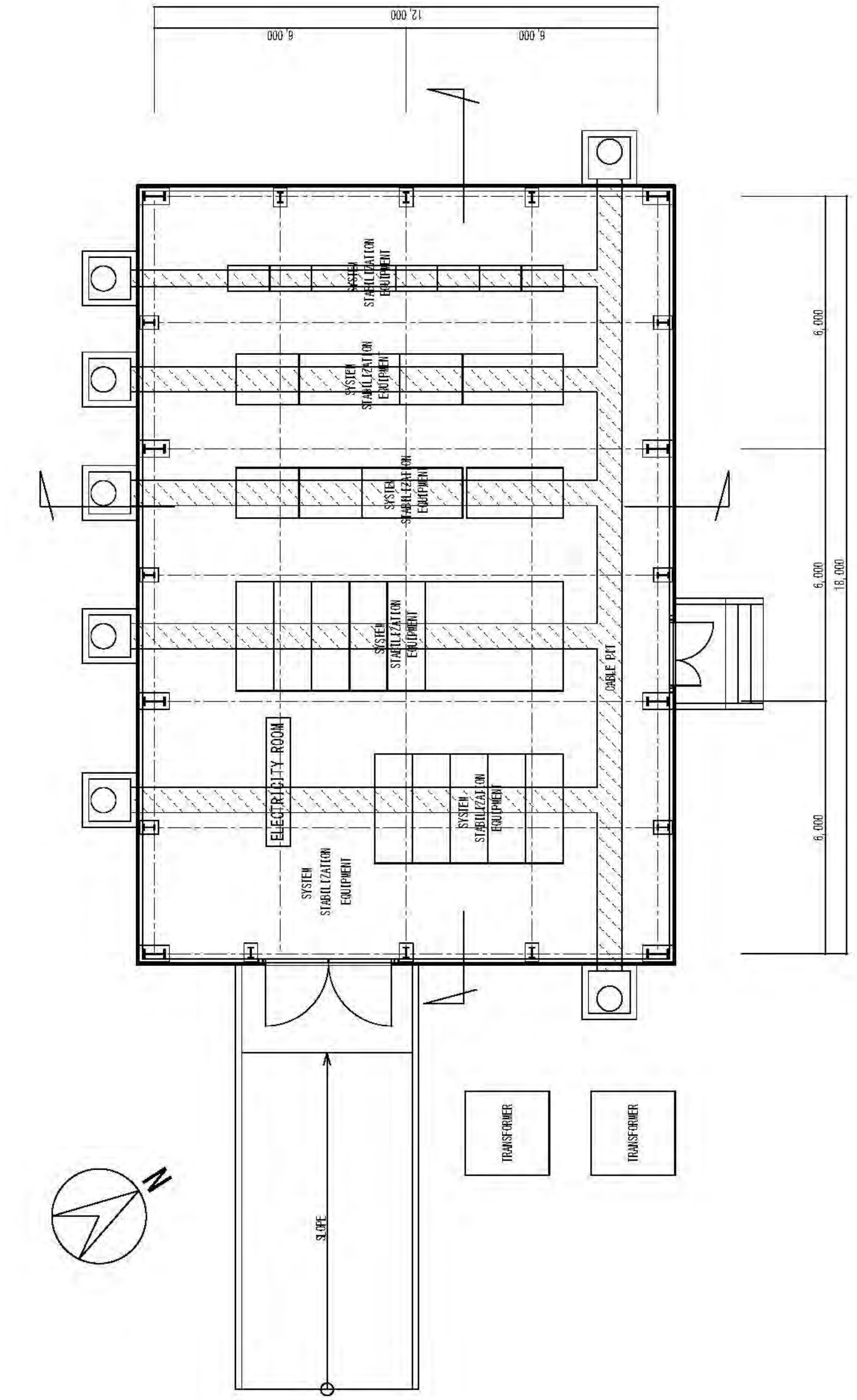


Figure 2-36: Plain View of Power Storage Facility Building

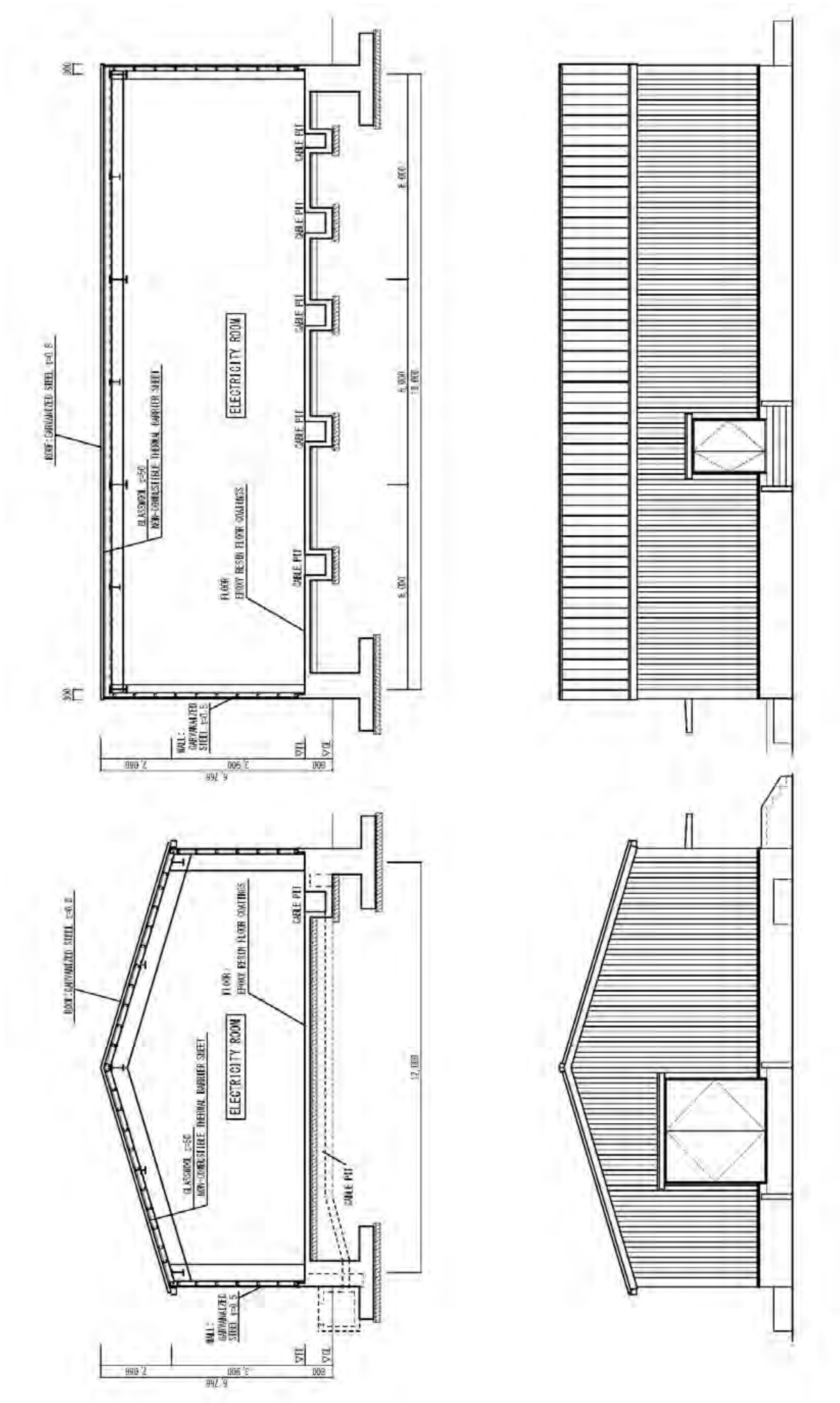


Figure 2-37: Closs Section of Power Storage Facility Building

Route Plan of Communication Line

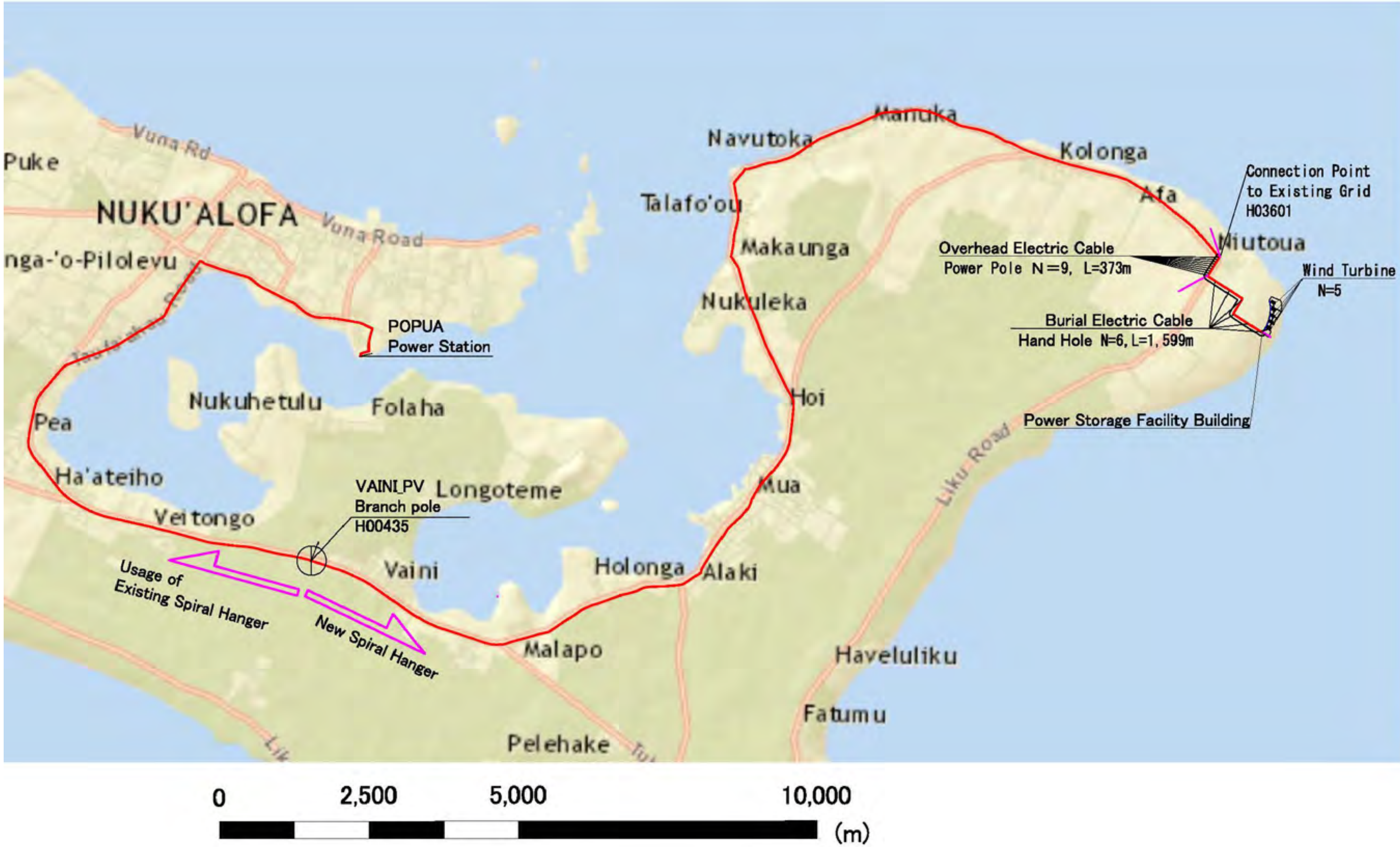


Figure 2-38: Route Plan of Optical Cable

2-2-4 Implementation Plan

2-2-4-1 Implementation Policy

The Project will be implemented based on the exchange of notes (E/N) concluded between Tonga and Japan and the subsequent grant agreement (G/A) concluded between Tonga and JICA. The basic and special points for performance of this project are shown below.

2-2-4-1-1 Project Implementation Agency of Tongan Side

TPL, the implementation agency of the Project, needs to be in charge of maintaining the facilities after achievement of the Project.

Moreover, TPL should be in close contact with the Japanese consultant and the contractor to proceed smoothly with the business, and needs to select counterparts who will be in charge of the abovementioned and Project related work.

The selected counterparts of TPL have to explain the Project concept to the relevant staff of TPL, relevant organizations and residents, and raise their understanding to promote cooperation with the Project.

2-2-4-1-2 Consultant

Japanese consultant which is recommended by JICA for procurement and construction of the Project will conclude a contract about design and supervision with TPL and will design, procure and supervise the Project. Moreover, the Japanese consultant will also make a tender document(s) and carry out the tendering on behalf of TPL.

2-2-4-1-3 Contractors

In accordance with a framework of Japanese Grant Aid, Japanese contractors chosen by Tonga through open tendering will carry out procurement of materials and the construction of the facilities required under the Project. Moreover, after the completion of the Project related construction it will be necessary on a continuing basis to have after-sales service that includes dealing with break-downs and a supply of spare parts. Such matters should be fully taken into consideration when stipulating the requirements (in the tender contract) for the post-Project completion system of communication.

2-2-4-1-4 Necessity of Dispatching Japanese Engineers

This project includes laying optical cables and the additional construction of SCADA in order to operate the 1.3MW wind power station, its materials and storage batteries including buildings they are housed in.

These will be constructed by different groups, so the groups have to carry out construction cooperatively. Moreover, these works are carried out at the same time, and the site supervisor should be dispatched from Japan in order to manage the whole construction consistently.

2-2-4-2 Implementation Conditions

2-2-4-2-1 Access Conditions

The road from Nuku’alofa Port to Niutoua is covered by asphalt, but it will be necessary to construct new access roads due to rough road conditions from Niutoua to the site. When long materials like wind turbine blades or towers are transported, the Project may have to move impediments like traffic signs or electric power poles. In some cases the Project needs to plan the construction schedule taking into account renovation of the port or roads.

2-2-4-2-2 Points for Construction

The New Zealand report confirmed that at a depth of roughly 2.5 m underground the bed rock is composed of limestone and there is adequate bearing power (N value is over 50). However, in the case that a turbine with a tiltable tower (in the event of a storm/cyclone to prevent damage) is selected, the foundations of the wind turbine will need five anchors to be fixed in place. Therefore, standard penetration tests should be carried out for all of the locations of the anchors to confirm the frictional force.

As for the entrance of the site, the width of the road, grade, curb and the weight limits should be adequately considered. The timing of construction of a prefabricated building (construction-site office), site perimeter fence/wall and electrical work is planned for the same time frame, therefore an adequate time schedule needs to be arranged for each activity.

2-2-4-2-3 Country of Procurement for Equipment and Materials

The materials to be procured in this Project including electric cabling and piping materials are not produced in Tonga and therefore must be imported. Hence, as a principle, all of the materials for the Project other than crushed stone, cement, sand and aggregates for concrete shall be procured from Japan and/or third countries. Moreover, in 2019, the Pacific Games will be held in the Tongan capital Nuku'alofa, and it is presumed there will be a lack of construction materials or inflation of costs for the arrangements of athletic fields, etc. Therefore, we have to carefully consider the present situation of local procurement of the materials.

2-2-4-2-4 Safety Measures

From the view of security, there are not many problems in the project site, but we need to pay attention to theft of the materials and the worker's safety during construction. Hence, Japanese contractors should think of safety measures, for example to set a fence around material yard and/or deploy a guard. Moreover, the wind turbine is so large that we have to take some measures for strong wind, rain, lightning and transporting or installing (raising of towers, etc.) heavy materials.

Wind turbines are naturally installed at sites with strong winds, therefore it is important to make predictions on when work will be possible based on the past data of wind conditions and radar data issued by the Tongan government.

2-2-4-2-5 Tax Exemption

Regarding this Grant Aid Project, tax exemption will be applied in accordance with Exchange of Notes. Contractors of the Project have to submit an application with the necessary documentation such as a copy of Bill of Landing and the list of materials to Aid Management Division under the Ministry of Finance and National Planning through Procurement Officer of TPL for acquiring tax exemption when the contractor's materials arrive at Nuku'alofa Port.

At the same time, the copy of the documentation should be submitted to the Ministry of Revenue and the contractors have to acquire an agreement of both the Ministry of Revenue and the Ministry of Finance and National Planning before the documentation is signed. After the signed documentation with the list of materials is submitted to Customs, the contractors do not need to pay import taxes (namely, no refund process is necessary) on the materials.

2-2-4-2-6 Transport

Normally materials delivered by ship to Tonga pass through Customs in Nuku'alofa Port. As mentioned before the tax exemption is applied, but the cargo-handling-fee should be calculated as a part of the transport cost. As for long materials like wind turbine towers or blades, when they are transported on land, impediments such as the width of the road or sign posts should be taken into consideration and careful planning is necessary. Moreover, there are no cranes in Tonga capable of carrying the heavy weights required in the Project, so the contractors need to prepare other measures like a ship with cranes or movable cranes. Additionally,, the wrapping of materials should be sufficiently durable for the long-haul transport from Japan, the handling of the materials upon landing, the transporting on land and the storage.

2-2-4-2-7 Consideration for Procurement of Equipment and Materials

Local contractors are deemed to have the necessary capacity to implement the Project according to the specifications and necessary scale; therefore, they are to be actively employed under the supervision of Japanese engineers.

The necessary materials of the Project are generally procured locally since the materials are inexpensive when compared to market costs. However, some materials which cannot be bought locally or materials with issues in quality and transport shall be procured from Japan.

2-2-4-3 Scope of Works

The following table shows the aspects of construction to be borne by the Japanese and Tongan sides.

Table 2-17: The scope of work to be borne by the Japanese and Tongan sides

No	Item to be borne	Japan	Tonga
1	Commission based on bank arrangement		
	(1) Issuance of Authorization to Pay (AP)		○
	(2) Various expenses related to the bank procedure		○
2	Procedures for Environmental and Social Consideration		○
3	Securing the site, removing trees, leveling, removing obstacles		○
4	Acquisition of building permit		○
5	Equipment procurement		
	(1) Wind turbine generator system	○	
	(2) System stabilization system	○	
	(3) Control device	○	
	(4) Materials for electrical facilities	○	
	(5) Spare parts and materials for maintenance	○	
	(6) Building for power storage system	○	
	(7) Fence		○
	(8) Street light	○	
	(9) Lavatory		○
	(10) Guard station		○
6	Infrastructure		
	(1) Electricity		
	① Procedure for grid connection		○
	② Construction of transmission lines and incidental facilities	○	
	③ Circuit breaker, transformer, in-site wiring	○	
	(2) Water supply and drainage		
	① Water supply on site		○
	② Drainage on site		○
	(3) Road		
	① Road in the site	○	
	② Road of out site, access road		○
	(4) Furniture / Fixtures		○
7	Transportation & Customs		
	(1) Marine transport	○	
	(2) Customs clearance at unloading port, tax exemption		○
	(3) Transport from unloading port to project site	○	
8	Tax exemption procedure (tariff, VAT, etc.)		○
9	Permission, procedures and costs necessary for immigration and stay of related person of the Project		○
10	Proper use of project equipment		○
11	Burden of expenses for related work not included in grant aid		○

Source: The study team

2-2-4-4 Consultant Supervision

In compliance with Japanese Grant Aid policy, the consultant shall organize a consistent project team for actual design, management of construction and procurement based on the general design in the previous investigation, and shall plan smooth work.

The consultant will arrange at least one engineer on site at the procuring and constructing stage. Moreover, Japanese experts will oversee the materials of manufacturing inspection and departure inspection so as to prevent trouble after the materials arrive.

2-2-4-4-1 Basic Policy of Management of Construction and Procurement

The consultant is basically supposed to manage and instruct the contractors on site to carry out construction safely and verify the quality, present form of the building compared with the original design and the due date of procurement. It will be important to complete procurement and construction within the individual work schedules for each task so as to complete the entire Project within the overall project timeframe.

Moreover, it will also be important to keep up to date on progress of the items to be borne by Tonga. The contents of the management are various, i.e. procurement, temporary construction, foundation, building, equipment and interior work, etc. Therefore, the consultant shall communicate and cooperate with the residents and contractors, and related Ministries of Infrastructure to manage the procurement and construction properly. The main points of construction management are shown below.

(1) Schedule Management

The contractors have to check actual progress, either weekly or monthly, in comparison with the schedule indicated in the contract. If it seems the schedule will be delayed, the consultant should warn and instruct the contractors to submit countermeasures and urge them to take the measures to complete procurement and work until the deadline. The main items for checking the progress are shown as follows:

① Completion and Interim Inspection including Inspection in Factory
② Checking materials delivered to the site such as wind turbines or storage batteries, etc.
③ Checking temporary work and preparation of heavy equipment
④ Checking actual working days of engineers, technicians and workers in comparison with the planned working days

(2) Safety Management

The consultant will ensure—through discussions and cooperation with the contractors—site safety to prevent accidents on site and accidents to third parties from happening during the construction. The points of safety management are shown as follows:

① Determining safety regulations and the person(s) in charge
② Holding a regular safety management meeting
③ Preventing the accidents from happening through regular checks of the heavy equipment
④ Selecting a proper route for the construction vehicles and heavy equipment, and making sure workers drive at slow speeds.
⑤ Taking some measures to ensure benefit packages and encourage workers to take days off.

(3) Supervisors

Regarding the contract, Japanese contractors shall employ local contractors for building facilities and installing the wind turbines. Therefore, the Japanese contractors should dispatch engineers who have similar work experience overseas. This way the local contractors can thoroughly carry out time, quality and safety management.

2-2-4-5 Quality Control Plan

Supervisors of the consultant will confirm whether the condition and quality of the materials procured and provided by the Project match the specifications and the design of the contract in accordance with the items below. If the quality and condition does not meet the required level, the consultant should request the materials be modified, changed, repaired or otherwise .

① Inspecting the specification and the design of the materials
② Inspecting the results of the inspection report of factories
③ Inspecting the way of packing, transporting and storing
④ Inspecting the working drawing for heavy equipment and the installation manual
⑤ Confirming the inspection manual, the way of trial operations and arrangement of equipment
⑥ Overseeing installation of wind turbines and auditing trial operations, arrangements and inspections.
⑦ Inspecting the actual form of the constructed and installed items compared with the original design and the working and production drawings
⑧ Inspecting completion drawings

2-2-4-5-1 Concrete

(1) Concrete mix design

It is necessary to determine the concrete mix design for each nominal strength through kneading tests. As for concrete mix design, the average compression strength of test pieces must surpass a target strength which is set by each nominal strength, and the slump should be within a permissible range. The target strength is to be the nominal strength plus the standard deviation.

Concrete compression test is supposed to be carried out in a laboratory of the concrete manufacturer or on site. Test pieces are picked up on site every pour of 100 m3 or less. Six test pieces are collected at once, and three of them are to be compressed seven days after pouring (of the concrete) and the others are to be compressed 28 days after pouring.

(2) Concrete manufacture

There are some ready-mixed-concrete manufacturers in Tongatapu so it is possible to purchase ready-mixed-concrete in Tongatapu. Therefore, all of the concrete will be procured from the manufacturers and be transported to the site.

(3) Slump test

Slump test shall be carried out for every concrete pour. The permissible range shall be within ±2.5cm.

(4) Concrete compression test

The concrete compression test shall be carried out in a laboratory of a concrete plant company. Test pieces are collected every pour of 100 m3 or less and there are three pieces for every batch.

(5) Reinforced steel bars

To verify the strength of reinforced steel bars a tensile test must be carried out for every diameter used.

(6) Aggregates for concrete

Aggregate test for fine and coarse aggregates should be carried out to confirm the quality. All of the aggregates in Tonga are limestone which were confirmed to have the required strength. Therefore, it will be possible to use the limestone as aggregates in the Project.

(7) Bearing Capacity of Soil and frictional force around anchors

The New Zealand report confirmed that at a depth of roughly 2.5 m underground the bed rock is composed of limestone and there is adequate bearing power (N value is over 50). However, in the case that a turbine with a tiltable tower (in the event of a storm/cyclone to prevent damage) is selected, the foundations of the wind turbine will need five anchors to be fixed in place. Therefore, standard penetration tests should be carried out for all of the locations of the anchors to confirm the frictional force.

2-2-4-6 Procurement Plan

2-2-4-6-1 Construction Materials

The next table shows the countries involved with procurement for this project. As for the wind power station and the power system stabilizer, system integration of these will be considered, and it will be necessary to bring them from Japan in order to design and compose the system.

Moreover, if the procurement items are to be imported from Japan, we need to wait for development of the fixed-type wind turbine (that is capable of withstanding cyclone winds as strong as for the tiltable type), though competitiveness can be guaranteed since there are multiple makers of such systems and facilities.

Besides, Tonga wishes to import from Japan because of satisfactory experience with operations and after-sales services, and most other materials are to be procured from Japan or third countries because they are not manufactured in Tonga. However, some construction materials like crushed stone or sand which can be purchased in Tonga are to be procured locally.

As mentioned above, the materials, excluding aggregates of concrete, are supposed to be procured from Japan or third countries.

Table 2-18: Procurement of construction materials

Equipment and materials	Country of Origin		
	Tonga	Japan	Third countries
<Main Equipment>			
1. Wind turbine		○	
2. System stabilization system		○	
3. Instrumentation equipment, transformer		○	
4. Materials for electrical facilities		○	
5. Spare parts and materials for maintenance		○	
<Equipment and Materials for Construction Work>			
1. Fresh concrete	○		
2. Cement	○		
3. Sand and gravel	○		
4. Reinforcing bar		○	
5. Steel beam		○	
6. Interior and exterior materials, joinery		○	
7. Air conditioning		○	
8. Light fixture		○	
9. Electric cable		○	

Source: The study team

2-2-4-6-2 Construction Machinery

General construction equipment such as backhoe, tamper, and concrete mixer are to be leased locally because it is more reasonable from the viewpoints of cost and time of transport. However, trailers for the wind turbines and large cranes for blades and nacelles cannot be procured locally so they are supposed to be procured from Japan or third countries.

2-2-4-6-3 Transporting and Packing Plan

It will take about a month to transport materials from Japan, and it takes two days for miscellaneous procedures in Port, after that it will be transported from Queen Salote Wharf (Nuku’alofa) Port for 35 km to the project site. Therefore, the necessary days for transporting and packing have to be considered in the planning.

2-2-4-7 Operational Guidance Plan

The wind power station (1.3 MW), electricity storage facility (lithium ion capacitor; 500kW) and data management system are relatively large and instructions for initial operation after construction shall be carried out by Japanese contractors as shown below.

2-2-4-7-1 Initial Operation Guidance

Initial operation guidance for transferring the operating and maintenance skills for the facility of the Project will be carried out for TPL staff after the trial operation.

TPL staff have basic skills for maintenance of the solar power station and its system. Moreover, the micro-grid system and storage batteries installed from Japan are also operated and maintained. However, this will be the first time a wind power station of megawatt scale will be connected to the Tongan grid system. For this reason, they have to get the necessary initial instructions again regarding data management system and storage batteries.

Therefore, during construction and trial operations, engineers from the wind turbine manufacturer(s) will train the Tongan engineers about the whole system and operations and maintenance skills.

Moreover, training operations of individual essential gauges for maintenance shall be carried out with the aim of ensuring effective operation of the installed wind power station.

(1) Term and location for practicing and training

- Lecture: for about a week after trial operations in Tonga
- Training: for about three weeks after trial operations in Tonga

(2) Instructor

Trainers are the engineers who are in charge of installing the power station facilities and trial operations and are dispatched from Japanese manufactures of the turbine and storage batteries.

(3) Trainees

TPL has to select trainees directly in charge of operations and maintenance. The list below shows the type of trainees. Therefore, TPL is supposed to select the trainees before finishing the trial operation of wind power station.

- General engineer: 1
- Operation management staff
  - Electrical engineer: 1
  - Mechanical engineer: 1
  - Electricians: 2
  - Mechanics: 2
  - subtotal :6
- Maintenance Staff
  - Electric engineer: 1
  - Mechanical engineer: 1
  - Electricians: 2
  - Mechanics: 3
  - subtotal: 7
  - total: 13

(4) Contents of Training

The initial operational training will mostly be conducted at the power station site, as well as some classroom lectures. Mechanics and electricians should have adequate knowledge about the facilities for maintaining the wind power station and the storage batteries.

The facility of this project is composed of three systems: wind power station, storage battery and data management system. The instructor gives training on the roles, components and electric features of the systems for initial operations.

TPL has already acquired some basic skills and knowledge of equipment and devices to ensure stability of the power system, including use of a micro-grid system (solar photovoltaic project), but this project is about wind power and the technology for system stability is different from each system, so the training will begin again from the basics.

2-2-4-8 Soft Component (Technical Assistance) Plan

2-2-4-8-1 Background of Soft Component

Tonga is depending on the diesel power generation for most of its power supply by using imported fuels because of geographical conditions as an island nation. For this reason, Tonga is signifficantly influenced by international variation of crude oil cost, and it is very weak in the view of energy security. To overcome this situation, Tonga plans ‘‘Tonga Energy Road Map, TERM’’ that aims for 50 % of power supply to be converted to renewable energy by 2020 and reduction of emission greenhouse gas.

This Project provides the wind power generation system (output power:1.3 MW) and power storage facilities in order to interconnect the power system at Niutoua, which is the target site located in the northeast of Tongatapu Island.

This soft component plan is about the technical assistance which aims to develop the skill for operation and maintenance of the wind power generation system with the existing electric facilities in order to reduce the fuel consumption and supply stable power through renewable energy.

(1) The current situation of operation and maintenance for the existing electric facility

A 1.3 MW capacity solar power system interconnected with the existing electrical grid had already been installed by New Zealand in 2012 in Tongatapu. TPL entrusted the maintenance to a private New Zealand company for five years. As a result, TPL could not accumulate the maintenance skill of solar power system.

In response to this, Japan carried out the project, “Introduction of a Micro-Grid System with Renewable Energy for the Tonga Energy Road Map” to improve the operation and maintenance skill by soft component and to install more renewable energy. As a result of this project, a maximum output 1.0 MW solar power system, power storage and micro-grid system including SCADA were installed, and the ratio of diesel generation reduced to 93 %.

Meanwhile, TPL had installed a compact tiltable wind power system (output power: 11 kW) by itself and it directly connects to a low voltage power grid without power storage. To avoid the breakdown of the wind turbine when the cyclone comes close to Tongatapu island, TPL staff are trained and organised to tilt the wind turbine.

(2) Background of Soft Component

In this Project, installation of the storage batteries and charge-discharge control system were planned because TPL needs to limit as much frequency of the existing power system and variation of voltage as possible, and we will install the lithium Ion Capacitor, LIC, for compensation of the short-term variation of voltage.

The previous project, ‘The Project for Introduction of a Micro-Grid System with Renewable Energy for the Tonga Energy Road Map’ installed a lithium ion capacitor (LIC) and TPL has been transferred skills for maintenance of LIC.

However it is necessary for Japan side to support more operation and maintenance skills to control the existing diesel generator, the new wind power station and storage batteries because this plan installs the wind power station of over 1.3 MW.

In response to this situation, soft component of this project aims to support a smooth start up operation and to have TPL use the materials of grant aid properly, and Japan will transfer operation and maintenance skills of wind power station and skill of control of diesel generators to generation department and distribution department of TPL. In addition, skills regarding the system operation and treatment of accidents shall also be transferred.

The skill for handling the wind power station are currently a little beyond the ability of the present system of TPL so the soft component should be planned for supporting this situation. The following system has problems.

- Task 1: No experience of operation of middle-size-wind power station

As mentioned before TPL has already operated a compact wind power station that is tiltable. However, this wind power station has only a wind turbine which connects directly to distribution electric line without a system security facility. Therefore, this is the first time of installation of a megawatt grade of wind power station with system security facility.

Comparing wind power and solar power, wind power is more effective as renewable energy because it generates for 24 hours in principle. However, it is dependent on wind speed and an intense variation of output from 0 % to 100 % or from 100 % to 0 % may sometimes occur. Hence the operational skill for minimizing the influence to the wind power system with comprehension of output features are required.

- Task 2: No experience for operation of solar power station and wind power station at the same time.

As mentioned before, TPL has already operated the compact wind power station which is tiltable. However, this wind power station only has a wind turbine which connects directly to distribution electric line without a system security facility. Therefore, this is the first time for installation of a megawatt grade wind power station with a system security facility.

2-2-4-8-2 Objective of Soft Component

Soft component aims are as follows. The sustainable positive effects of this grant aid will occur through the achievement of the soft component.

Objective 1: Smooth operation and maintenance.

Objective 2: Appropriate output control of generator according to operating status of wind power station and solar power station.

2-2-4-8-3 Output of Soft Component

Output of the soft component for building up operation and maintenance system are set as follows.

Output 1-1: Correspondence of wind power generation at the time of cyclone is efficiently implemented through cooperation with related organizations.
Output 2-1: Appropriate operation control of the wind power station will be monitored by the data control system.
Output 2-2: Appropriate operation control of diesel generator will be monitored by the data control system.

2-2-4-8-4 Confirmation Procedure of the Output Achievement

The achievement and index of the soft component is supposed to be measured as shown in the following table in order to confirm a variety of necessary skills and the system for smooth start up of the Project under TPL's responsibility.

Table 2-19: Achievement of output

No.	Output	Confirmation item of achievement	Method of confirmation (draft)
Output 1-1	Correspondence of wind power generation at the time of cyclone is efficiently implemented through cooperation with related organizations.	Understand that the staff of TPL moves within a prescribed time through collaboration with relevant organizations and coordinates necessary work	Report of lecture and exercise, manual for work procedure
Output 2-1	Appropriate operation control of the wind power station will be monitored by the data control system.	To control the operation of the wind turbine by grasping the power demand by SCADA and data management system	Report of lecture and exercise, operation manual (draft)
Output 2-2	Appropriate operation control of diesel generator will be monitored by the data control system.	To control the number of diesel generator by grasping the power demand, power output of solar and wind power generation	Report of lecture and exercise, operation manual (draft)

Source: The study team

2-2-4-8-5 Plan of Soft Component Activities (Input Plan)

(1) Coverage of Activity

In order to achieve the outputs, the following activities are carried out for each output.

Output 1-1	⇒	Activity 1	: Communicate and cooperate with relevant organizations
Output 2-1	⇒	Activity 2	: Explanation of operation of existing power generation facilitie:
		Activity 3	: Formulation of operation control manual (draft) (wind turbine
Output 2-2	⇒	Activity 4	: Explanation about system condition in demand
		Activity 5	: Formulation of operation control manual (draft) (DG)

(2) Contents of Activity

Output 1-1: Correspondence of wind power generation at the time of cyclone is efficiently implemented through cooperation with related organizations.

Activity 1: Communicate and cooperate with relevant organizations

In Tonga, information about cyclone is handled by Tonga Meteorological & Coast Radio Services of the Meteorological Department which is under the Ministry of Meteorology, Energy, Information, Disaster

Management, Environment Climate Change, and Communications (MEIDECC). It is necessary to cooperate with MEIDECC and the Meteorological Department, not TPL alone, to handle the wind turbine when a cyclone is approaching.

When a cyclone hits, the information of the cyclone is reported to the TPL from the Meteorological Department through MEIDECC. Then, TPL monitors the wind speed data of the anemometer installed in Niutoua's wind power generation facility. Therefore, building cooperation with MEIDECC and the Meteorological Department is an important factor. It is important for these organizations to understand the operation of wind power generation facilities.

Therefore, the actions to be taken when a cyclone is approaching Tonga will be shared with TPL and related organizations. The cooperation between TPL and relevant organizations will also be explained.

Output 2-1: Appropriate operation control of the wind power station will be monitored by the data control system.

Activity 2: Explanation of operation of existing power generation facilities

The system security facilities in the Project are storage batteries to compensate for a short-term variation of the frequency using LIC. It will be necessary to control the number of diesel generators activated and their ability against load for dealing with mid-term variation of output (10-15 min)

For this reason, it is necessary to confirm the transition of demand of electricity and operation situation of the diesel generator and the solar power, predict how the existing power station will behave after installation of the wind power station against the demand of electricity, and consider how to control the wind power station in advance.

Furthermore, the past data of such situations in Tonga will be analyzed and a control model for the wind power station will be made. After that lectures and training for the TPL staff shall be carried out relating to how the existing power station will behave.

Activity 3: Formulation of operation control manual (draft) (wind turbine)

The training of an operation control of the wind power station shall be performed after Activity 2. At present, the situation that can be considered is how to respond in case the wind turbines will cut out at strong gusts making its output to decline rapidly from 100% to 0%. In this case, the expectation of the time for resistance to the short-term variation of frequency will be about one minute. However, it takes about five minutes for a subsequent response from the CAT diesel generator, so the rapid reduction of output of the over 1.3 MW wind power station causes high resistance against the diesel generator, and it is not possible for the existing diesel generator and the subsequent CAT diesel generator to deal with the electric resistance. Considering the above scenario, it is necessary to set the number of wind turbines which stop when the resistance goes beyond the ability of wind turbines.

As for operation of these wind power stations, Japanese instructors will hold lectures and train TPL staff in charge, and after that they will consider a draft of operation control manual through supervision of the Japanese consultant.

Output 2-2: Appropriate operation control of diesel generator will be monitored by the data control system.

Activity 4: Explanation about system condition in demand

Objective of the Project is to install a wind power station and a system security facility, and it will connect to the existing system. Therefore, operations will be considered not only operation for the wind generator but also for the existing facility, and it will be necessary to take some measures for the operation of the existing facility. Hence, basic theory and the aftermath of the gain of renewable energy are to be lectured on.

Moreover, the variation of demand of feeder power will be grasped by monitoring the systems, and the power demand will be predicted by comparing past records. Also a lecture regarding the operation from renewable energy to diesel generator will be carried out, and a manual for general operation of facility and troubleshooting, including influence of the frequency and voltage of the diesel generator, will be prepared.

Activity5: Formulation of operation control manual (draft) (DG)

For achievement of Activity 4, the Consultant will give lectures on the operation control of the diesel generator because stable power supply shall be required in response to the output variation of renewable energy and the variation of power demand. This will include lectures about trouble shooting, the proper number of wind turbines in relation to output of the diesel generator and the operation style at each time, and a draft of diesel generator operation control manual will be made under the supervision of the Japanese consultants.

2-2-4-8-6 Procurement Method of Implementation Resources

Involved organization for performance of the soft component is shown as follows.

(1) Japanese Consultant

As performing the activities mentioned above, Japanese consultants will manage the overall soft component plan in which they will be responsible for preparation, direction, incorporation and reports. In addition to this, TPL, as a implementation organization, will comprehend how the wind power station, the system security, and the data management system will be operated and maintained in detail, and receive the necessary skill to activate the wind power system appropriately. Furthermore, TPL will recieve skills for stable operation of power distribution system composed by the new wind power station and the existing one.

Japanese consultant will consist of two members who will be dispatched to Tonga and they are experts in the following areas;

Consultant 1: Grid analysis and wind turbine control

Consultant 2: Grid interconnection and diesel generators

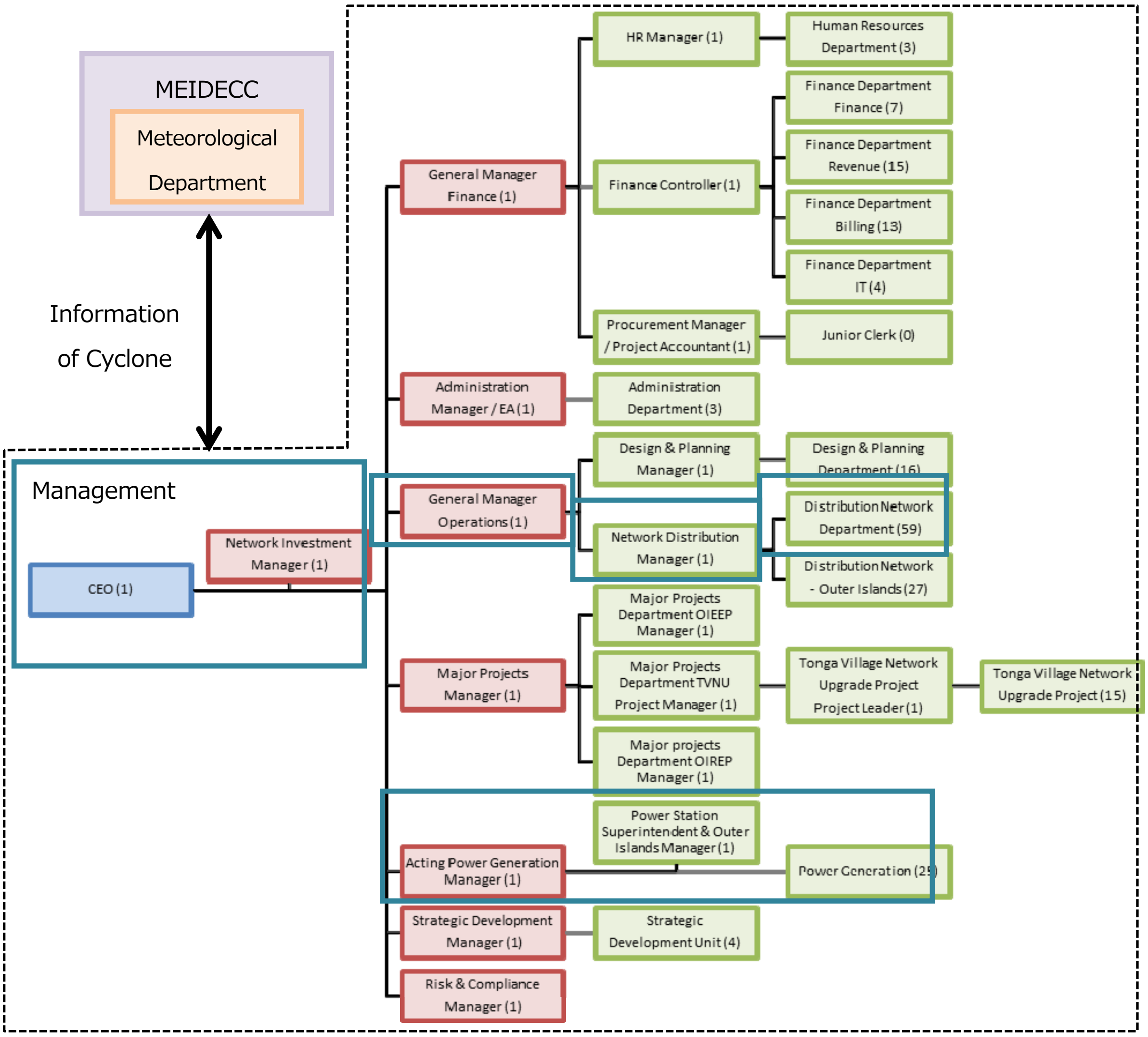
(2) Tongan Side

a) TPL

The provision of responsible trainees, their attendance to the lectures and the full support of TPL as inputs of Tonga will be necessary for smooth performance of the soft component. The consultant will implement transfer of skills to the department and people in the blue box of the following table.

b) Relevant Organization (MEIDECC and Meteorological Department)

The information of cyclone from MEIDECC and the Meteorological Department is important for tilting-returning wind turbines at the time of cyclone occurrence. It is necessary to work under cooperation with these related organizations.



Source: TPL

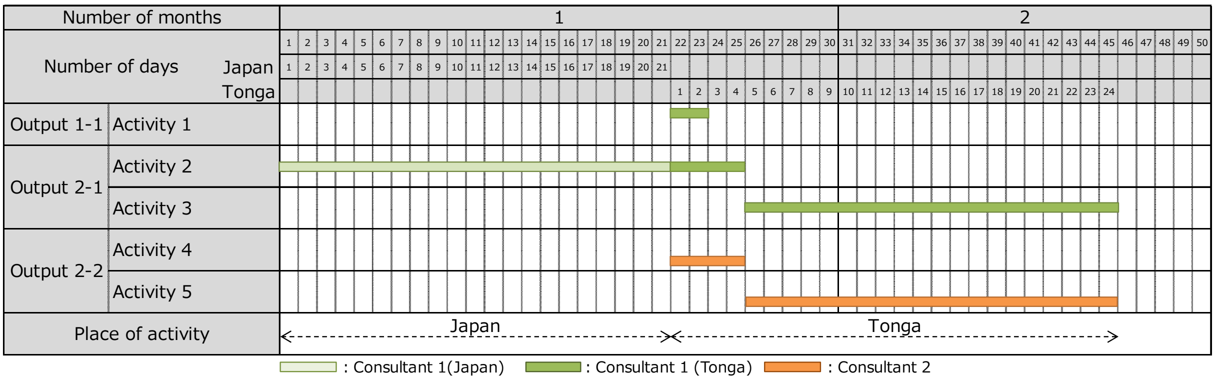
Figure 2-39: Implementation structure of Tongan side

2-2-4-8-7 Implementation Schedule of Soft component

According to the contents of activities mentioned above, Japanese consultants conduct activities in Japan and Toga. The soft component is started after the inspection and handover of the costruction and procurement are completed. Then, after the completion of the soft component, Japanese consultant submits the completion report to Tonga.

The following table shows the implementation schedule of the soft component.

Table 2-20: Implementation schedule of soft component



Source: The study team

2-2-4-8-8 Output for Soft Component

Outputs for the Soft Component are as follows.

At the completion	: completion report (Tonga, Japan)
Activity 1	: minutes of meeting, manual for work procedure
Activity 2	: report of lecture and exercise
Activity 3	: operation manual (draft for wind turbine)
Activity 4	: report of lecture and exercise
Activity 5	: operation manual (draft for diesel generator)

2-2-4-8-9 Obligation of the recipient country

To achieve the objectives of the soft component it is essential to continuously accumulate data of output of power by each generator and data of demand of power by TPL in addition to the outcomes of inputs by the soft component.

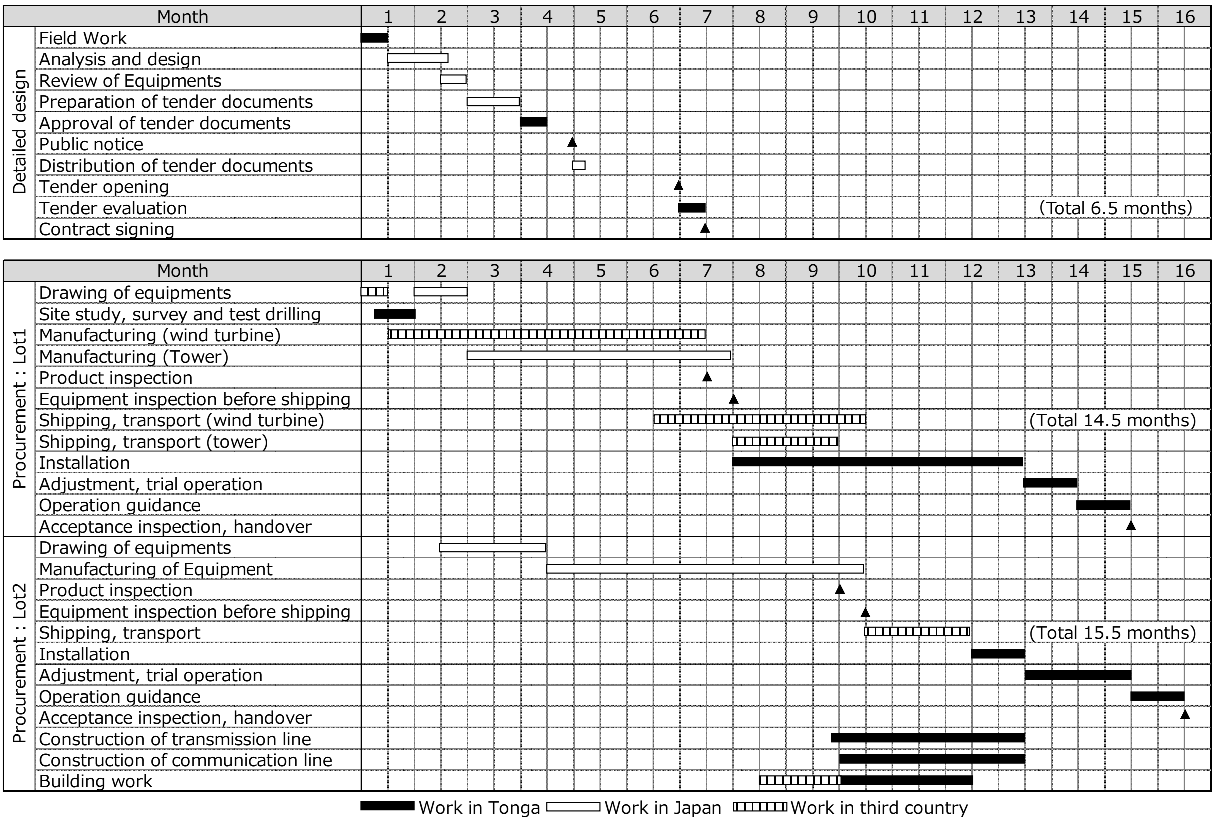
These accumulated data will enable prediction of how to control operation of the diesel generator effectively by power demand, output of solar power and output of wind power in advance, and the renewable energy will be made stably.

If daily allowances, transport allowances and accommodation fees are not accounted for in the budget of the year of the Project, it would be difficult to hold the trainings locally. Hence, it will be significant for TPL to apply for the budget in advance considering with the time schedule of the Project.

2-2-4-9 Implementation Schedule

E/N will be concluded after the approval of the Project by Japanese government, and the Project will commence based on the Japanese Grant Aid Policy. The Project includes three stages: actual design; selection of contractor including making tender document, announcement of the tender, evaluation of the tender; and procurement of materials. The following table shows the Project schedule.

Table 2-21: Implementation schedule



Source: The study team

2-3 Obligation of the Recipient Country

2-3-1-1-1 Securement of Budget for Bank Commission Fees

On implementation of this Project, TPL as the implementation agency (or assigned agency) has to open an account named the Government of Tonga based on the need for banking arrangements. TPL has to cover the cost of various banking fees/commissions related with the banking arrangements. Therefore TPL has to secure the commission fees for the banking arrangements immediately, and must not delay its payments.

2-3-1-1-2 Protocol of Tax Exemption

This Project is conducted within the grant aid framework; therefore, custom duties for Japanese and the persons from third countries involved in the Project, VAT and financial duties are exempted. The implementing agency will have sufficient capacity to arrange the tax exemptions judging from the track record of other grant aid Projects in Tonga. However, there could be delays in gaining tax exemptions because of insufficient preparation, therefore, it is important to share information, including with relevant government agencies, to ensure that the tax exemption work is done in a timely manner. Ministry of Finance is the contact point for tax exemption procedures and together with TPL will conduct such work.

2-3-1-1-3 Securement of Construction Land

In the Project, the project site for wind power station and system security facilities shall be secured. TPL needs to contact the land leasees early and carry out procedures of compensation. Moreover, in the project site, there are various trees, and TPL has to cut down such trees and level the land.

2-3-1-1-4 Securement of Access Road

There are paved roads and leveled non-paved roads in Niutoua Village, the target site. However, it is not possible to access the site at present, hence it will be necessary to expand the road. Tonga government has already secured the area of the access road, so TPL needs to level unleveled sections of the road. Furthermore, it will be necessary to go through the land of leasees which needs to be leveled at the front of the project site.

2-3-1-1-5 Securement of Storage Space for Construction Materials

In the implementation plan, wind power station materials, system security facilities and storage batteries are transported to the site. These materials are large in quantity and implementation periods are necessary for setting equipment and construction. Thus it will be necessary to secure the storage space for construction materials.

2-3-1-1-6 Construction of Steel Fence

Steel fences are needed to prevent the entry of inhabitants and domestic animals to the wind power station and system security facilities. The construction of fences is not within the scope of the Project; therefore, TPL has to construct them. There is a possibility that the implementation schedule will be affected during construction, therefore it is better to correspond to such matters during the test operation period or before operation. Accordingly, TPL has to prepare the budget to construct fences made of steel and to commence this work immediately.

2-3-1-1-7 Securement of Staff for Soft Component

Soft component for the strengthening of the capacity of operation and maintenance for wind power station is conducted by TPL. Therefore, TPL is to make sure that its staff are able to join the soft component activities as the first priority and that it can cover personnel expenses.

2-3-1-1-8 Others

Overview of the burden of Tonga is shown below

① Providing necessary information and data of the Project
② Implementation of the swift unloading of materials at port and proceeding Customs clearance
③ Convenient procedures toward Japanese who send materials or is dispatched
④ The burden of all of the necessary expenses of the Project other than Japanese Grant.
⑤ Verifying the construction and visiting the quality inspection of materials
⑥ Proper Maintenance and operation of the facilities and equipment by Japanese Grant Aid
⑦ Implementation of the environment monitoring
⑧ Providing an office for construction and its land
⑨ Concluding of Maintenance contract with the makers and the burden of purchasing spare parts after one year of completion

2-4 Project Operation Plan

2-4-1 Basic Policy

The most important facilities of the installed wind power station of the Project are wind power generator and the system security facility which stabilizes the variation of outputs of the wind power generator. It will be essential to conserve the facility environment and operation and maintenance: O&M for stable power supply according to the immediate variation of daily power demand for maintaining these facilities.

To maintain the ability and function of the system security facilities and the wind power station, and to supply power stably, it will be necessary to carry out maintenance and prevention of each facility installed in the Project and the existing diesel generator for improving reliability, security and efficiency.

Furthermore, as for the system security facilities and the wind power station, it is cutting-edge technology in Japan and has not yet disseminated much (is still an unfamiliar technology); therefore, Tonga should conclude a maintenance contract for one year after completion of the Project with the manufacturer for appropriate maintenance.

2-4-2 System of Operation and Maintenance

In the Project TPL is in charge of implementation system such as maintenance of equipment and the facility. In particular, the power generation department of TPL is in charge of operation and maintenance of the procured wind power facility and the system security facilities. The department retains good engineers who had graduated from a university in Australia or New Zealand, and it has higher technology than other countries in the South Pacific. The engineers have been operating the existing solar power station and diesel generator without problems. They are obeying a cycle of changing lubricant of diesel engine or a cycle of overhaul to maintain according to plan.

In Tonga, the skill of operation and maintenance has been learned with installation of solar power station and micro-grid system. However, the megawatts grade wind power station of the Project is the first facility for TPL to operate. As for the facility installed by New Zealand, the solar power station, TPL concluded the Asset Management Contract with Meridian Energy Limited of New Zealand, which is in charge of the facility until 2017.

Regarding the Project, Tonga should conclude a maintenance contract with material makers to enable extension of the maintenance period to some extent after finishing the warranty period.

As mentioned above, the skill level of TPL is relatively high, and if initial operation, training of operation, transferring the operation and maintenance skill by Soft Component will be carried out, the facility of the Project can be operated and maintained without problems.

2-4-3 Regular Inspection Items

2-4-3-1 Inspection Items

2-4-3-1-1 Standard Inspection Items of Wind turbine

Daily check and maintenance are essential for using a wind power generator continuously. Moreover, it will be necessary to check rotating parts, receiver of vibration and electrical parts regularly, that is three months after installation and every six months thereafter. Daily visual (indirect) checks should be undertaken, but regular inspections should also include retightening and applying lubricants using tools directly. The practical standard daily check items are shown below

① Blades are normal shape
② Tower and nacelles do not move or vibrate abnormally
③ There are no abnormal appearances.
④ There are no damage of pluc, smoke and odour
⑤ Screws and nuts are strongly tightened
⑥ Monitors demonstrate normally

The practical standard regular inspection items are shown below.

① Checking appearance visually
② Checking distribution and electrical parts
③ Retightening each part
⑤ Checking gear boxes
⑥ Checking YAW Driving device
⑦ Checking Components of a hydraulic system
⑦ Applying or pouring lubricants
⑧ Checking Brake
⑨ Measuring generator and insulation resistance
⑩ Checking device control and operation
⑪ Checking abnormal noise
⑫ Checking monitors
⑬ Checking individual data

Table 2-22: Standard periodic inspection of wind turbine

Inspection item	Points to be checked		Criteria and/or measure	Tools to be used
Visual appearance inspection	Main unit	Stain on blade and nacelle	No small solids such as soil	Visual check, binoculars, etc.
		Damage of blade and nacelle	Replace parts if needed	
		Direction of wind mill and wind	Replace parts if needed	
		Vibrational state	No large vibrations during normal operation	
		Stain on blade and yaw	No oil leakage	
	Tower	Rust and damage of tower	Some discoloration of the surface	
		Rust of joint and anchor of footing	Some discoloration of the surface	
		Fastening status of anchor bolt	Not loose	
	Control unit	Discoloration of device and cable	No burnt deposits or discoloration	Visual check
		Extraordinary smell	Confirm discoloration generated or not	Visual check, smelling
Cable and electric parts	Condition of termination of generator		Insulation process of terminal	Visual check, insulation tape
	Twisting of terminal cable of tower		Less than twice twisting	Visual check, specified tool
	Connection status of control unit		No slack at terminal	
	Indicator of wind vane		Indication of appropriate signal	
	Indicator of anemometer		Indication of appropriate signal	
	Indicator of location sensor		Indication of appropriate signal, adjusting indicator if needed	
	Condition of slip ring		Abrasion of brush	
Retightening of each part	Attaching part of blade		Confirm no loosening and specified bolt tension	Specified tool
	Terminal block			
	Footing of tower, anchor part			
	Attachment part of main unit, etc.			
	Control unit			
Gearbox	Extraordinary noise of bearing		Replace bearing when making noise	Visual check
	Sealing		No oil leakage	
	Oil		Component analysis of oil sample	
	Changing oil		Component analysis of oil sample, replacing filter if needed	
	Proper quantity of oil		Refill oil if needed	
Hydraulic component	Tank of rotor		Adjust quantity and pressure of oil	Visual check, gauge
	Pitch actuator		No oil leakage	
	Tank of nacelle		Adjust quantity and pressure of oil	
Application of grease	Main shaft		Fill (grease) regularly	Grease gun
	Bearing of generator			
	Bearing of gearbox			
	Bearing of blade			
	Structure of yaw		Apply (grease) regularly	Waste cloth
Brake	Brake of rotor		Heating and sliding condition	Visual check, specified tool
	Brakeshoe		No oil leakage	
	Brake friction pad		Confirm pad movement and pad wear is low; replace pad if needed	
Insulation resistance test of generator, motor, etc.	Generator		3MΩ or more	Insulation resistance tester
	Motor of yaw			
	Cable route			
	Control device		1MΩ or more	
Control operation check	Pitch control system		Manual operation of PLC	Visual check
	Yaw control system			
	Brake control system			
Noise check	Hub part		No noise like cracked	Visual check,
	Low-speed side of gearbox		No noise when rotor rotating	
	High-speed side of gearbox		No high frequency noise	
	Tower vibration		Compare with noise at the construction time	
Displayed content	SCADA		No abnormal signal	Visual check, hearing
	Control panel			
Data	Power output (voltage, current, frequency)		Collect data regularly	SCADA
	Generated energy			
	Wind direction, wind speed			

Source: The study team

Other than these items, there will be specified inspection items provided by the wind turbine manufacturer, and TPL shall perform the regular inspection and daily checks in accordance with the items in an operation manual. Furthermore TPL has to deal with any issues that may arise in accordance with the operation manual.

2-4-3-1-2 Standard Inspection Items of System Security Facility

Daily check and maintenance are essential for using an electric facility such as system security facilities and micro-grid systems continuously as well as wind power generator. Inspection items by operator are categorized into three types. System security facilities and electric facilities procured in the Project will be maintained by TPL; therefore, Mainly TPL has to carry out the following daily check, regular inspection and purchasing spare parts.

The three categories are shown below.

① Patrol inside the facility and check abnormal things like noise using the five senses

② Devices are not overheating, bolts are tightened appropriately, surface of the insulator is not dirty; Storage batteries are to be checked when it is not able to be checked by patrol.

③ Scrutiny inspection for keeping accuracy of gauges & Function test of interlock, etc.

Normally, standard inspection of electric facilities are conducted once a year or every two years. On the other hand, scrutinized inspection is carried out once every four years. Furthermore, micro-grid controller, storage batteries, breaker boards, fuse of distribution boards, gauges, the function of relay, the function of inflator, friction of contact points and the expendables shall be replaced in standard inspection or detailed inspection after checking features of the parts and frequency of use.

Table 2-23: Standard periodic inspection of grid stabilization system and electrical equipment

Inspection item	Points to be checked	Patrol inspection	Regular inspection	Detailed inspection
Appearance of facility	Condition of opening/closing indicator and light	○	○	
	Extraordinary noise and smell	○	○	
	Heat-discoloring of terminal area	○	○	
	Damage of bushing and porcelain tube	○	○	
	Rust on enclosure and stand	○	○	
	Temperature anomaly	○	○	
	Fastening status of bushing terminal	○	○	
Operating device and control panel	Indication status of meter	○	○	
	Status of number of operating times display device		○	○
	Wet condition, rust and damage of control panel		○	○
	Status of lubrication and cleaning		○	○
	Fastening status of wiring terminal	○	○	○
	Condition of opening/closing indicator and light		○	○
	Air and oil leakage		○	○
	Pressure measurement before and after operation		○	○
	Condition of operation meter		○	○
	Rust, deformation and damage of spring	○	○	○
	Fastening status of pin		○	○
	Condition of auxiliary switchgear and relay		○	○
	Condition of DC control power supply	○		
Test	Insulation resistance test		○	○
	Contact resistance test			○
	Heater burnout		○	○
	Operation test of relay		○	○

Source: The study team

2-4-3-2 Record and Store the Daily Check

Operating manager records the results of the check and stores them after checking the list above. Storing records helps in grasping the trouble of each device earlier. Moreover, he or she also has to record the following operation situation of the wind power generator and the system security facilities on a daily basis.

① Check the output of the wind power generator, the wind direction and wind speed

② Operating status of the diesel generator

③ Operating status of the storage batteries.

④ System voltage and power frequency

Checking these items helps operating managers to consistently monitor bugs in the wind power generator, PLC, system security facilities and he or she will be able to grasp the abnormal status early.

2-4-3-3 Measurements and Safety Measures

Before the inspection, the operating manager and workers of the wind power station and system security facilities will take the following safety measures.

2-4-3-3-1 Safety measures

The workers have to comply with the safety measures before starting works such as wearing safety uniforms and measurements against electric shock, and they need to obey the following points.

(1) Clothes

Wearing helmets, uniforms and safety shoes

(2) Measurements against electric shock

a) Wearing insulating gloves
b) Using insulating tools
c) Not working when it rains.

2-4-3-3-2 Measurements of insulation resistance

Insulation resistance shall be measured for each device. After the construction of the facility, insulation resistance has to be measured at regular inspection, before starting operation and when an accident happens in order to specify the part with the trouble after restoring the part. The results of the measurement shall be recorded.

2-4-3-3-3 Measurements of Earth Resistance

Earth Resistance at Niutoua must be classified Category A in Japanese standard which means earth resistance has to be under 10 Ω when using metallic outer box for highvoltage.
At regular inspection earth resistance shall be confirmed less than 10 10 Ω by earth resistance meters.

2-4-4 Procurement Plan of Purchasing Spare Parts

The wind power generator is a rotating machine; therefore, oils for friction against the activating parts, exchange of the parts and brush for slip rings in which oils cannot be applied will be needed.

Basically, system security facility and electric equipment do not need to be maintained because there are no activating parts inside them. This means that there will be no breakdown caused by friction; however, it will be possible to break a semiconductor because it consists of an inverter.

The breakdown of the semiconductor mostly occurs at the beginning of the operation. Therefore, if there are no initial defects, it will activate without problems.

Nonetheless, it cannot be said that there will not be any damages because it is necessary to consider the possibility of disaster, human-error and fatigue failure through long-term use, therefore it is necessary to prepare spark parts for activating the system.

2-4-4-1 Cycle of Exchange of Equipment and Contents of Inspection

The provided materials of the Project will deteriorate as time goes by and will lose their function. It will be possible to grasp such conditions by checking wear and tear and measuring insulation resistance. However it is difficult to judge whether most materials such as electric facilities deteriorate.

There is a way to replace parts before breakdown to prevent occurrences and retain reliability of the system.

The following table demonstrates the recommendation cycle of replacement of the materials and the list of inspection method.

Table 2-24: Cycle of replacement and inspection items for major equipment

Parts type	Recommended replacement cycle	Inspection item
<Wind turbine>		
Main unit	15～20 years	Visual judgment
Control PLC	15～20 years	Malfunction
Transformer	20 years or more	Rise in temperature
<System stabilizing and incidental equipment>		
Power conditioner	10～15 years	Malfunction
Cooling fan	10 years or more	Change in air volume and rotational noise
Fuse	7 years or 50,000 hours	Meltdown
Control PLC	15～20 years	Malfunction and drop in performance
Power storage	15～20 years	Malfunction and drop in performance
Air conditioning	10～15 years	Malfunction
Transformer	20 years or more	Rise in temperature
<Circuit breaker>	10～15 years	Malfunction
<Piping, wiring, cable>	10～15 years	Drop in performance

Source: The study team

2-4-4-2 Procurement Plan of Spare Parts

Expendables of the Project mainly are oils for the rotating parts, filters and brushes, which are desirable to be prepared in advance. In particular, the brushes shall be prepared all the time because deterioration of the brushes causes ceasing of functions of the system.

Damages and breakdown of main equipment of power system stabilizer causes ceasing of functions of the system.

When trouble occurs, it is desirable to change the materials or make repairs quickly. For that reason, spare parts shall be stored for swift restoration of the system. However, storing expensive parts or parts in large quantity costs a lot; therefore, it will be necessary to set the proper kind and amount considering features of the materials, economical efficiency and the time needed for restoration,

The following table shows the kinds and amounts of the expendables and repleacable parts of wind turbines and power system stabilizer.

Table 2-25: Spare parts of wind turbine

Types of equipment	Quantity
Slip ring brush (communication)	100
Slip ring brush (power)	30
Brake pad	10
Pitch hydraulic oil 20L	15
Gear box oil 20L	15
Tilting device hydraulic oil 20L	5
Tilting device oil 4L	4
Grease for wire (400 g × 20 pieces)	15
Bearing grease (400 g × 20 pieces)	10
Silicone grease	4
Hydraulic fluid filter	2
Oil filter	4
Aair filter	2

Source: The study team

Table 2-26: Spare parts of cycle of exchange of equipment and contents of inspection

Types of equipment	Quantity
Cooling fan for PCS	2
Electromagnetic contactor for PCS	2
Display panel for PCS	2
Relay unit for PCS	2
Electrolytic capacitor for PCS	2
PCS fuse	2
Control power for PCS	1
Small battery for micro-grid control panel	1
Display/operating panel for micro-grid control panel	1
Control power for micro-grid control panel	1
Cooling fun for micro-grid control panel	1
Lithium ion capacitor	1line
PC for PLC Software Maintenance	1
Maintenance tool	1

Source: The study team

2-5 Project Cost Estimation

2-5-1 Initial Cost Estimation

2-5-1-1 Obligation of Tongan Side

The following cost shall be the burden of the Tongan side.

Table 2-27: Cost borne by the Tongan side

The cost borne by Tongan side: 1,811,100TOP

Contents	Price in TOP
Site acquisition	243,000
Ground leveling, cutting tree	903,000
Fence and gate	65,000
Access road	492,000
Guard station	8,000
Lavatory	5,600
Water supply and drainage	62,000
Procurement of fixtures	500
Commission related to B/A (assumption)	32,000
Total	1,811,100

Source: The study team

2-5-1-2 Condition of Quotation

2-5-1-2-1 Time of Estimation

The Project cost was estimated in September of 2016.

2-5-1-2-2 Exchange Rate

The Project cost was estimated using the following exchange rate.

1 USD = JPY 104.59

1 Euro = JPY 117.17

1 TOP = JPY 48.13

2-5-1-2-3 Construction Schedule

Construction schedule is 15.5 months shown in the implementation schedule.

2-5-1-2-4 Others

The Project cost was estimated according to the Guideline of Japanese Grant Aid.

2-5-2 Operation and Maintenance Cost

2-5-2-1 Elements of Operation and Maintenance Cost

The operational cost of this plant shall be included in the balance sheet of Tonga Power Limited, TPL, because TPL is processing settlement based on the fiscal year and has not currently predicted the estimated income of the planned wind power plant.

In short, TPL encompasses all of Tonga's electricity, so we review their balance sheet from when we will complete the construction, 2020, until 2040, in accordance with the items which TPL should consider.

Table 2-28: Projection of operating revenue by TPL

Unit : TOP

西暦	2017年	2018年	2019年	2020年	2021年	2022年	2023年	2024年	2025年	2026年
Revenue										
Fuel	12,900,000	13,200,000	13,600,000	13,900,000	14,200,000	14,500,000	14,900,000	15,200,000	15,600,000	16,000,000
Savings from Renewables	-1,900,000	-1,900,000	-3,200,000	-3,200,000	-3,200,000	-3,200,000	-3,200,000	-3,200,000	-3,200,000	-3,200,000
Net Fuel Revenue	11,000,000	11,300,000	10,400,000	10,700,000	11,000,000	11,300,000	11,700,000	12,000,000	12,400,000	12,800,000
Non-fuel	22,100,000	22,100,000	22,700,000	23,200,000	23,700,000	24,300,000	24,900,000	25,500,000	26,100,000	26,700,000
Other revenue	3,700,000	3,700,000	3,700,000	3,700,000	3,800,000	3,800,000	3,800,000	3,900,000	3,900,000	3,900,000
Total Revenue	36,800,000	37,100,000	36,800,000	37,600,000	38,500,000	39,400,000	40,400,000	41,400,000	42,400,000	43,400,000
Expenses										
Fuel	11,000,000	11,300,000	10,400,000	10,700,000	11,000,000	11,300,000	11,700,000	12,000,000	12,400,000	12,800,000
Renewables costs	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000
Non-fuel										
Repairs & maintenance	2,200,000	1,900,000	2,000,000	1,900,000	1,800,000	2,100,000	1,700,000	1,800,000	1,800,000	1,800,000
Salary & wages	4,500,000	4,600,000	4,600,000	4,700,000	4,900,000	5,000,000	5,000,000	5,100,000	5,100,000	5,200,000
Materials	400,000	400,000	400,000	400,000	400,000	500,000	500,000	500,000	500,000	500,000
Operating overhead	1,900,000	2,000,000	2,100,000	2,100,000	2,100,000	2,100,000	2,100,000	2,100,000	2,200,000	2,200,000
Administration	3,700,000	3,600,000	3,600,000	3,700,000	3,600,000	3,600,000	3,700,000	3,700,000	3,800,000	3,700,000
Bad debt	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000
Total non-fuel expense	12,800,000	12,600,000	12,800,000	12,900,000	12,900,000	13,400,000	13,100,000	13,300,000	13,500,000	13,500,000
Total expense	23,900,000	24,000,000	23,300,000	23,700,000	24,000,000	24,800,000	24,900,000	25,400,000	26,000,000	26,400,000
Depreciation and non-operating expenses										
EBITDA	12,900,000	13,100,000	13,500,000	13,900,000	14,500,000	14,600,000	15,500,000	16,000,000	16,400,000	17,000,000
Depreciation	6,900,000	7,400,000	7,900,000	8,200,000	8,700,000	9,100,000	9,400,000	9,800,000	10,300,000	10,800,000
Interest	1,200,000	1,200,000	1,200,000	1,100,000	900,000	700,000	600,000	400,000	200,000	200,000
Net profit before tax	4,800,000	4,500,000	4,400,000	4,600,000	4,900,000	4,800,000	5,500,000	5,800,000	5,900,000	6,000,000
Income tax	1,200,000	1,100,000	1,100,000	1,200,000	1,200,000	1,200,000	1,400,000	1,400,000	1,500,000	1,500,000
Net profit after tax	3,600,000	3,400,000	3,300,000	3,400,000	3,700,000	3,600,000	4,100,000	4,400,000	4,400,000	4,500,000
Provision for dividend	1,200,000	1,200,000	1,200,000	1,200,000	1,300,000	1,300,000	1,500,000	1,500,000	1,500,000	1,600,000
ransfer to retained earnings	2,400,000	2,200,000	2,100,000	2,200,000	2,400,000	2,300,000	2,600,000	2,900,000	2,900,000	2,900,000

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Source: The study team

2-5-2-1-1 Item of Revenues

The income of TPL is categorized into fuel, non-fuel and others; however, fuel and non-fuel are both listed under the item of electricity fee. Thus, for the purposes of this project income will be divided into two items, electricity fee and others.

(1) Revenue of Electricity fee

Currently the electricity fee is calculated by the electricity demand amount multiplied by the unit rate. Four types of the estimated electricity could be set by calculating from the conventional rate of diesel.

(2) Others

According to the plan of TPL, the revenue of 'others' is estimated to increase gradually and continue until 2040, and the Project will try to calculate on the basis of these values.

2-5-2-1-2 Item of Expenses

(1) Fuel Cost

Fuel cost is based on the future estimated electric-generating capacity and it depends on diesel expenses. There are four types of the estimated rate of diesel; thus, fuel fees for each type were calculated.

(2) Management Expense of the Renewable Energy

The main management expense of the renewable energy is an outsourcing fee to the permanent guard. TPL estimated it will cost 100,000TOP/y until 2040. The calculation will be carried out on the basis of this value.

(3) Maintenance Expense

Maintenance cost includes the regular exchange of parts and repair of the power plant. TPL's estimates until 2026 will be used.

The estimated cost has some variations, though shows an overall downward trend until 2026. However, it is difficult to determine if the cost will continuously decrease from 2026 to 2040. Therefore, to be on the safe side, we will apply the 2026 cost for this period.

(4) Employment Cost

Employment cost is expected to increase at a constant rate until 2026, and futher, this tendency is expected to continue until 2040. Accordingly, it is assumed that the rate of increase until 2026 would be applied until 2040.

(5) Material Cost

TPL estimated that material costs are increasing at a constant rate until 2026. Accordingly, it is assumed that the increasing rate until 2026 would be applied until 2040.

(6) Maintenance Cost of the Facility

Maintenance cost of the facility is an indirect cost of operating the power plant. It is increasing at almost the same rate until 2026. Accordingly, the maintenance cost of the facility is set assuming that the rate until 2016 will continue to 2040.

(7) General Administrative Expenses

There is some variation in the numerical value of general administrative expenses, but it will gradually increase until 2026; and the estimates are set assuming the tendency will continue until 2040.

(8) Allowance for Doubtful Accounts

The Project applies TPL's estimated value, 100,000TOP/y, for allowance of doubtful accounts up until 2040.

2-5-2-1-3 Earnings Before Interest, Taxes, Depreciation and Amortization

(1) Depreciation

The Project applies depreciation to the existing plant and the planned wind power station.

(2) Interest

TPL estimated the interest expense will decrease to 200,000TOP/per year by 2026. The estimated expense of 2016 is applied for the estimated expense from 2027 to 2040.

(3) Income Tax

Income tax shall be 25% of net profit before tax.

(4) Provision for Dividend

Provision for dividend shall be 35% of net profit after tax until 2040.

(5) Transfer to Retained Earnings

Retained earnings are set as the balance that subtracted provision for dividend from net profit after tax.

2-5-2-2 Calculation of Operation and Maintenance Cost

TPL encompasses all the islands of Tonga including Vava'u, Ha'apai, 'Eua and Tongatapu. However, this project will be carried out in Tongatapu Island, hence the project cost estimation will also be limited to Tongatapu Island.

2-5-2-3 Power Output and Power Demand

2-5-2-3-1 Power Output and Power Demand whole in Tonga

The Project set the annual production and demands of the electricity as shown in the following table. We will calculate the demands of the electricity based on the existing actual achievements. On the other hand, the Project use the value of the loss of energy in the table until 2020. After 2020, the Project assumes that the value of 2020 continues until 2040.

Table 2-29: Power output and power demand whole in Tonga

Item		2010	2011	2012	2013	2014	2015	2020	2025	2030	2035	2040
Power output	kWh/y: past record	51,845	53,160	52,391	53,313	54,561	55,405					
	kWh/y: forecast						55,405	60,808	67,733	74,659	81,584	88,509
Power demand	kWh/y: past record	42,625	44,566	44,731	46,388	47,818	49,165					
	kWh/y: forecast						49,165	55,335	61,637	67,939	74,241	80,543
Energy loss	kWh/year	9,220	8,593	7,661	6,925	6,743	6,239	5,473	6,096	6,719	7,343	7,966
Rate of loss	%	17.78%	16.17%	14.62%	12.99%	12.36%	11.26%	9.00%	9.00%	9.00%	9.00%	9.00%

Source: The study team

2-5-2-3-2 Power Output and Power Demand in Tongatapu Island

The Project sets power output and power demand in Tongatapu Island as shown in the following table for the operation and maintenance cost. Besides power output, the Project uses the value of loss of energy estimated by TPL until 2020. After 2020, the Project assumes that the value of 2020 continues until 2040.

Table 2-30: Power output and power demand in Tongatapu Island

項目		2010	2011	2012	2013	2014	2015	2020	2025	2030	2035	2040
Power output	kWh/y: past record	44,068	45,398	44,939	46,720	47,139	49,004					
	kWh/y: forecast						49,004	54,833	62,222	69,611	77,000	84,389
Power demand	kWh/y: past record	36,615	38,346	38,765	41,123	41,425	43,756					
	kWh/y: forecast						43,756	50,140	56,897	63,653	70,410	77,166
Energy loss	kWh/year	7,453	7,052	6,174	5,596	5,714	5,248	4,693	5,326	5,958	6,590	7,223
Rate of loss	%	16.91%	15.53%	13.74%	11.98%	12.12%	10.71%	8.56%	8.56%	8.56%	8.56%	8.56%

Source: The study team

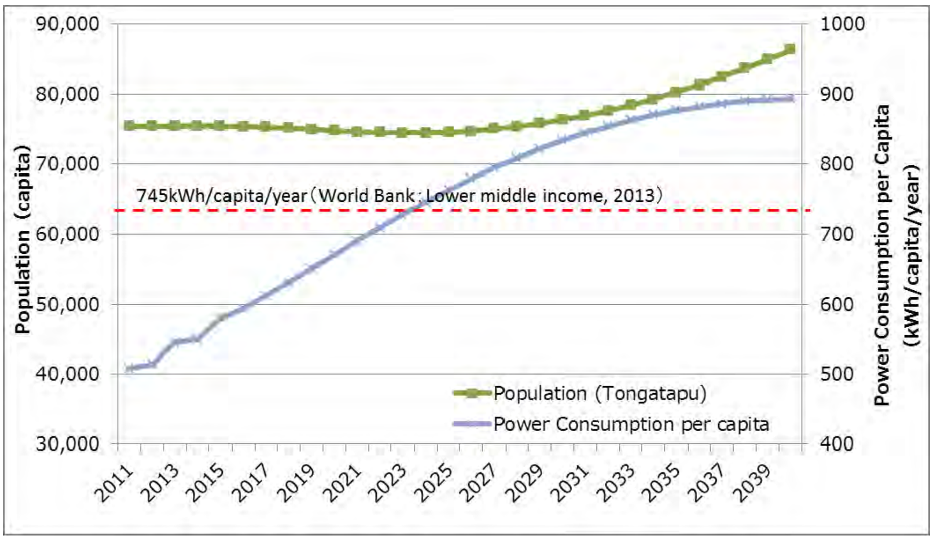
2-5-2-3-3 Future Population Estimates and Annual Power Consumption per Capita

The validity of the estimated demands of electricity until 2040 are calculated by comparison with the annual power consumption per capita by World Bank and by the future population. As for the future population, this project team uses estimates of the population based on the census Tonga carried out in 2011 (estimated value until 2031), to estimate the future population from 2032 to 2040. In addition, estimates of the population of Tonga include all the islands, thus the population of Tongatapu Island is divided by the actual population of 2011.

Table 2-31: Future population and annual power consumption per capita

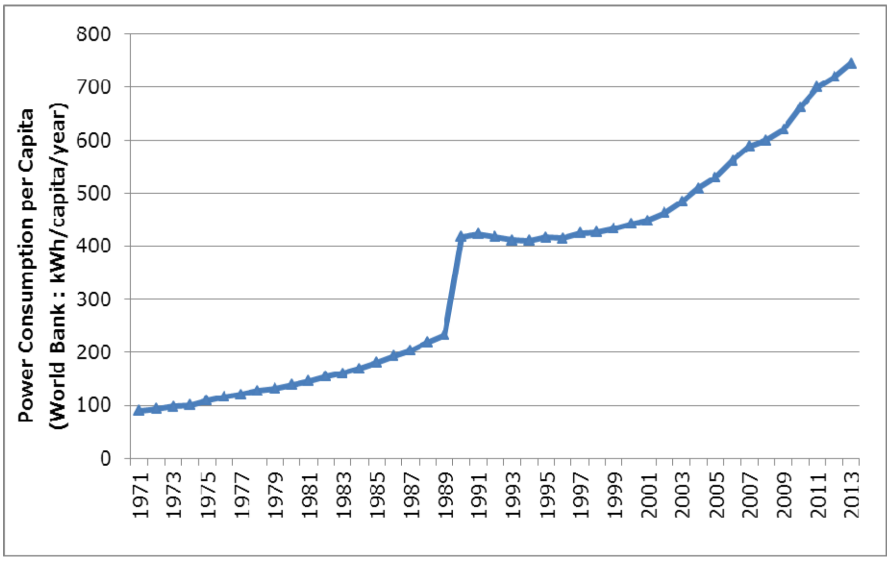
Item	Unit	Past Record					Forecast				
		2011年	2012年	2013年	2014年	2015年	2020年	2025年	2030年	2035年	2040年
Population (Total)	Capita	103,252	103,219	103,302	103,321	103,283	102,430	102,089	104,535	109,908	118,207
Population (Tongatapu)	Capita	75,416	75,392	75,453	75,466	75,439	74,816	74,567	76,353	80,278	86,339
Power Output (Tongatapu)	MWh/y	45,398	44,939	46,720	47,139	49,004	54,833	62,222	69,611	77,000	84,389
Power Demand (Tongatapu)	MWh/y	38,346	38,765	41,123	41,425	43,756	50,140	56,897	63,653	70,410	77,166
Power Consumption per Capita	kWh/capita/y	508	514	545	549	580	670	763	834	877	894

Source: The study team



Source: The study team

Figure 2-40: Future population and power consumption per capita



Source: World Bank

Figure 2-41: Trends of power consumption in low and middle income countries (World Bank)

According to World Bank, earnings in Tonga are categorized into Lower Middle Income. In 2013 Lower-Middle-Income countries consume on average 745 kWh/capita/y. In 2015 Tonga only consumed 580kWh/capita/y but increases in demand in recent years indicates that the demands could catch up with the value of World Bank. Moreover, the consumption rate of World Bank has been going up and the data will probably increase. This project team assumes the increasing rate of electricity after 2030 is not large. Hence, the data in table 3-26 would be valid and we decided to base calculations of operation and maintenance cost on these data.

2-5-2-4 Breakdown of Revenue

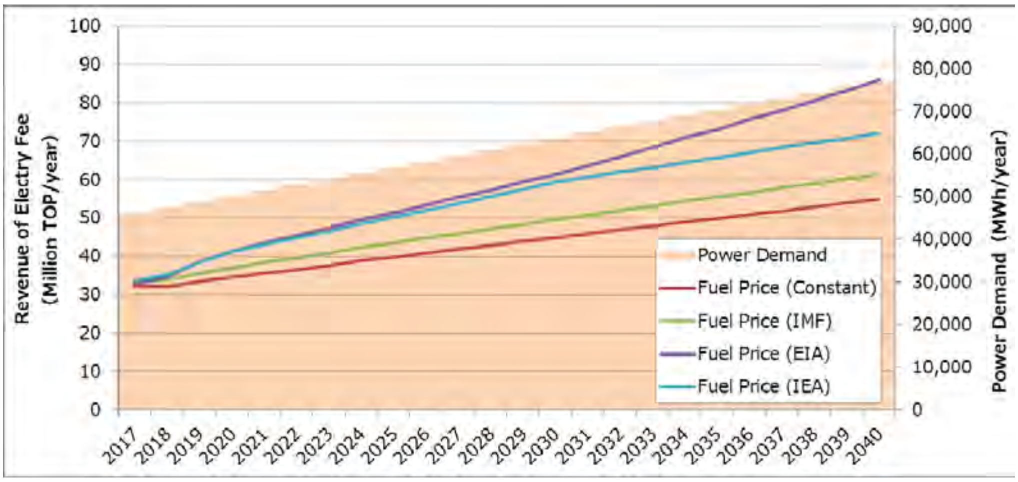
2-5-2-4-1 Revenue of electricity fees

The revenue of electricity fees is calculated from each expense below such as miscellaneous expenses and retained earnings in order to sustainably ensure the cost of maintenance for the planned wind power station. The validity of the revenue is confirmed in 2-5-3 . In addition, the most important estimated rate of diesel is divided into four cases and we need to calculate the revenues for each case.

Table 2-32: Revenue of electricity fees

		2017	2018	2019	2020	2021	2022	2023	2024	2025	2030	2035	2040
Power Demand	MWh/y	46,086	47,438	48,789	50,140	51,492	52,843	54,194	55,546	56,897	63,653	70,410	77,166
Fuel Price (Constant)	TOP/y	32,129	32,148	33,547	34,537	35,612	36,592	37,589	38,946	39,929	44,905	49,901	54,892
Fuel Price (IMF)	TOP/y	33,098	33,835	35,622	37,065	38,512	39,602	40,829	42,404	43,598	49,556	55,486	61,396
Fuel Price (EIA)	TOP/y	32,840	34,582	38,805	41,315	43,591	45,586	47,407	49,521	51,386	61,294	73,019	86,062
Fuel Price (IEA)	TOP/y	33,639	35,267	38,540	41,405	43,125	44,774	46,467	48,545	50,276	59,376	65,772	72,098

Source: The study team



Source: The study team

Figure 2-42: Revenue of electricity fees

2-5-2-4-2 Other revenues

In accordance with the increasing rate of the other revenues until 2026, the revenue in Tongatapu is shown in the following table.

Table 2-33: Other revenues

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2030	2035	2040
Forecast of Tonga (TPL)	3,700,000	3,700,000	3,700,000	3,700,000	3,800,000	3,800,000	3,800,000	3,900,000	3,900,000	3,900,000			
Forecast of Tonga (JICA Team)										3,900,000	4,022,000	4,158,000	4,295,000
Forecast of Tongatapu	3,307,581	3,323,314	3,338,313	3,352,630	3,457,290	3,470,726	3,483,589	3,587,913	3,600,047	3,611,694	3,768,264	3,943,406	4,114,915

Source: The study team

2-5-2-5 Breakdown of expenses

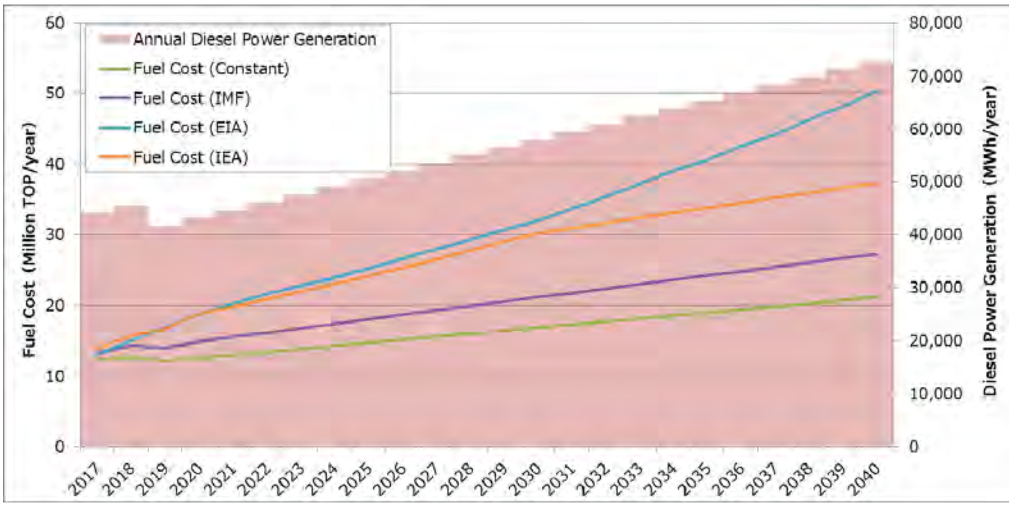
2-5-2-5-1 Fuel Cost

Fuel fee will be based on the future estimated rate of fuel and the production volume of electricity which is made by a generator.

Table 2-34: Fuel cost

Item			2017	2018	2019	2020	2021	2022	2023	2024	2025	2030	2035	2040
Annual Diesel Power Generation		MWh/y	44,268	45,492	41,689	43,166	44,644	46,122	47,600	49,078	50,555	57,944	65,333	72,722
Fuel Cosumption per kWh		L/kWh	0.241	0.242	0.253	0.253	0.253	0.253	0.253	0.253	0.253	0.253	0.253	0.253
Fuel Consumption		kL/y	10,667	11,015	10,554	10,928	11,302	11,676	12,051	12,425	12,799	14,669	16,540	18,411
Unit Price of Diesel Oil	Constant	TOP/L	1.150	1.150	1.150	1.150	1.150	1.150	1.150	1.150	1.150	1.150	1.150	1.150
	IMF	TOP/L	1.240	1.303	1.326	1.358	1.382	1.383	1.394	1.403	1.412	1.443	1.464	1.481
	EIA	TOP/L	1.216	1.371	1.597	1.709	1.788	1.848	1.891	1.926	1.968	2.182	2.453	2.739
	IEA	TOP/L	1.291	1.433	1.574	1.716	1.751	1.785	1.820	1.854	1.889	2.062	2.044	2.027
Fuel Cost	Constant	TOP	12,262,664	12,662,829	12,132,962	12,563,053	12,993,144	13,423,235	13,853,326	14,283,417	14,713,508	16,863,964	19,014,420	21,164,875
	IMF	TOP	13,232,135	14,350,602	13,996,134	14,840,998	15,614,575	16,153,565	16,800,423	17,437,565	18,067,801	21,163,735	24,221,848	27,270,830
	EIA	TOP	12,973,882	15,097,348	16,854,492	18,671,013	20,206,513	21,580,252	22,782,616	23,928,240	25,188,814	32,015,030	40,569,620	50,429,164
	IEA	TOP	13,772,982	15,782,038	16,615,993	18,752,315	19,784,894	20,843,332	21,927,630	23,037,786	24,173,800	30,241,758	33,812,314	37,318,222

Source: The study team



Source: The study team

Figure 2-43: Annual power output of diesel generator and fuel cost

2-5-2-5-2 Management expense of the renewable energy

Management expense in Tongatapu is calculated by the ratio of Tongatapu against the demand of electricity of the entire TPL (100,000TOP/y).

Table 2-35: Management expense of the renewable energy

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2030	2035	2040
Forecast of Tonga (TPL)	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000			
Forecast of Tonga (JICA Team)										100,000	100,000	100,000	100,000
Forecast of Tongatapu	89,394	89,819	90,225	90,612	90,981	91,335	91,673	91,998	92,309	92,608	93,691	94,839	95,807

Source: The study team

2-5-2-5-3 Maintenance Expense

As for maintenance expense, we use the estimated value of TPL until 2016, and applied the value of 2026 for the period 2026 to 2040. The expenses of Tongatapu are obtained by calculating the percentage of electricity demand in Tongatapu in relation to that of the total for Tonga.

Table 2-36: Maintenance expense

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2030	2035	2040
Forecast of Tonga (TPL)	2,200,000	1,900,000	2,000,000	1,900,000	1,800,000	2,100,000	1,700,000	1,800,000	1,800,000	1,800,000			
Forecast of Tonga (JICA Team)										1,800,000	1,800,000	1,800,000	1,800,000
Forecast of Tongatapu	1,966,670	1,706,567	1,804,494	1,721,621	1,637,664	1,918,033	1,558,448	1,655,960	1,661,560	1,666,936	1,686,443	1,707,102	1,724,528

Source: The study team

2-5-2-5-4 Employment cost

Employment cost will be constantly increasing until 2026. Hence, we set the employment cost as follows: the cost of Tongatapu is obtained by calculating the percentage of electricity demand in Tongatapu in relation to that of the total for Tonga.

Table 2-37: Employment cost

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2030	2035	2040
Forecast of Tonga (TPL)	4,500,000	4,600,000	4,600,000	4,700,000	4,900,000	5,000,000	5,000,000	5,100,000	5,100,000	5,200,000			
Forecast of Tonga (JICA Team)										5,200,000	5,555,000	5,958,000	6,361,000
Forecast of Tongatapu	4,022,733	4,131,687	4,150,336	4,258,746	4,458,084	4,566,745	4,583,670	4,691,887	4,707,753	4,815,592	5,204,551	5,650,508	6,094,290

Source: The study team

2-5-2-5-5 Material Cost

Material costs TPL estimated will be increasing until 2026. Hence we set the material cost as follows: the cost of Tongatapu is obtained by calculating the percentage of electricity demand in Tongatapu in relation to that of the total for Tonga.

Table 2-38: Material Cost

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2030	2035	2040
Forecast of Tonga (TPL)	400,000	400,000	400,000	400,000	400,000	500,000	500,000	500,000	500,000	500,000			
Forecast of Tonga (JICA Team)										500,000	579,000	655,000	730,000
Forecast of Tongatapu	357,576	359,277	360,899	362,446	363,925	456,674	458,367	459,989	461,544	463,038	542,473	621,195	699,392

Source: The study team

2-5-2-5-6 Maintenance cost of the facility

Maintenance cost of the facility will be increasing until 2026. Hence we set the cost as follows: the cost of Tongatapu is obtained by calculating the percentage of electricity demand in Tongatapu in relation to that of the total for Tonga.

Table 2-39: Maintenance cost of the facility

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2030	2035	2040
Forecast of Tonga (TPL)	1,900,000	2,000,000	2,100,000	2,100,000	2,100,000	2,100,000	2,100,000	2,100,000	2,200,000	2,200,000			
Forecast of Tonga (JICA Team)										2,200,000	2,301,000	2,425,000	2,550,000
Forecast of Tongatapu	1,698,487	1,796,386	1,894,718	1,902,844	1,910,608	1,918,033	1,925,142	1,931,953	2,030,796	2,037,366	2,155,837	2,299,846	2,443,081

Source: The study team

2-5-2-5-7 General administrative expenses

General administrative expenses of the facility will be increasing until 2026. Hence, we set the cost as follows: the cost of Tongatapu is obtained by calculating the percentage of electricity demand in Tongatapu in relation to that of the total for Tonga.

Table 2-40: General administrative expenses

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2030	2035	2040
Forecast of Tonga (TPL)	3,700,000	3,600,000	3,600,000	3,700,000	3,600,000	3,600,000	3,700,000	3,700,000	3,800,000	3,700,000			
Forecast of Tonga (JICA Team)										3,700,000	3,768,000	3,825,000	3,883,000
Forecast of Tongatapu	3,307,581	3,233,495	3,248,089	3,352,630	3,275,327	3,288,056	3,391,916	3,403,918	3,507,738	3,426,479	3,530,288	3,627,592	3,720,190

Source: The study team

2-5-2-5-8 Bad Debt

Bad debt of Tongatapu is obtained by calculating the percentage of electricity demand in Tongatapu in relation to that of the total for Tonga.

Table 2-41: Bad Debt

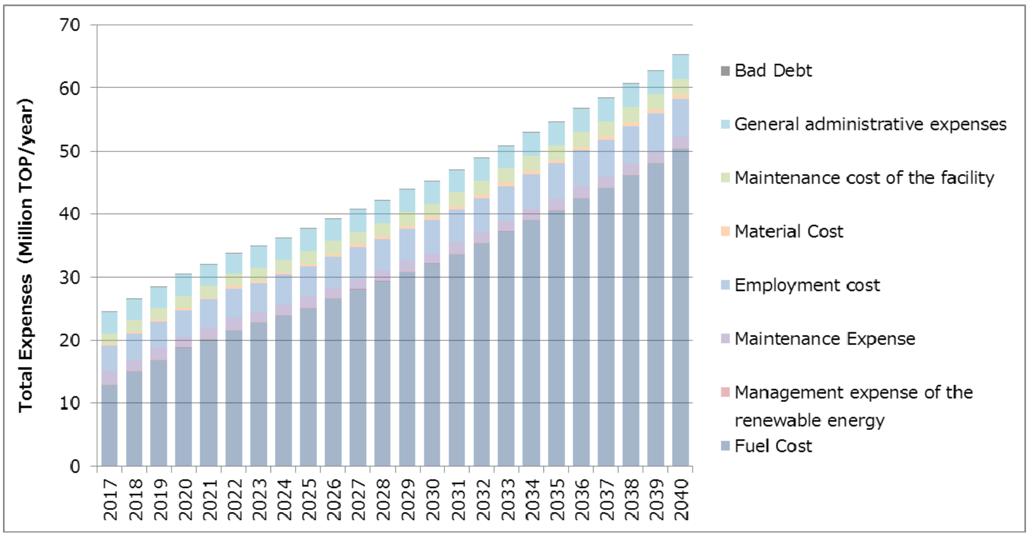
	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2030	2035	2040
Forecast of Tonga (TPL)	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000			
Forecast of Tonga (JICA Team)										100,000	100,000	100,000	100,000
Forecast of Tongatapu	89,394	89,819	90,225	90,612	90,981	91,335	91,673	91,998	92,309	92,608	93,691	94,839	95,807

Source: The study team

2-5-2-5-9 Total expenses

Total expenses shall be calculated on the basis of the aforementioned items.

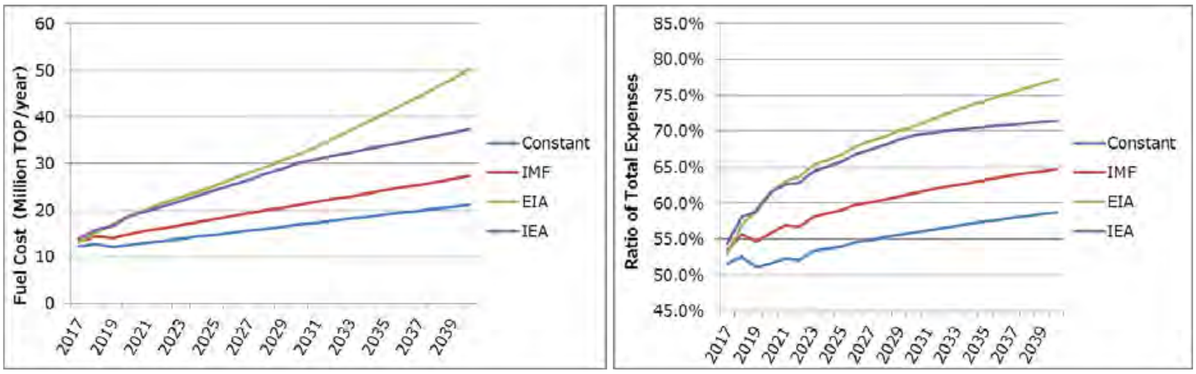
The following figure shows the diesel unit price remains substantially constant until 2040. The greater the ratio of the output by the diesel generator, the greater the demand of electricity and fuel consumption. The percentage of fuel fee was about 52 % in 2017 and will become about 59 % of expenditures in 2040.



Source: The study team

Figure 2-44: Total expenses

The following figure illustrates the percentage of estimated fuel fee and estimated fuel fee of total expenditure. If diesel unit price increases in accordance with EIA's projections, the percentage of the fuel fee would go up by 77 % in the worst case scenario.



Source: The study team

Figure 2-45: Fuel cost of each case, ratio of total expenditure

2-5-2-6 Earnings before Interest, Taxes, Depreciation and Amortization

2-5-2-6-1 Depreciation

(1) Existing facility (TPL's estimate)

The percentage of the existing facilities of the depreciation and amortization expenses will be based on TPL's estimates until 2040, and the percentage of Tongatapu Island will be obtained by calculating the percentage of electricity demand in Tongatapu in relation to that of the total for Tonga.

Table 2-42: Depreciation

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2030	2035	2040
Forecast of Tonga (TPL)	6,900,000	7,400,000	7,900,000	8,200,000	8,700,000	9,100,000	9,400,000	9,800,000	10,300,000	10,800,000			
Forecast of Tonga (JICA Team)										10,800,000	12,399,000	14,487,000	16,575,000
Forecast of Tongatapu	6,168,191	6,646,628	7,127,750	7,430,152	7,915,374	8,311,476	8,617,300	9,015,782	9,507,816	10,001,613	11,616,783	13,739,326	15,880,028

Source: The study team

(2) Wind power plant

The percentage of depreciation and amortization of the wind power plant should be considered to be based on the service life of the plant. However, in estimates for this project, we could consider cut-backs of diesel as offsets to future (wind power) plant upgrade costs. Thus, we will try to grasp how much it will cost to install the plant in each case of estimated fuel fee.

Table 2-43: Depreciation (Wind power plant)

		2019	2020	2021	2022	2023	2024	2025	2030	2035	2040
Wind Power Generation	MWh/y	4,736	4,736	4,736	4,736	4,736	4,736	4,736	4,736	4,736	4,736
Fuel reduction by wind power	kL/y	1,199	1,199	1,199	1,199	1,199	1,199	1,199	1,199	1,199	1,199
Fuel Reduction Cost (Constant)	TOP/y	1,378,322	1,378,322	1,378,322	1,378,322	1,378,322	1,378,322	1,378,322	1,378,322	1,378,322	1,378,322
Fuel Reduction Cost (IMF)	TOP/y	1,589,981	1,628,241	1,656,406	1,658,678	1,671,541	1,682,692	1,692,544	1,729,751	1,755,800	1,775,961
Fuel Reduction Cost (EIA)	TOP/y	1,914,695	2,048,441	2,143,522	2,215,900	2,266,733	2,309,029	2,359,621	2,616,647	2,940,822	3,284,104
Fuel Reduction Cost (IEA)	TOP/y	1,887,601	2,057,361	2,098,796	2,140,232	2,181,667	2,223,102	2,264,537	2,471,714	2,450,996	2,430,279

Source: The study team

2-5-2-6-2 Interest

Interest expense in Tongatapu will be obtained by calculating the percentage of electricity demand in Tongatapu in relation to that of the total for Tonga.

Table 2-44: Interest

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2030	2035	2040
Forecast of Tonga (TPL)	1,200,000	1,200,000	1,200,000	1,100,000	900,000	700,000	600,000	400,000	200,000	200,000			
Forecast of Tonga (JICA Team)										200,000	200,000	200,000	200,000
Forecast of Tongatapu	1,072,729	1,077,832	1,082,696	996,728	818,832	639,344	550,040	367,991	184,618	185,215	187,383	189,678	191,614

Source: The study team

2-5-2-6-3 Income Tax and Provision for Dividend

Income tax is 25% of pre-tax-profit, and dividend allowance is 35% of profit-after-tax. This is shown in the following table.

Table 2-45: Income tax and provision for dividend

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2030	2035	2040
Net profit before tax	4,400,939	4,053,383	3,886,602	4,089,140	4,479,080	4,309,134	4,889,248	5,472,688	5,491,196	5,573,431	5,641,705	5,699,294
Income tax (25%)	1,100,235	1,013,346	971,650	1,022,285	1,119,770	1,077,283	1,222,312	1,368,172	1,372,799	1,393,358	1,410,426	1,424,824
Net profit after tax	3,300,704	3,040,038	2,914,951	3,066,855	3,359,310	3,231,850	3,666,936	4,104,516	4,118,397	4,180,073	4,231,278	4,274,471
Provision for dividend（35%）	1,155,247	1,064,013	1,020,233	1,073,399	1,175,758	1,131,148	1,283,428	1,436,581	1,441,439	1,463,026	1,480,947	1,496,065

Source: The study team

2-5-2-6-4 Transfer to retained earnings

TPL has already calculated expected retained earnings until 2026, and this expense is supposed to be available as a prerequisite of this project, and will set new retained earnings. We assume that the earnings will continue to 2026 and apply this value for the years following 2026 as well. Tongatapu's retained earnings will be obtained by calculating the percentage of electricity demand in Tongatapu in relation to that of the total for Tonga.

Table 2-46: Retained earnings

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2030	2035	2040
Forecast of Tonga (TPL)	2,400,000	2,200,000	2,100,000	2,200,000	2,400,000	2,300,000	2,600,000	2,900,000	2,900,000	2,900,000			
Forecast of Tonga (JICA Team)										2,900,000	2,900,000	2,900,000	2,900,000
Forecast of Tongatapu	2,145,458	1,976,024	1,894,718	1,993,456	2,183,551	2,100,703	2,383,509	2,667,936	2,676,958	2,685,618	2,717,047	2,750,331	2,778,406

Source: The study team

2-5-3 Comparison and consideration of the revenue and expenditure of operation and maintenance

2-5-3-1 The validity of revenue and expenditure plan

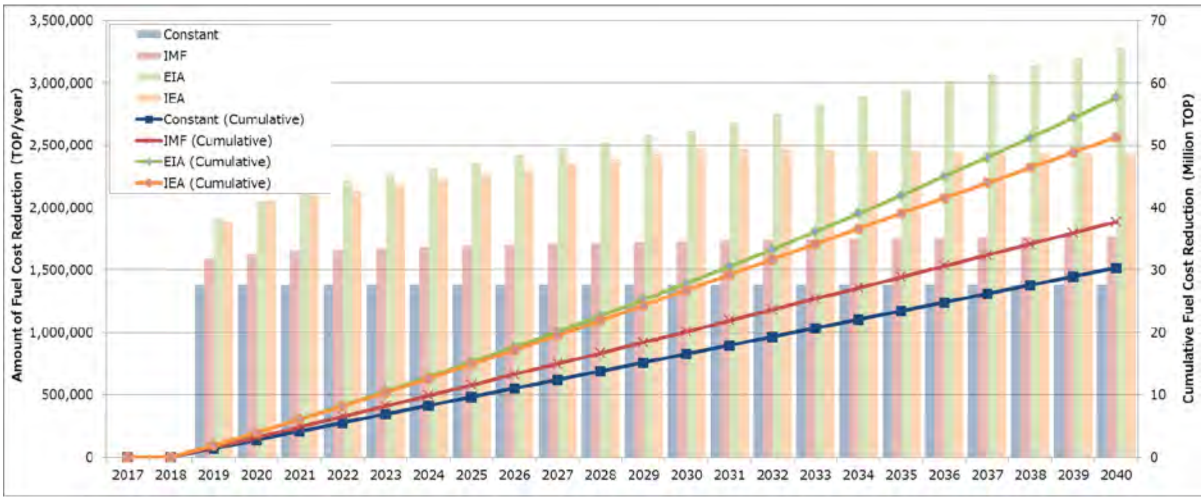
2-5-3-1-1 Depreciation expense of wind power plant

It is assumed that the business of TPL is facing no hindrances in the previous description above, and the business plan was considered until 2040. However, there is no actual expenditure of depreciation expenses in TPL's finances because the capital of this project comes from Japanese grants. Still, when it comes to necessary operations of the plant, the estimated depreciation expenses should be retained in the future for upgrade expenses of the plant.

2-5-3-2 The scale of the wind power plant

When we consider the scale of this project, TPL has to ensure they can cover the proper expenses in a timely manner after installation of the plant and can update the plant by themselves.

The graph below shows the amount they would save in fuel fees until the year the plant is expected to need upgrading, assuming the service life of the plant is estimated to be 20 years.



Source: The study team

Figure 2-46: Fuel cost reduction and cumulative amount by wind power generation

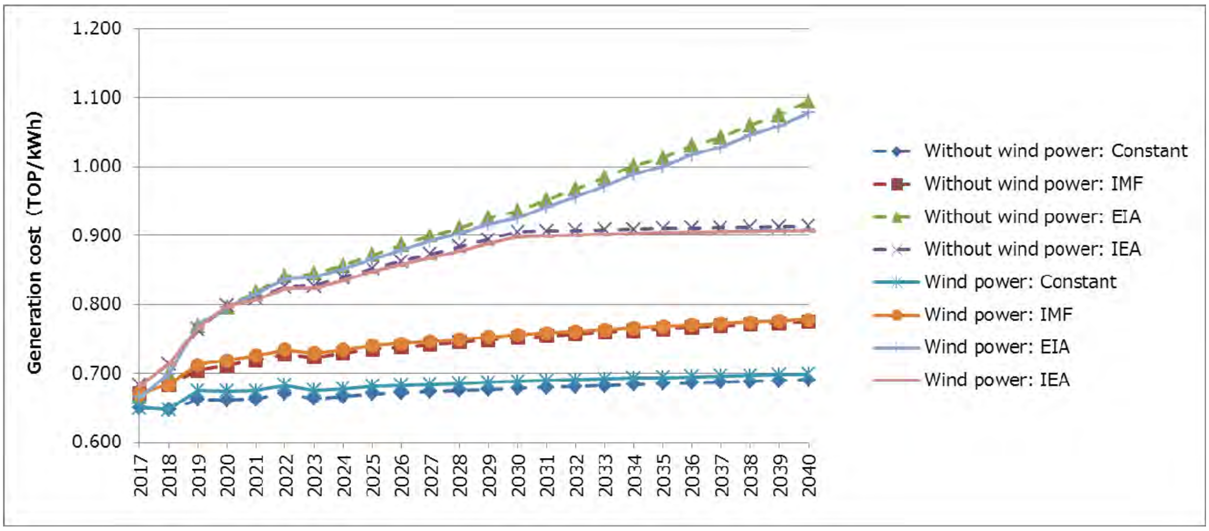
We planned for the wind power plant to start up in 2019, and the entire amount saved by not using fuel is estimated to be 29 million TOP (about 1.4 billion yen) using the current fuel fee from Figure 2-46.

However, other estimates from IMF indicates about 36 million TOP (about 1.7 billion yen), and estimates from EIA indicates about 54 million TOP (about 2.6 billion yen). If diesel cost increases, IEA indicates about 49 million TOP (about 2.4 billion yen).

In short, if TPL operates the plant by keeping the savings from fuel for ugrading expenses; they will sustain the plant after 2039 by upgrading the plant.

2-5-3-3 Transition in Power Generation Cost Assumed by Installation of Wind Turbine Generator System

Transition in the generation cost of wind turbine generator system installation are shown as below. In the calculation of power generation cost, it is compared the case of installaing wind turbine generator system and the case of not installing wind turbine generator system considering capital cost, operation and maintenance cost and fuel cost.



Source: The study team

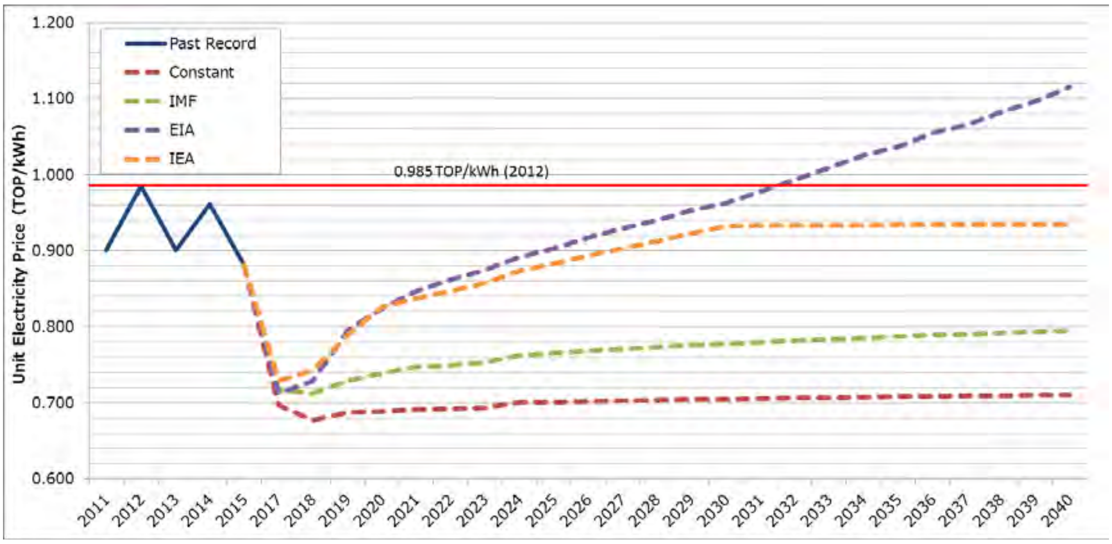
Figure 2-47: Estimation of power generation cost in future

If the diesel unit price stays at the current price, the generation cost of wind power generation increases to about 0.01 TOP/kWh (about 0.48 yen/kWh) until the renewal time of wind turbine generation. Under the assumption that the diesel unit price will rise in the future, the generation cost will be the same according to IMF estimation. The higher the diesel unit price, the higher the power generation cost (approximately 0.02 TOP/kWh (about 0.96 yen/kWh) according to the EIA estimation, and about 0.01 TOP/kWh (about 0.48 yen/kWh) according to the IEA estimation), so the impact of installation of the wind turbine generator system in the Project will become high.

2-5-3-4 Setting of Electricity Fee

If TPL would like to upgrade the plant in a timely manner, TPL needs to collect the necessary costs for upgrading and ensure they have the revenue to achieve such a business plan. Thus, we have to consider whether the expected electricity fee is appropriate and whether this fee is within a reasonable range for collecting.

The following figure shows the variation of the rate of electricity fee calculated under each case. From the past performance, all estimates will not be over the maximum value of electricity fee and the fee-setting range is probably within an attainable range.

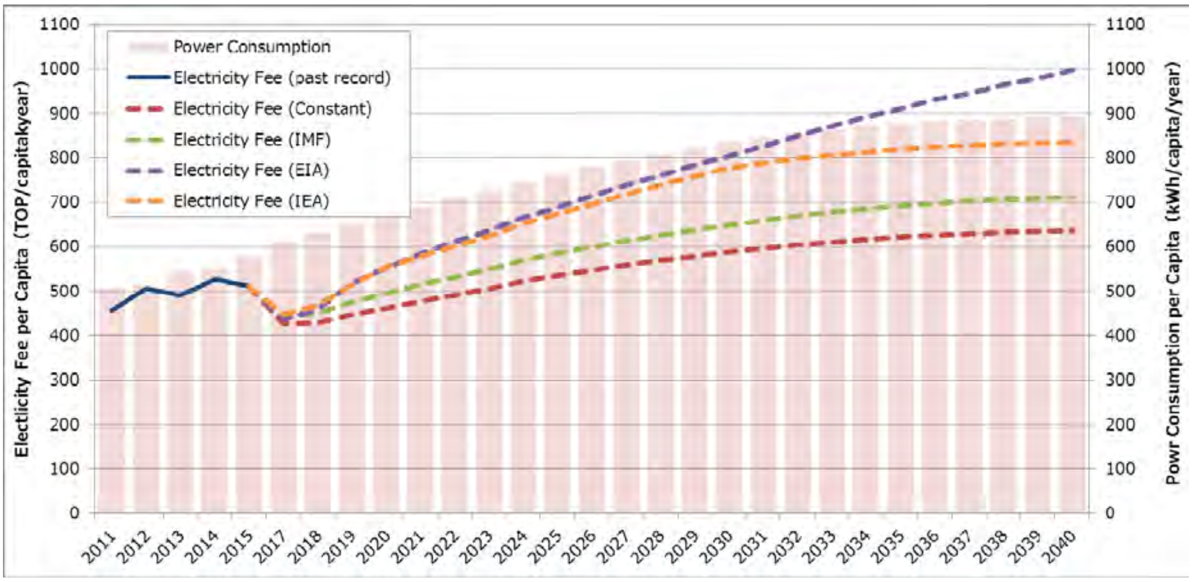


Source: The study team

Figure 2-48: Transition of Unit Price of Electricity Fee

2-5-3-5 Proper electricity fee for users

The following figure shows the transition of the electricity fee per capita and the usage of electricity per capita per year. The electricity fee per capita is based on the future diesel price under each case.



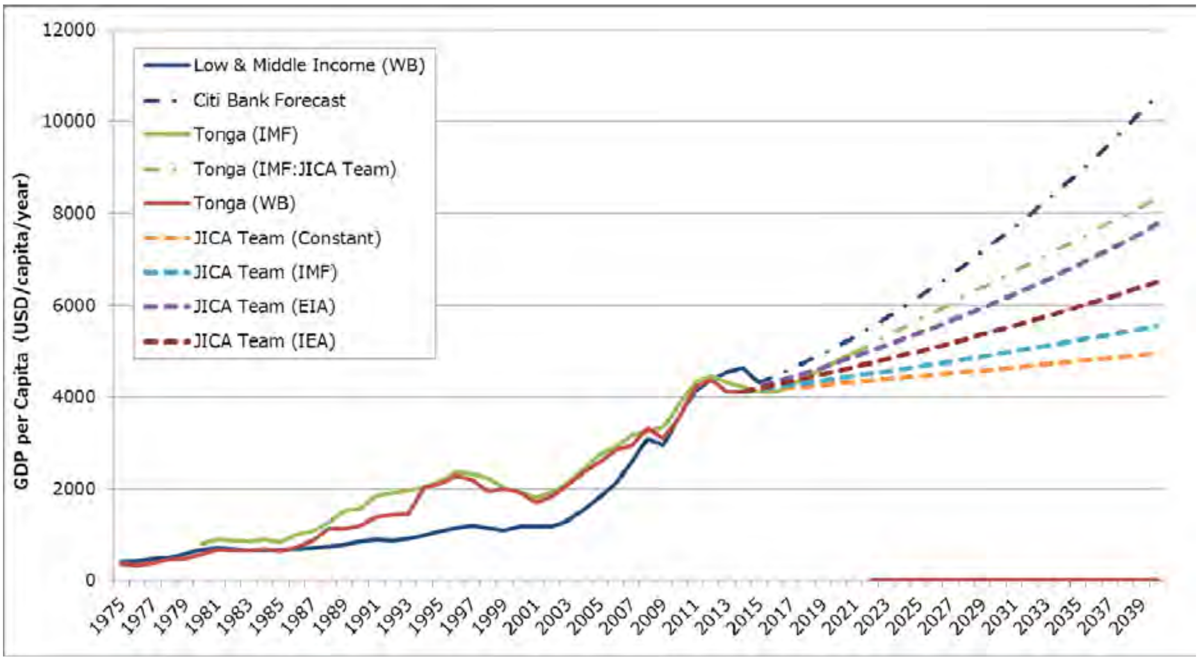
Source: The study team

Figure 2-49: Power consumption and payment amount per capita

As future consumption of electricity will increase, the usage of electricity per capita will also increase.

Hence even if the rate of diesel is fixed, the electricity fee per capita always increases. It is assumed that the value of 2040 (about 640 TOP per capita per year) will be 1.2 times as much as the value of the maximum during 2011 to 2015 (527.8 TOP per capita per year). As for estimates of EIA, which shows the maximum electricity per capita, the fee per capita will be about 1,000 TOP /per capita/per year and it is 1.9 times as much as the most expensive fee in the past. It is about 2 times as much as the present situation.

If the transition of the electricity fee in each case occurred, the people in Tonga would be able to pay in the future as follows.



Source: The study team

Figure 2-50: Actual and forecast of GDP per capita

Figure 2-50 demonstrates how GDP per capita is expected to change according to various forecasts up until 2040. These estimates (dotted lines) start at the present situation and are estimated assuming the final maximum point reached is the past maximum ratio of electricity fees to GDP per capita, which was 5.9 % in 2014. This graph uses the data of Tongan GDP of the IMF and of Low & Middle Income Countries, as categorized by the World Bank.

Table 2-47: Estimate of increasing rate in GDP per capita

Classification of GDP Forecast	2010-2020	2020-2030	2030-2040	Remarks
Low & Middle Income (World Bank)	3.500%	3.800%	3.600%	Citi Bank
Tonga (IMF)	1.036%	2.787%	2.136%	2010 - 2021: IMF 2022 - JICA team
Unit Diesel Oil Price (Constant)	0.718%			JICA team forecastss the GDP in the case that the share of electricity charges per capita in 2040 will be 5.9% of 2014, which is the largest in actual GDP figures.
Unit Diesel Oil Price (IMF)	1.153%			
Unit Diesel Oil Price (EIA)	2.476%			
Unit Diesel Oil Price (IEA)	1.780%			

Source: The study team

GDP growth rates calculated in Figure 2-50 are shown in Table 2-47. The percentage of EIA (2.476%) only exceeds that of IMF, but the others are below that of IMF. That is, we could tell the percentage of IMF is reasonable. In addition, with respect to the estimated value of GDP, the four cases are below the GDP estimates of the IMF.

Although it depends on the trend of the Tongan economy, as long as the growth of the world economy does not go down below the IMF estimates, the rate of electricity and electricity fee set by this plan enables it to be paid and the burden on consumers is not as much as the present situation.

Chapter 3

Project Evaluation

CHAPTER 3 PROJECT EVALUATION

3-1 Preconditions

For the smooth implementation of the Project, preconditions to be corresponded by Tongan side are shown in Table 3-1. It is important that these are conducted properly and timely by Tongan side

Table 3-1: Preconditions for implementation of the Project

Precondition	Implementation deadline
Project site condition	
To secure the land for wind turbine and storage system, access road and power transmission line	Within 1 month after G/A
To clear, level and reclaim for Project site (wind turbine, storage system, power transmission line)	Before notice of the tender document
To secure or construction the access road	Before notice of the tender document
To secure the storage space for construction materials and procured equipment	Before the beginning of construction and installation work
To install the fence around wind turbines and storage system	Before the beginning of operation
Permission and authorization	
Building permission	Before notice of the tender document
To submit the project monitoring report	Before preparation of the tender document
Expediency	
To open a Bank Account	Within 1 month after G/A
Procedures for tax exemption and customs clearance	As appropriate
Operation and maintenance	
To ensure the operation and maintenance system in TPL	Before the beginning of soft component
To secure TPL staff to participate in soft component	Before the beginning of soft component

Source: The study team

3-2 Necessary Inputs by Recipient Country

(1) Promotion of Appropriate Electricity Price and Development Plan for Renewable Energy

In order for the wind turbine generator system introduced by the Project to be continuously managed by TPL, it is necessary to revise appropriate electricity tariff at any time according to the trends of diesel fuel price and business balance .

Especially by implementing of this Project, although diesel fuel and fuel cost are reduced, periodic maintenance of wind turbine generator system and renewal of those facilities at the end of useful life are required. Therefore, it is important that electricity tariff are appropriately set for securing such costs.

In addition, although this Project is planning to introduce the grid stabilization system for short period fluctuation compensation, it is necessary to more severely control the existing diesel generator than the current situation. Existing diesel generators are limited to responding to output fluctuations of the existing photovoltaics system and wind power generators introduced by this project. If TPL introduces further renewable energy after this Project, it is necessary to consider the grid stabilization system by mid-period or long-period.

Fortunately, in the renewable energy development plan of TPL, a long-period energy storage facility (output: 3 MW, capacity: 18 MWh) is planned to introduce. In order to secure Tonga's energy security and stable power supply, it is necessary to promote the development plan in the future.

(2) Monitoring on Environmental Impact

In this project, the impact on the environment of Nituwa which is the project site of wind turbine generator system is estimated to be small. However, it is necessary for the TPL to periodically monitor temporary land acquisition, land erosion, air pollution / dust damage, noise / vibration damage occurring during the construction period. In addition, it is necessary to positively encourage Japanese contractors to implement these mitigation measures.

3-3 Important Assumptions

Important assumptions for implementation of the Project are mentioned below.

- There is no change in policy concerning Tonga's energy security.
- There is no change in the policy of TPL concering introduction of renewable energy.

3-4 Project Evaluation

3-4-1 Relevance

The Project implementation by Grant Aid is evaluated to be reasonable based on the result of this survey for the following reasons.

- The Project is implemented in Tongatapu Island, the largest island in Tonga. With a population of 75,416 people, residents from Tongatapu Island make up approximately 73% of the total population of Tonga, ensuring a considerable number of citizens are beneficiaries of the Project.

- Tonga is an island country and relies on diesel power with imported fuel for the majority of its electricity generation. Through implementation of this Project, Tonga can generate renewable energy itself. Therefore, from the viewpoint of reducing greenhouse gas emissions and improving energy security, this Project will greatly contribute to a stable supply of energy.

- TPL aims for renewable energy to meet 50 % of the demand for electric energy. This Project contributes to achieve this goal.

- TPL has already installed photovoltaic power systems as renewable energy systems and has the experience and technical expertise in repairing, operating and maintaining photovoltaic power systems as well as diesel generators. Although this is the first time for the development of a Megawatt (MW) class of wind power generation in Tonga, this Project designed the grid stabilization system according to the existing system and sustained operation and maintenance by TPL can be expected.

- This Project is the development of an electric power generation system that will play a key role in the life of the Tongan people and is consistent with the framework of grant aid.
- Although environmental impacts including air pollution, waste, land acquisition and accidents are predicted through this Project, it is estimated that the environmental impact can be minimized by implementing mitigation of measures.

3-4-2 Effectiveness

(1) Quantitative Impact

The quantitative impact to be expected from implementation of this Project is shown in the following table. The electricity generated by the wind turbine generator system means an increase in the amount of renewable energy and contributes to the reduction of fuel by diesel power generation. Also, the increase of ratio of renewable energy to electric demand and fossil fuel reduction will also contribute to easing climate change through curbing greenhouse gas emissions.

Table 3-2: Quantitative impact after implementation of this Project

Output indicator	Present value (Actual values in 2016)	Target value (2022) (After three years of project completion)
Wind power generation amount	0 MWh/year	4,296 MWh/year
Capacity factor	0 %	35.7 %
Availability	0 %	90.7 %
Reduction in diesel fuel consumption	0 kL/year 0 TOP/year	1,079 kL/year (IMF) 1,492,810 TOP/year
Proportion of renewable energy	7.42 % (PV) 0 % (Wind power)	6.42 % (PV) 7.32 % (Wind power)
CO_2 emissions reduction	0 t CO_2/year	2,903 t CO_2/year

Source: The study team

1) Wind Power Generation Amount

From the wind condition data (from April 2015 to March 2016), the annual power generation capacity of wind turbine generator system is 4,736 MWh/year. In this project, availability is set at 90.7%, the annual power generation by the wind turbine shall be 4,296 MWh/year (generating side).

2) Capacity Factor

If the output of the wind turbine generator system is 1.375 MW, capacity factor can be calculated as follows.

4,296 MWh/year ÷ (1.375 MW×24h×365day) = 35.7%

3) Availability

As described in 2-2-2-1-6, availability of the Project is set to 90.7%.

4) Reduction in Diesel Fuel Consumption

According to the preliminary calculation of TPL, the fuel consumption of diesel generators is 0.253 L/kWh.

Therefore, since the amount of wind power generation is 4,262 MWh/year, the reduction amount of diesel fuel is 1,079 kL/year. In addition, the unit price of diesel fuel per 1 L based on the IMF estimate is 1.383 TOP/L. Therefore, the diesel fuel reduction amount of 2022 will be 1,492,810 TOP/year.

5) Proportion of Renewable Energy

The total power generation, including renewable energy of Tongatapu Island in 2016 is 49,962 MWh/year. Among these, power generation of photovoltaic is 2,095 MWh/year (Popua), 1,612 MWh/year (Vaini). Therefore, the proportion of renewable energy (photovoltaic power generation) in 2016 to the total is calculated as 7.42%.

In addition, in 2022, the total power generation will be 57,789 MWh/year, and power generation of photovoltaic is same (2,095 MWh/year: Popua, 1,612 MWh/year: Vaini). Therefore, the proportion of renewable energy (photovoltaic power generation) in 2022 to the total is calculated as 6.42%. Since the wind power generation amount is 4,262 MWh/year, the ratio of wind power generation to total is 7.32%.

6) CO_2 Emissions Reduction

Greenhouse gas reduction is 2,903 tCO_2/year since greenhouse gas emissions are 0.681 tCO_2/MWh and annual power generation by wind turbine generator system is 4,262 MWh / year.

(2) Qualitative Impact

Qualitative impact to be expected by implementation of this Project is mentioned below.

- Diversification of source of electricity supply
- Stable supply of energy

From the above-mentioned contents, implementation of this Project is assessed as reasonable and effective.

[Appendices]

1. Member List of the Study Team
2. Study Schedule
3. List of Parties Concerned in the Recipient Country
4. Minutes of Discussions
5. Soft Component (Technical Assistance) Plan
6. Other Relevant Data
   * Collected Data List
7. References

Appendices

Appendix 1

Member List of the Study Team

A1. Member List of the Study Team

(1) First Field Study (3rd July to 19th July, 2016)

	Name	Position	Affiliation
1	Mr.Fuyuki Sagara	Leader	Director, Team 1,Energy and Mining Group, Industrial Development and Public Policy Departmejnt, Japan International Cooperation Agency
2	Mr.Yamato Kawamata	Cooperation Planning 1	Assistant Director, Team 1, Energy and Mining Group, Industrial Development and Public Policy Departmejnt, Japan International Cooperation Agency
3	Ms.Yumi Nakagawa	Cooperation Planning 2	Deputy Assistant Director, Pacific and Southeast Asia Division 6, Southeast Asia and Pacific Department, Japan International Cooperation Agency
4	Mr.Kenji Shinoda	Chief Consultant	Kokusai Kogyo Co., Ltd.
5	Mr.Yoshifumi Nishizawa	Sub Chief Consultant／Wind Power System／System Stabilization	Toyo Sekkei Co., Ltd.
6	Mr.Shunsuke Nakai	Project Coordinator	Kokusai Kogyo Co., Ltd.

(2) Second Field Study (14th August to 7th September, 2016)

	Name	Position	Affiliation
1	Mr.Kenji Shinoda	Chief Consultant	Kokusai Kogyo Co., Ltd.
2	Mr.Yoshifumi Nishizawa	Sub Chief Consultant／Wind Power System／System Stabilization	Toyo Sekkei Co., Ltd.
3	Mr.Tamotsu Ishii	Power Distribution Plannning	Ogino Kenko Co., Ltd.
4	Mr.Takeshi Abe	Equipment Plannning	Kokusai Kogyo Co., Ltd.
5	Ms.Shuko Kato	Facility Planning／Natural Condition	Toyo Sekkei Co., Ltd.
6	Mr.Tetsuya Suzuki	Procurement Plannning ／ Cost Estimation	Kokusai Kogyo Co., Ltd.
7	Ms.Izumi Kasai	Environmental and Social Consideration	Kokusai Kogyo Co., Ltd.
8	Mr.Hiroaki Ito	System Analysis／System Monitoring	Toyo Sekkei Co., Ltd.
9	Mr.Kentaro Seya	Project Coordinator	Kokusai Kogyo Co., Ltd.

(3) Third Field Study (6th January to 15th January, 2017)

	Name	Position	Affiliation
1	Mr.Hiroyuki Kobayashi	Leader	Deputy Director, Industrial Development and Public Policy Departmejnt, Japan International Cooperation Agency
2	Mr.Yamato Kawamata	Cooperation Planning 1	Assistant Director, Team 1, Energy and Mining Group, Industrial Development and Public Policy Departmejnt, Japan International Cooperation Agency
3	Mr.Kenji Shinoda	Chief Consultant	Kokusai Kogyo Co., Ltd.
4	Mr.Yoshifumi Nishizawa	Sub Chief Consultant ／ Wind Power System／System Stabilization	Toyo Sekkei Co., Ltd.
5	Mr.Tetsuya Suzuki	Procurement Plannning ／ Cost Estimation	Kokusai Kogyo Co., Ltd.

Appendix 2

Study Schedule

A2. Study Schedule

(1) First Field Study (3rd July to 19th July, 2016)

Date		JICA Team			Consultant Team		
		Leader	Cooperation Planning 1	Cooperation Planning 2	Chief Consultant	Sub Chief Consultant／Wind Power System／System Stabilization	Project Coordinator
		Fuyuki Sagara	Yamato Kawamata	Yumi Nakagawa	Kenji Shinoda	Yoshifumi Nishizawa	Shunsuke Nakai
2016/7/3	Sun				NRT→AKL		
2016/7/4	Mon				AKL→TBU		
2016/7/5	Tue				Meeting with TPL		
2016/7/6	Wed				Field survey	Noise level survey	Field survey
2016/7/7	Thu				Meeting with TPL	Field survey	
2016/7/8	Fri		NRT→AKL		Courtesy to stakeholders		
2016/7/9	Sat		AKL→TBU		Site visit to Quarry		
2016/7/10	Sun	NRT→AKL	Internal meeting				
2016/7/11	Mon	AKL→TBU	Discussion on Minutes			Data collection	
2016/7/12	Tue	Discussion on Minutes				Data collection	
2016/7/13	Wed	Field survey				SCADA data collection	
2016/7/14	Thu	Minute signature、TBU→AKL	Minute signature			Port harbor study	
2016/7/15	Fri	AKL→NRT	TBU→AKL		Meeting with TPL	Confirm impedance map	Data collection
2016/7/16	Sat		AKL→DXB→CAI	AKL→NRT	TBU→AKL		
2016/7/17	Sun				AKL→WLG		
2016/7/18	Mon				WLG→AKL		
2016/7/19	Tue				AKL→NRT		

NRT:Narita(Tokyo), AKL:Auckland, TBU:Nukualofa (Fua'amotu International Airport)、WLG: Wellingoton

(2) Second Field Study (14th August to 7th September, 2016)

Date		Consultant Team				
		Chief Consultant	Sub Chief Consultant／Wind Power System／System Stabilization	Power Distribution Plannning	Equipment Plannning	Facility Planning／Natural Condition
		Kenji Shinoda	Yoshifumi Nishizawa	Tamotsu Ishii	Takeshi Abe	Shuko Kato
2016/8/14	Sun	NRT→AKL				
2016/8/15	Mon	AKL→TBU				
2016/8/16	Tue	Meeting with TPL				
2016/8/17	Wed	Field survey	Analysis of DG･PV	Field survey		
2016/8/18	Thu	Study on regulations	Study on accumulator	Study on Power system		
2016/8/19	Fri	Study on regulations	Analysis of DG･PV	Study on accumulator	NRT→AKL	
2016/8/20	Sat	Data analysis	Analysis of wind turbin	Field survey	AKL→TBU	
2016/8/21	Sun	Data analysis				
2016/8/22	Mon	Facility Planning	Analysis of DG･PV	Facility planning	Courtesy call to JICA	Field survey
2016/8/23	Tue	Facility Planning	Study on Vaini PV	Facility planning	Interview to TPL	Facility planning
2016/8/24	Wed	Facility Planning	Study on accumulator	Facility planning	Interview to contractor	Facility planning
2016/8/25	Thu	Basic planning	Analysis of DG･PV	Design drawing	Interview to MOI	Facility planning
2016/8/26	Fri	Basic planning	Power demand projection	Design drawing	Equipment plannning	Facility planning
2016/8/27	Sat	Data analysis	Field survey	Data analysis		Field survey
2016/8/28	Sun	Data analysis				
2016/8/29	Mon	Basic planning	Data collection	Design drawing	Field survey	Facility planning
2016/8/30	Tue	Basic planning	Analysis of DG･PV	Design drawing	Equipment plannning	Facility planning
2016/8/31	Wed	Meeting with TPL	Micro grid analysis	Field survey	Equipment plannning	Facility planning
2016/9/1	Thu	Meeting with TPL	System analysis	Field survey	Equipment plannning	Facility planning
2016/9/2	Fri	Meeting with TPL	Power quality analysis	Meeting with TPL	Equipment plannning	Facility planning
2016/9/3	Sat	Data analysis				
2016/9/4	Sun	Data analysis				
2016/9/5	Mon	Meeting with TPL	Data collection	Field survey	Data analysis	Facility planning
2016/9/6	Tue	TBU→AKL	System analysis, TBU→AKL	TBU→AKL		
2016/9/7	Wed	AKL→NRT				

Date		Consultant Team			
		Procurement Plannning／Cost Estimation	Environmental and Social Consideration	System Analysis／System Monitoring	Project Coordinator
		Tetsuya Suzuki	Izumi Kasai	Hiroaki Ito	Kentaro Seya
2016/8/14	Sun	NRT→AKL			NRT→AKL
2016/8/15	Mon	AKL→TBU			AKL→TBU
2016/8/16	Tue	Meeting with TPL	Meeting with TPL		Meeting with TPL
2016/8/17	Wed	Field survey	Field survey		Field survey
2016/8/18	Thu	System Analysis	Study on regulations		Cordination work
2016/8/19	Fri	Study on accumulator	Study on regulations	NRT→AKL	Cordination work
2016/8/20	Sat	Data analysis		AKL→TBU	Data analysis
2016/8/21	Sun	Data analysis			
2016/8/22	Mon	Procurement plannning	Social survey	Field survey	Field survey
2016/8/23	Tue	Procurement plannning	Social survey	System analysis	Cordination work
2016/8/24	Wed	Estimation collection	Social survey	System monitoring	Cordination work
2016/8/25	Thu	Estimation collection	Social survey	System monitoring	Cordination work
2016/8/26	Fri	Estimation collection	Social survey	System monitoring	Cordination work
2016/8/27	Sat	Data analysis			
2016/8/28	Sun	Data analysis			
2016/8/29	Mon	Estimation collection	Social survey	System monitoring	Cordination work
2016/8/30	Tue	Estimation collection	Social survey	System monitoring	Cordination work
2016/8/31	Wed	Estimation collection	Social survey	System monitoring	Cordination work
2016/9/1	Thu	Estimation collection	Social survey	Micro grid analysis	Cordination work
2016/9/2	Fri	Estimation collection	Social survey	Micro grid analysis	Cordination work
2016/9/3	Sat	Data analysis			
2016/9/4	Sun	Data analysis			
2016/9/5	Mon	Estimation collection	Social survey	Micro grid analysis	Cordination work
2016/9/6	Tue	TBU→AKL			
2016/9/7	Wed	AKL→NRT			

NRT:Narita(Tokyo), AKL:Auckland, TBU:Nukualofa (Fua'amotu International Airport)

(2) Third Field Study (6th January to 15th January, 2017)

Date		JICA Team		Consultant Team		
		Leader	Cooperation Planning 1	Chief Consultant	Sub Chief Consultant／Wind Power System／System Stabilization	Procurement Plannning／Cost Estimation
		Hiroyuki Kobayashi	Yamato Kawamata	Kenji Shinoda	Yoshifumi Nishizawa	Tetsuya Suzuki
2017/1/6	Fri			NRT→AKL	NRT→AKL	NRT→AKL
2017/1/7	Sat			AKL→TBU	AKL→TBU	AKL→TBU
2017/1/8	Sun		NRT→AKL	Data analysis		
2017/1/9	Mon	NRT→AKL	AKL→TBU	Explanation of draft report		
2017/1/10	Tue	AKL→TBU	Discussion on Minutes		Explanation of draft report	
2017/1/11	Wed	Discussion on Minutes		Study on land use	Progress confirmation	Confirm Construction STD
2017/1/12	Thu	Field survey		Study on optical cable	Study on Chinese PV	Confirm Construction STD
2017/1/13	Fri	Minutes signature				
2017/1/14	Sat	TBU→AKL				
2017/1/15	Sun	AKL→NRT				

NRT:Narita(Tokyo), AKL:Auckland, TBU:Nukualofa (Fua'amotu International Airport)、WLG: Wellingoton

Appendix 3

List of Parties Concerned in the Recipient Country

A3. List of Parties Concerned in the Recipient Country

(1) Tonga Power Limited (TPL)

Mr. Carl Sanft	Chairman
Mr. Rober Matthews	CEO
Mr. Steven Esau	General Manager of Finance
Mr. Setitaia Chen	General Manager of Operations
Mr. Simon Wilson	Major Projects Manager
Ms. Sosefina Maileseni	Risk Compliance Manager
Mr. Nikolas Fonua	Strategic Development Manager
Ms. Andrea Talia’uli	Strategic Development Manager
Mr. Finau Katoanga	Business Devvelopment Engineer
Mr. Murray Sheerin	Power Generation Manager
Mr. Ernest	Powe Generation Engineer
Ms. Jane Guttenbeil	In Charge of EIA

(2) Ministry of Environment, Energy, Climate Change, Disaster Management, Meteorology, Information and Communications (MEIDECC)

Mr. Hon Siaosi Sovaloni	Deputy Prime Minister / Minister of MEIDECC
Mr. Paula Mau	CEO
Mr. Ofa Fa'anunu	A/CEO / Director of National Meteorological Service
Mr. Kakau Foliaki	Principal Energy Planner
Ms. Winnie Veikoso	Principle Assistant Secretary
Ms. Selu Finaulahi	Climate Officer of National Meteorological Service

(3) TERM-IU

Mr. Tuoky Vala	Major Projects Manager

(4) Ministry of Public Enterprise (MPE)

Mr. Sione Alauola	CEO
Mr. Finau Moa	A/CEO
Mr. Sione Utaiaiu	Principal Finance Analyst
Mr. Feleti Vaka	Program Officer

(5) Ministry of Finance and National Planning

Mr. Tatafu Moeaki	CEO
Ms. Balwyn Fa'otusia	CEO

(6) Ministry of Infrastructure

Mr. Pesalili F Tu'iano	A/CEO for Infrastructure
Mr. Fotu Veikune	Cheif Architect

(7) Ministry of Revenue & Customs

Mr. Heiloni Latu	Customs Officer, Ports Authority Tonga

(8) Waste Authority LTD

Ms. Sonia Chirgwin	Solid Waste/Sanitation Specialist

(9) New Zealand

Mr. Ray Brown	AECOM: Associatet Directoer-Distribution, Transmission & Renewables
Mr. Blair Walter	Aurecon: Renewable Energy Leader
Mr. Keith Scoles	Infratec: Technical Manager
Mr. Mansoor Ali Shah	Infratec: Power System & SCADA Engineer

(10) Embassy of Japan in Tonga

Mr. Yukio Numata	Ambassador
Mr. Tetsumi Murata	Counselor
Ms. Hitomi OBATA	Second Secretary, Chief of Political and Economic Section, Aid Coordinator,
Mr. Kenji NIWA	Professional Investigator

(11) Japan International Cooperation Agency Tonga Office

Mr. Hiroshi Kikawa	Chief Representative
Mr. Shinji Yoshiura	Chief Representative
Mr. Shoichi Iwata	Representative

Appendix 4

Minutes of Discussions

A4. Minutes of Discussions

(1) Signed Minutes of Discussions on July 14, 2016 at First Field Study

Minutes of Discussions
on the Preparatory Survey for
the Project for Installation of Wind Power Generation System in the Kingdom of Tonga

In response to the request from the Government of Kingdom of Tonga (hereinafter referred to as "Tonga"), Japan International Cooperation Agency (hereinafter referred to as “JICA”), in consultation with the Government of Japan, decided to conduct a Preparatory Survey for the Project for Installation of Wind Power Generation System (hereinafter referred to as “the Project”).

JICA sent the Preparatory Survey Team for the outline design (hereinafter referred to as “the Team”) to Tonga, headed by Mr. Fuyuki Sagara, Director, Team 1, Energy and Mining Group, Industry Development and Public Policy Department, JICA, and is scheduled to stay in the country from 4 to 16 July, 2016.

The Team held a series of discussions with the officials concerned of the Government of Tonga and conducted a field survey in the Project area. In the course of the discussions, both sides have confirmed the main items described in the attached sheets. The Team will proceed to further works and prepare the Preparatory Survey Report.

Nuku’alofa, 14 June, 2016

相良冬木

Fuyuki Sagara
Leader
Preparatory Survey Team
Japan International Cooperation Agency
Japan

(STEVEN ESAU CFO).

for Robert Matthews
Chief Executive Officer
Tonga Power Limited
The Kingdom of Tonga

Paula Ma’u
Chief Executive Officer
Ministry of Meteorology, Energy, Information, Disaster Management, Environment, Climate Change and Communication (MEIDECC)
The Kingdom of Tonga

Sione ‘Akauola
Chief Executive Officer
Ministry of Public Enterprises
The Kingdom of Tonga

Tatafu Moeaki
Chief Executive Officer
Ministry of Finance and National Planning
The Kingdom of Tonga

ATTACHEMENT

1. Objective of the Project
   The objective of the Project is to improve sustainability of power supply in Tongatapu Island by introducing renewable energy sources for power generation through installation of wind power generation system and grid stabilization system, thereby contributing to economic development of Tonga.

2. Title of the Preparatory Survey
   Both sides confirmed the title of the Preparatory Survey as "the Preparatory Survey for the Project for Installation of Wind Power Generation System".

3. Project Site
   Both sides confirmed that the site of the Project is "Niutoua" for wind generation system and eastern district for related distribution network facilities, which is shown in Annex 1.

4. Line Agencies and Executing Agency
   Both sides confirmed the line agencies and executing agency as follows:
   4-1. The line agencies are Ministry of Meteorology, Energy, Information, Disaster Management, Climate Change and Communication (hereinafter referred to as "MEIDCC") and Ministry of Public Enterprises, which would be the agencies to supervise the executing agency.
   4-2. The executing agency is Tonga Power Limited (hereinafter referred to as "TPL"). The executing agency shall coordinate with all the relevant agencies to ensure smooth implementation of the Project and ensure that the undertakings are taken by relevant agencies properly and on time. The organization charts are shown in Annex 2.

5. Items requested by the Government of Tonga
   5-1. As a result of discussions, both sides confirmed that the items requested by the Government of Tonga are as follows:
   - Installation of Wind Turbines
   - Grid Stabilization System
   - Installation of Network Facilities
   - Training for operation and maintenance of installed equipment and systems, and power grid system control

   5-2. The Team took note that Tongan side requested to analyze technical limitation, financial limitation, impact on the tariff, achievement of renewable energy target to determine optimal capacity of wind turbines.
   5-3. JICA will assess the appropriateness of the above requested items through the survey and will report findings to the Government of Japan. The final components of the Project would be decided by the Government of Japan.

6. Japanese Grant Scheme
   6-1. The Tongan side understood the Japanese Grant Scheme and its procedures as described in Annex 3 and Annex 4, and necessary measures to be taken by the Government of Tonga.
   6-2. The Tongan side understood to take the necessary measures, as described in Annex 6, for smooth implementation of the Project, as a condition for the Japanese Grant to be implemented. The detailed contents of the Annex 6 will be worked out during the survey and shall be agreed no later than by the Explanation of the Draft Preparatory Survey Report.
   The contents of Annex 6 will be used to determine the following:
   (1) The scope of the Project.
   (2) The timing of the Project implementation.

(3) Timing and possibility of budget allocation.
Contents of Annex 6 will be updated as the Preparatory Survey progresses, and will finally be the Attachment to the Grant Agreement.

7. Schedule of the Survey
  7-1. The Team will proceed with further survey in Tonga in August, 2016.
  7-2. JICA will prepare a draft Preparatory Survey Report in English and dispatch a mission to Tonga in order to explain its contents around December 2016.
  7-3. If the contents of the draft Preparatory Survey Report is accepted in principle and the undertakings are fully agreed by the Tongan side, JICA will complete the final report in English and send it to Tonga around April 2017.
  7-4. The above schedule is tentative and subject to change. The Team took note that Tongan side requested to shorten the schedule of the survey because of the renewable energy target for 2020.

8. Environmental and Social Considerations
  8-1. The Tongan side confirmed to give due environmental and social considerations during implementation of the Project, and after completion of the Project, in accordance with the JICA Guidelines for Environmental and Social Considerations (April, 2010).
  8-2. The Project is categorized as "B" under the JICA guidelines for environmental and social considerations April 2010, because the project area is not located in a sensitive area, nor has sensitive characteristics, nor falls into sensitive sectors and its potential adverse impacts on the environment are not likely to be significant. The Tongan side has already conducted the necessary procedures in Tonga concerning the environmental assessment (including Environmental Impact Assessment (EIA), etc.) and make EIA report of the Project. The Team will fully examine the EIA report and the addendum undertaken through New Zealand feasibility study in accordance with the JICA guidelines, and necessary measures such as "Stakeholder Meeting" should be conducted by Tongan side during this preparatory survey.
  8-3 Both sides agreed that JICA guidelines require stakeholder meetings targeting all those who are potentially affected by the Project.
  8-4 Tongan side confirmed to take the necessary measures to secure the lands for the Project site.

9. Other Relevant Issues
  9-1. Prioritizing contents of the project
  The Team explained that items that requested from Tonga, mentioned in 5-1, will be studied and made prioritizing from the viewpoints of its urgency and effectiveness contribution to stable power supply in Tongatapu Island.
  9-2. Design for Extreme Wind Speed
  Both side agreed that the design for extreme wind speed will be determined taking into consideration of the actual records of cyclone.
  9-3. Design for Capacity of Grid Stabilization System
  Both side agreed that the optimal capacity of grid stabilization system to stabilize power voltage and frequency for wind power generation system will be adopted.
  9-4. Connecting signal cables from the existing solar PV system
  Tongan side confirmed to obtain approval to connect signal cables and/or install radio communication from the project site in Niutoua to the Vaini Power Station, in order to send its generation conditions to the existing micro-grid controller.
  9-5. Undertakings of the Tongan side
  Both sides confirmed and highlighted that the following matters are included in the Undertakings of the Tongan side in the Annex 6.
    1) Securing the land of the project site for the wind turbine system including grid stabilization systems and power conditioners, and distribution lines, etc.
    2) Construction of access road outside the project site

4-A

3) Construction of fence around the project site, as necessary
4) Replacement and proper disposal of the Power Storage Systems

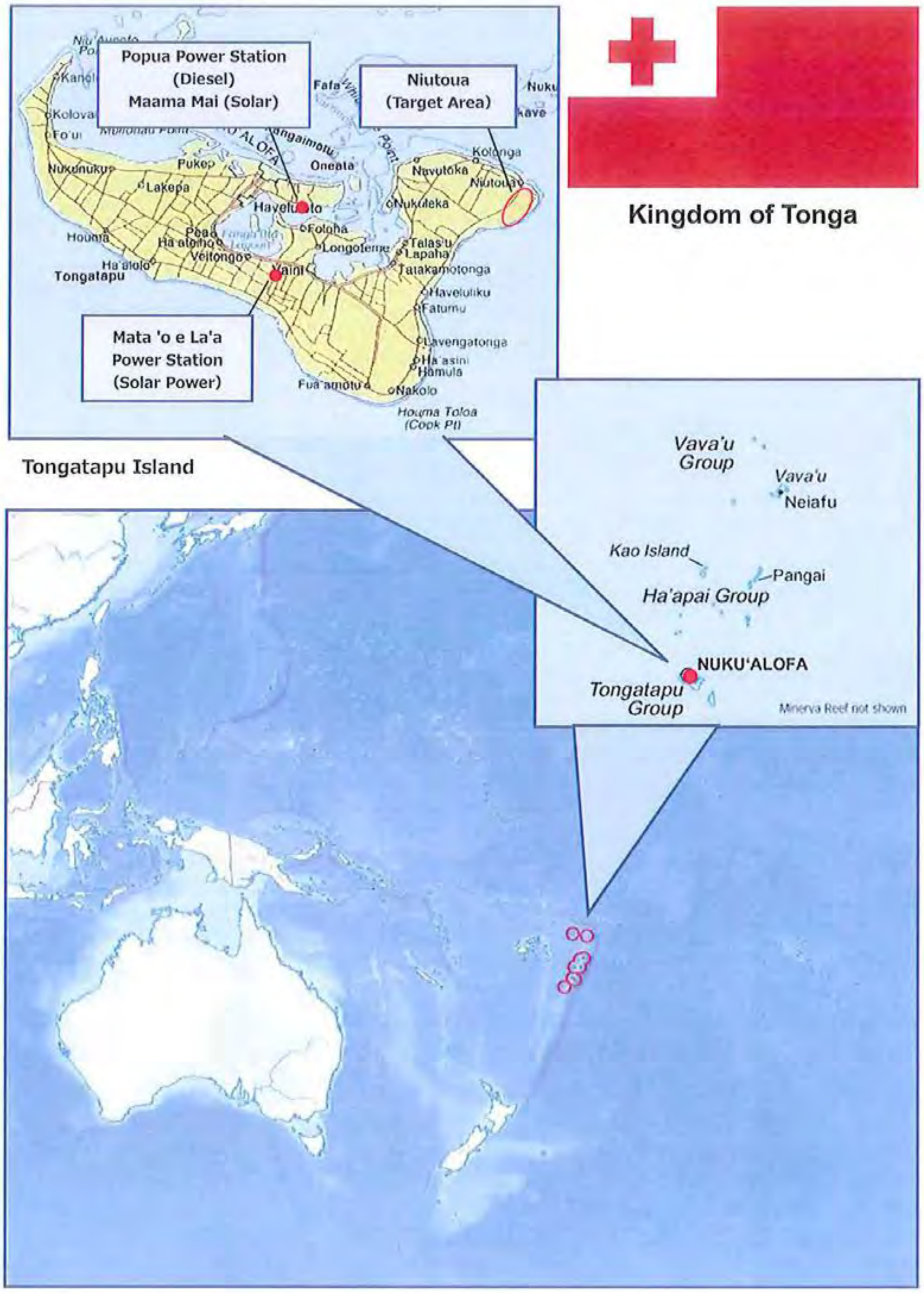
9-6. Coordination with other countries and/or development partners

Both sides confirmed the following matters;

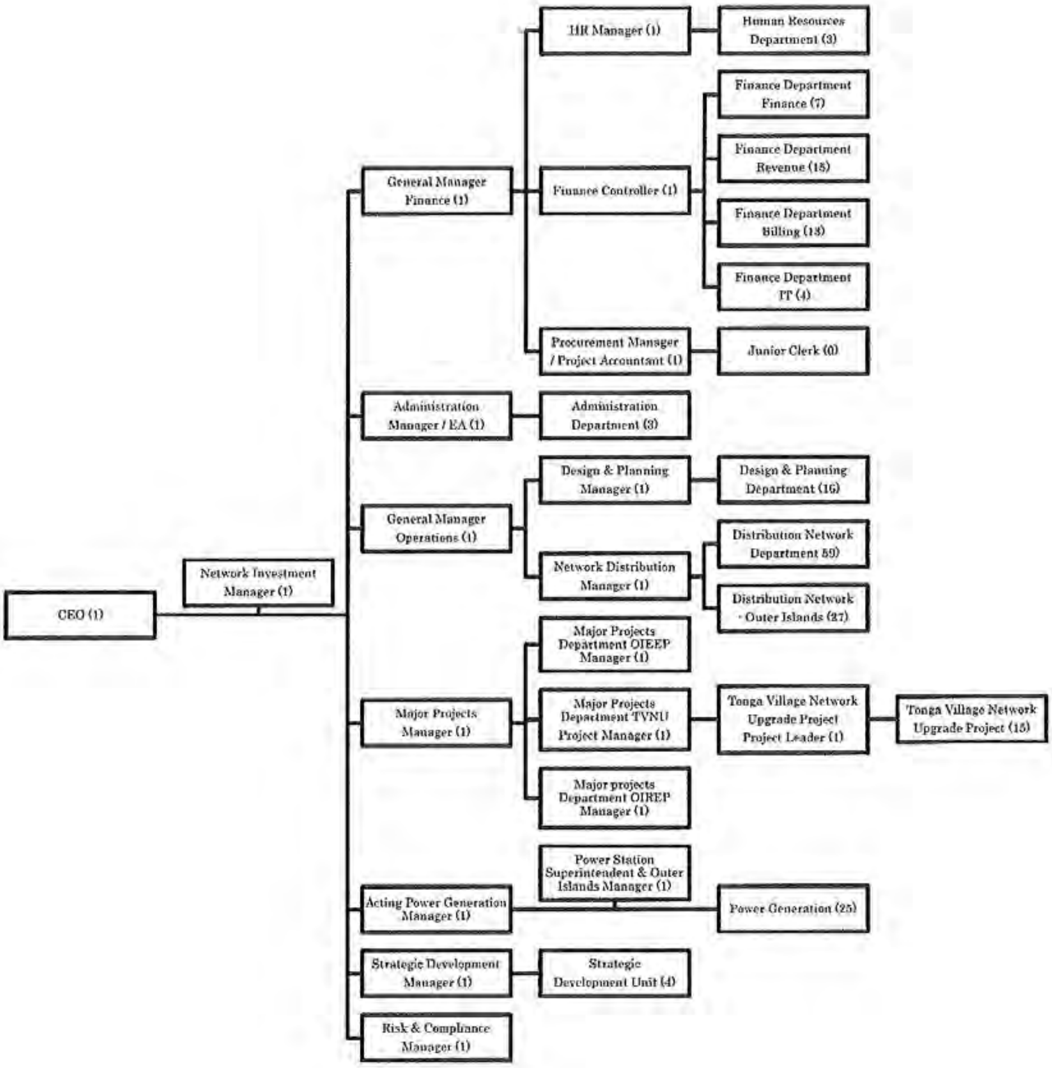
1) The Team will fully utilize the feasibility study conducted by the government of New Zealand. Both side confirmed that TPL will make the necessary coordination with New Zealand government for finalizing the scope of the Project.
2) There will be no other duplication of facilities and equipment between those requested to JICA and those requested to other countries and/or development partners.

Annex 1 Project Site
Annex 2 Organization Chart of TPL
Annex 3 Japanese Grant
Annex 4 Flow Chart of Japanese Grant Procedures
Annex 5 Financial Flow of Japanese Grant
Annex 6 Major Undertakings to be taken by Each Government
Annex 7 Project Monitoring Report (template)

Annex 1


Popua Power Station
(Diesel)
Maama Mai (Solar)
Niutoua
(Target Area)
Mata 'o e La'a
Power Station
(Solar Power)
Tongatapu Island
Kingdom of Tonga
Vava'u
Group
Vava'u
Neiafu
Kao Island
Pangai
Ha'apai Group
NUKU'ALOFA
Tongatapu
Group
Minerva Reef not shown

Annex 2


CEO (1)
Network Investment Manager (1)
General Manager Finance (1)
HR Manager (1)
Human Resources Department (3)
Finance Controller (1)
Finance Department Finance (7)
Finance Department Revenue (15)
Finance Department Billing (13)
Finance Department IT (4)
Procurement Manager / Project Accountant (1)
Junior Clerk (0)
Administration Manager / EA (1)
Administration Department (3)
General Manager Operations (1)
Design & Planning Manager (1)
Design & Planning Department (16)
Network Distribution Manager (1)
Distribution Network Department 59)
Distribution Network - Outer Islands (27)
Major Projects Manager (1)
Major Projects Department OIEEP Manager (1)
Major Projects Department TVNU Project Manager (1)
Tonga Village Network Upgrade Project Project Leader (1)
Tonga Village Network Upgrade Project (15)
Major projects Department OIREP Manager (1)
Acting Power Generation Manager (1)
Power Station Superintendent & Outer Islands Manager (1)
Power Generation (25)
Strategic Development Manager (1)
Strategic Development Unit (4)
Risk & Compliance Manager (1)

Annex 3

JAPANESE GRANT

The Japanese Grant (hereinafter referred to as the "Grant") is non-reimbursable fund provided to a recipient country to procure the facilities, equipment and services (engineering services and transportation of the products, etc.) for its economic and social development in accordance with the relevant laws and regulations of Japan. The Grant is not supplied through the donation of materials as such.

Based on a JICA law which was entered into effect on October 1, 2008 and the decision of the GOJ, JICA has become the executing agency of the Japanese Grant for Projects for construction of facilities, purchase of equipment, etc.

1. Grant Procedures

The Grant is supplied through following procedures:

· Preparatory Survey
- The Survey conducted by JICA

· Appraisal &Approval
-Appraisal by the GOJ and JICA, and Approval by the Japanese Cabinet

· Authority for Determining Implementation
-The Notes exchanged between the GOJ and a recipient country

· Grant Agreement (hereinafter referred to as "the G/A")
-Agreement concluded between JICA and a recipient country

· Implementation
-Implementation of the Project on the basis of the G/A

2. Preparatory Survey

(1) Contents of the Survey

The aim of the preparatory Survey is to provide a basic document necessary for the appraisal of the Project made by the GOJ and JICA. The contents of the Survey are as follows:

- Confirmation of the background, objectives, and benefits of the Project and also institutional capacity of relevant agencies of the recipient country necessary for the implementation of the Project.
- Evaluation of the appropriateness of the Project to be implemented under the Grant Scheme from a technical, financial, social and economic point of view.
- Confirmation of items agreed between both parties concerning the basic concept of the Project.
- Preparation of an outline design of the Project.
- Estimation of costs of the Project.

FA

The contents of the original request by the recipient country are not necessarily approved in their initial form as the contents of the Grant project. The Outline Design of the Project is confirmed based on the guidelines of the Japanese Grant scheme.

JICA requests the Government of the recipient country to take whatever measures necessary to achieve its self-reliance in the implementation of the Project. Such measures must be guaranteed even though they may fall outside of the jurisdiction of the organization of the recipient country which actually implements the Project. Therefore, the implementation of the Project is confirmed by all relevant organizations of the recipient country based on the Minutes of Discussions.

(2) Selection of Consultants

For smooth implementation of the Survey, JICA employs (a) consulting firm(s). JICA selects (a) firm(s) based on proposals submitted by interested firms.

(3) Result of the Survey

JICA reviews the Report on the results of the Survey and recommends the GOJ to appraise the implementation of the Project after confirming the appropriateness of the Project.

3. Japanese Grant Scheme

(1) The E/N and the G/A

After the Project is approved by the Cabinet of Japan, the Exchange of Notes(hereinafter referred to as "the E/N") will be singed between the GOJ and the Government of the recipient country to make a pledge for assistance, which is followed by the conclusion of the G/A between JICA and the Government of the recipient country to define the necessary articles, in accordance with the E/N, to implement the Project, such as payment conditions, responsibilities of the Government of the recipient country, and procurement conditions.

(2) Selection of Consultants

In order to maintain technical consistency, the consulting firm(s) which conducted the Survey will be recommended by JICA to the recipient country to continue to work on the Project's implementation after the E/N and G/A.

(3) Eligible source country

Under the Grant, in principle, Japanese products and services including transport or those of the recipient country are to be purchased. The Grant may be used for the purchase of the products or services of a third country, if necessary, taking into account the quality, competitiveness and economic rationality of products and services necessary for achieving the objective of the Project. However, the prime contractors, namely, constructing and procurement firms, and the prime consulting firm are limited to "Japanese nationals", in principle.

(4) Necessity of "Verification"

The Government of the recipient country or its designated authority will conclude contracts denominated in Japanese yen with Japanese nationals, in principle. Those contracts shall be verified by JICA. This "Verification" is deemed necessary to fulfill accountability to Japanese taxpayers.

(5) Major undertakings to be taken by the Government of the Recipient Country

In the implementation of the Grant Project, the recipient country is required to undertake such necessary measures as Annex. The Japanese Government requests the Government of the recipient country to exempt all customs duties, internal taxes and other fiscal levies such as VAT, commercial tax, income tax, corporate tax, resident tax, fuel tax, but not limited, which may be imposed in the recipient country with respect to the supply of the products and services under the verified contract, since the Grant fund comes from the Japanese taxpayers.

(6) "Proper Use"

The Government of the recipient country is required to maintain and use properly and effectively the facilities constructed and the equipment purchased under the Grant, to assign staff necessary for this operation and maintenance and to bear all the expenses other than those covered by the Grant.

(7) "Export and Re-export"

The products purchased under the Grant should not be exported or re-exported from the recipient country.

(8) Banking Arrangements (B/A)

a) The Government of the recipient country or its designated authority should open an account under the name of the Government of the recipient country in a bank in Japan (hereinafter referred to as "the Bank"), in principle. JICA will execute the Grant by making payments in Japanese yen to cover the obligations incurred by the Government of the recipient country or its designated authority under the Verified Contracts.

b) The payments will be made when payment requests are presented by the Bank to JICA under an Authorization to Pay (A/P) issued by the Government of the recipient country or its designated authority.

(9) Authorization to Pay (A/P)

The Government of the recipient country should bear an advising commission of an Authorization to Pay and payment commissions paid to the Bank.

(10) Environmental and Social Considerations

The Government of the recipient country must carefully consider environmental and social impacts by the Project and must comply with the environmental regulations of the recipient country and JICA Guidelines for Environmental and Social Consideration (April, 2010) .

(11) Monitoring

The Government of the recipient country must take their initiative to carefully monitor the progress of the Project in order to ensure its smooth implementation as part of their responsibility in the G/A, and must regularly report to JICA about its status by using the Project Monitoring Report (PMR).

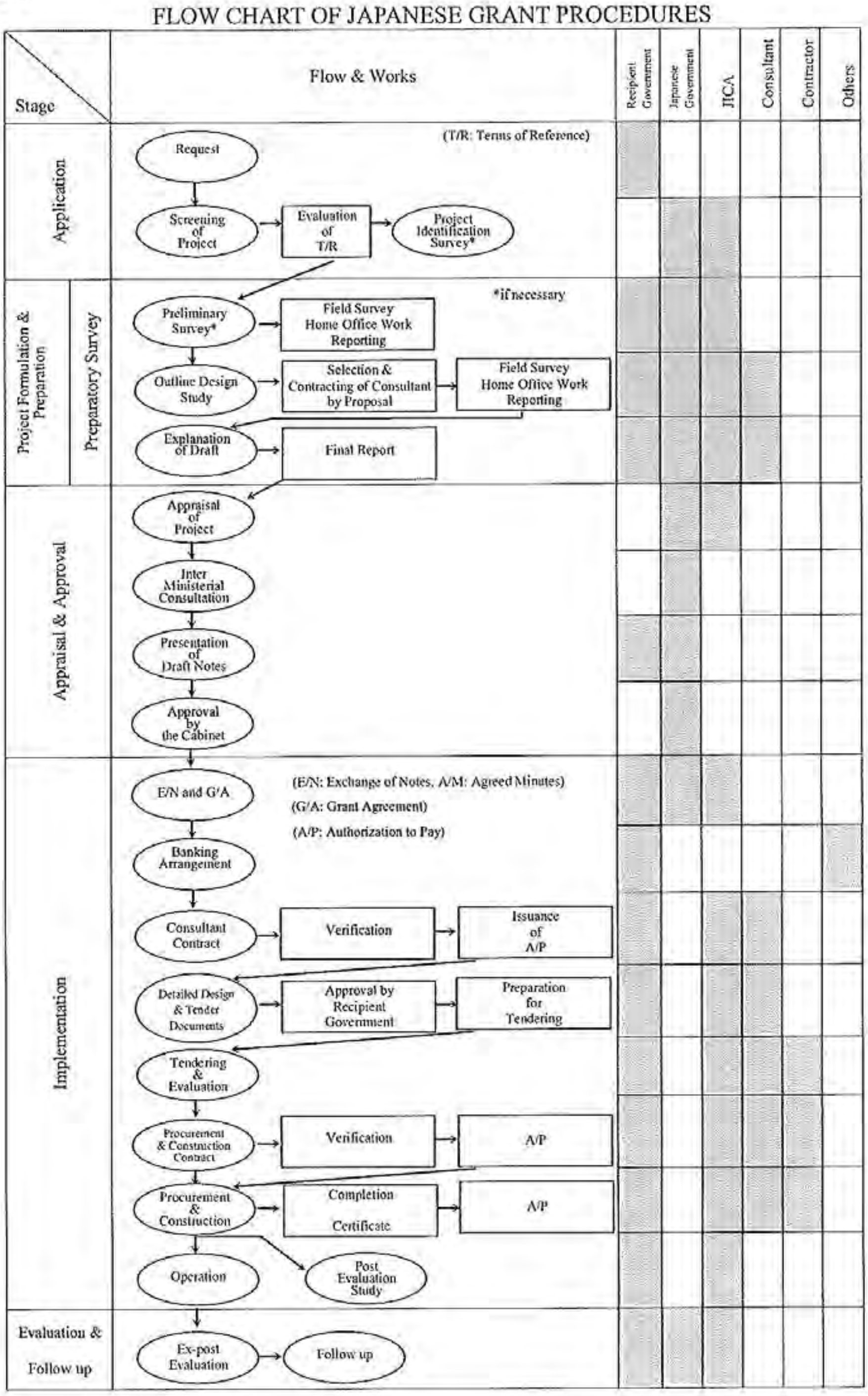
(12) Safety Measures

The Government of the recipient country must ensure that the safety is highly observed during the implementation of the Project.

end

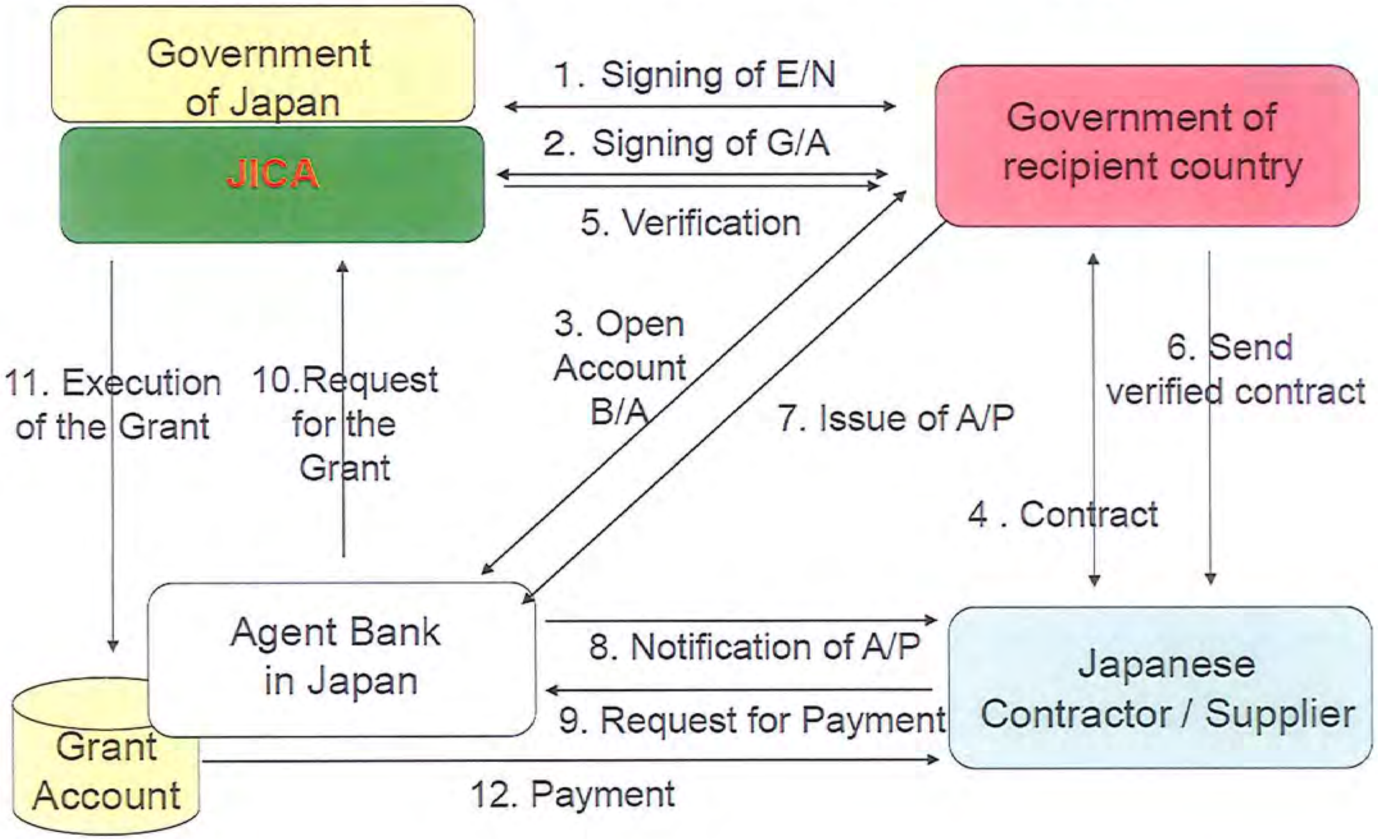
Annex 4

FLOW CHART OF JAPANESE GRANT PROCEDURES



Annex 5

Financial Flow of Grant Aid (A/P Type)



Annex 6

Major Undertakings to be taken by Each Government
<To be covered by Government of Tonga>

1. Before the Tender

NO	Items	Deadline	In charge	Cost	Ref.
1	To open Bank Account (Banking Arrangement (B/A))	within 1 month after G/A	TPL		
2	To approve IEE/EIA	within 1 month after G/A	TPL MEIDCC		
3	To implement EIA including stakeholder meeting for all those who possibly affected by the Project	before start of the construction	TPL MEIDCC		
4	To secure the following lands for 1) project sites for wind turbine and storage system 2) access road outside of the project site 3) distribution line	before notice of the tender document	TPL		
5	To obtain the planning, zoning, building permit	before notice of the tender document	TPL		
6	To clear, level and reclaim the following sites 1) project sites for wind turbine and stabilization system (batteries) 2) access road (outside the project site) 3) right of way of distribution line	before notice of the tender document	TPL		
7	To construct access road for materials transportation	before notice of the tender document	TPL		

2. During the Project Implementation

NO	Items	Deadline	In charge	Cost	Ref.
1	To bear the following commissions to a bank of Japan for the banking services based upon the B/A				
	1) Advising commission of A/P	within 1 month after the singing of the contract	TPL MOFNP		
	2) Payment commission for A/P	every payment	TPL MOFNP		
2	To ensure prompt unloading and customs clearance at the port of disembarkation in recipient country				
	1) Tax exemption and customs clearance of the products at the port of disembarkation	during the Project	TPL MOFNP		
	2) Internal transportation from the port of disembarkation to the project site	during the Project	TPL MOFNP		
3	To accord Japanese nationals and/or physical persons of third countries whose services may be required in connection with the supply of the products and the services under the verified contract such facilities as may be necessary for their entry into the recipient country and stay therein for the performance of their work	during the Project	TPL		

4	To ensure that customs duties, internal taxes and other fiscal levies which may be imposed in the country of the Recipient with respect to the purchase of the Products and/or the Services be exempted; Such customs duties, internal taxes and other fiscal levies mentioned above include VAT, commercial tax, income tax and corporate tax of Japanese nationals, resident tax, fuel tax, but not limited, which may be imposed in the recipient country with respect to the supply of the products and services under the verified contract	during the Project	TPL MOFNP		
5	To bear all the expenses, other than those to be borne by the Grant Aid, necessary for construction of the facilities as well as for the transportation and installation of the equipment	during the Project	TPL		
6	To submit Project Monitoring Report	during the Project	TPL		
7	To fence around the site for security as necessary	3 months before completion of the construction	TPL		
8	To implement Environmental Management Plan (EMP) and Environmental Monitoring Plan (EMoP) of the Project	during the construction	TPL		
9	To submit results of environmental monitoring to JICA, by using the monitoring form, on a quarterly basis as a part of Project Monitoring Report	during the construction	TPL		

3. After the Project

NO	Items	Deadline	In charge	Cost	Ref.
1	To maintain and use properly and effectively the facilities constructed and equipment provided under the Grant Aid 1) Allocation of maintenance cost 2) Operation and maintenance structure 3) Routine check/Periodic inspection	After completion of the construction	TPL		
2	To implement EMP and EMoP	for a period based on EMP and EMoP	TPL		
	To submit results of environmental monitoring to JICA, by using the monitoring form, semiannually - The period of environmental monitoring may be extended if any significant negative impacts on the environment are found. The extension of environmental monitoring will be decided based on the agreement between *Implementation Agency of Tonga* and JICA.	for three years after the Project	TPL		

(B/A: Banking Arrangement, A/P: Authorization to pay, N/A: Not Applicable)

G/A NO. XXXXXXX
PMR prepared on DD/MM/YY

Annex 6

Major Undertakings to be taken by Each Government
<To be covered by Japanese Grant>

No	Items	Deadline	Cost Estimated (Million Japanese Yen)*	
1	To install wind power generation system and related facilities			
	1) Marine transportation of the products from Japan to the recipient country			
	2) Internal transportation from the port of disembarkation to the project site		XX.XX	
	3) To install facilities			
	4) To provide equipment with installation related facilities and commissioning			
	5) Temporally fence and gate during the construction			
	6) Roads within the project site			
	7) Installation of equipment for connection to existing distribution grid			
2	To provide soft component for operation and maintenance of provided products, facilities and equipment			
3	To implement detailed design, tender support and construction supervision (Consultant)			
4	Contingencies		YY.YY	
	Total		ww.ww	
			ZZ.ZZ	

*; The cost estimates are provisional. This is subject to the approval of the Government of Japan.

14

G/A NO. XXXXXXX
PMR prepared on DD/MM/YY

Annex 7

Project Monitoring Report

on

The Project for Installation of Wind Power Generation System

Grant Agreement No. XXXXXXX

20XX, Month

Organization Information

1) Authority (Signer of the G/A)	Person in Charge ______ (Division) ______ Contacts Address: ______ Phone/FAX: ______ Email: ______
Executing Agency	Person in Charge ______ (Division) ______ Contacts Address: ______ Phone/FAX: ______ Email: ______
Line Agency	Person in Charge ______ (Division) ______ Contacts Address: ______ Phone/FAX: ______ Email: ______

Outline of Grant Agreement:

Source of Finance	Government of Japan: Not exceeding JPY ______ mil. Government of (______): ______
Project Title	
E/N	Signed date: Duration:
G/A	Signed date: Duration:

FH

15

G/A NO. XXXXXXX
PMR prepared on DD/MM/YY

1: Project Description

1-1 Project Objective

1-2 Necessity and Priority of the Project

- Consistency with development policy, sector plan, national/regional development plans and demand of target group and the recipient country.

1-3 Effectiveness and the indicators

- Effectiveness by the project

Quantitative Effect (Operation and Effect indicators)		
Indicators	Original (Yr)	Target (Yr)
Qualitative Effect		

2: Project Implementation

2-1 Project Scope

Table 2-1-1a: Comparison of Original and Actual Location

Location	**Original:** *(M/D)* **Attachment(s):Map**	**Actual:** *(PMR)* **Attachment(s):Map**

Table 2-1-1b: Comparison of Original and Actual Scope

Items	Original	Actual
(M/D)	*(M/D)*	*(PMR)*

FA

G/A NO. XXXXXXX
PMR prepared on DD/MM/YY

'Soft component' shall be included in 'Items'.		Please state not only the most updated sc hedule but also other past revisions chron ologically. All change of design shal l be recorded regardless of its degree.

(Sample)Table 2-1-1b: Comparison of Original and Actual Scope

Items	Original	Actual
1. Upgrading of the Kukum Highway	length 20km, single lane (3.47m*2), path(1.25m*2) Concrete Pavement 200mm (motor lane only)	length 20km, single lane (3.47m*2), path(1.00m*2) C oncrete Pavement 200mm (motor lane only)
2. Replacement of Old Mataniko Bridge	Bridge length 40m, Width 9.5m, path(1.00m*2), compound steel box-girder bridge, Inverted T type-abutment spread foundation	Ditto

(Sample)Table 2-1-1b: Comparison of Original and Actual Scope

Items	Original	Actual
1. Outpatient Department	RC, Double Storey Ground floor: Consultation room 6 Reception Satellite Lab. Pharmacy, etc 1st floor: Consultation room 5 Dental Clinic 2	RC, Double Storey Ground floor: Consultation room 5 ditto
2. Operation Theatre, Casualty Unit, Maternity Ward	RC, Double Storey Ground Floor: Operation room 2 Casualty Unit 1st Floor: Maternity Ward 50 beds	ditto Maternity Ward 60 beds

(Sample)Table 2-1-1b: Comparison of Original and Actual Scope

Items	Original	Actual
1. Primary and Secondary Surveillance Radars at Chittagong Int'l Airport	i) OSR/SSR 1 set ii) RDP 1 set iii) VHF Transmitters 2 sets	Ditto
2. Access Control System for Dhaka Int'l Airport	1 set	Ditto

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3. Doppler VOR/DME at Saidpur Airport	1 set	Ditto
4. Aerodrome Simulator for Civil Aviation Training Center	1 set	Ditto
5. Baggage Inspection System for Dhaka Int'l Airport	i) Hold Baggage Xray Inspectin system 7sets ii) Hold Baggage Explosive Trace Detecting System 7sets iii) Cabin Baggage Xray Inspection System 2sets	Ditto
6. Airport Fire Fighting Vehicles for Dhaka Int'l Airport	2 sets	3 sets

2-1-2 Reason(s) for the modification if there have been any.

(PMR)

2-2 Implementation Schedule

2-2-1 Implementation Schedule

Table 2-2-1: Comparison of Original and Actual Schedule

Items	Original		Actual
	DOD	G/A	
[M/D] 'Soft component' shall be stated in the column of 'Items'. Project Completion Date*	*(M/D)*		*(PMR)* As of (Date of Revision) Please state not only the most updated schedule but also other past revisions chronologically.

*Project Completion was defined as ______________________ at the time of G/A.

(Sample)Table 2-2-1: Comparison of Original and Actual Schedule

Items	Original		Actual
	DOD	G/A	
Cabinet Approval	11/2015	-	-

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E/N	12/2015	1/2016	24/1/2016
G/A	12/2015	1/2016	24/1/2016 Amended 13/3/2017
Detailed Design	12/2015-4/2016	1/2016-5/2016	1/2016-5/2016
Tender Notice	5/2016	5/2016	1/6/2016
Tender	6/2016	6/2016	15/7/2016
(Lot1) Construction Period	7/2016-11/2018	7/2016-11/2018	8/8/2016-30/11/2018
(Lot2) Installarion of Equipement	7/2016-6/2018	7/2016-6/2018	6/8/2016-30/60/2017
Project Completion Date	11/2018	11/2018	30/11/2018
Defect Liability Period	11/2019	11/2019	30/11/2019

*Project Completion was defined as <u>Check-out of Construction work</u> at the time of G/A.

2-2-2 Reasons for any changes of the schedule, and their effects on the project.

2-3 Undertakings by each Government

2-3-1 Major Undertakings

See Attachment 2.

2-3-2 Activities

See Attachment 3.

2-3-3 Report on RD

See Attachment 4.

2-4 Project Cost

2-4-1 Project Cost

Table 2-4-1a Comparison of Original and Actual Cost by the Government of Japan

(Confidential until the Tender)

Items			Cost (Million Yen)	
	Original	Actual	Original	Actual
Construction Facilities (or	'Soft component' shall be included in 'Items'.			Please state not only the most

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Equipment)				updated schedule but also other past revisions chronologically.
Consulting Services	- Detailed design -Procurement Management -Construction Supervision			
Total				

Note: 1) Date of estimation:
2) Exchange rate: 1 US Dollar = Yen

Table 2-4-1b Comparison of Original and Actual Cost by the Government of XX

Items			Cost (Million USD)	
	Original	Actual	Original	Actual
				Please state not only the most updated schedule but also other past revisions chronologically.

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Total		

Note: 1) Date of estimation:
2) Exchange rate: 1 US Dollar = (local currency)

(Sample)Table 2-4-1a Comparison of Original and Actual Cost by the Government of Japan

(Confidential until the Tender)

Items			Cost (Million Yen)	
	Original	Actual	Original[1),2)]	Actual
Construction Facilities	1. Outpatient Department 2. Operation Theatre, Casualty Unit, Maternity Ward	Ditto Ditto	1,169.5	1,035.0
Equipment	1) Primary and Secondary Surveillance Radars at Chittagong Int'l Airport 2) Access Control System for Dhaka Int'l Airport 3) Doppler VOR/DME at Saidpur Airport 4) Aerodrome Simulator for Civil Aviation Training Center 5) Baggage Inspection System for Dhaka Int'l Airport 6) Airport Fire Fighting Vehicles for Dhaka Int'l Airport	Ditto	2,374.6	2,110.0
Consulting Services	- Detailed design -Procurement Management -Construction Supervision -Soft Component	Ditto	0.87	0.87
Total			3544.97	3145.87

Note: 1) Date of estimation: October, 2014
2) Exchange rate: 1 US Dollar = 99.93 Yen

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(Sample)Table 2-4-1b Comparison of Original and Actual Cost by the Government of Bangladesh

Items			Cost (1,000 Taka)	
	Original	Actual	Original1),2)	Actual
Dhaka International Airport	Modification of software of existing Rader Data Processing System	Ditto	8,000	9,240
	Provision of a partition, lighting, air conditioning and electric power supply at transfer hold baggage check point	Ditto	5,000	2,453
	Replacement of five doors in the international passenger terminal building	Ditto	4,000	5,340
Chittagong Int'l Airport	Preparation of the radar site including felling of trees, clearing and grabbing	Ditto	5,000	3,400
Total			22,000	20,433

Note: 1) Date of estimation: October, 2014
2) Exchange rate: 1 US Dollar = 0.887 Bangladesh Taka (local currency)

2-4-2 Reason(s) for the wide gap between the original and actual, if there have been any, the remedies you have taken, and their results.

(PMR)

2-5 Organizations for Implementation

2-5-1 Executing Agency:

- Organization's role, financial position, capacity, cost recovery etc,
- Organization Chart including the unit in charge of the implementation and number of employees.

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Original: *(M/D)*
Actual, if changed: *(PMR)*

2-6 Environmental and Social Impacts

- The results of environmental monitoring as attached in Attachment 5 in accordance with Schedule 4 of the Grant Agreement.
- The results of social monitoring as attached in Attachment 5 in accordance with Schedule 4 of the Grant Agreement.
- Information on the disclosed results of environmental and social monitoring to local stakeholders, whenever applicable.

3: Operation and Maintenance (O&M)

3-1 O&M and Management

- Organization chart of O&M
- Operational and maintenance system (structure and the number ,qualification and skill of staff or other conditions necessary to maintain the outputs and benefits of the project soundly, such as manuals, facilities and equipment for maintenance, and spare part stocks etc)

Original: *(M/D)*
Actual: *(PMR)*

3-2 O&M Cost and Budget

- The actual annual O&M cost for the duration of the project up to today, as well as the annual O&M budget.

Original: *(M/D)*

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4: Precautions (Risk Management)

- Risks and issues, if any, which may affect the project implementation, outcome, sustainability and planned countermeasures to be adapted are below.

Original Issues and Countermeasure(s): *(M/D)*	
Potential Project Risks	Assessment
1.	Probability: H/M/L
(Description of Risk)	Impact: H/M/L
	Analysis of Probability and Impact:
	Mitigation Measures:
	Action during the Implementation:
	Contingency Plan (if applicable):
2.	Probability: H/M/L
(Description of Risk)	Impact: H/M/L
	Analysis of Probability and Impact:
	Mitigation Measures:
	Action during the Implementation:
	Contingency Plan (if applicable):
3.	Probability: H/M/L
(Description of Risk)	Impact: H/M/L
	Analysis of Probability and Impact:
	Mitigation Measures:

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	Action during the Implementation:
	Contingency Plan (if applicable):
Actual issues and Countermeasure(s)	
(PMR)	

5: Evaluation at Project Completion and Monitoring Plan

5-1 Overall evaluation

Please describe your overall evaluation on the project.

5-2 Lessons Learnt and Recommendations

Please raise any lessons learned from the project experience, which might be valuable for the future assistance or similar type of projects, as well as any recommendations, which might be beneficial for better realization of the project effect, impact and assurance of sustainability.

5-3 Monitoring Plan for the Indicators for Post-Evaluation

Please describe monitoring methods, section(s)/department(s) in charge of monitoring, frequency, the term to monitor the indicators stipulated in 1-3.

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Attachment

1. Project Location Map
2. Undertakings to be taken by each Government
3. Monthly Report
4. Report on RD
5. Environmental Monitoring Form / Social Monitoring Form
6. Monitoring sheet on price of specified materials (Quarterly)
7. Report on Proportion of Procurement (Recipient Country, Japan and Third Countries)
   (Final Report Only)

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Attachment 6

Monitoring sheet on price of specified materials

1. Initial Conditions (Confirmed)

	Items of Specified Materials	Initial Volume A	Initial Unit Price (¥) B	Initial total Price C=A×B	1% of Contract Price D	Condition of payment	
						Price (Decreased) E=C−D	Price (Increased) F=C+D
1	Item 1	●●t	●	●	●	●	●
2	Item 2	●●t	●	●	●		
3	Item 3						
4	Item 4						
5	Item 5						

2. Monitoring of the Unit Price of Specified Materials

(1) Method of Monitoring : ●●

(2) Result of the Monitoring Survey on Unit Price for each specified materials

	Items of Specified Materials	1st ●month, 2015	2nd ●month, 2015	3rd ●month, 2015	4th	5th	6th
1	Item 1						
2	Item 2						
3	Item 3						
4	Item 4						
5	Item 5						

(3) Summary of Discussion with Contractor (if necessary)

-
-
-

Report on Proportion of Procurement (Recipient Country, Japan and Third Countries)
(Actual Expenditure by Construction and Equipment each)

		Domestic Procurement (Recipient Country) A	Foreign Procurement (Japan) B	Foreign Procurement (Third Countries) C	Total D
Construction Cost		(A/D%)	(B/D%)	(C/D%)	
	Direct Construction Cost	(A/D%)	(B/D%)	(C/D%)	
	others	(A/D%)	(B/D%)	(C/D%)	
Equipment Cost		(A/D%)	(B/D%)	(C/D%)	
Design and Supervision Cost		(A/D%)	(B/D%)	(C/D%)	
	Total	(A/D%)	(B/D%)	(C/D%)	

(1) Signed Minutes of Discussions on January 13, 2017 at Third Field Study

Minutes of Discussions
on the Preparatory Survey for the Project for
Installation of Wind Power Generation System in the Kingdom of Tonga (Explanation on Draft Preparatory Survey Report)

With reference to the minutes of discussions signed between Tonga Power Limited (hereinafter referred to as "TPL"), Ministry of Meteorology, Energy, Information, Disaster Management, Environment, Climate Change and Communication (hereinafter referred to as "MEIDECC"), Ministry of Public Enterprises (hereinafter referred to as "MPE") and Ministry of Finance and National Planning and the Japan International Cooperation Agency (hereinafter referred to as "JICA") on July 14, 2016 and in response to the request from the Government of Kingdom of Tonga(hereinafter referred to as "Tonga") dated August 7, 2014, JICA dispatched the Preparatory Survey Team (hereinafter referred to as "the Team") for the explanation of Draft Preparatory Survey Report (hereinafter referred to as "the Draft Report") for the Project for installation of wind power generation system(hereinafter referred to as "the Project"), headed by Mr. Hiroyuki Kobayashi, Deputy Director General, Industry Development and Public Policy Department, JICA from January 9 to January 13, 2017.

As a result of the discussions, both sides agreed on the main items described in the attached sheets.

Nuku'alofa, January 13, 2017

Hiroyuki Kobayashi
Leader
Preparatory Survey Team
Japan International Cooperation Agency
Japan

Robert Matthews
Chief Executive Officer
Tonga Power Limited
The Kingdom of Tonga

'Ofa Fa'anunu
Acting Chief Executive Officer
Ministry of Meteorology, Energy, Information, Disaster Mangement, Environment, Climate Change and Communication
The Kingdom of Tonga

Finau Moa
Acting Chief Executive Officer
Ministry of Public Enterprises

The Kingdom of Tonga

Balwyn Fa'otusia
Chief Executive Officer
Ministry of Finance and National Planning
The Kingdom of Tonga

ATTACHEMENT

1. Objective of the Project
   The objective of the Project is to introducing renewable energy and diverse the power supply sources by installation of wind power generation system and grid stabilization system in Tongatapu Island, thereby contributing to stable energy supply.

2. Title of the Preparatory Survey
   Both sides confirmed the title of the Preparatory Survey as "the Preparatory Survey for the Project for Installation of Wind Power Generation System".

3. Project site
   Both sides confirmed that the site of the Project is in "Niutoua", which is shown in Annex 1.

4. Responsible authority for the Project
   Both sides confirmed the authorities responsible for the Project are as follows:
   4-1. The Executing Agency for the Project is the Ministry of Finance and National Planning, and Implementing Agency for the Project is TPL. The Executing Agency and Implementing Agency shall coordinate with all the relevant authorities to ensure smooth implementation of the Project and ensure that the undertakings for the Project shall be taken care by relevant authorities properly and on time. The organization charts of TPL are shown in Annex 2.

5. Contents of the Draft Report
   After the explanation of the contents of the Draft Report by the Team, the Tongan side agreed to its contents.

6. Cost estimate
   Both sides confirmed that the cost estimate described in the Draft Report is provisional and will be examined further by the Government of Japan for its approval.
   Both sides confirmed that the cost estimate including the contingency described in the Draft Report is provisional and will be examined further by the Government of Japan for its approval. The contingency would cover the additional cost against natural disaster, unexpected natural conditions, etc.

7. Confidentiality of the cost estimate and technical specifications
   Both sides confirmed that the cost estimate and technical specifications in the Draft Report should never be duplicated or disclosed to any third parties until all the contracts under the Project are concluded.

8. Timeline for the project implementation
   The Team explained to the Tongan side that the expected timeline for the project implementation is as attached in Annex 3.

9. Expected outcomes and indicators
   Both sides agreed that key indicators for expected outcomes are as follows. The Tongan side will be responsible for the achievement of agreed key indicators targeted in year 2022 and shall monitor the progress based on those indicators.

[Quantitative indicators]

Indicators	Standard value (Actual values in 2016)	Target value (2022) (After three years of project completion)
Power generation by wind turbine	0 MWh/year	4,296 MWh/year
Load factor	0%	35.70%
Availability factor	0%	90.70%
Reduction of diesel oil	0 kL/year 0 TOP/year	1,079 kL/year 1,492,810 TOP/year
Ratio of renewable energy	7.42 % (photovoltaics) 0 % (wind generation)	6.42 % (photovoltaics) 7.32 % (wind generation)
Greenhouse gas reduction	0 t CO_2/year	2,903 t CO_2/year

[Qualitative indicators]
Stable energy supply

10. Technical assistance ("Soft Component" of the Project)

Considering the sustainable operation and maintenance of the products and services granted through the Project, soft component is planned under the Project. The Tongan side confirmed to deploy necessary number of counterparts who are appropriate and competent in terms of its purpose of the technical assistance as described in the Draft Report.

11. Undertakings of the Project
Both sides confirmed the undertakings of the Project as described in Annex 4. With regard to exemption of customs duties, internal taxes and other fiscal levies as stipulated in 2. 4 of Annex 4, both sides confirmed that such customs duties, internal taxes and other fiscal levies include VAT, commercial tax, income tax and corporate tax, which shall be clarified in the bid documents by the Executing Agency during the implementation stage of the Project.
The Tongan side assured to take the necessary measures and coordination including allocation of the necessary budget which are preconditions of implementation of the Project. It is further agreed that the costs are indicative at Outline Design level. More accurate costs will be calculated at the Detailed Design stage.
Both sides also confirmed that the Annex 4 will be used as an attachment of G/A.

12. Monitoring during the implementation
The Project will be monitored by the Executing Agency and reported to JICA by using the form of Project Monitoring Report (PMR) attached as Annex 5. The timing of submission of the PMR is described in Annex 4.

13. Project completion
Both sides confirmed that the project completes when all the facilities constructed and equipment procured by the grant are in operation. The completion of the Project will be reported to JICA promptly, but in any event not later than six months after completion of the Project.

14. Ex-Post Evaluation
JICA will conduct ex-post evaluation after three (3) years from the project completion, in principle, with respect to five evaluation criteria (Relevance, Effectiveness, Efficiency, Impact, and Sustainability). The result of the evaluation will be publicized. The Tongan side is required to provide

necessary support for the data collection.

15. Items and measures to be considered for the smooth implementation of the Project
    Both sides confirmed the items and measures to be considered for the smooth implementation of the Project as follows.

15-1 Operation and Maintenance
    Both sides confirmed that TPL will secure adequate human resources for daily and periodical maintenance, mainly from destributuion network department.

15-2 Mid-Long Term Service Agreement
    JICA recommended TPL for concluding mid-long term service agreement with the manufacturer for maintenance and trouble shooting, because 300 kW scale wind turbine system will be the first time in Tonga.

15-3 Strengthening of Grid Network
    JICA recommended TPL for strengthening their grid network in the Tongatapu Island in order to stabilize the grid system by the time when the wind turbines start of operation.

15-4 Land Acquisition
    Land acquisition will be one of the important conditions for starting the tender process. TPL agreed that land acquisition will be done within 1 month after G/A is sighed described as Annex 4.

16. Schedule of the Study
    JICA will finalize the Preparatory Survey Report based on the confirmed items. The report will be sent to the Tongan side around May, 2017.

17. Environmental and Social Considerations

17-1 General Issues

17-1-1 Environmental Guidelines and Environmental Category
    The Team explained that 'JICA Guidelines for Environmental and Social Considerations (April 2010)' (hereinafter referred to as "the Guidelines") is applicable for the Project. The Project is categorized as B because the Project is not located in a sensitive area, nor has sensitive characteristics, nor falls into sensitive sectors under the JICA guidelines for environmental and social considerations (April 2010), and its potential adverse impacts on the environment are not likely to be significant.

17-1-2 Environmental Checklist
    The environmental and social considerations including major impacts and mitigation measures for the Project are summarized in the Environmental Checklist attached as Annex 7. Both sides confirmed that in case of major modification of the content of the Environmental Checklist, the Tongan side shall submit the modified version to JICA in a timely manner.

17-2 Environmental Issues

17-2-1 Environmental Impact Assessment (EIA)
    Both sides confirmed the EIA report has been approved by MEIDECC in July 2014.
    The Tongan side agreed JICA's disclosure of provided EIA report on its website.

17-2-2 Environmental Management Plan and Environmental Monitoring Plan
    Both sides confirmed Environmental Management Plan (EMP) and Environmental Monitoring Plan (EMoP) of the Project is as Annex 7, respectively. Both side agreed that environmental mitigation measures and monitoring shall be conducted based on the EMP and EMoP, which may be updated during the detailed design stage.

17-3 Social Issues

17-3-1 Land Acquisition

Both sides confirmed the around 2.8 ha of land would be acquired and 7 people would be affected due to the implementation of the Project.

Such land acquisition shall be implemented based on the Abbreviated Resettlement Action Plan (RAP) as Annex 8 which was prepared in line with the Guidelines and authorized by the Tongan side within one month after G/A.

17-4 Environmental and Social Monitoring

17-4-1 Environmental Monitoring

Both sides agreed that the Tongan side will submit results of environmental monitoring to JICA with PMR by using the monitoring form attached as Annex 9. The timing of submission of the monitoring form is described in Annex 4.

17-4-2 Social Monitoring

Both sides confirmed that the Tongan side will implement social monitoring about land acquisition and resettlement plan proposed in the RAP. The Tongan side and the Team agreed that TPL will submit results of social monitoring to JICA with PMR by using the monitoring form attached as Annex 9.

17-4-3 Information Disclosure of Monitoring Results

Both sides confirmed that the Tongan side will disclose results of environmental and social monitoring to local stakeholders through their website.

The Tongan side agreed JICA will disclose results of environmental and social monitoring submitted by the Tongan side as the monitoring forms attached as Annex 9 on its website.

18. Other Relevant Issues

18-1 Disclosure of Information

Both sides confirmed that the Preparatory Survey Report from which project cost is excluded will be disclosed to the public after completion of the Preparatory Survey. The comprehensive report including the project cost will be disclosed to the public after all the contracts under the Project are concluded.

18-2 Policy on Class of Wind Turbine and Maximum Wind Speed

Tongan side requested JICA that the class of wind turbines under International Electrotechnical Commission (IEC) should be "Class S" which can endure the size of current cyclones.

Based on the Tongan request, the class of wind turbine and maximum wind speed will be proposed detail during the detailed design stage. The final draft of specificationo will be also proposed considering the competitiveness of bidding.

In addition, JICA recommended TPL that "S class" would be considered for the specification not only for this project but also all other future wind power project in Tonga in the view of recent trend of cyclone occured.

18-3 Other Renewable Energy Project

Both sides confirmed that a IPP solar power project (installed capacity: 2MW) at Matatoa is underway, and JICA requested TPL to take necessary action for grid stabilization in the Tongatapu Island such as installing batteries.

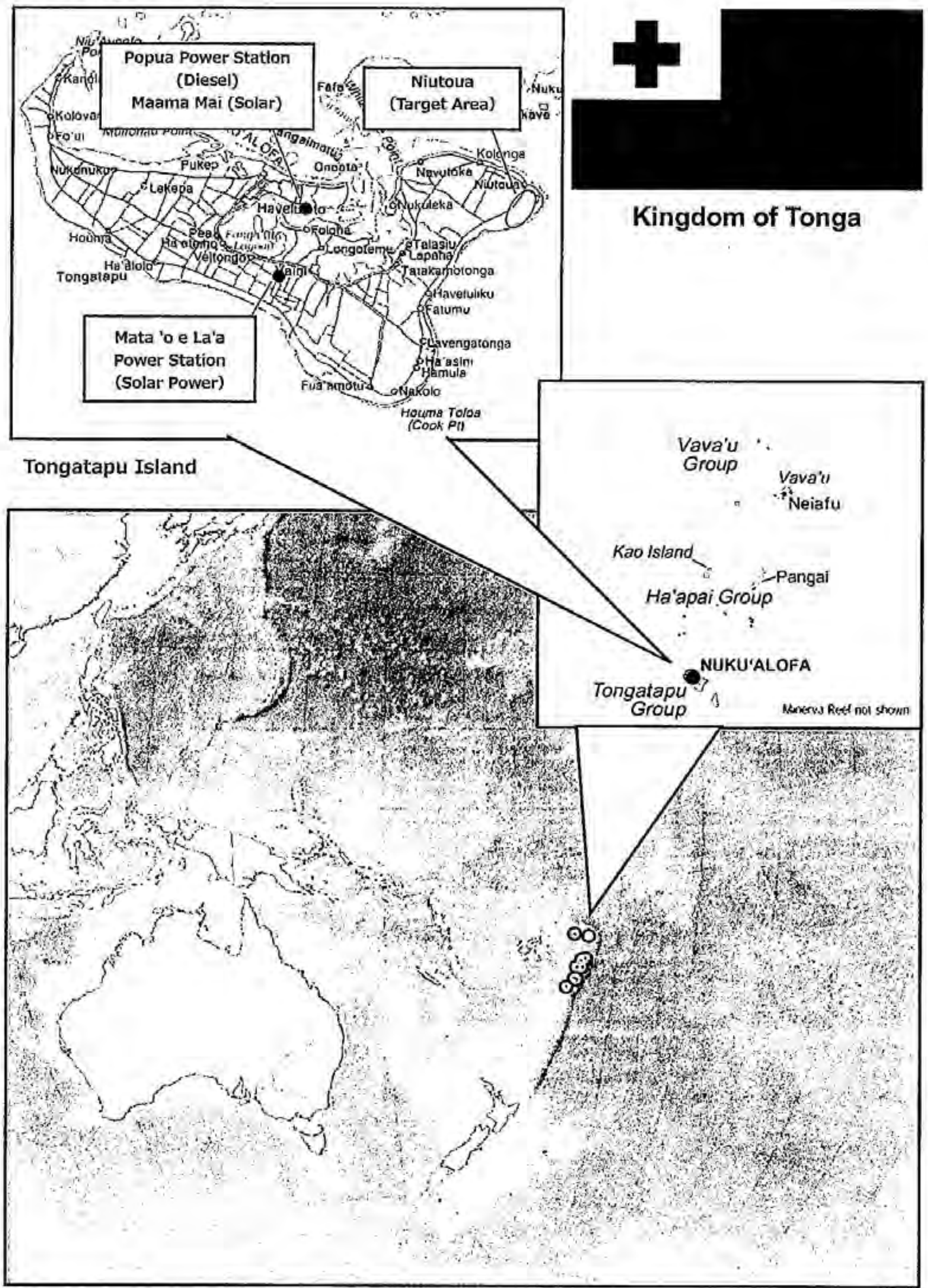
Annex 1 Project Site

Annex 2 Organization Chart

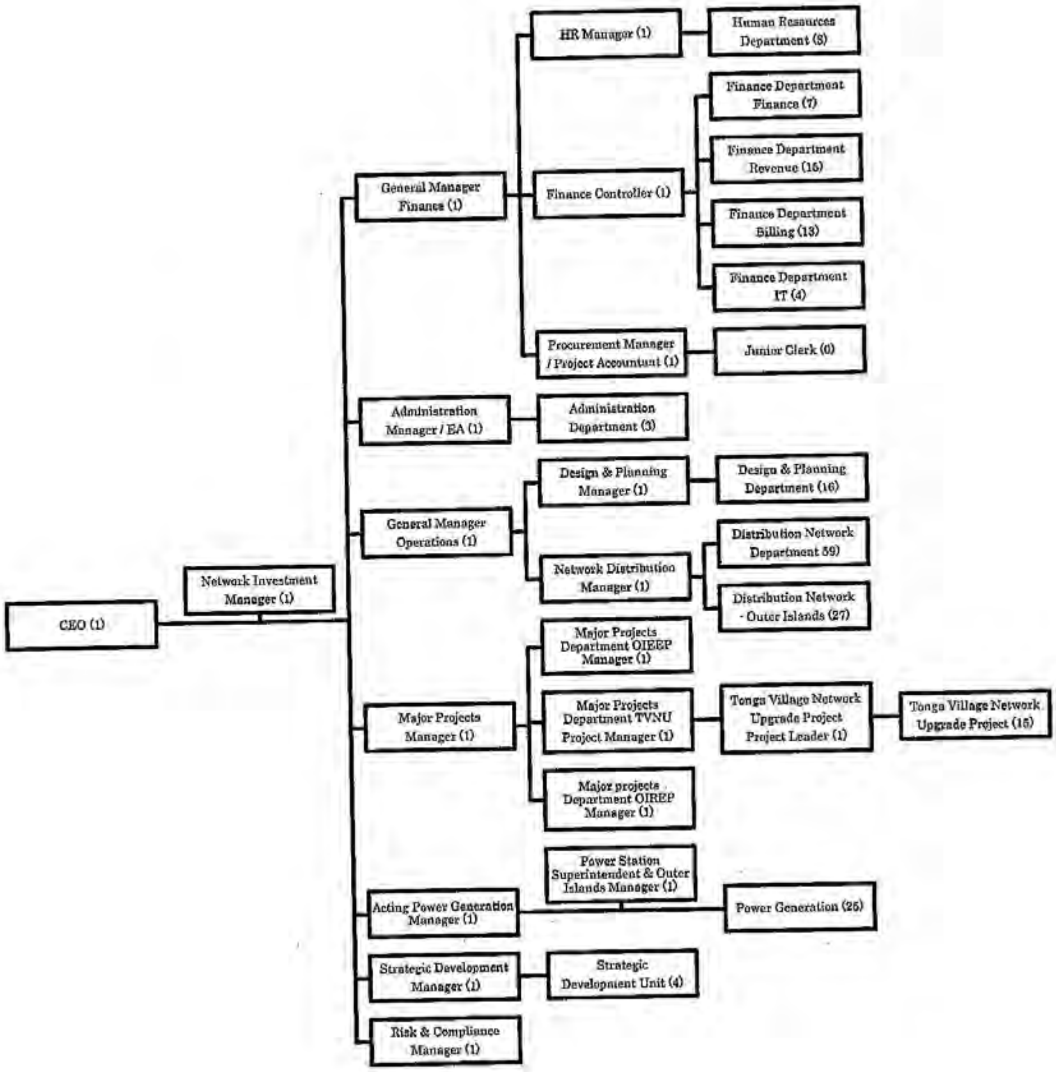
Annex 3 Project Implementation Schedule

Annex 4 Major Undertakings to be taken by the Government of Tonga
Annex 5 Project Monitoring Report (template)
Annex 6 Environmental Check List
Annex 7 Environmental Management Plan/Environmental Monitoring Plan
Annex 8 Abbreviated Resettlement Action Plan
Annex 9 Environmental and Social Monitoring Form

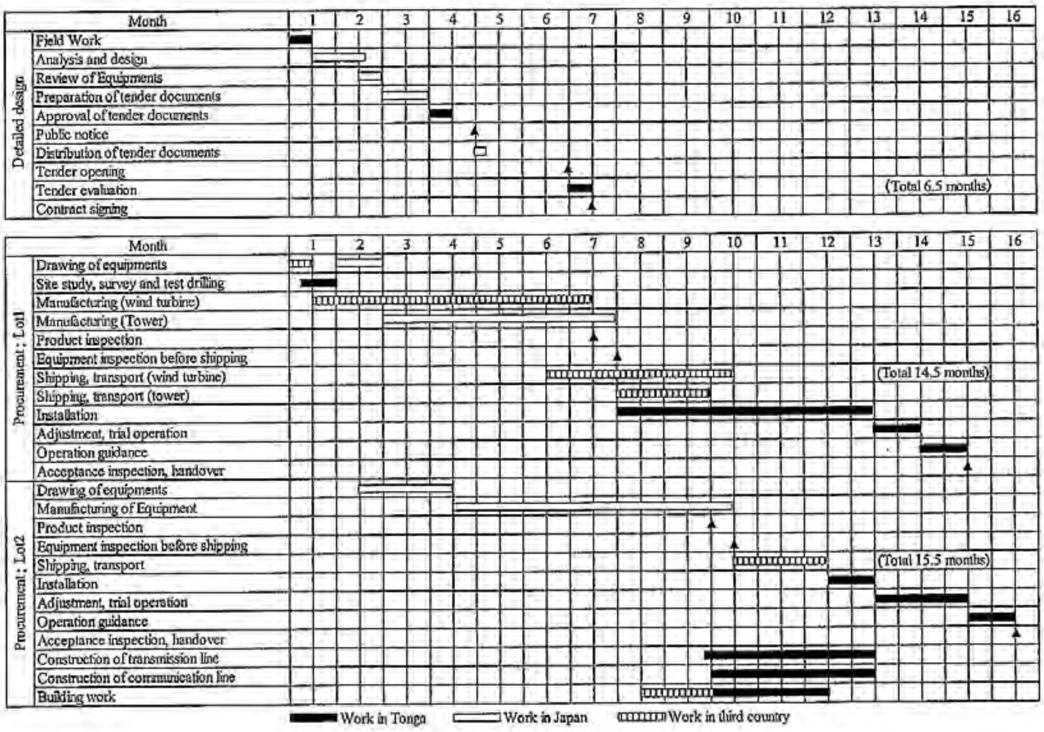
Annex 1 Project Site



Annex 2 Organization Chart



Annex 3 Project Implementation Schedule



Annex 4 Major Undertakings to be taken by the Government of Tonga

Major Undertakings to be taken by the Government of Tonga

1. Specific obligations of the Government of Tonga which will not be funded with the Grant

(1) Before the Tender

NO	Items	Deadline	In charge	Cost	Ref.
1	To open Bank Account (Banking Arrangement (B/A))	within 1 month after G/A	TPL MOFNP	32,000 TOP	
2	To approve IEE/EIA (Conditions of approval should be fulfilled, if any) and secure the necessary budget for implementation.	Done	TPL MEIDCC		
3	To secure the necessary budget and implement land acquisition, and compensation with full replacement cost in accordance with RAP	till land acquisition and resettlement complete	TPL MEIDCC		
4	To secure the following lands for 1) project sites for wind turbine and storage system 2) access road outside of the project site 3) distribution line	within 1 month after G/A	TPL	143,000 TOP	
5	To implement RAP, and to submit the monitoring results to JICA	within 1 month after G/A	TPL		
5	To obtain the planning, zoning, building permit	before notice of the tender document	TPL		
6	To clear, level and reclaim the following sites 1) project sites for wind turbine and stabilization system (batteries) 2) access road (outside the project site) 3) right of way of distribution line	before notice of the tender document	TPL	903,000 TOP	
7	To construct access road for materials transportation	before notice of the tender document	TPL	492,000 TOP	
8	To submit Project Monitoring Report (with the result of Detail Design)	before preparation of bidding documents	TPL		

(2) During the Project Implementation

NO	Items	Deadline	In charge	Estimated Cost	Ref.
1	To issue A/P to a bank in Japan (the Agent Bank) for the payment to the Supplier(s)	within 1 month after the signing of the contract(s)	TPL		
2	To bear the following commissions to a bank in Japan for the banking services based upon the B/A				
	1) Advising commission of A/P	within 1 month after the signing of the contract(s)	TPL		
	2) Payment commission for A/P	every payment	TPL/MOFNP		
3	To ensure prompt unloading and customs clearance at ports of disembarkation in recipient country and to assist the Supplier(s) with internal transportation therein	during the Project	TPL/NOFNP		
4	To accord Japanese nationals and/or physical persons of third countries whose services may be required in connection with the supply of the products and the services such facilities as may be necessary for their entry into the country of the Recipient and stay therein for the	during the Project	TPL		

	performance of their work				
5	To ensure that customs duties, internal taxes and other fiscal levies which may be imposed in the country of the Recipient with respect to the purchase of the products and/or the services be exempted;	during the Project	TPL		
6	To bear all the expenses, other than those covered by the Grant, necessary for the implementation of the Project	during the Project	TPL		
7	To submit Project Monitoring Report after each work under the contract(s) such as shipping, hand over, installation and operational training	within one month after completion of each work	TPL		
	1) To submit Project Monitoring Report (final)	within one month after signing of Certificate of Completion for the works under the contract(s)	TPL		
8	To submit a report concerning completion of the Project	within six months after completion of the Project	TPL		
9	To take necessary measure for safety construction - traffic control - rope off	during the construction	TPL		
10	To implement EMP and EMoP	during the construction	TPL		
11	To submit results of environmental monitoring to JICA, by using the monitoring form, on a quarterly basis as a part of Project Monitoring Report	during the construction	TPL		
12	To implement RAP	for a period based on livelihood restoration program	TPL		
13	To implement social monitoring, and to submit the monitoring results to JICA, by using the monitoring form, on a quarterly basis as a part of Project Monitoring Report	- until the end of livelihood restoration program (In case that livelihood restoration program is provided) - for two years after land acquisition and resettlement complete (In case that livelihood restoration program is not provided)	TPL		

(3) After the Project

NO	Items	Deadline	In charge	Estimated Cost	Ref.

1	To implement EMP and EMoP	for a period based on EMP and EMoP	TPL		
2	To submit results of environmental monitoring to JICA, by using the monitoring form, semiannually - The period of environmental monitoring may be extended if any significant negative impacts on the environment are found. The extension of environmental monitoring will be decided based on the agreement between TPL and JICA.	for three years after the Project	TPL		
3	To maintain and use properly and effectively the facilities constructed and equipment provided under the Grant Aid 1) Allocation of maintenance cost 2) Operation and maintenance structure 3) Routine check/Periodic inspection	After completion of the construction	TPL		

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2. Other obligations of the Government of Tonga funded with the Grant

NO	Items	Deadline (project completion)	Amount (Million Japanese Yen)*
1	To install wind power generation system and related facilities 1) To conduct the following transportation a) Marin transportation of the products from Japan and/or third countries to the recipient country b) Internal transportation from the port of disembarkation to the project site	July 2019	
	2) To provide equipment with installation and commissioning		
	3) To construct roads within the project site		
2	To implement detailed design, bidding support and procurement supervision (Consulting Service)		
	Total		

*The Amount is provisional. This is subject to the approval of the Government of Japan.

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Annex 5 Project Monitoring Report (template)

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Annex 5

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Project Monitoring Report
on
The Project for installation of wind power generation system
Grant Agreement No. XXXXXXX

20XX, Month

Organizational Information

Signer of the G/A (Recipient)	Person in Charge(Designation) Contacts Address: Phone/FAX: Email:
Executing Agency	Person in Charge(Designation) Contacts Address: Phone/FAX: Email:
Line Ministry	Person in Charge(Designation) Contacts Address: Phone/FAX: Email:

General Information:

Project Title	The Project for installation of wind power generation system
E/N	Signed date: Duration:
G/A	Signed date: Duration:
Source of Finance	Government of Japan: Not exceeding JPY _______ mil. Government of (_________): _____________

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1: Project Description	

1-1 Project Objective

This project will procure the 1.3 MW wind power generation system in Niutoua, including system stabilization system, connection of electric cable to existing grid, and optical cable, to achieve the energy security by increasing of the ratio of renewable energy in Tonga and ensuring the quality of electric power.

1-2 Project Rationale

- Higher-level objectives to which the project contributes (national/regional/sectoral policies and strategies)
- Situation of the target groups to which the project addresses

- Higher-level objectives
Achieving 50% electricity generation from renewable energy generation by 2020 in order to achieve the government Tonga Energy Road Map (TERM) objective and significant tariff reductions.
- Situation of the target groups
Tonga Power Limited (TPL), the imprementating agency of the Project, has totally 210 staff. Although sales and profits are up and down every few years, overall sales are steadily rising. In addition, gross profit is the highest in 2015. Operating profit is also maintaining high level. TPL posted net income from fiscal year of 2009 and secured profit of about 2 million TOP in recent years.

1-3 Indicators for measurement of "Effectiveness"

Quantitative indicators to measure the attainment of project objectives		
Indicators	Original (Yr 2016)	Target (Yr 2022)
Power generation by wind turbine	0 MWh/Yr	4,296 MWh/Yr
Load factor	0 %	35.7%
Availability factor	0 %	90.7%
Reduction of diesel oil	0 kL/Yr 0 TOP/Yr	1,079 kL/Yr 1,492,810 TOP/Yr
Ratio of renewable energy	7.42 % (photovoltaics) 0 % (wind generation)	6.42 % (photovoltaics) 7.32 % (wind generation)
Greenhouse gas reduction	0 tCO_2/Yr	2,903 tCO_2/Yr
Qualitative indicators to measure the attainment of project objectives		
Diversification of source for power supply *Stable supply of energy*		

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2: Details of the Project

2-1 Location

Components	Original (proposed in the outline design)	Actual
1. Wind power generation system	Niutoua, Tongatapu Island	

2-2 Scope of the work

Components	Original* (proposed in the outline design)	Actual*
1. Wind turbine	275kW x 5 unit = 1.375MW	
2. System stabilization system	Type: lithium-ion capacitor (Lic) Use: for cycle use Capacity: 14 kWh or more (7kWh×2)	
3. Electric cable	Connection to existing grid at Niutoua	
4. Optical cable	Connection between wind power station at Niutoua and Popua power station	

Reasons for modification of scope (if any).

(PMR)

2-3 Implementation Schedule

Items	Original		Actual
	(proposed in the outline design)	(at the time of signing the Grant Agreement)	
1. Detailed design			
Field Work	May, 2017		
Analysis and design	May to June, 2017		
Review of Equipments	June, 2017		
Preparation of tender documents	July, 2017		
Approval of tender documents	August, 2017		
Public notice	September, 2017		
Distribution of tender documents	September, 2017		
Tender opening	Nobember, 2017		
Tender evaluation	Nobember, 2017		
Contract signing	Nobember, 2017		
2. Lot 1 (wind turbine)			
Drawing of equipments	December 2017 to January 2018		
Site study, survey and test drilling	December 2017		

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Manufacturing (wind turbine)	December 2017 to June 2018		
Manufacturing (Tower)	Februaly 2018 to June 2018		
Product inspection	June 2018		
Equipment inspection before shipping	July 2018		
Shipping, transport (wind turbine)	May 2018 to Septembe 2018		
Shipping, transport (tower)	July 2018 to September 2018		
Installation	July 2018 to December 2018		
Adjustment, trial operation	December 2018 to Jauary 2019		
Operation guidance	January 2019 to Februaly 2019		
Acceptance inspection, handover	Februaly 2019		
3. Lot 2 (system stabilization system and cables)			
Drawing of equipments	January 2018 to March 2018		
Manufacturing of Equipment	March 2018 to September 2018		
Product inspection	September 2018		
Equipment inspection before shipping	September 2018		
Shipping, transport	September 2018 to Nobember 2018		
Installation	Nobember 2018 to December 2018		
Adjustment, trial operation	December 2018 to Februaly 2019		
Operation guidance	Februaly 2019 to March 2019		
Acceptance inspection, handover	March 2019		
Construction of transmission line	August 2018 to December 2018		
Construction of communication line	September 2018 to December 2018		
Building work	July 2018 to Nobember 2018		

Reasons for any changes of the schedule, and their effects on the project (if any)

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2-4 Obligations by the Recipient

2-4-1 Progress of Specific Obligations
See Attachment 2.

2-4-2 Activities
See Attachment 3.

2-4-3 Report on RD
See Attachment 11.

2-5 Project Cost

2-5-1 Cost borne by the Grant(<u>Confidential until the Bidding</u>)

Components			Cost (Million Yen)	
	Original *(proposed in the outline design)*	Actual *(in case of any modification)*	Original1),2) *(proposed in the outline design)*	Actual
	1.			
Total				

Note: 1) Date of estimation:
2) Exchange rate: 1 US Dollar = Yen

2-5-2 Cost borne by the Recipient

Components			Cost (1,000 TOP)	
	Original *(proposed in the outline design)*	Actual *(in case of any modification)*	Original1),2) *(proposed in the outline design)*	Actual
	1. Site acquisition		243,000	
	2. Ground leveling, cutting tree		903,000	
	3. Fence and gate		65,000	

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	4. Access road		492,000	
	5. Guard station		8,000	
	6. Lavatory		5,600	
	7. Water supply and drainage		62,000	
	8. Procurement of fixtures		500	
	9. Commission related to B/A (assumption)		32,000	
			1,811,100	

Note: 1) Date of estimation:
2) Exchange rate: 1 US Dollar =

Reasons for the remarkable gaps between the original and actual cost, and the countermeasures (if any)

(PMR)

2-6 Executing Agency

- Organization's role, financial position, capacity, cost recovery etc,
- Organization Chart including the unit in charge of the implementation and number of employees.

Original *(at the time of outline design)* name: Toga Power Limited (TPL) role: power supply to all of country financial situation: soundness institutional and organizational arrangement (organogram): Business Plan 2017 - 2020 human resources (number and ability of staff): 210
Actual *(PMR)*

2-7 Environmental and Social Impacts

- The results of environmental monitoring based on Attachment 5 (in accordance with Schedule 4 of the Grant Agreement).
- The results of social monitoring based on in Attachment 5 (in accordance with Schedule 4 of the Grant Agreement).
- Disclosed information related to results of environmental and social monitoring to local stakeholders (whenever applicable).

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3: Operation and Maintenance (O&M)

3-1 Physical Arrangement
- Plan for O&M (number and skills of the staff in the responsible division or section, availability of manuals and guidelines, availability of spareparts, etc.)

Original *(at the time of outline design)*
TPL is operating power stations (diesel, PV) in whole countlies, is maintaining those facilities by cooperation with manufactures of diesel generator and PV, and TPL has accumulated experience and gotten knowlaege and skills. Therefore, Japan recommended that TPL had better conclude mid-long term service agreement with the manufacturer for maintenance and trouble shooting, because 300 kW scale wind turbine system will be the first time in Tonga.
Actual *(PMR)*

3-2 Budgetary Arrangement
- Required O&M cost and actual budget allocation for O&M

Original *(at the time of outline design)*
365,000TOP/Year for O&M of wind turbine
Actual *(PMR)*

4: Potential Risks and Mitigation Measures

- Potential risks which may affect the project implementation, attainment of objectives, sustainability
- Mitigation measures corresponding to the potential risks

Assessment of Potential Risks *(at the time of outline design)*

Potential Risks	Assessment
1. Renewable Energy Project funded by China	Probability: $\boxed{\text{High}}$/Moderate/Low
	Impact: $\boxed{\text{High}}$/Moderate/Low
	Analysis of Probability and Impact:
	Voltage instability, large-scale blackout in whole of Tongatatapu Island
	Mitigation Measures:

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	Grid stabilization in the Tongatapu Island such as installing batteries
	Action required during the implementation stage:
	Installation of storage batteries, power limitation of PV funded by China
	Contingency Plan (if applicable):
2. (Description of Risk)	Probability: High/Moderate/Low
	Impact: High/Moderate/Low
	Analysis of Probability and Impact:
	Mitigation Measures:
	Action required during the implementation stage:
	Contingency Plan (if applicable):
3. (Description of Risk)	Probability: High/Moderate/Low
	Impact: High/Moderate/Low
	Analysis of Probability and Impact:
	Mitigation Measures:
	Action required during the implementation stage:
	Contingency Plan (if applicable):
Actual Situation and Countermeasures	
(PMR)	

5: Evaluation and Monitoring Plan (after the work completion)

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5-1 Overall evaluation

Please describe your overall evaluation on the project.

5-2 Lessons Learnt and Recommendations

Please raise any lessons learned from the project experience, which might be valuable for the future assistance or similar type of projects, as well as any recommendations, which might be beneficial for better realization of the project effect, impact and assurance of sustainability.

5-3 Monitoring Plan of the Indicators for Post-Evaluation

Please describe monitoring methods, section(s)/department(s) in charge of monitoring, frequency, the term to monitor the indicators stipulated in 1-3.

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Attachment

1. Project Location Map
2. Specific obligations of the Recipient which will not be funded with the Grant
3. Monthly Report submitted by the Consultant

Appendix - Photocopy of Contractor's Progress Report (if any)
- Consultant Member List
- Contractor's Main Staff List

4. Check list for the Contract (including Record of Amendment of the Contract/ Agreement and Schedule of Payment)
5. Environmental Monitoring Form / Social Monitoring Form
6. Monitoring sheet on price of specified materials (Quarterly)
7. Report on Proportion of Procurement (Recipient Country, Japan and Third Countries) (PMR (final)only)
8. Pictures (by JPEG style by CD-R) (PMR (final)only)
9. Equipment List (PMR (final)only)
10. Drawing (PMR (final)only)
11. Report on RD (After project)

Attachment 6

Monitoring sheet on price of specified materials

1. Initial Conditions (Confirmed)

	Items of Specified Materials	Initial Volume A	Initial Unit Price (¥) B	Initial total Price C=A×B	1% of Contract Price D	Condition of payment	
						Price (Decreased) E=C−D	Price (Increased) F=C+D
1	Item 1	●●t	●	●	●	●	●
2	Item 2	●●t	●	●	●		
3	Item 3						
4	Item 4						
5	Item 5						

2. Monitoring of the Unit Price of Specified Materials

(1) Method of Monitoring : ●●

(2) Result of the Monitoring Survey on Unit Price for each specified materials

	Items of Specified Materials	1st ●month, 2015	2nd ●month, 2015	3rd ●month, 2015	4th	5th	6th
1	Item 1						
2	Item 2						
3	Item 3						
4	Item 4						
5	Item 5						

(3) Summary of Discussion with Contractor (if necessary)

-
-
-

Report on Proportion of Procurement (Recipient Country, Japan and Third Countries)
(Actual Expenditure by Construction and Equipment each)

		Domestic Procurement (Recipient Country) A	Foreign Procurement (Japan) B	Foreign Procurement (Third Countries) C	Total D
Construction Cost		(A/D%)	(B/D%)	(C/D%)	
	Direct Construction Cost	(A/D%)	(B/D%)	(C/D%)	
	others	(A/D%)	(B/D%)	(C/D%)	
Equipment Cost		(A/D%)	(B/D%)	(C/D%)	
Design and Supervision Cost		(A/D%)	(B/D%)	(C/D%)	
Total		(A/D%)	(B/D%)	(C/D%)	

Annex 6 Environmental Check List

Environmental Check List - Power Plant and Transmission Line

Category	Environmental Item	Main Check Items	Yes: Y No: N	Confirmation of Environmental Considerations (Reasons, Mitigation Measures)
1 Permits and Explanation	(1) EIA and Environmental Permits	(a) Have EIA reports been already prepared in official process? (b) Have EIA reports been approved by authorities of the host country's government? (c) Have EIA reports been unconditionally approved? If conditions are imposed on the approval of EIA reports, are the conditions satisfied? (d) In addition to the above approvals, have other required environmental permits been obtained from the appropriate regulatory authorities of the host country's government?	(a) Y (b) Y (c) Y (d) Y	(a) TPL and New Zealand have prepared EIA. (b) The EIA Report was approved by the Ministry of lands, Environment, Climate Change and Natural Resources (MLECCNR). (c) EIA report has been unconditionally approved. (d) The EIA report required for building permission has been prepared by TPL and will be submitted to MLECCNR.
	(2) Explanation to the Local Stakeholders	(a) Have contents of the project and the potential impacts been adequately explained to the Local stakeholders based on appropriate procedures, including information disclosure? Is understanding obtained from the Local stakeholders? (b) Have the comment from the stakeholders (such as local residents) been reflected to the project design?	(a) Y (b) Y	(a) Stakeholder meetings were held in August 2014 and April 2016. (b) The comments from stakeholders was reflected to the transmission line route plan.
	(3) Examination of Alternatives	(a) Have alternative plans of the project been examined with social and environmental considerations?	(a) Y	(a) The alternative routes of distribution lines and Zero-option were compared in order to minimize the impact on environment and society.
2 Pollution Control	(1) Air pollution	(a) Is there any possibility that SOx, NOx, or air polluting particles from the power plant cause air pollution? If the air pollution is anticipated, are adequate measures considered?	(a) N	(a) There is no possibility of air pollution.
	(2) Water Quality	(a) Is there any possibility that soil runoff from the power plant? If the water quality degradation is anticipated, are adequate measures considered?	(a) N	(a) There is no possibility of soil runoff from the power plant.
	(3) Wastes	(a) Will wastes from the power plant adequately disposed?	(a) Y	(a) Storage battery will be recycled or adequately disposed based on the Law of Tonga.
	(4) Soil pollution	(a) Has the soil been contaminated before? If so, are adequate measures considered?	(a) N	(a) The soil has not been contaminated before.

	(5) Noise, vibration, electromagnetic effect, low frequency effect	(a) Is there any possibility that noise and vibration from the power plant meets the local requirement? (b) Is there any possibility that low frequency sound meets the local requirement?	(a) Y (b) Y	(a) There is no regulation in Tonga, so the 40dB regulated in New Zealand is applied. The noise level is 35dB, so it meets the requirement. (b) ditto
	(6) Ground subsistence	(a) Is there any possibility that overuse of ground water cause ground subsistence?	(a) N	(a) There is no possibility of pumping of groundwater.
	(7) Offensive odor	(a) Is there any offensive odor emission source? Will adequate measures be considered?	(a) N	(a) There is no possibility of offensive odor emission source.
3 Natural Environment	(1) Protected Areas	(a) Is the project site located in protected areas designated by the country's laws or international treaties and conventions? Is there a possibility that the project will affect the protected areas?	(a) N	(a) There are no protected forest areas near the project area.
	(2) Ecosystem	(a) Does the project site encompass primeval forests, tropical rain forests, ecologically valuable habitats (e.g., coral reefs, mangroves, or tidal flats)? (b) Does the project site encompass the protected habitats of endangered species designated by the country's laws or international treaties and conventions? (c) If significant ecological impacts are anticipated, are adequate protection measures taken to reduce the impacts on the ecosystem? (d) Are adequate measures taken to prevent disruption of migration routes and habitat fragmentation of wildlife and livestock? (e) Is there any possibility that the project will cause the negative impacts, such as destruction of forest, poaching, desertification, reduction in wetland areas, and disturbance of ecosystem due to introduction of exotic (non-native invasive) species and pests? Are adequate measures for preventing such impacts considered? (f) Are adequate measures taken to prevent disruption of migration routes and habitat fragmentation of wildlife and livestock? (g) Is there any possibility that the project will cause the negative impacts, such as destruction of forest, poaching, desertification, reduction in wetland areas, and disturbance of ecosystem due to introduction of exotic (non-native invasive) species and pests? Are adequate measures for preventing such impacts considered? (h) In cases where the project site is located in undeveloped areas, is	(a) N (b) N (c) N (d) N (e) N (f) N (g) N (h) N	(a) There are no ecological valuable habitats in the project area. (b) There are no protected habitats living in the project area. (c)(d)(e)(f) (g) (h) The impact on ecosystem is not expected.

		there any possibility that the new development will result in extensive loss of natural environments?		
	(3) Water system	(a) Is there any impact on water system such as stream regime, wave, or water tide?	(a) N	(a) There is no impact on water system.
	(4) Topography and Geology	(a) Is there any possibility that civil works, such as cutting and filling will cause change in topography or geology? (b) Is there any soft ground on the route of power transmission and distribution lines that may cause slope failures or landslides? Are adequate measures considered to prevent slope failures or landslides, where needed? (c) Is there any possibility that civil works, such as cutting and filling will cause slope failures or landslides? Are adequate measures considered to prevent slope failures or landslides? (d) Is there a possibility that soil runoff will result from cut and fill areas, waste soil disposal sites, and borrow sites? Are adequate measures taken to prevent soil runoff?	(a) N (b) N (c) N (d) N	(a) Works which cause slope failures or landslides are not expected. (b) The project sites are almost flat and don't have the soft ground that may cause slope failures or landslides. (c)(d) Works which cause slope failures or landslides are not expected.
4 Social Environment	(1) Resettlement	(a) Is involuntary resettlement caused by project implementation? If involuntary resettlement is caused, are efforts made to minimize the impacts caused by the resettlement? (b) Is adequate explanation on compensation and resettlement assistance given to affected people prior to resettlement? (c) Is the resettlement plan, including compensation with full replacement costs, restoration of livelihoods and living standards developed based on socioeconomic studies on resettlement? (d) Are the compensations going to be paid prior to the resettlement? (e) Are the compensation policies prepared in document? (f) Does the resettlement plan pay particular attention to vulnerable groups or people, including women, children, the elderly, people below the poverty line, ethnic minorities, and indigenous peoples? (g) Are agreements with the affected people obtained prior to resettlement? (h) Is the organizational framework established to properly implement resettlement? Are the capacity and budget secured to implement the plan? (i) Are any plans developed to	(a) N (b) Y (c) Y (d) Y (e) N (f) Y (g) Y (h) Y (i) Y (j) Y	(a) (b)(c) Land acquisition for the project does not involve resettlement because the project is developed in the unused land. (d) The compensation payment is completed before starting the construction. (e) Compensation policies for land acquisition was explained in the public meeting and no objection was raised. (f)(g)(h)(i) Land acquisition for the project does not involve resettlement because the project is developed in the unused land. (j) TPL handles complaints through its customer service section.

		monitor the impacts of resettlement? (j) Is the grievance redress mechanism established?		
4 Social Environment	(2) Living and Livelihood	(a) Is there a possibility that the project will adversely affect the living conditions of inhabitants? Are adequate measures considered to reduce the impacts, if necessary? (b) Is there a possibility that water intake for the project impact the current water use?	(a) N (b) N	(a) there is no impact on residents around the Project site. (b) There is no water intake for the project.
	(3) Heritage	(a) Is there a possibility that the project will damage the local archeological, historical, cultural, and religious heritage? Are adequate measures considered to protect these sites in accordance with the country's laws?	(a) N	(a) There is no local archaeological, historical, cultural, and religious heritage affected by project.
	(4) Landscape	(a) Is there a possibility that the project will adversely affect the local landscape? Are necessary measures taken?	(a) N	(a) There is not any local landscape affected by project.
	(5) Ethnic Minorities and Indigenous Peoples	(a) Are considerations given to reduce impacts on the culture and lifestyle of ethnic minorities and indigenous peoples? (b) Are all of the rights of ethnic minorities and indigenous peoples in relation to land and resources respected?	(a) N (b) N	(a) (b) There are not any ethnic minority and indigenous people in and around the project area.
	(6) Working Conditions	(a) Is the project proponent not violating any laws and ordinances associated with the working conditions of the country which the project proponent should observe in the project? (b) Are tangible safety considerations in place for individuals involved in the project, such as the installation of safety equipment which prevents industrial accidents, and management of hazardous materials? (c) Are intangible measures being planned and implemented for individuals involved in the project, such as the establishment of a safety and health program, and safety training (including traffic safety and public health) for workers etc.? (d) Are adequate measures being planned and implemented for guard for the project not to affect safety of the individuals involved in the project and residents?	(a) Y (b) Y (c) Y (d) Y	(a) The project will be implemented in compliance with the Labor Law stipulated in Tonga. (b) The contractor shall conduct the safety consideration measures on hardware in accordance with all safety working standards. (c)(d)The contractor shall prepare the safety and health management plan and conduct safety education and training for workers.

5 Others	(1) Impacts during Construction	(a) Are adequate measures considered to reduce impacts during construction (e.g., noise, vibrations, turbid water, dust, exhaust gases, and wastes)? (b) If construction activities adversely affect the natural environment (ecosystem), are adequate measures considered to reduce impacts? (c) If construction activities adversely affect the social environment, are adequate measures considered to reduce impacts?	(a) Y (b) Y (c) Y	(a) Pollution is hardly expected. (b) The impact on natural environment is hardly expected. (c) There is possibility of the impact on social environment. The contractor shall take appropriate safety measures to avoid traffic and construction accidents.
	(2) Monitoring	(a) Does the proponent develop and implement monitoring program for the environmental items that are considered to have potential impacts? (b) What are the items, methods and frequencies of the monitoring program? (c) Does the proponent establish an adequate monitoring framework (organization, personnel, equipment, and adequate budget to sustain the monitoring framework)? (d) Are any regulatory requirements pertaining to the monitoring report system identified, such as the format and frequency of reports from the proponent to the regulatory authorities?	(a) Y (b) Y (c) Y (d) N	(a) Monitoring program is prepared on air pollution, noise/ vibration, protected area/ ecosystem, living, traffic and working condition. . (b) Public meeting and monthly observation survey in the site will be conducted. (c) EDC will establish the monitoring system and conduct monitoring with responsibility of the monitoring cost. (d) At present, the format and the frequency of the report are not provided from regulatory authorities.
6 Note	Reference to Checklist of Other Sectors	(a) Where necessary, pertinent items described in the Transmission line and facilities checklist should also be checked (e.g., projects including installation of electric transmission lines and/or electric distribution facilities). (b) Where necessary, pertinent items described in the Road checklist should also be checked (e.g., projects including installation of electric transmission lines and/or electric distribution facilities).	(a) Y (b) N	(a) Check list for Transmission line and facilities iscompiled. (b) Temporary access road is not constructed because a road that can be used as access road is planned to have been constructed before the construction of the Project starts.
	Note on Using Environmental Checklist	(a) If necessary, the impacts to transboundary or global issues should be confirmed, (e.g., the project includes factors that may cause problems, such as transboundary waste treatment, acid rain, destruction of the ozone layer, or global warming).	(a) N	(a) There is no possibility to impact on the transboundary or global environment due to the small construction work.

Annex 7 Environmental Management Plan/Environmental Monitoring Plan

1. Mitigation Measures

The mitigation measures were examined about the negative impact items assumed in the impact assessment.

No.	Items	Mitigation measure	Implementation organization	Responsible organization
1	Wastes	➢ The disposal of lead-acid storage batteries as facility of storage electricity is managed by the sole recycling company in Tonga, called "GIO Recycling", which export them to Korea to recycle. TPL will keep the budget for this and execute the disposal of battery. Regarding capacitor of lithium-ion, it needs to be disposed under the approval of Waste Authority Ltd (WAL) which established the regulation of waste disposal management in Tonga.	TPL Waste Authority Limited (WAL)	TPL
2	Land Acquisition	➢ TPL will explain about the construction well with land owners of targeted site. ➢ The payment of compensation of the land will proceed after the discussion between TPL and land owners. ➢ After the lease agreement between TPL and land owners, the contract will be submitted to Department of Lands and Survey. ➢ On the contract, the duration of lease (usually 50 years), the condition of the use during the construction, customer service center to receive the complaint from customers and other necessary items need to be mentioned.	TPL, Department of Lands and Survey	TPL
		➢ In order to settle the transmission line, the plotted map needs to be submitted to Ministry of Lands Survey and Natural Resources and get approval of ROW.	TPL MLSNRE	TPL
3	Accident	➢ Needs to be pay attention to working environment of workers. ➢ With safety standard and climate of Tonga, safety management guidance needs to be structured. ➢ Safety management assembly needs to be executed to enhance self awareness of accident by each worker.	Contractor	TPL

*TPL : Tonga Power Limited, MLSNRE: Ministry of Lands Survey and Natural Resources

2. Implementation System of Eivironmental Management and Monitoring

TPL is responsible for entire implementation of the project and explains the detailed construction schedule to local people before construction. TPL regularly patrols surrounding of the site during construction and if the problem is found. In the case that residents in the project area have grievance or any environmental and social problems occurs, EDC will attempt to solve them.

The implementation system of environmental management and monitoring plan is as follows

Organization	Responsibilities
TPL	➢ TPL is directly responsible for EMP and the monitoring plan. ➢ TPL explains the detailed construction schedule and route. ➢ TPL regularly patrols the surrounding of the sites. ➢ If a problem is found, TPL provides staff in charge of environmental matters to the site for the status check. ➢ TPL solves the grievance during construction and operation.
WAL	➢ WAL approves disposal of a battery.
MLSNRE	➢ MLSNRE reviews the application of transmission line and approves the Right of the Way.

3. Monitoring Plan

The monitoring plan is prepared according to the mitigation measures.

Item	Parameters to be Monitored and Measures	Location	Frequency	Implementing /Responsible Organization
Pre-construction phase				
All items	Checking the final engineering design	–	At the detailed and the final design stage	TPL
	Preparation and verification of the safety and health management plan	–	At the final design stage	TPL
	Public consultation	Project sites	Once or twice	TPL
Construction phase				
Waste	Wastes of construction: interview of leader at the construction site to check the amount of wastes and its final place to be disposed. Lead battery: check the receipt of the wastes by final receiver. Lithium-ion capacitor: check the way of disposal	Around the project site, Offices of receiver and WAL	At the time of disposal	TPL, Contractor, WAL,
Accident	Implementation of safety management assembly Public consultation of status of management of construction material and accidents	Around the project site	Monthly	Contractor, TPL
Operation and maintenance phase				
Waste	Wastes of construction: interview of leader at the construction site to check the amount of wastes and its final place to be disposed. Lead battery: check the receipt of the wastes by final receiver. Lithium-ion capacitor: check the way of disposal.	Around the project site, Offices of receiver and WAL	At the time of disposal	TPL, WAL
Accident	Implementation of safety management assembly. Public consultation of status of accidents.	Around the project site	Monthly	TPL

Annex 8 (Abbreviated) Resettlement Action Plan

Abbreviated Resettlement Plan

1. Project outline

The objective of this Project is to install a wind power station by Japan's Grant Aid. Therefore, the Project also aims to install a storage battery facility which will be connected to the existing power supply grid to secure and stabilize the system of wind power facilities. The planned site for the construction of the wind power station, Niutoua Village, is located at the northeast of Tonga's largest island, Tongatapu. The site encompasses seven blocks of farmland and is 180 m from the eastern coastline. Resettlement for this Project is not necessary because the planned site is almost unused farmland.

2. Latent impact of resettlement

a. Project component that requires land lease

Wind power station and a storage battery facility

b. Affected area

Seven blocks of farmland planned for construction of the wind power station and the residential area in Niutoua Village which is 1 km away from the planned site

c. Alternative plan

A comparison table of the case of implementing the Project and the zero option (non-implementation) of the construction is as shown in the following table. By carrying out the Project, environmental impacts, such as land acquisition, air pollution from the exhaust gas, noise and dust during construction, will occur. Also the Project will incur a financial cost. However, the construction of a wind power station will provide sustainable and economical power supply in Tonga.

Table 1: Comparison of the case of building wind power station and the zero option

Item		Zero option	Implementation of the Project
Facility of wind power station		0 point	5 points
Installation of electrical line		0m	approximately 2.0km
Technical consideration		• Power generation by diesel engine will be main source and against Tonga government policy of saving energy, which prevents reducing the consumption of imported energy.	• The acquisition of power by renewable energy will enable for residents to reduce the payment of tariff of electricity.
Environmental and social consideration	Social environment	• If the electrical line is not installed, the facility of wind power system is left unattended.	• For the purpose of installing the facility of wind power system, the acquisition of ROW is necessary, however, on the basis of discussion with landowner and TPL, the compensation will be paid. The agreement between TPL and landowner on this moment prevents the trouble which might happen prior to construction and after starting actual service. • The construction is not implemented in the residential area, therefore, residents shall not need to move.
	Natural environment	• Already most lands have been developed as farmland or rangeland, thus neither animals nor plants to be protected inhabit. • Power is generated by diesel fuel, so the damage for natural environment is not evitable.	• No animals or plants inhabit which needs to be protected. Thus, no bad influence on natural environment. • No bad influence on natural environment such as trees because the electrical line is planned to be build along the public road.
	Anti-pollution measures	• Exhaust gas or dust is observed from trucks or buses on unpaved roads.	• Exhaust gas or dust is emitted by vehicles for construction, however, the pollution does not exceed over the average because of short period of construction. • No influence on the residents in terms of noise because the construction site is remote from residential area.
Recommended proposal and reason		Deprecated	Recommended as optimal proposal
		• On the current condition, the consumption of imported diesel does not change, which is problem in the view of saving energy. • Against the TERM settled by Tonga government to take measures in high price of imported fuel.	• Applying renewable energy contributes to lower consumption of imported fuel and lower burden of electricity tariff by residents.

d. Measures to minimize impact of latent resettlement

- Due explanation to leaseholders of the planned site by Tonga Power Limited (TPL)
- Prompt procedure for compensation of land lease
- Clear stipulation of lease conditions, such as lease year (usually 50 years), use of land during the Project implementation, complaint handling mechanism, and other important conditions

3. Purpose of This Abbreviated Resettlement Plan

Although resettlement for this Project is not necessary, rights (consent from the leaseholders) to use the land needs to be obtained. In order for appropriate consideration for leaseholders, this abbreviated resettlement plan is prepared.

4. Social and Economic Survey

Most residential areas in Niutoua Village are in the northeast of Tongatapu, which is 1 km away from the target site. Main industries are fisheries, agriculture, livestock farming, sale of livestock, commerce and tourism. The population of the area is about 750. All of the land is owned by the King of Tonga; however, the residents can lease blocks of land. The Department of Lands and Survey under the Ministry of Lands Survey and Natural Resources (MLSNRE) has registered each land lessee. There are seven land lessees (of seven blocks of land) at the Project site as of the day when the first resident meeting on November 3rd, 2016 was public announced. Nobody lives on there, and resettlement is not necessary. There is no designated reserve for nature conservation or cultural heritage.

5. Legal Framework in accordance with the Land Acquisition

Since some of the King of Tonga's land has been subdivided to people in Tonga, the property rights of the land belongs to the leaseholders of each block. The Constitution of Tonga, revised 1988, banned the trade of the land but allowed land to be leased in accordance with Land Act, 1988 Revised Edition. Therefore, this Project site will be acquired through a lease agreement between the TPL and the leaseholders.

Moreover, the lease agreement was deliberated by Cabinet of Tonga and approved by MLSNRE. The terms of the lease are limited up to 99 years and the agreement is registered to Department of Lands and Survey. Experience shows that this process takes approximately one month from signing lease agreement.

Tongan Government does not set the price of the land legally. For this reason, the TPL has to set the compensation price with the leaseholders. The desirable compensation depends on the leaseholders, so the TPL must calculate the adequate price on the basis of the market price and proceed with the negotiation. The compensation should be paid before the beginning of the Project. However, the TPL does not need to obtain Right of Way (ROW) or pay compensation relating to the overhead lines or underground cables because the use of road is regarded as public use.

The following table compares "JICA investigation of environmental and social guidelines (April 2010)" and Tonga Land Act, 1988 Revised Edition.

Table 2: Comparison between JICA Guideline and Laws of Tonga

No.	JICA Guideline (A)	Laws of Tonga (B)	Gap between (A) and (B)	Policy of this Project
1	Compensation must be based on the full replacement cost as much as possible.	The holder of a hereditary estate shall receive from every tax allotment holder on that estate the rent prescribed by this Act without deduction.	Same level of compensation is required.	Market lease cost shall be paid.
2	When consultations are held, explanations must be given in a form, manner, and language that are understandable to the affected people.	NA	Obligation of explanation is not stipulated.	Explanation shall be given to all leaseholders.
3	Appropriate and accessible grievance mechanisms must be established for the affected people and their communications.	Before making a grant of a tax allotment out of an hereditary estate the Minister shall consult the holder thereof and hear any objections he may make to the grant being made and where the Minister and the holder of the hereditary estate fail to agree, the Minister shall nevertheless grant the land as a tax allotment but such grant shall within 3 months of the making thereof be liable to review by the Court, the decision of which on the matter shall be final.	JICA Guideline stipulates establishment of grivance mechanisms, whereas Land Law defines function of Ministry and Court as the final decision maker.	Based on JICA Guideline, the customer service section in TPL will deal with complaints.
4	Affected people are to be identified and recorded as early as possible in order to establish their eligibility through an intial baseline survey (including population census that serves as an eligibility cut-off date, asset inventory, and socioeconomic survey), preferably at the project identification stage, to prevent a subsequent influx of encroachers of others who wish to take advance of such benefits.	NA	Land Law does not give the lease acquisition mechanism associated with Project implementation.	Affeceted people are identified and recorded.
5	Eligibility of benefits includes, the PAPs who have formal legal rights to land (including customary and traditional land rights recognized under law), the PAPs who don't have a claim to such land or assets and the PAPs who have no recognizable legal right to the land they are occupaying.	NA	Land Law does not give the lease acquisition mechanism associated with Project implementation.	There are only the PAPs who have formal legal rights to land who are eligible for benefits.
6	For projects that entail land acquisition or involuntary resettlement of fewer than 200 people, abbreviated resettlement plan is to be prepared.	NA	preparation of resettlement plan is not required.	This abbreviate resettlement plan is prepared.

6. Executive System

The TPL is proceeding with the land acquisition for the site, and it has experience negotiating for land acquisition. The person in charge of the financial department will consider the necessity and the impact of the land acquisition, scope the target area, explain details to the residents, hold a consultant meeting, and proceed with the compensation on the basis of the scale of assessment of the compensation. The customer service section will deal with complaints during the construction.

Incidentally, Figure 1 shows TPL's organizational structure regarding land acquisition.

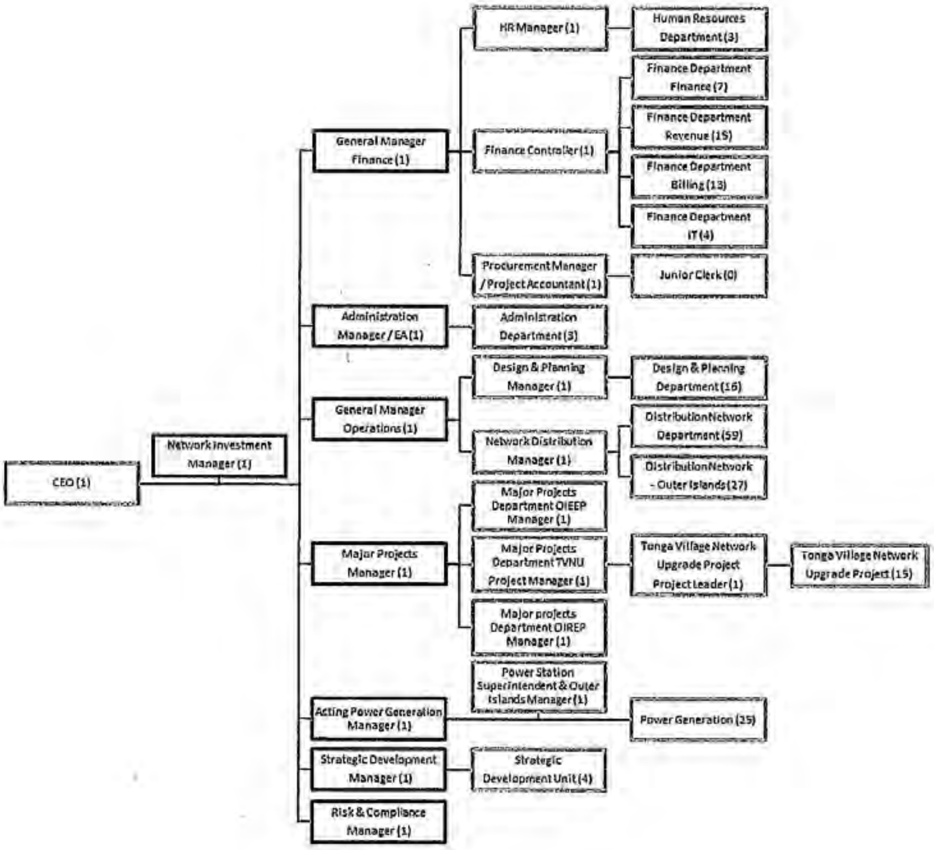


Figure 1: TPL Organization structure

Table 3: Entitlement matrix

No.	loss	beneficiaries of compensation	detail of compensation	responsibility organization
1	farm land	land owners（farmers）	Based on the judgement of TPL, compensation which is equivalent to the reacquisition price, will be paid to each land owner.	Tonga energy road map office and TPL
2	crop		Based on the judgement of TPL, compensation depending on the income from crops will be paid to each land owner.	

Tonga regulation referred: Constitution of Tonga, Revised 1988
Land Act, 1988 Revised Edition

7. Eligibility

The actual land acquisition will be maximum seven blocks as this Project plans five wind turbines. However, the compensation for the site is based on whether the TPL is able to acquire the land, and we assumed seven blocks will be necessary in the worst-case scenario.

In this Project, we calculated the area needed for the foundations of the turbines as wells as to conduct necessary future maintenance to confirm the applicable leaseholders. Lease agreements are planned to be concluded with these applicable leaseholders. Table 4 below demonstrates the area of land acquisition, land use and asset to be resettled.

Table 4: Land area and use and other asset to be resettled

Lot	Number of leaseholders	Area of compensation for land acquisition (m^2)	Land use	Asset to be resettled
A	1	3,032.261	unused	None
B	1	4,345.035	unused	None
C	1	4,578.846	unused	None
D	1	3,364.133	unused	None
E	1	5,826.452	unused	None
F	1	2,960.644	unused	None
G	1	3,927.156	unused	None
Total	7	28,034.527		

Note: Area includes foundation of wind turbines and maintenance space.

8. Compensation Calculation

The financial resources for the compensation cost of the land acquisition are from TPL's budget and the cost will be paid to the individual leaseholders. The cost is according to the area used for the construction. It will also be taken into account if the land acquisition causes a loss of earnings from crops. Accordingly, if there were no crops at the farm, the TPL would not need to pay any compensation costs to the leaseholders. Table 2-26 below demonstrates the compensation cost in accordance with the market price. There is no standard price of compensation by Land Act of Tonga, so the final decision depends on the present land situation and/or the market price.

9. Residents Meeting

TPL has already held a few residents meetings regarding the expansion of the existing power lines and construction of a new solar power station. Therefore, the residents already understand the significance for the land acquisition. Moreover, there have been two resident meetings regarding this wind power site in the past. The most recent meeting was held for 32 residents of Nutoua Village including leaseholders, local leaders and pastors in April 2016 regarding the EIA conducted by New Zealand. No serious objection was raised.

Furthermore, TPL has already consulted with some of the leaseholders of the target site, and they agreed to cooperate with the Project, although there were a few questions. A residents meeting was not held by this Project Team because the most recent residents meeting was held just four months earlier and the target leaseholders were not present (when the team was in Tonga). The TPL will have an official consultant meeting with residents again after the Project Team returns to Japan. In the meeting, the TPL has to explain the Project to the residents in order to proceed with the compensation fairly and smoothly, and has to collect the proper opinions regarding the plan, and finally has to review the plan.

10. Mechanism of the Complaints Processing

A residents meeting is to be held regarding the safe management of construction and questions from the residents. Opinions and complaints from residents relating to the wind power station are processed by the TPL through a local leader. If necessary, the TPL will hold a residents meeting at any time to solve the problems early. As for the leaseholders, they will promise not to complain about the Project in the lease agreement. The TPL also has a customer service section to deal with any risks or complaints by means of telephone, e-mail or written correspondence.

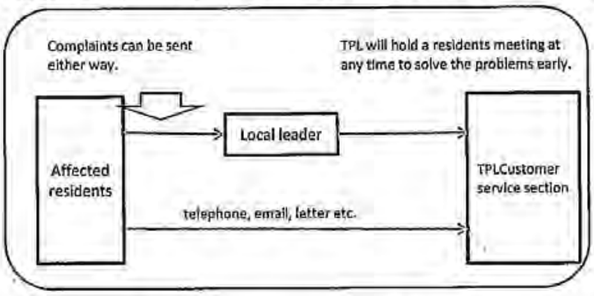


Figure 2: Complaints processing flow

11. Implementation Schedule/ Financing Resources and Cost

All the procedures for the land acquisition should be completed before starting the construction. The schedule of the land acquisition is as follows.

Table 5: Implementation schedule

Month	1				2			
Week	1	2	3	4	1	2	3	4
Confirmation of targeted area of construction								
Confirmation of land owners								
Confirmation of total cost of compensation								
Negotiation of land owner								
Explain the outline of construction to residents								
Contract of lease agreement								
Acquisition of land								

As mentioned before, the affected area is maximum seven blocks as shown in Figure 3.

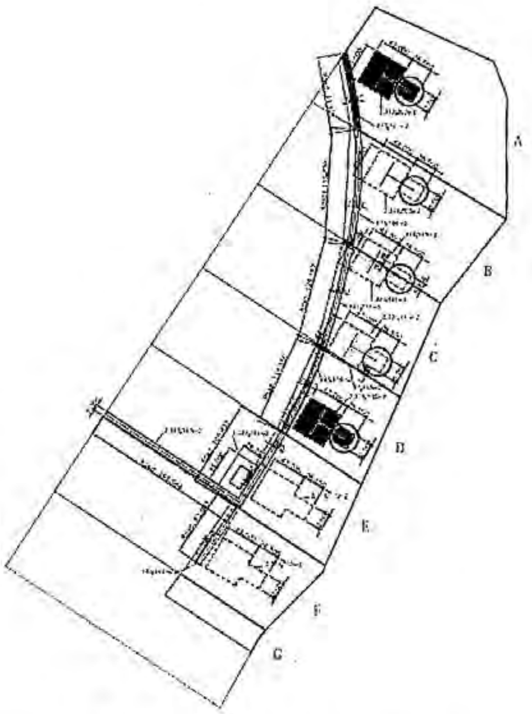


Figure 3: Area of land to be acquired

The financial resources for the compensation cost of the land acquisition are from TPL's budget and the cost will be paid to the individual leaseholders. The cost is according to the area used for the construction. Table 6 below demonstrates the compensation cost in accordance with the market price. The final decision depends on the present land situation and/or the market price.

Table 6: Compensation cost for the planned site by block

Lot	Area of compensation for land	Market price of land (TOP/m^2)	Amount of compensation (TOP)	
			TOP	JPY
A	3,032.261	9.848	29,860.400	1,375,967.219
B	4,345.035	9.910	43,060.996	1,984,250.693
C	4,578.846	12.328	56,449.080	2,601,173.611
D	3,364.133	12.386	41,666.972	1,920,014.078
E	5,826.452	12.229	71,254.208	3,283,393.924
F	2,960.644	12.242	36,244.026	1,670,124.715
G	3,927.156	11.459	45,000.000	2,073,600.000
total	28,034.527		323,535.682	14,908,524.240

Note: TOP : Tonga dollar (Pa'anga) (Source: TPL)
: exchange rate is based on the rate on cost estimation work (1TOP=46,080JPY)

Table 7: Total compensation cost and financing resources

total space of compensation area	amount of compensation (TOP)	detail	source of budget for resettlement
21,146.73	323,535.682	TPL will determine the compensation based on the total condition of the land such as market price of the land, current status of its use, the crop which is currently cultivated.	TPL

Note: TOP: Tonga dollar (pa'anga)

12. Monitoring and Evaluation

The whole procedure for compensation will be completed before starting construction. The TPL, however will continue to check whether any of the leaseholders have any issues or complaints on a regular basis (after the compensation has been settled). Basically TPL is in charge of complaints, but if they have difficulty resolving any issues, the TPL would need to consult with TERM-C (Tonga Energy Road Map Committee). Regarding the height of trees described in agreements, TPL should regularly check for maintaining the necessary amount of wind.

Table 8: Monitoring sheet

Lot	Name of leaseholder	Explanation of the site (e.g. height of trees)	Status (Completed (date) / not complete)	Details (e.g. Site Selection, discussion with PAPs)	Expected date of completion	Responsible organization
A						TPL
B						TPL
C						TPL
D						TPL
E						TPL
F						TPL
G						TPL

Table 9: Public consultation

	Date	Place	Contents of the consultation / main comments and answers
1			
2			
3			

Annex 9 Environmental and Social Monitoring Form

【Under Construction】

Item	Monitoring item	Date	Place	Condition	Frequency
Waste	Amount of wastes and its final place to be disposed				At the time of disposal
	The receipt of the wastes of lead battery by final receiver				
	Way of disposal of lithium-ion capacitor:				
Accident	Implementation of safety management assembly				Monthly
	Status of management of construction material				
	Status of accidents				
Claim	Comment of residents				At any time

【During Operatoin】

Item	Monitoring item	Date	Place	Condition	Frequency
Waste	Amount of wastes and its final place to be disposed				At the time of disposal
	The receipt of the wastes of lead battery by final receiver				
	Way of disposal of lithium-ion capacitor:				
Accident	Implementation of safety management assembly				Monthly
	Status of accidents				
Claim	Comment of residents				At any time

Appendix 5

Soft Component
(Technical Assistance) Plan

A5. Soft Component (Technical Assistance) Plan

1. Background of Soft Component

Tonga is depending on the diesel power generation for most of its power supply by using imported fuels because of geographical conditions as an island nation. For this reason, Tonga is signifficantly influenced by international variation of crude oil cost, and it is very weak in the view of energy security. To overcome this situation, Tonga plans ‘‘Tonga Energy Road Map, TERM’’ that aims for 50 % of power supply to be converted to renewable energy by 2020 and reduction of emission greenhouse gas.

This Project provides the wind power generation system (output power:1.3 MW) and power storage facilities in order to interconnect the power system at Niutoua, which is the target site located in the northeast of Tongatapu Island.

This soft component plan is about the technical assistance which aims to develop the skill for operation and maintenance of the wind power generation system with the existing electric facilities in order to reduce the fuel consumption and supply stable power through renewable energy.

(1) The current situation of operation and maintenance for the existing electric facility

A 1.3 MW capacity solar power system interconnected with the existing electrical grid had already been installed by New Zealand in 2012 in Tongatapu. TPL entrusted the maintenance to a private New Zealand company for five years. As a result, TPL could not accumulate the maintenance skill of solar power system.

In response to this, Japan carried out the project, “Introduction of a Micro-Grid System with Renewable Energy for the Tonga Energy Road Map” to improve the operation and maintenance skill by soft component and to install more renewable energy. As a result of this project, a maximum output 1.0 MW solar power system, power storage and micro-grid system including SCADA were installed, and the ratio of diesel generation reduced to 93 %.

Meanwhile, TPL had installed a compact tiltable wind power system (output power: 11 kW) by itself and it directly connects to a low voltage power grid without power storage. To avoid the breakdown of the wind turbine when the cyclone comes close to Tongatapu island, TPL staff are trained and organised to tilt the wind turbine.

(2) Background of Soft Component

In this Project, installation of the storage batteries and charge-discharge control system were planned because TPL needs to limit as much frequency of the existing power system and variation of voltage as possible, and we will install the lithium Ion Capacitor, LIC, for compensation of the short-term variation of voltage.

The previous project, ‘The Project for Introduction of a Micro-Grid System with Renewable Energy for the Tonga Energy Road Map’ installed a lithium ion capacitor (LIC) and TPL has been transferred skills for maintenance of LIC.

However it is necessary for Japan side to support more operation and maintenance skills to control the existing diesel generator, the new wind power station and storage batteries because this plan installs the wind power station of over 1.3 MW.

In response to this situation, soft component of this project aims to support a smooth start up operation and to have TPL use the materials of grant aid properly, and Japan will transfer operation and maintenance skills of wind power station and skill of control of diesel generators to generation department and distribution department of TPL. In addition, skills regarding the system operation and treatment of accidents shall also be transferred.

The skill for handling the wind power station are currently a little beyond the ability of the present system of TPL so the soft component should be planned for supporting this situation. The following system has problems.

- Task 1: No experience of operation of middle-size-wind power station

As mentioned before TPL has already operated a compact wind power station that is tiltable. However, this wind power station has only a wind turbine which connects directly to distribution electric line without a system security facility. Therefore, this is the first time of installation of a megawatt grade of wind power station with system security facility.

Comparing wind power and solar power, wind power is more effective as renewable energy because it generates for 24 hours in principle. However, it is dependent on wind speed and an intense variation of output from 0 % to 100 % or from 100 % to 0 % may sometimes occur. Hence the operational skill for minimizing the influence to the wind power system with comprehension of output features are required.

- Task 2: No experience for operation of solar power station and wind power station at the same time.

As mentioned before, TPL has already operated the compact wind power station which is tiltable. However, this wind power station only has a wind turbine which connects directly to distribution electric line without a system security facility. Therefore, this is the first time for installation of a megawatt grade wind power station with a system security facility.

2. Objective of Soft Component

Soft component aims are as follows. The sustainable positive effects of this grant aid will occur through the achievement of the soft component.

Objective 1: Smooth operation and maintenance.

Objective 2: Appropriate output control of generator according to operating status of wind power station and solar power station.

3. Output of Soft Component

Output of the soft component for building up operation and maintenance system are set as follows.

Output 1-1: Correspondence of wind power generation at the time of cyclone is efficiently implemented through cooperation with related organizations.

Output 2-1: Appropriate operation control of the wind power station will be monitored by the data control system.

Output 2-2: Appropriate operation control of diesel generator will be monitored by the data control system.

4. Confirmation Procedure of the Output Achievement

The achievement and index of the soft component is supposed to be measured as shown in the following table in order to confirm a variety of necessary skills and the system for smooth start up of the Project under TPL's responsibility.

Table 1: Achievement of output

No.	Output	Confirmation item of achievement	Method of confirmation (draft)
Output 1-1	Correspondence of wind power generation at the time of cyclone is efficiently implemented through cooperation with related organizations.	Understand that the staff of TPL moves within a prescribed time through collaboration with relevant organizations and coordinates necessary work	Report of lecture and exercise, manual for work procedure
Output 2-1	Appropriate operation control of the wind power station will be monitored by the data control system.	To control the operation of the wind turbine by grasping the power demand by SCADA and data management system	Report of lecture and exercise, operation manual (draft)
Output 2-2	Appropriate operation control of diesel generator will be monitored by the data control system.	To control the number of diesel generator by grasping the power demand, power output of solar and wind power generation	Report of lecture and exercise, operation manual (draft)

Source: The study team

5. Plan of Soft Component Activities (Input Plan)

(1) Coverage of Activity

In order to achieve the outputs, the following activities are carried out for each output.

Output 1-1 ⇒ Activity 1 : Communicate and cooperate with relevant organizations

Output 2-1 ⇒ Activity 2 : Explanation of operation of existing power generation facilitie:
Activity 3 : Formulation of operation control manual (draft) (wind turbine

Output 2-2 ⇒ Activity 4 : Explanation about system condition in demand
Activity 5 : Formulation of operation control manual (draft) (DG)

(2) Contents of Activity

Output 1-1: Correspondence of wind power generation at the time of cyclone is efficiently implemented through cooperation with related organizations.

Activity 1: Communicate and cooperate with relevant organizations

In Tonga, information about cyclone is handled by Tonga Meteorological & Coast Radio Services of the Meteorological Department which is under the Ministry of Meteorology, Energy, Information, Disaster Management, Environment Climate Change, and Communications (MEIDECC). It is necessary to cooperate with MEIDECC and the Meteorological Department, not TPL alone, to handle the wind turbine when a cyclone is approaching.

When a cyclone hits, the information of the cyclone is reported to the TPL from the Meteorological

Department through MEIDECC. Then, TPL monitors the wind speed data of the anemometer installed in Niutoua's wind power generation facility. Therefore, building cooperation with MEIDECC and the Meteorological Department is an important factor. It is important for these organizations to understand the operation of wind power generation facilities.

Therefore, the actions to be taken when a cyclone is approaching Tonga will be shared with TPL and related organizations. The cooperation between TPL and relevant organizations will also be explained.

Output 2-1: Appropriate operation control of the wind power station will be monitored by the data control system.

Activity 2: Explanation of operation of existing power generation facilities

The system security facilities in the Project are storage batteries to compensate for a short-term variation of the frequency using LIC. It will be necessary to control the number of diesel generators activated and their ability against load for dealing with mid-term variation of output (10-15 min)

For this reason, it is necessary to confirm the transition of demand of electricity and operation situation of the diesel generator and the solar power, predict how the existing power station will behave after installation of the wind power station against the demand of electricity, and consider how to control the wind power station in advance.

Furthermore, the past data of such situations in Tonga will be analyzed and a control model for the wind power station will be made. After that lectures and training for the TPL staff shall be carried out relating to how the existing power station will behave.

Activity 3: Formulation of operation control manual (draft) (wind turbine)

The training of an operation control of the wind power station shall be performed after Activity 2. At present, the situation that can be considered is how to respond in case the wind turbines will cut out at strong gusts making its output to decline rapidly from 100% to 0%. In this case, the expectation of the time for resistance to the short-term variation of frequency will be about one minute. However, it takes about five minutes for a subsequent response from the CAT diesel generator, so the rapid reduction of output of the over 1.3 MW wind power station causes high resistance against the diesel generator, and it is not possible for the existing diesel generator and the subsequent CAT diesel generator to deal with the electric resistance. Considering the above scenario, it is necessary to set the number of wind turbines which stop when the resistance goes beyond the ability of wind turbines.

As for operation of these wind power stations, Japanese instructors will hold lectures and train TPL staff in charge, and after that they will consider a draft of operation control manual through supervision of the Japanese consultant.

Output 2-2: Appropriate operation control of diesel generator will be monitored by the data control system.

Activity 4: Explanation about system condition in demand

Objective of the Project is to install a wind power station and a system security facility, and it will connect to the existing system. Therefore, operations will be considered not only operation for the wind generator but also for the existing facility, and it will be necessary to take some measures for the operation of the existing facility. Hence, basic theory and the aftermath of the gain of renewable energy are to be lectured on.

Moreover, the variation of demand of feeder power will be grasped by monitoring the systems, and the power demand will be predicted by comparing past records. Also a lecture regarding the operation from renewable energy to diesel generator will be carried out, and a manual for general operation of facility and troubleshooting, including influence of the frequency and voltage of the diesel generator, will be prepared.

Activity5: Formulation of operation control manual (draft) (DG)

For achievement of Activity 4, the Consultant will give lectures on the operation control of the diesel generator because stable power supply shall be required in response to the output variation of renewable energy and the variation of power demand. This will include lectures about trouble shooting, the proper number of wind turbines in relation to output of the diesel generator and the operation style at each time, and a draft of diesel generator operation control manual will be made under the supervision of the Japanese consultants.

6. Procurement Method of Implementation Resources

Involved organization for performance of the soft component is shown as follows.

(1) Japanese Consultant

As performing the activities mentioned above, Japanese consultants will manage the overall soft component plan in which they will be responsible for preparation, direction, incorporation and reports. In addition to this, TPL, as a implementation organization, will comprehend how the wind power station, the system security, and the data management system will be operated and maintained in detail, and receive the necessary skill to activate the wind power system appropriately. Furthermore, TPL will recieve skills for stable operation of power distribution system composed by the new wind power station and the existing one.

Japanese consultant will consist of two members who will be dispatched to Tonga and they are experts in the following areas;

Consultant 1: Grid analysis and wind turbine control

Consultant 2: Grid interconnection and diesel generators

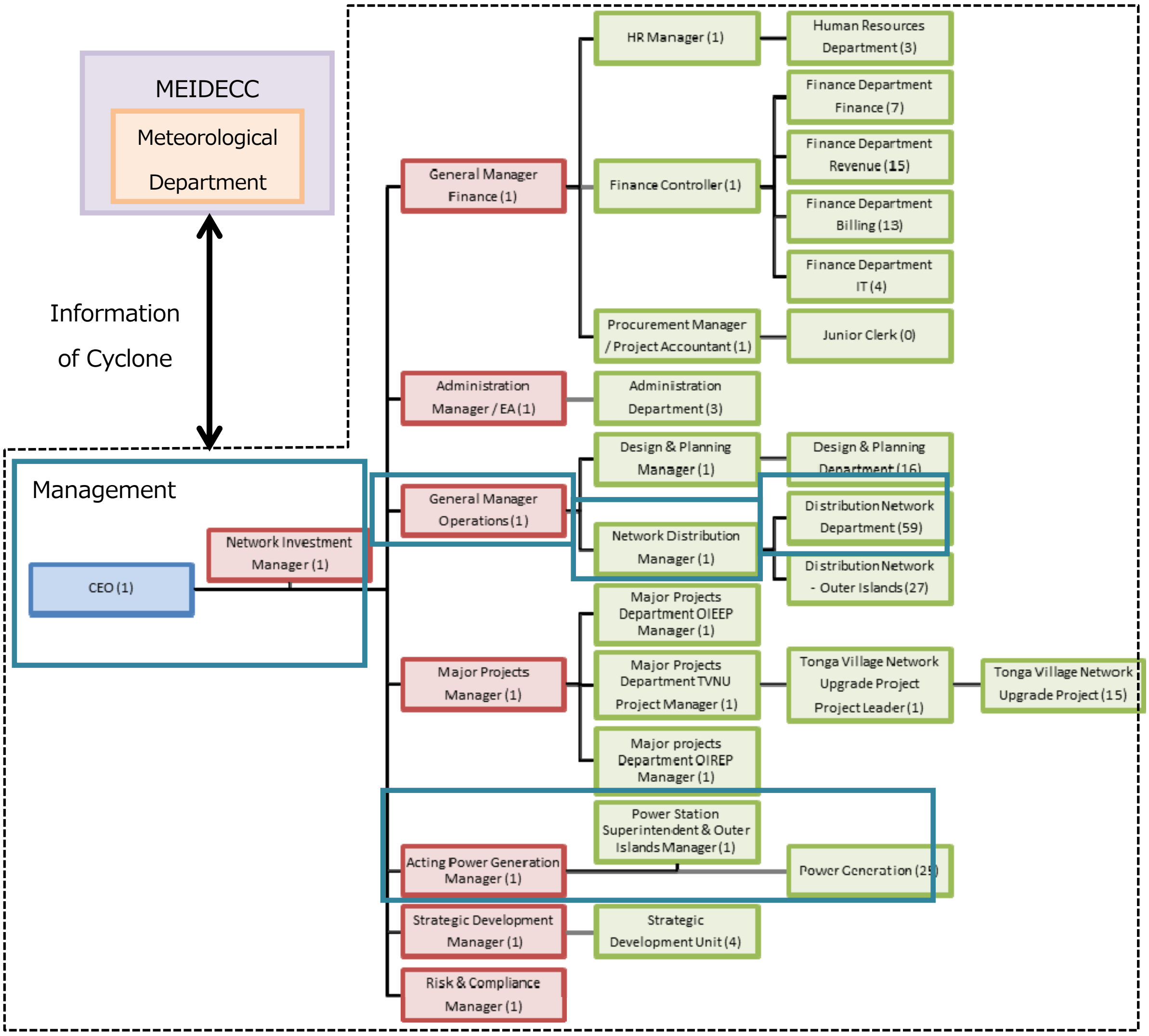
(2) Tongan Side

a) TPL

The provision of responsible trainees, their attendance to the lectures and the full support of TPL as inputs of Tonga will be necessary for smooth performance of the soft component. The consultant will implement transfer of skills to the department and people in the blue box of the following table.

b) Relevant Organization (MEIDECC and Meteorological Department)

The information of cyclone from MEIDECC and the Meteorological Department is important for tilting-returning wind turbines at the time of cyclone occurrence. It is necessary to work under cooperation with these related organizations.



Source: TPL

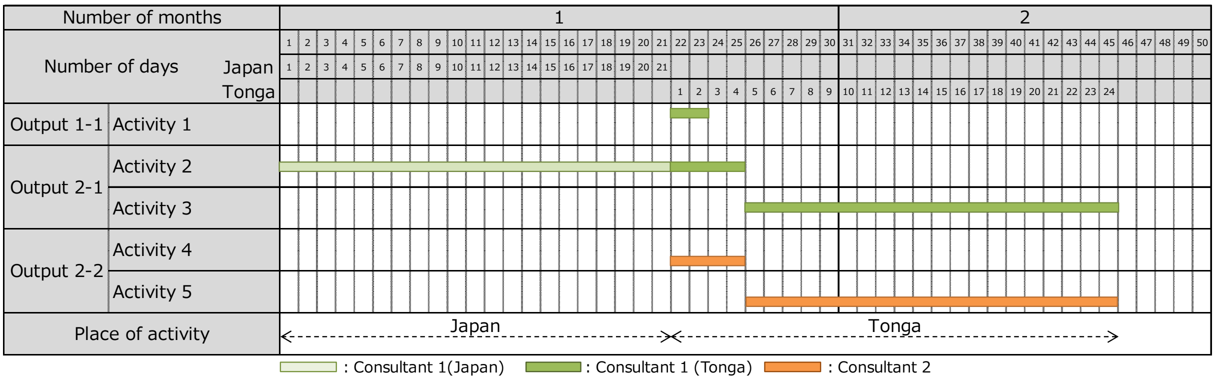
Figure 1: Implementation structure of Tongan side

7. Implementation Schedule of Soft component

According to the contents of activities mentioned above, Japanese consultants conduct activities in Japan and Toga. The soft component is started after the inspection and handover of the costruction and procurement are completed. Then, after the completion of the soft component, Japanese consultant submits the completion report to Tonga.

The following table shows the implementation schedule of the soft component.

Table 2: Implementation schedule of soft component



Source: The study team

8. Output for Soft Component

Outputs for the Soft Component are as follows.

At the completion	: completion report (Tonga, Japan)
Activity 1	: minutes of meeting, manual for work procedure
Activity 2	: report of lecture and exercise
Activity 3	: operation manual (draft for wind turbine)
Activity 4	: report of lecture and exercise
Activity 5	: operation manual (draft for diesel generator)

9. Obligation of the recipient country

To achieve the objectives of the soft component it is essential to continuously accumulate data of output of power by each generator and data of demand of power by TPL in addition to the outcomes of inputs by the soft component.

These accumulated data will enable prediction of how to control operation of the diesel generator effectively by power demand, output of solar power and output of wind power in advance, and the renewable energy will be made stably.

If daily allowances, transport allowances and accommodation fees are not accounted for in the budget of the year of the Project, it would be difficult to hold the trainings locally. Hence, it will be significant for TPL to apply for the budget in advance considering with the time schedule of the Project.

Appendix 6

Other Relevant Data

A6. Other Relevant Data

No	Title	Type Book/Video/Photo/Etc	Original/Copy	Issuing Institution	Year
1	Annual Report (2009 - 2015)	Book	Copy	Tonga Power Limited	2009 - 2015
2	Policy for the Connection of Embedded Generation	Book	Copy	Tonga Power Limited	2013. 3
3	The Second Electricity Concession Contract	Book	Copy	Tonga Power Limited	2015
4	Customer Service Agreement	Book	Copy	Tonga Power Limited	2015.11
5	Small Connected Generation Agreement	Book	Copy	Tonga Power Limited	---
6	Fee Structure	Book	Copy	Tonga Power Limited	2012
7	Electricity Concession Compliance Report	Book	Copy	Tonga Power Limited	2013-2016
8	Regulatory Annual Report	Book	Copy	Tonga Power Limited	2013 - 2014
9	Business Plan	Book	Copy	Tonga Power Limited	2014, 2016, 2017
10	EIA Reports	Book	Copy	Tonga Power Limited	2014.7
11	Tonga Climate Change Policy	Book	Copy	Tonga Power Limited	2016.2
12	Upgrade of Grids and Preparing the Utility for Operations with Renewable Energy Plants - Stage 1	Book	Copy	AECOM	2014.11
13	Upgrade of Grids and Preparing the Utility for Operations with Renewable Energy Plants - Stage 2	Book	Copy	AECOM	2015.5
14	A Pre-Feasibility Study on Wind Energy for Tongatapu Island, Kingdom of Tonga	Book	Copy	GIZ	2012.10
15	Distribution Asset Management Plan	Book	Copy	Tonga Power Limited	2016.3
16	Environmental Impact Assessment Regulations 2010	Book	Copy	Attoreny General Office, Tonga	2010
17	Generation Asset Management Plan	Book	Copy	Tonga Power Limited	2014.11
18	Tonga National Infrastructure Investment Plan	Book	Copy	The Government of Tonga	2013
19	Public Enterprises (Amendment) Act 2010	Book	Copy	Ministry of Public Enterprises	2010
20	Renewable Energy Act 2008	Book	Copy	The Government of Tonga	2008

No	Title	Type Book/Video/Photo/Etc	Original/Copy	Issuing Institution	Year
21	Tonga NIIP Annual Monitoring Report 2015	Book	Copy	The Government of Tonga	2015.7
22	Energy Road Map (TERM) ReviewImplementation Report 2010_2014	Book	Copy	Tonga Energy Road Map Implementation Unit	2015.8
23	Renewable Energy & Energy Efficiency Plan, Assessment Report	Book	Copy	AETS	2016.1
24	Renewable Energy & Energy Efficiency Plan II (REEEP II) – Monitoring & Evaluation Framework 2016_2020	Book	Copy	The Government of Tonga	2016
25	Tonga Electric Power Board (Repeal) Act 2007	Book	Copy	The Government of Tonga	2007
26	Feasibility Study of Wind Power Pants	Book	Copy	Electric Power Development Company	2001.4
27	Least Cost Development and Investment Plan 2015_2020	Book	Copy	Tonga Power Limited	2015
28	Tonga Strategic Development Framework 2015_2025	Book	Copy	The Government of Tonga	2015.5
29	Wind Mapping Tonga	Book	Copy	Winergy	2006.7
30	Tsunami Presentation	Book	Copy	The Government of Tonga	---
31	Feeder Log	Data	Copy	Tonga Power Limited	2016.9
32	Generation Master Template	Data	Copy	Tonga Power Limited	2016.9
33	Diesel Popua New Data	Data	Copy	Tonga Power Limited	2016.9
34	Tongatapu Wind Generation Study Detailed Design Report	Book	Copy	Aurecon New Zealand Limited	2016.10
35	Cat Generator 1 Line Circuit Diagram	Book	Copy	Tonga Power Limited	2016.9
36	MAK Woodward 723 Settings	Book	Copy	Tonga Power Limited	2016.9
37	G 1 to 6 Woodward Settings	Book	Copy	Tonga Power Limited	2016.9
38	Vaini Ring Settings Report - Rev01	Book	Copy	Aurecon New Zealand Limited	2016.10
39	The Villa PV - RMU Specification - Rev01	Book	Copy	Tonga Power Limited	2016.10

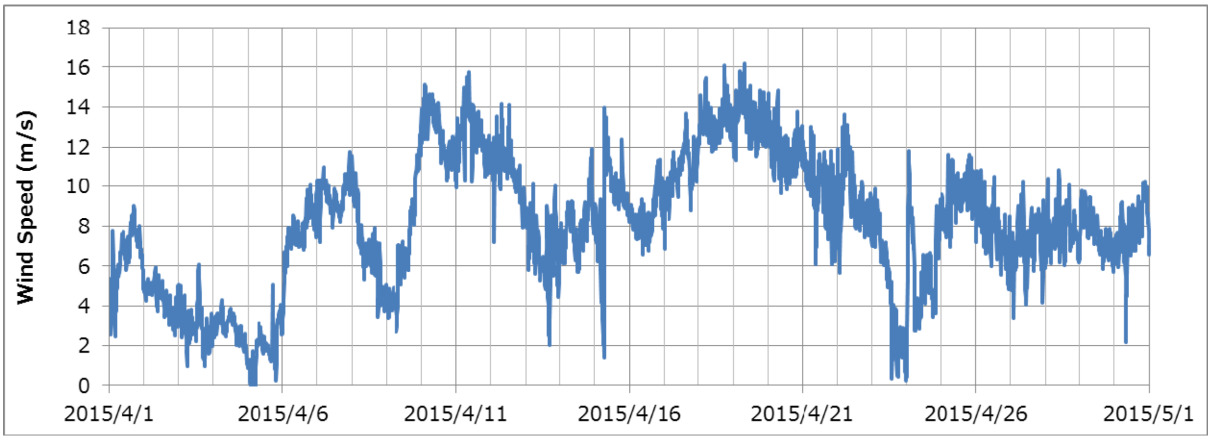
No	Title	Type Book/Video/Photo/Etc	Original/Copy	Issuing Institution	Year
40	Intended nationally determined contributions	Book	Copy	The Government of Tonga	2015.12
41	Climate Data	Data	Copy	Tonga Meteorological & Coast Radio Services	2016.7
42	Building Code	Data	Copy	Ministry of Infrastructure	2016.7
43	Wind Condition Data	Data	Copy	Tonga Power Limited	2016.7
44	Japanese Wind Power Generation Guidelines	Book	Copy	New Energy and Industrial Technology Development Organization	2008.3
45	Guidelines for Design of Wind Turbine Support Structures and Foundations	Book	Original	Japan Society of Civil Engineers	2010.12
46	Guidebook for Introducing Wind Power Generation	Book	Copy	New Energy and Industrial Technology Development Organization	2008.3

Appendix 7

References

A7. References

(1) Wind Condition Data (Niutoua, Heigt: 40m, Source from TPL)



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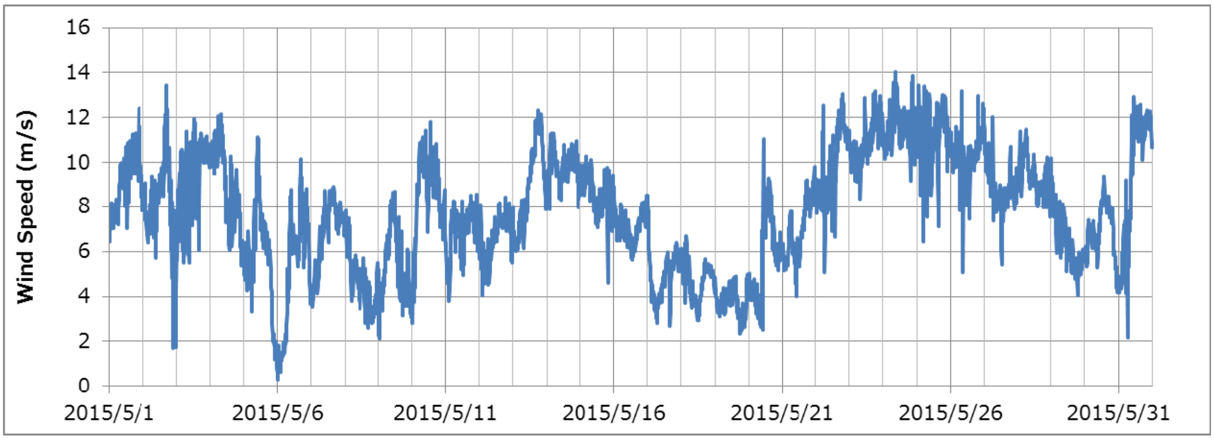

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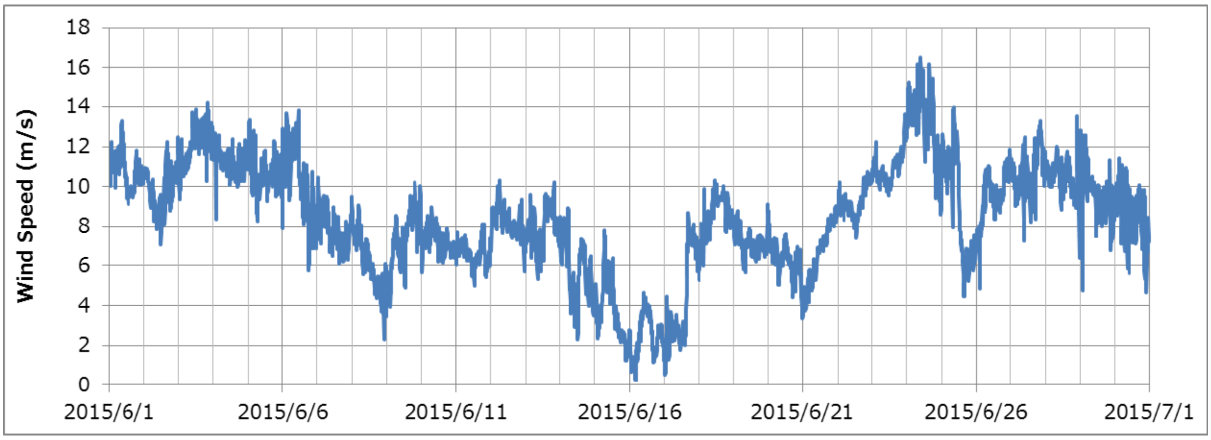

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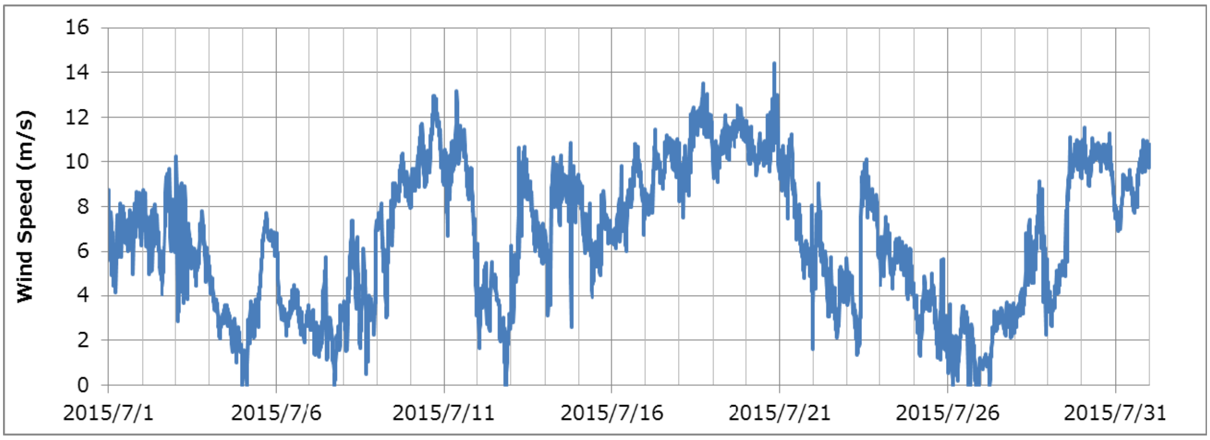

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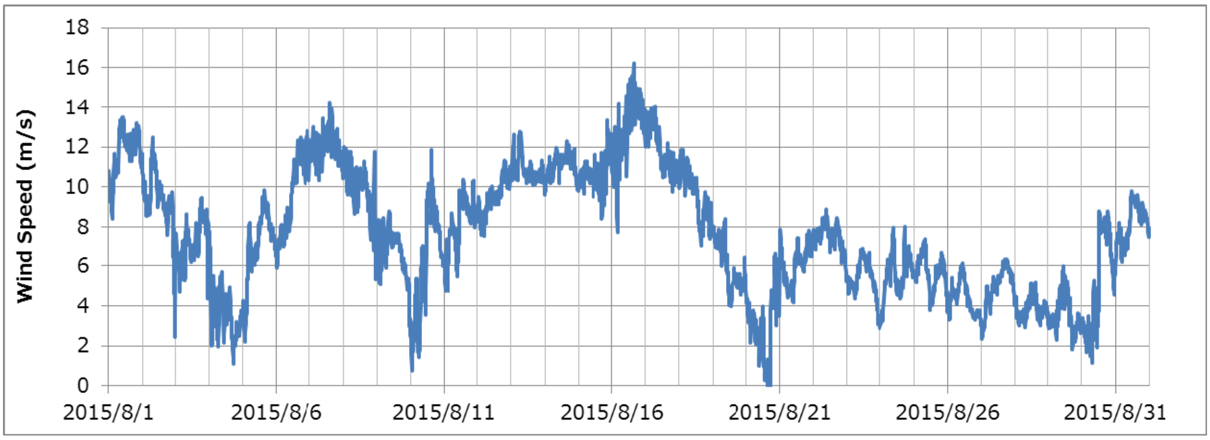

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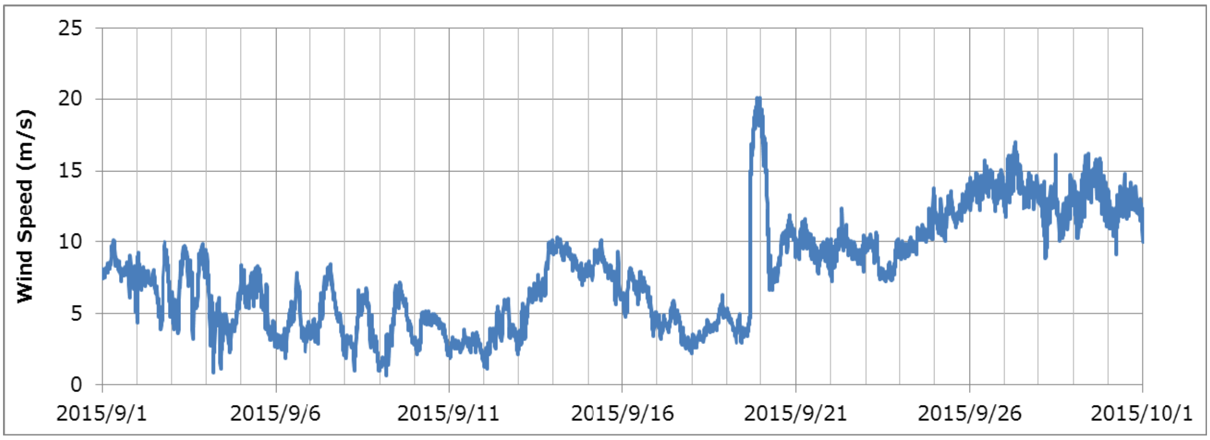

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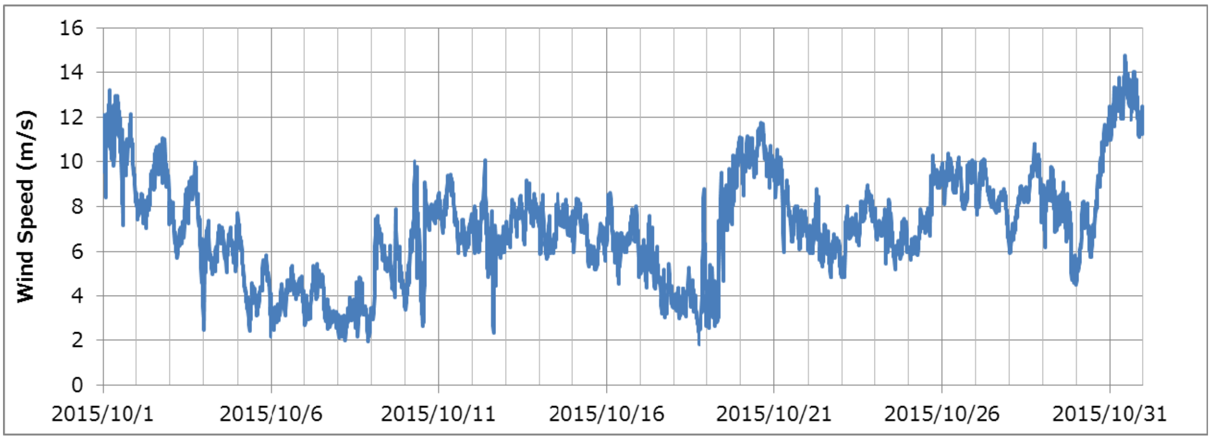

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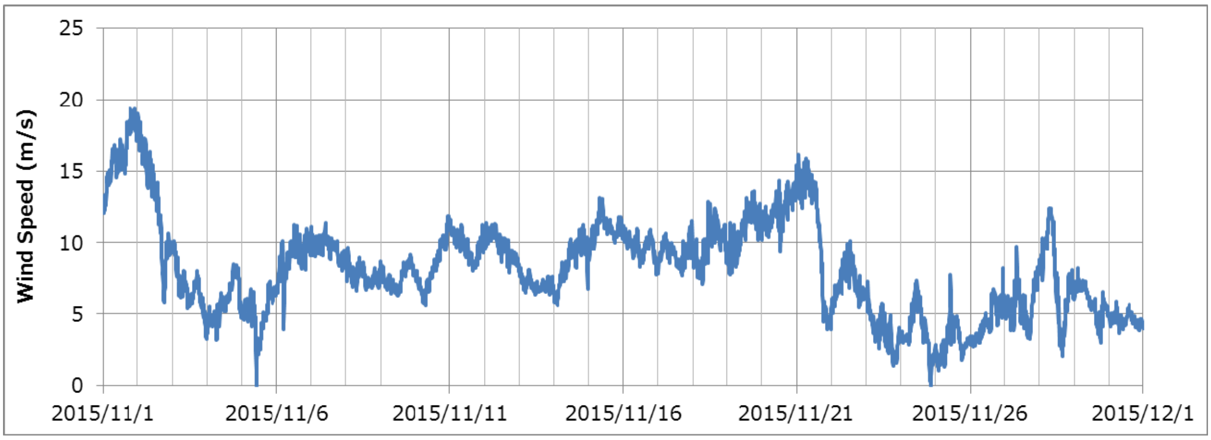

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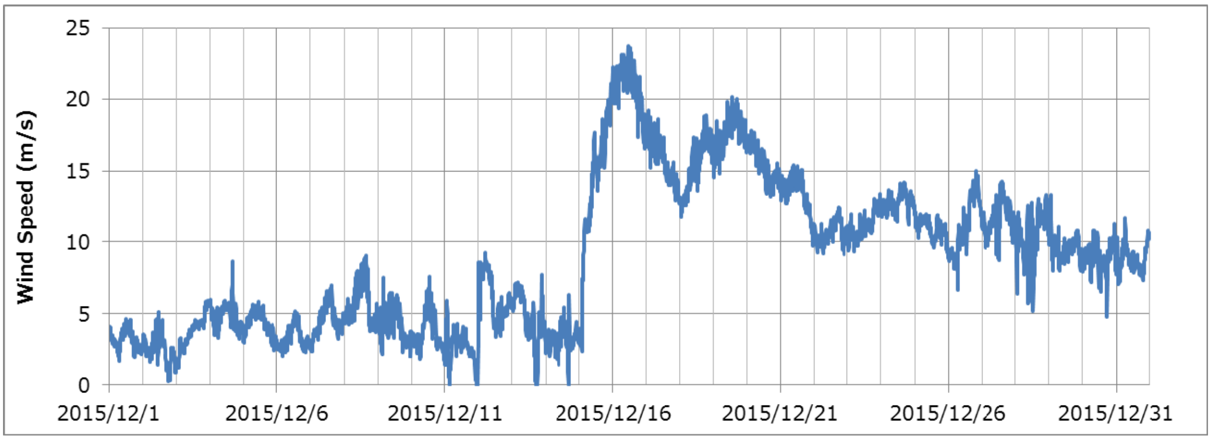

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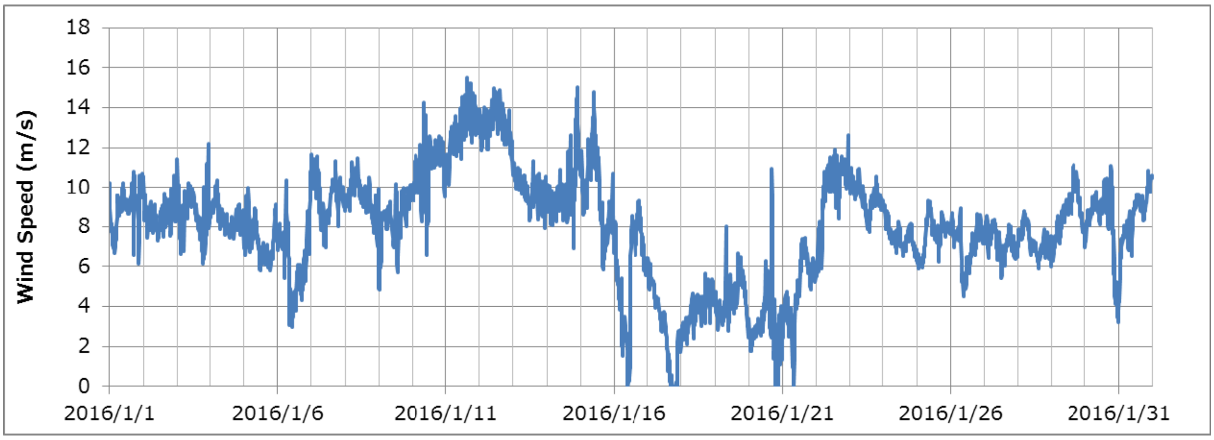

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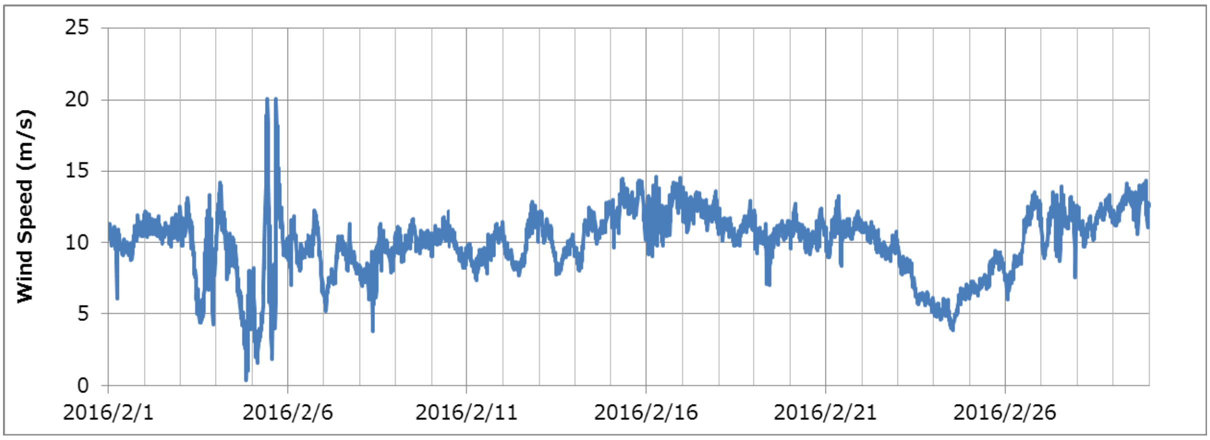

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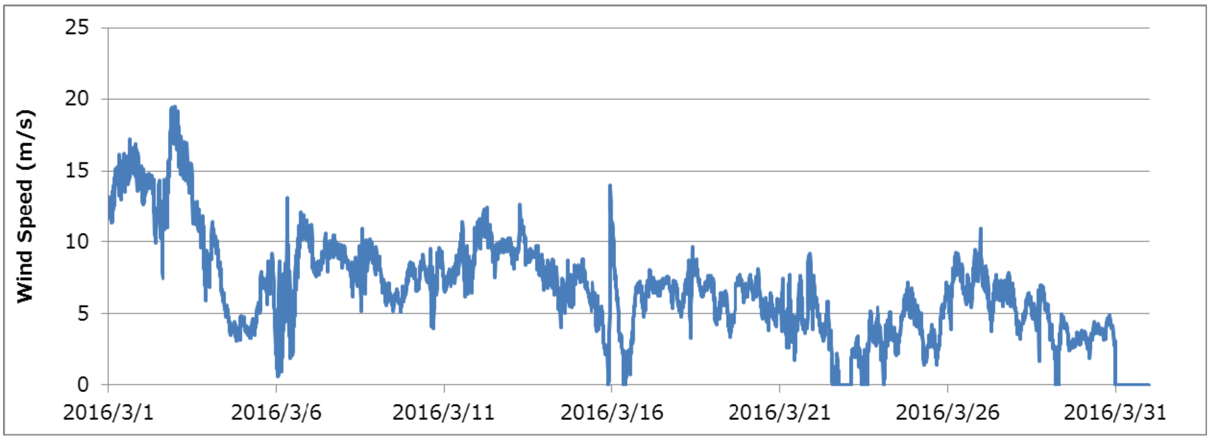
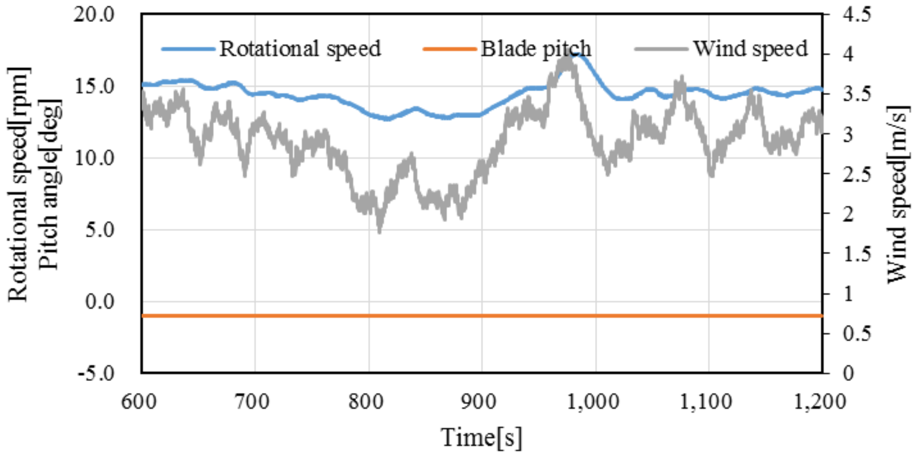
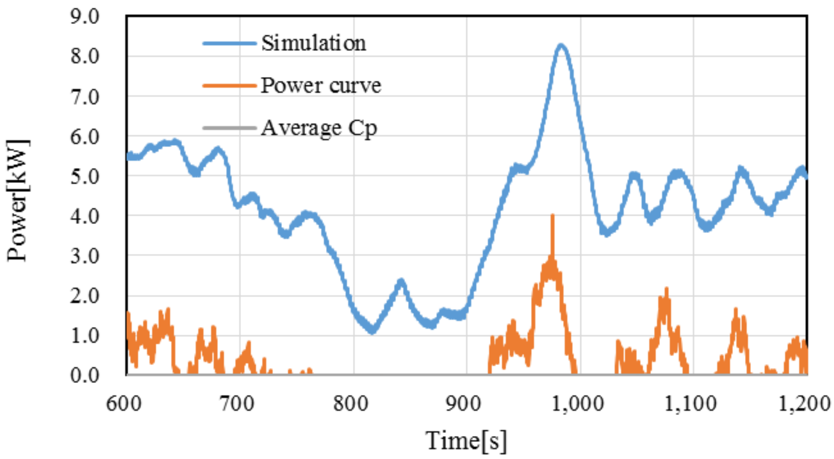


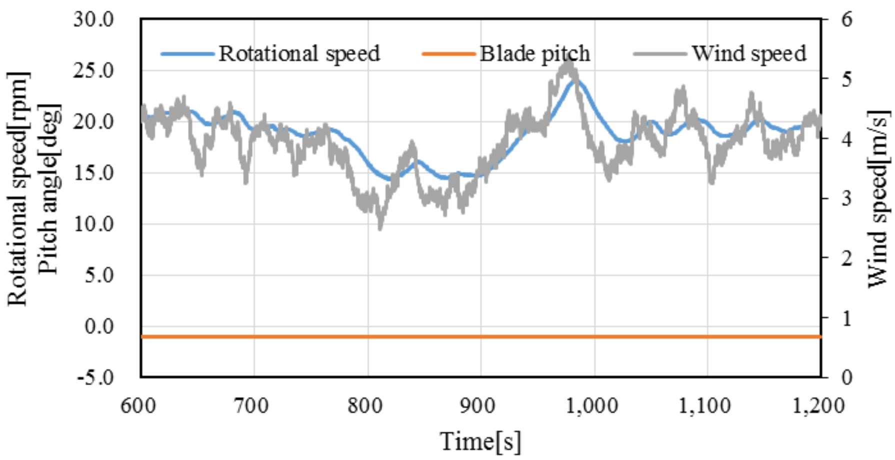
March 2016

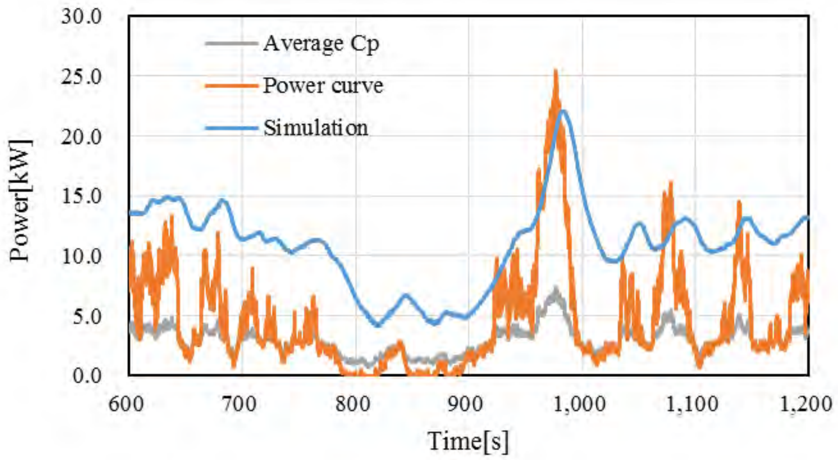
(2) Predicted Power simulated by FAST (wind turbine: 275kW)





Time series graph of 3 m/s wind speed





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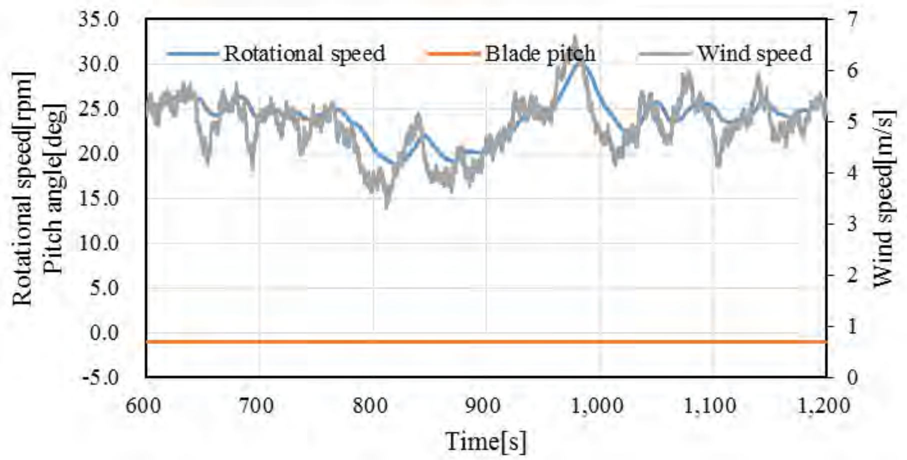

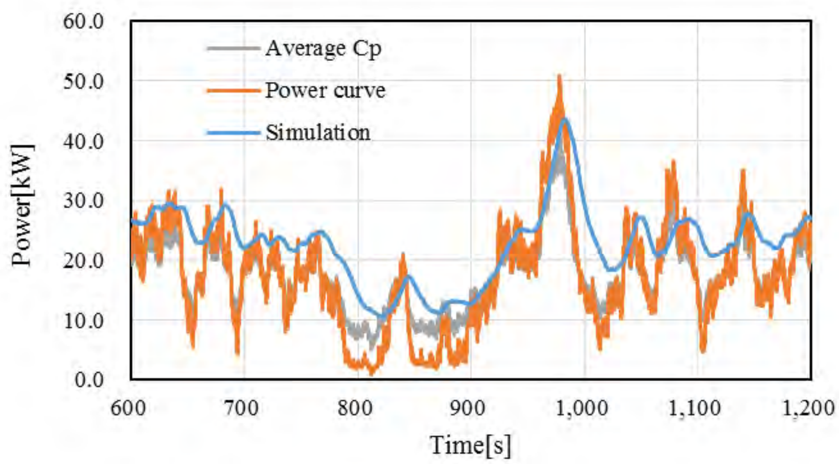

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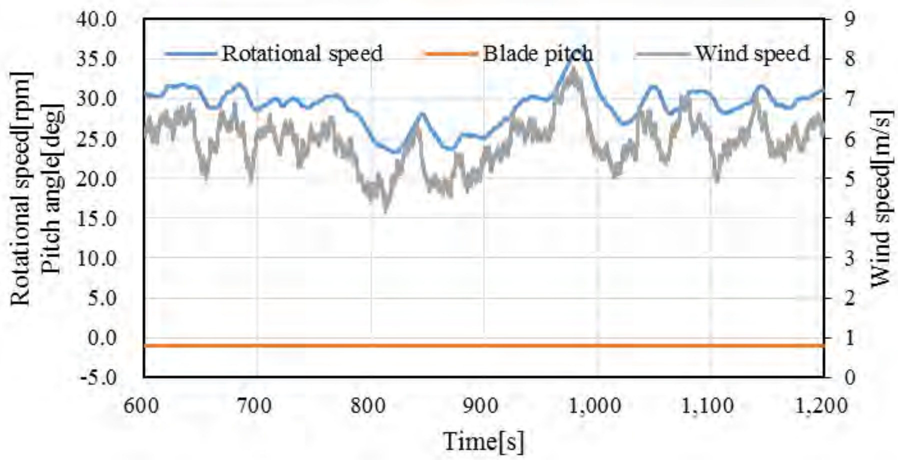

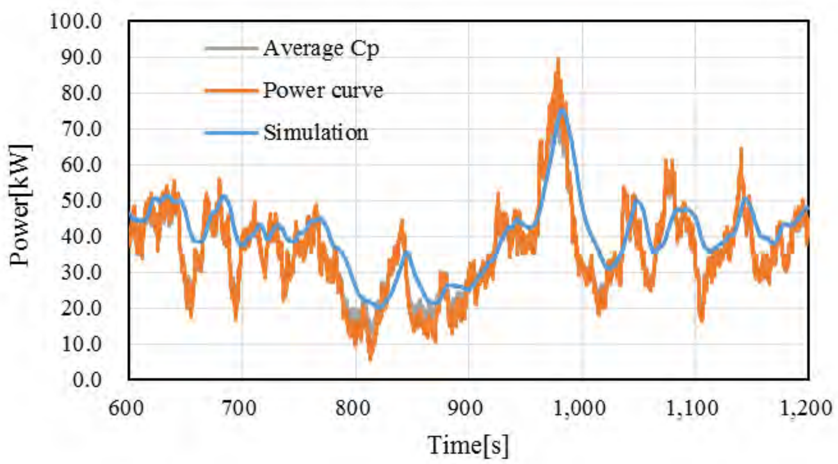

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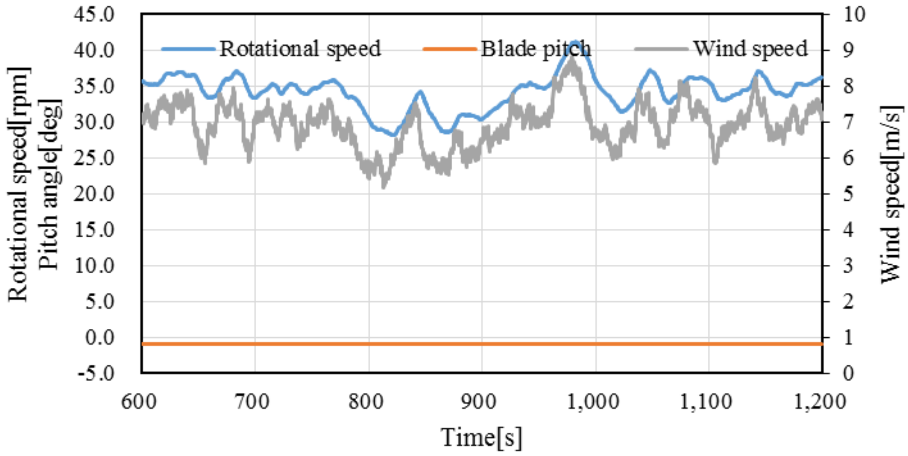

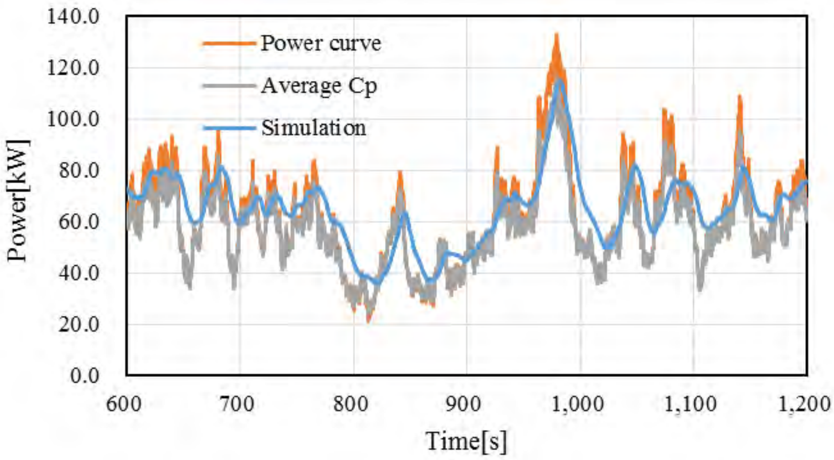

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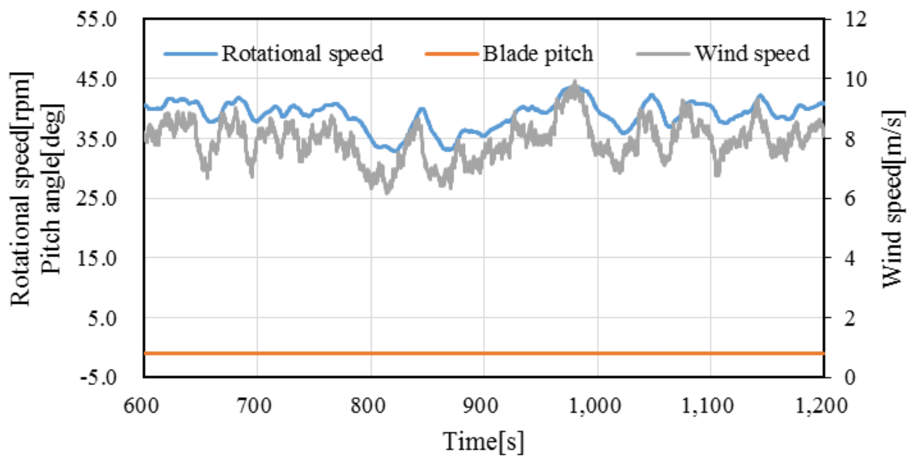

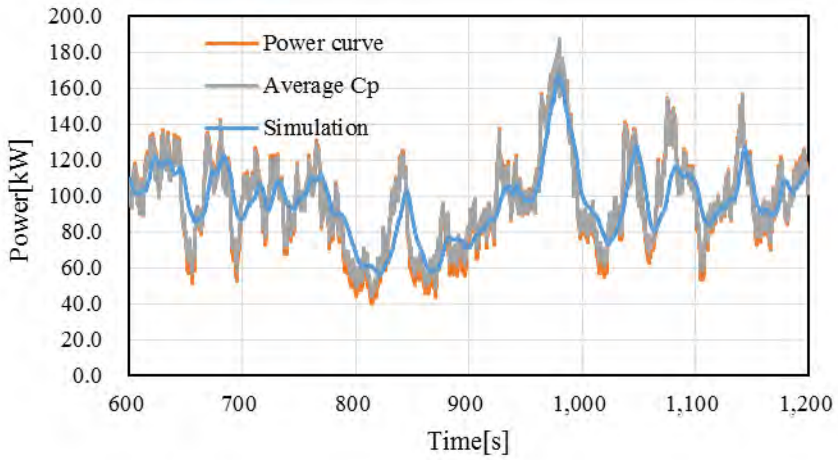

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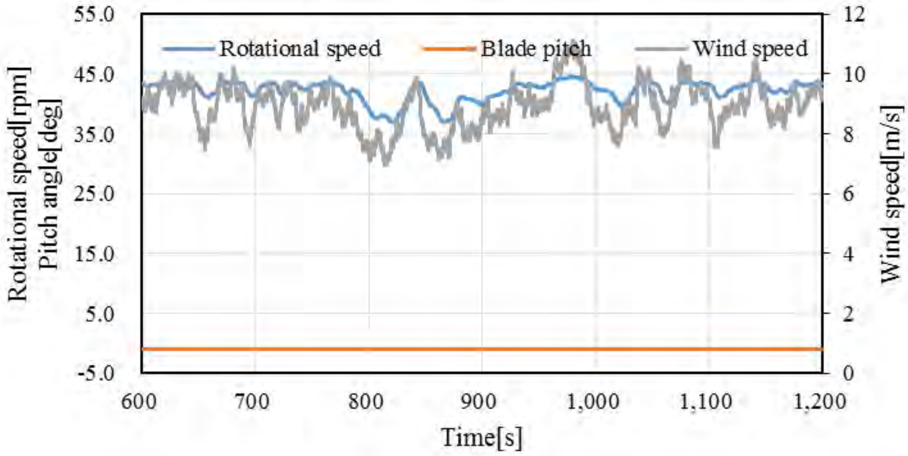

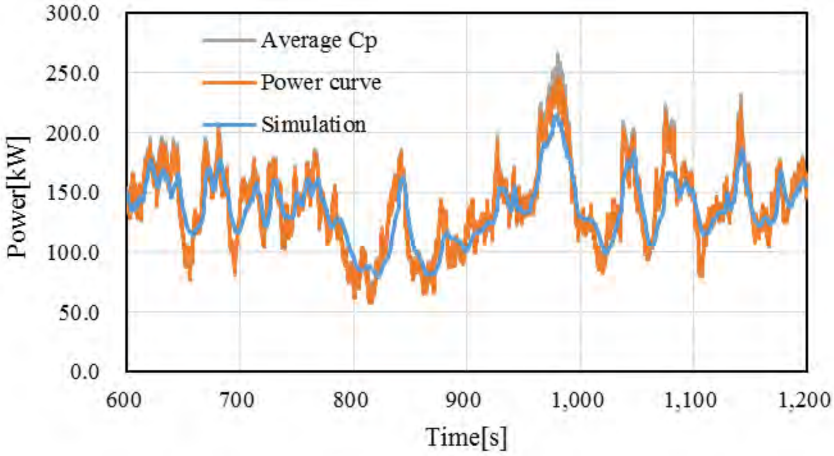

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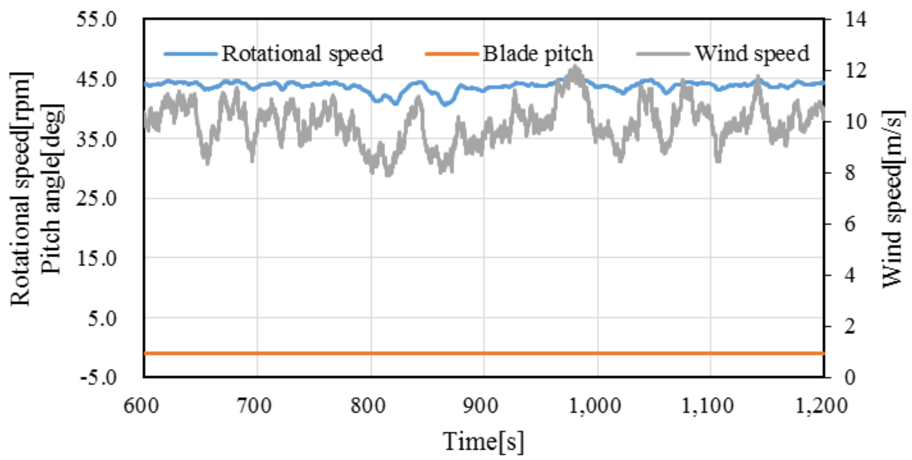

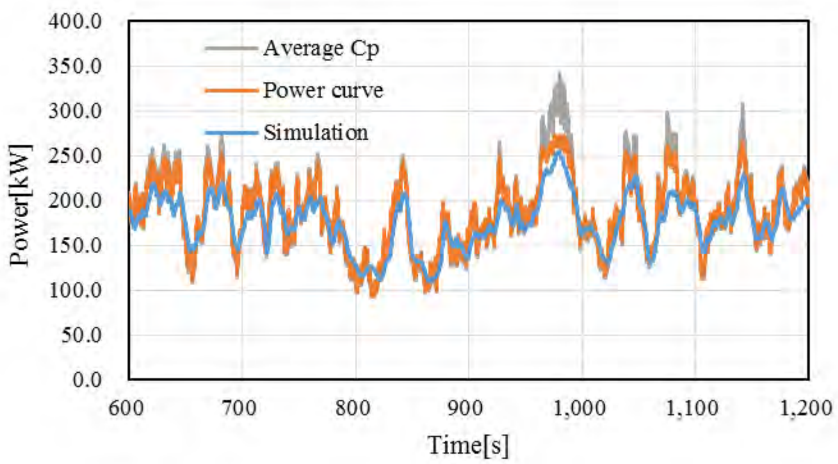

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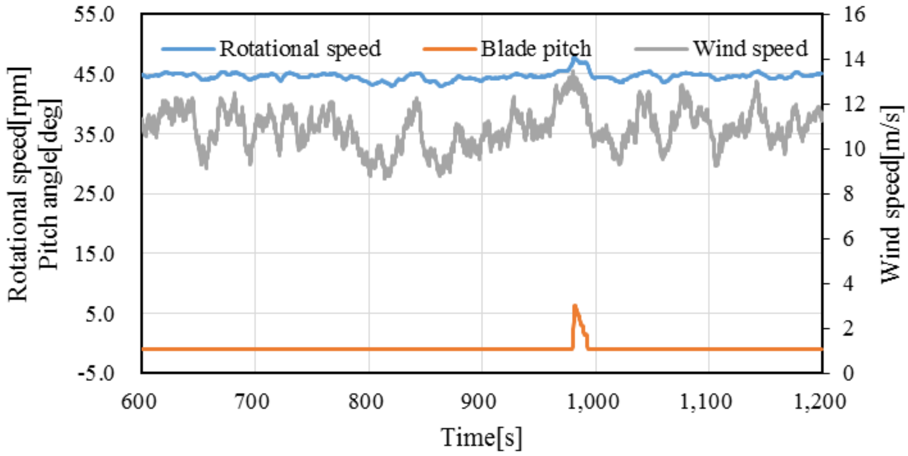

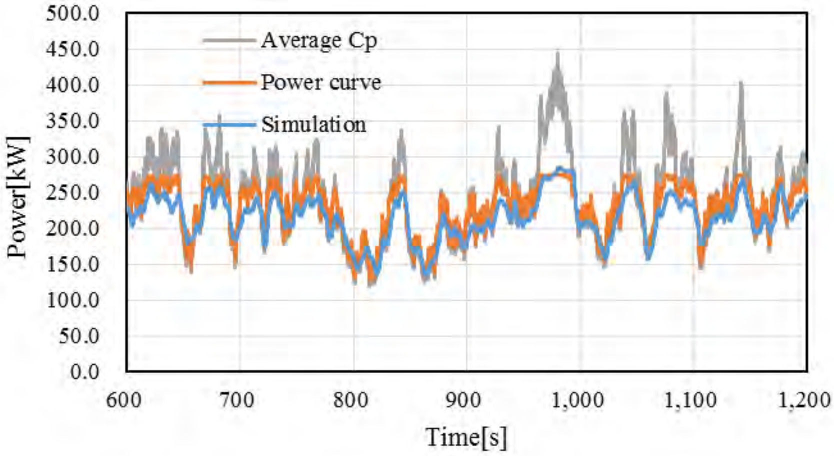

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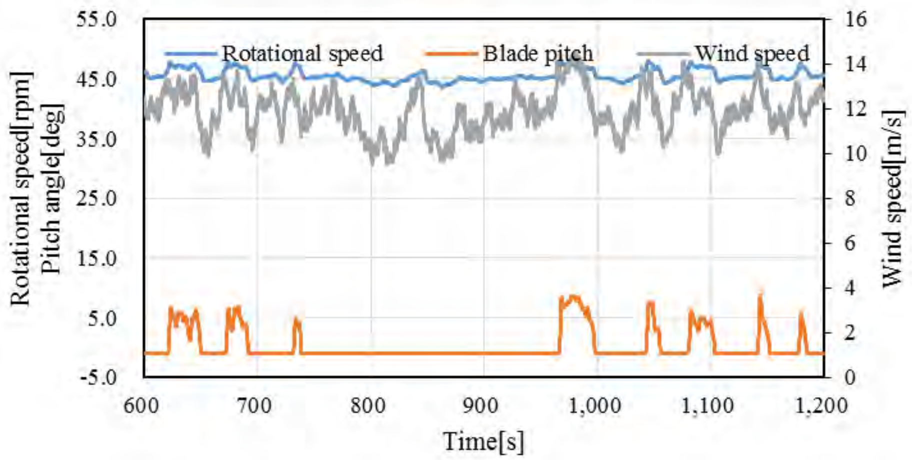

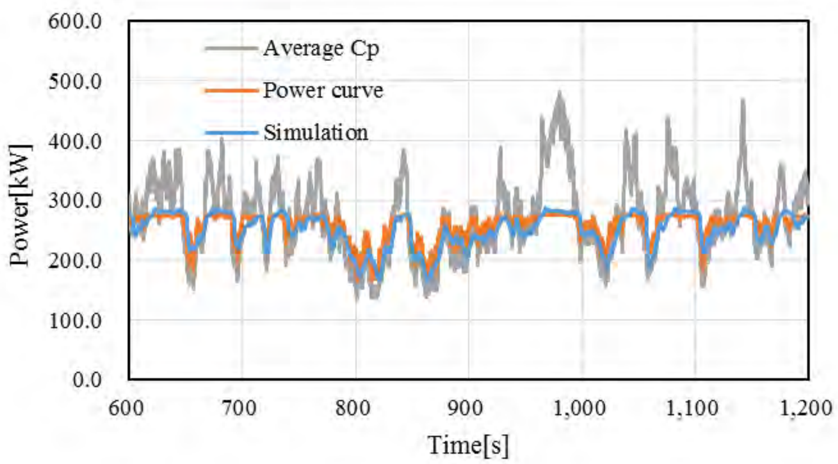

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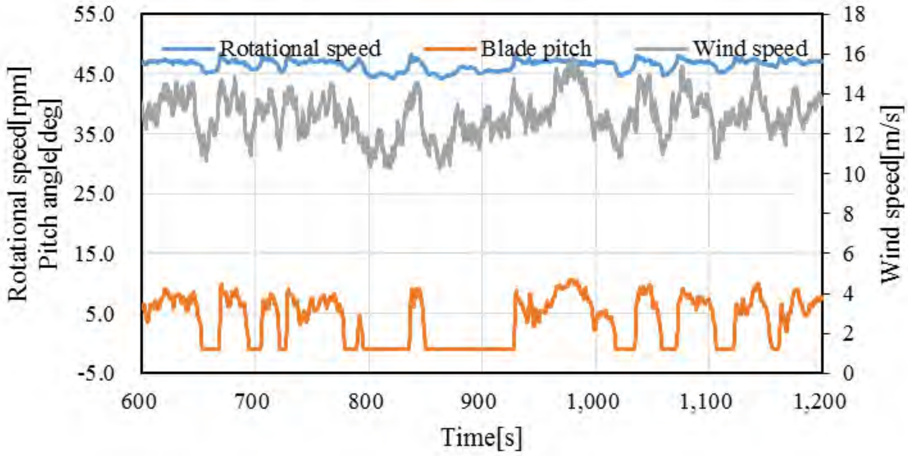

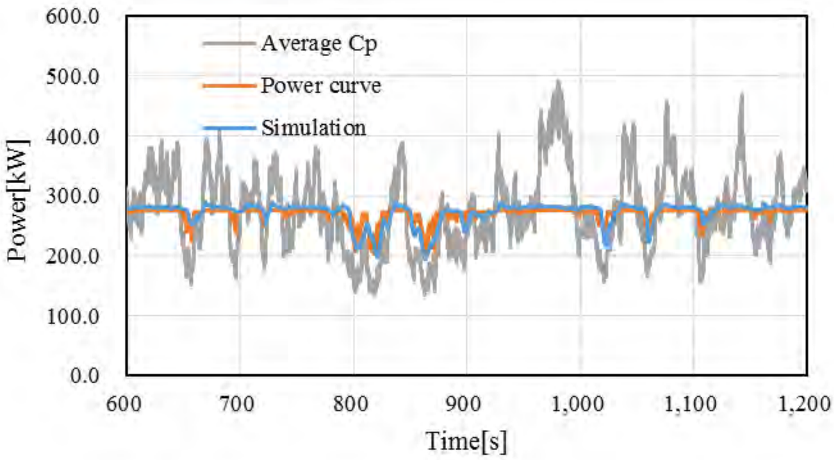

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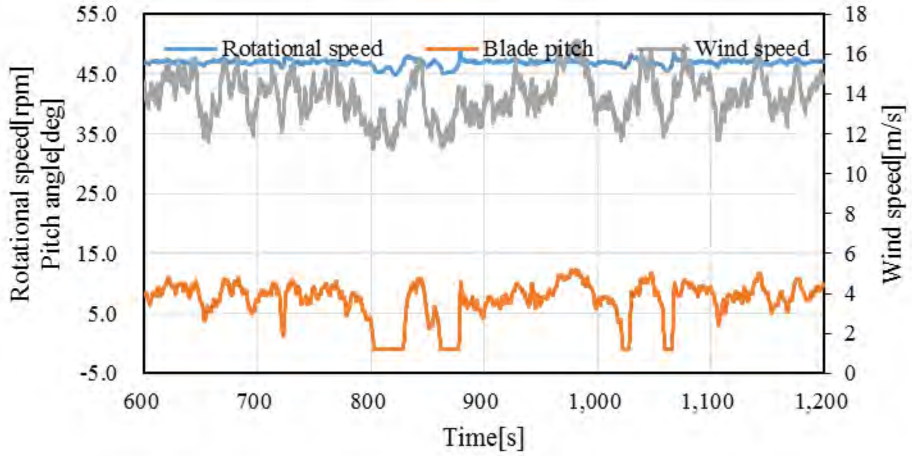

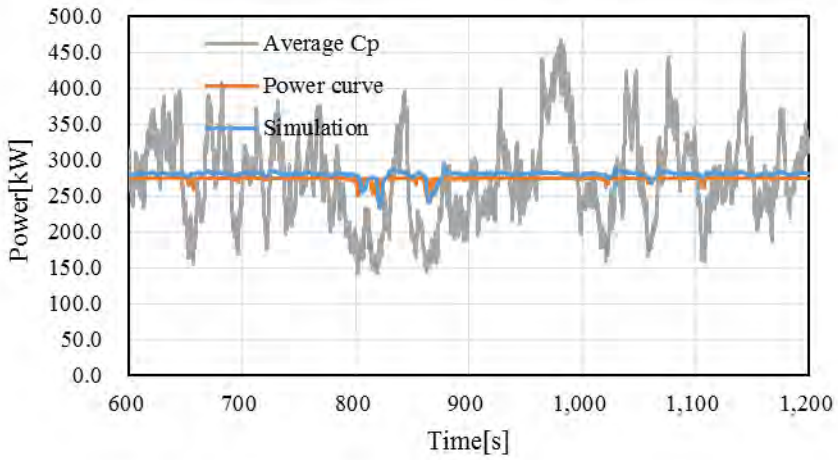

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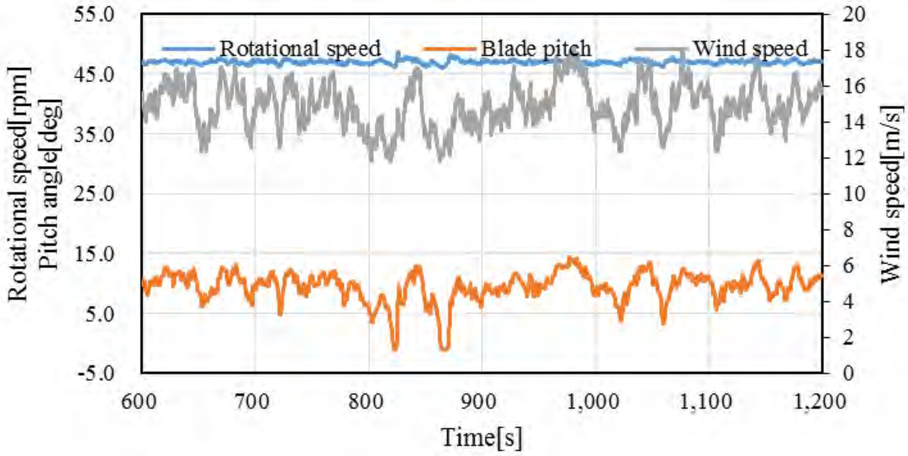

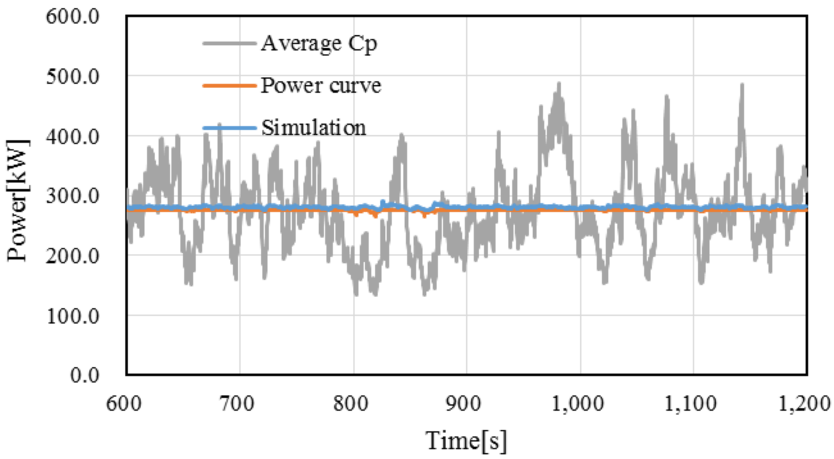

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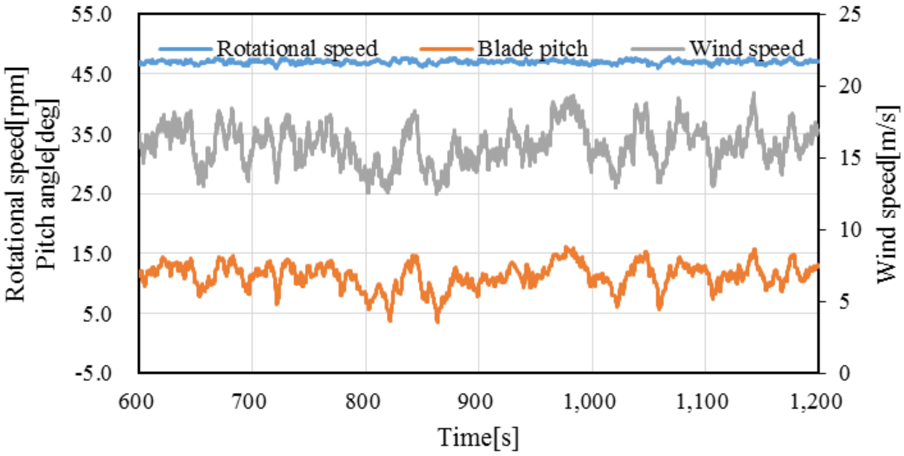

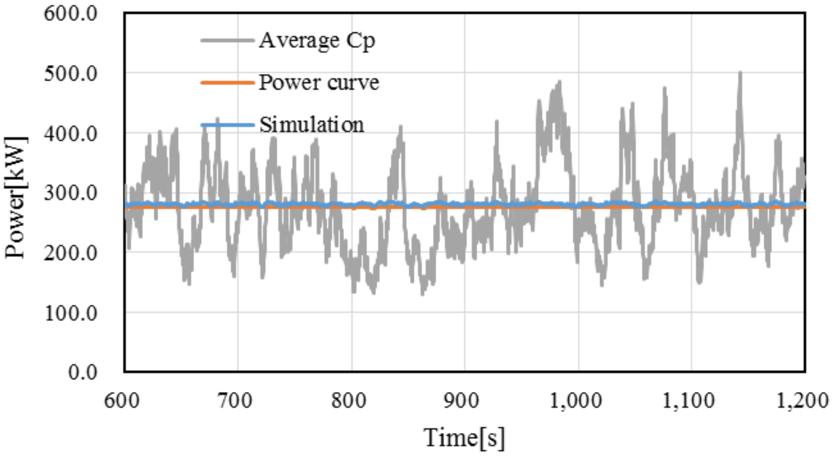

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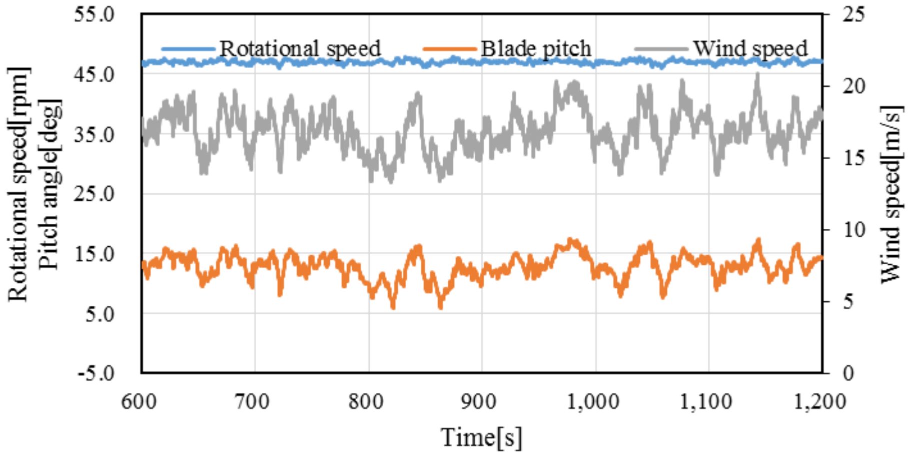

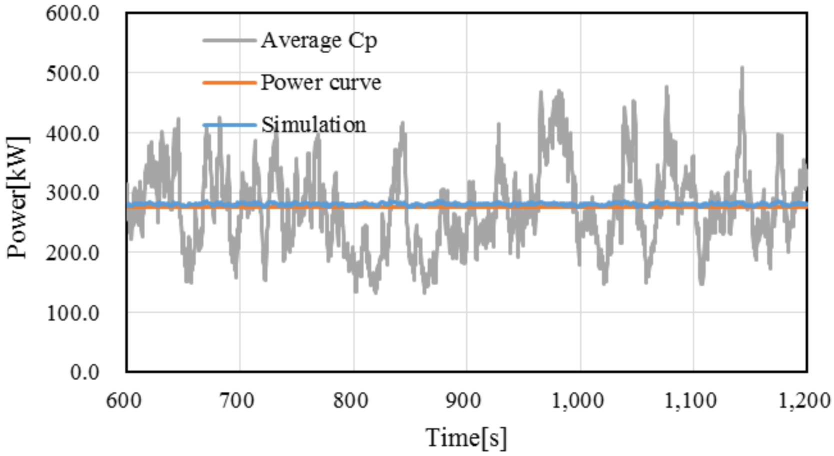

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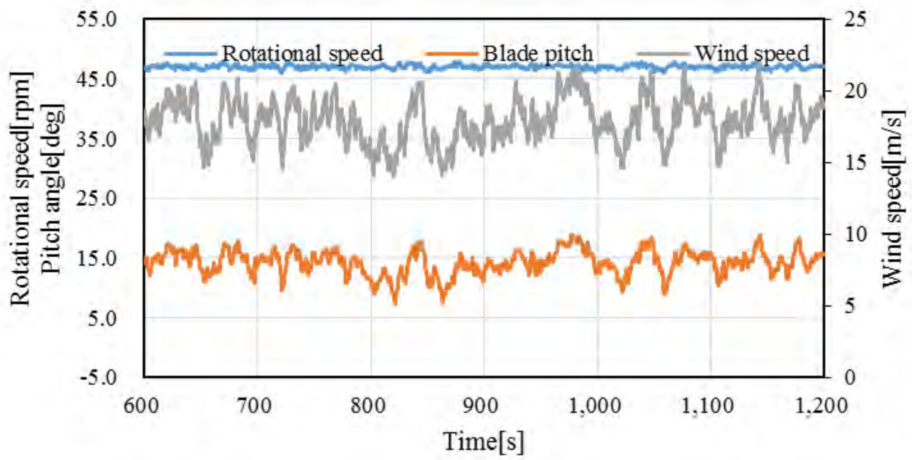

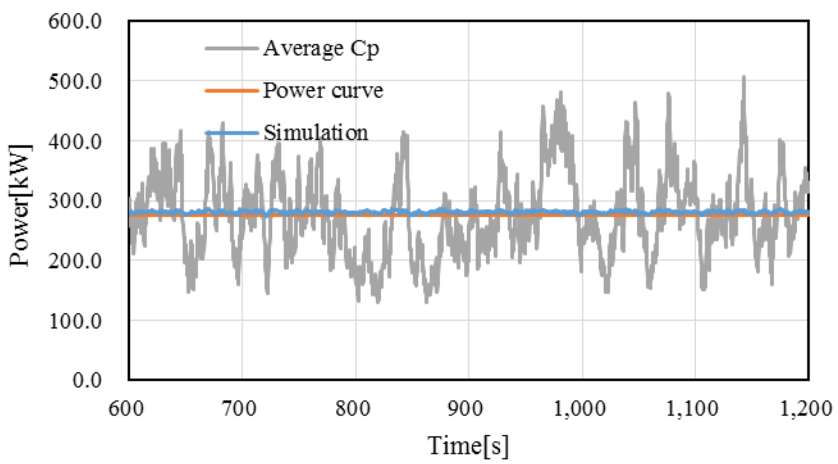

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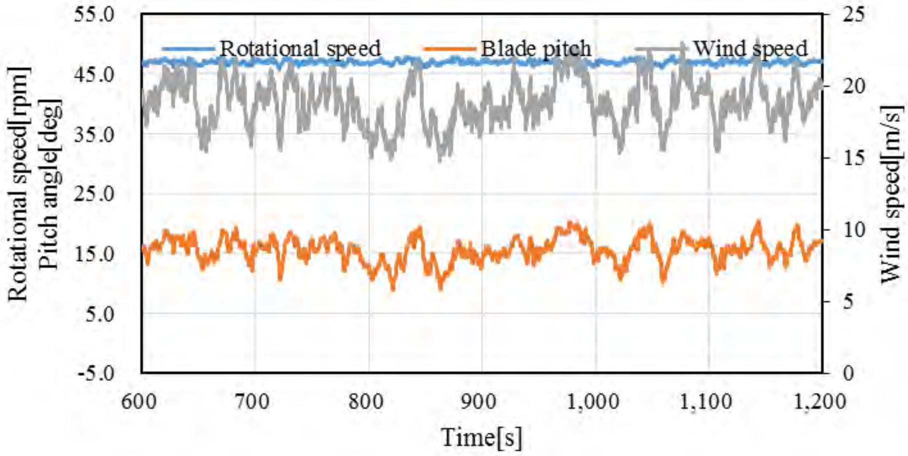

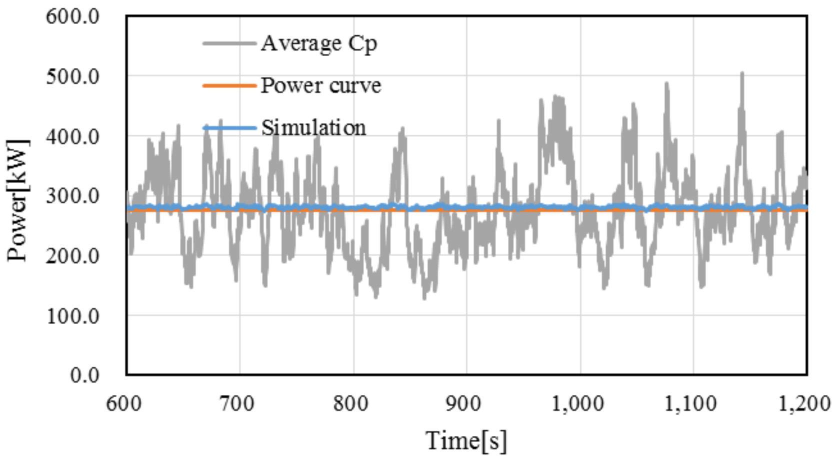

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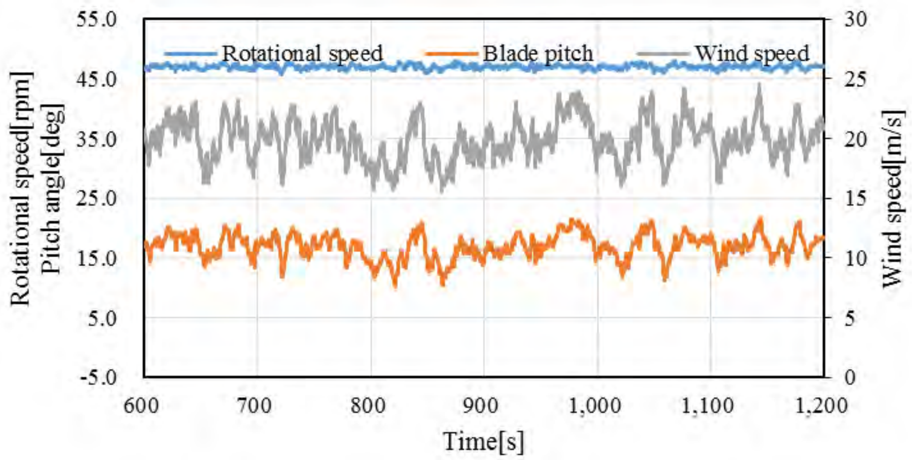

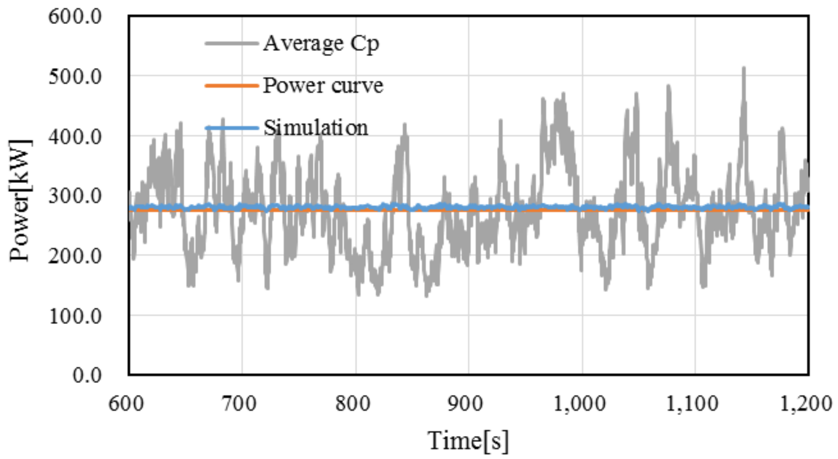

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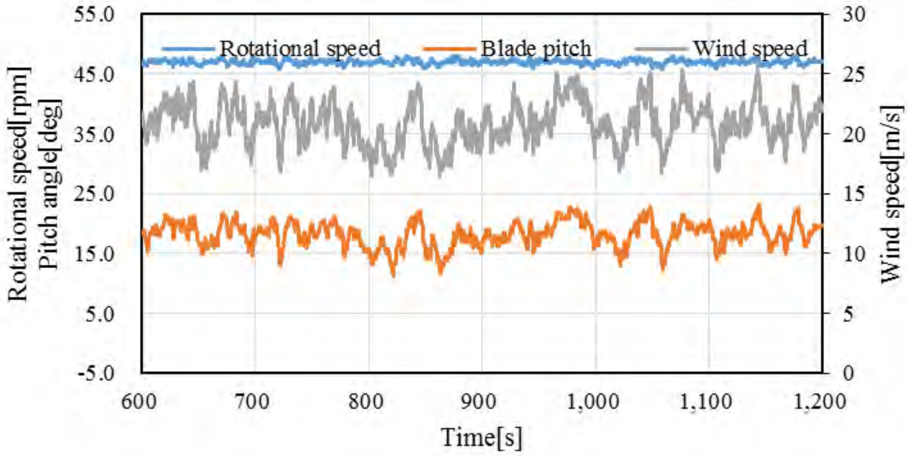

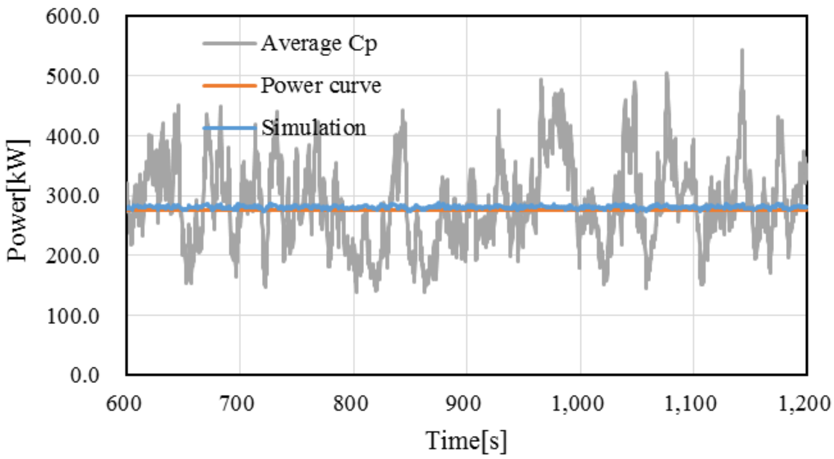

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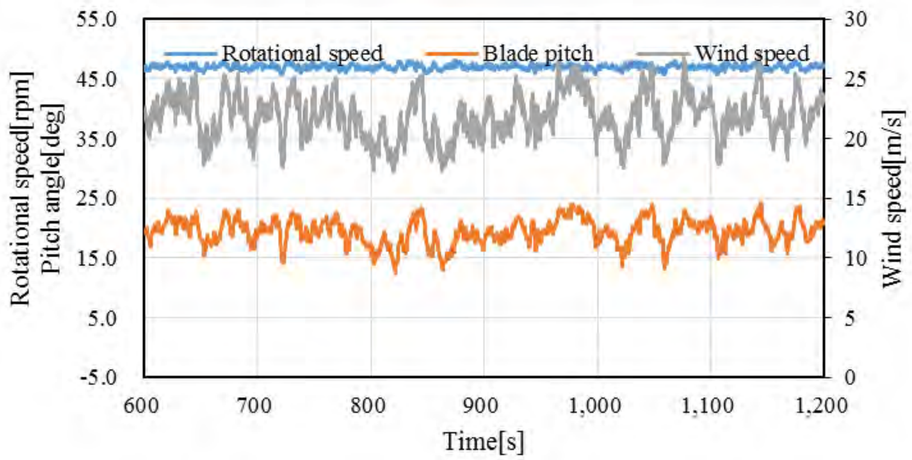

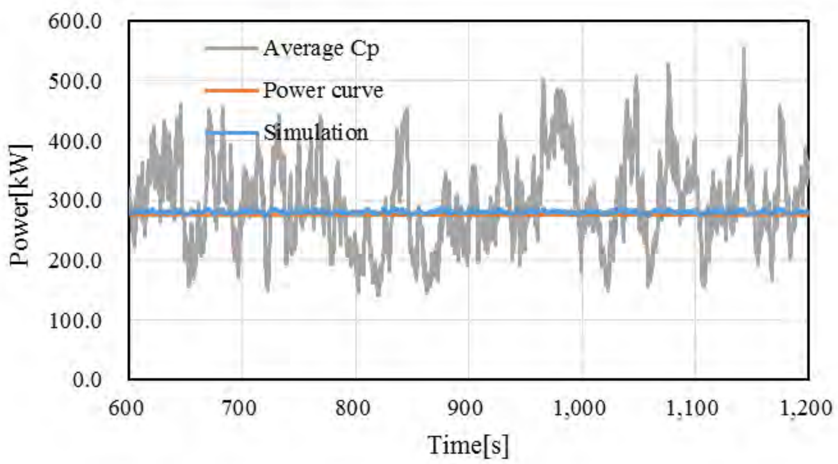

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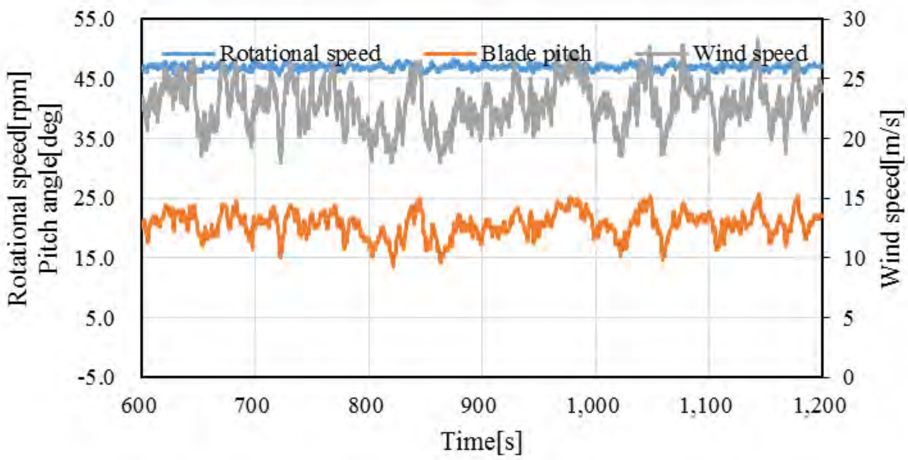

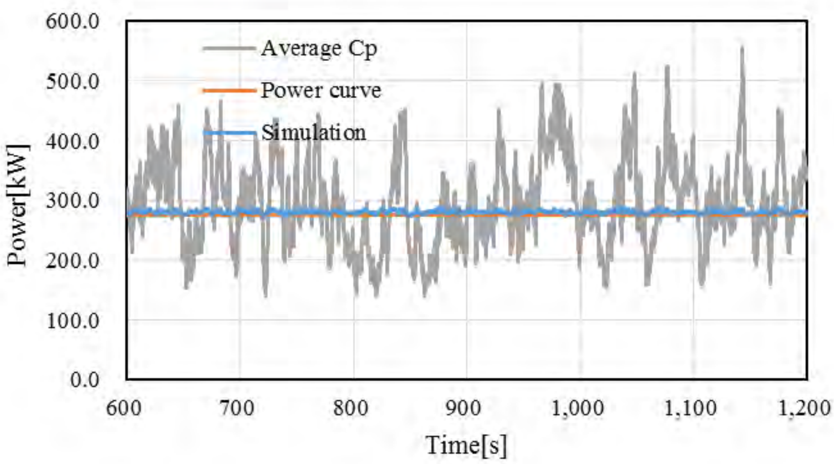

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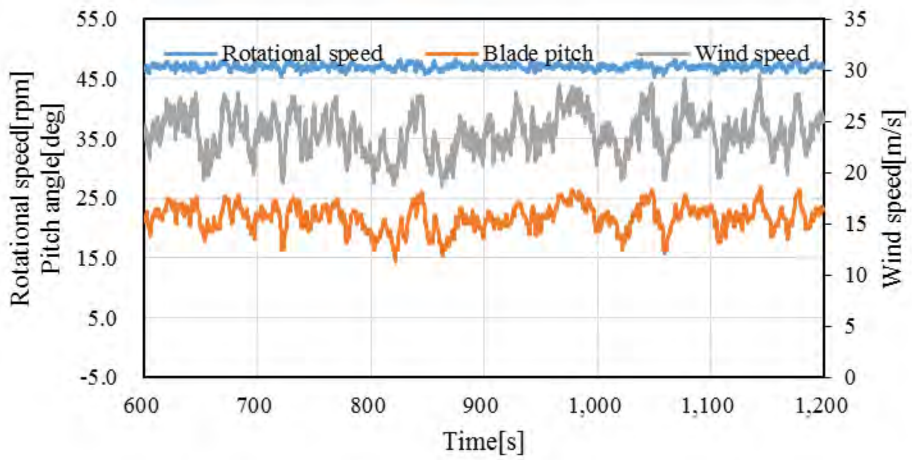

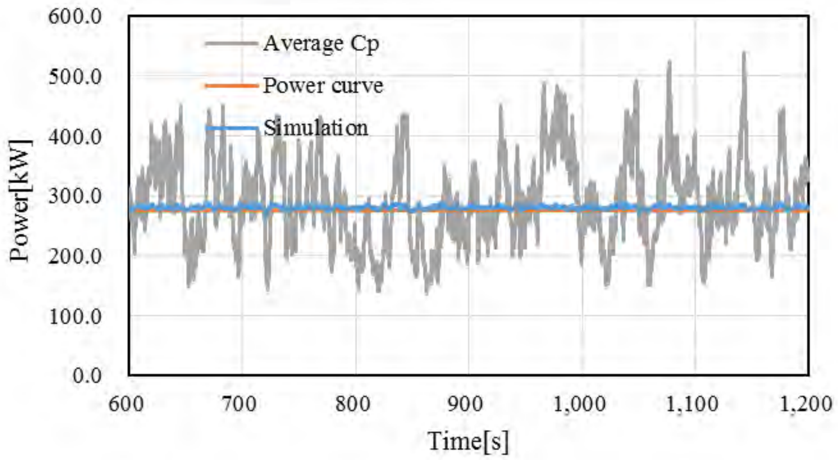

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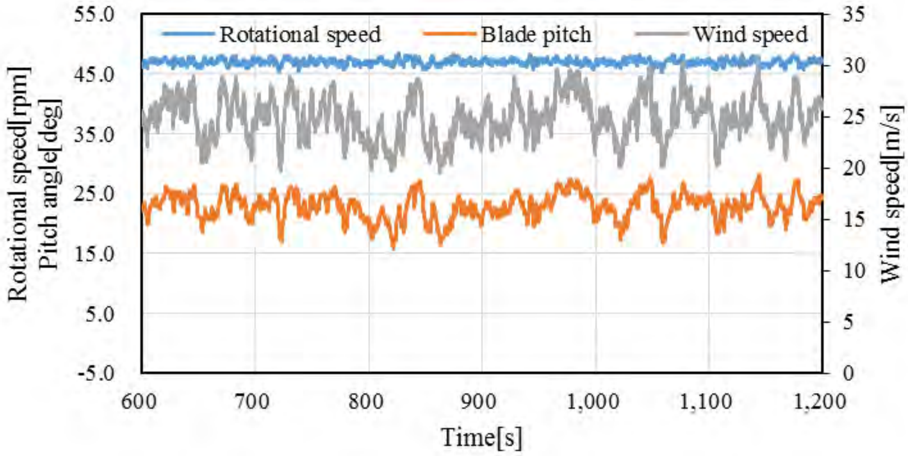

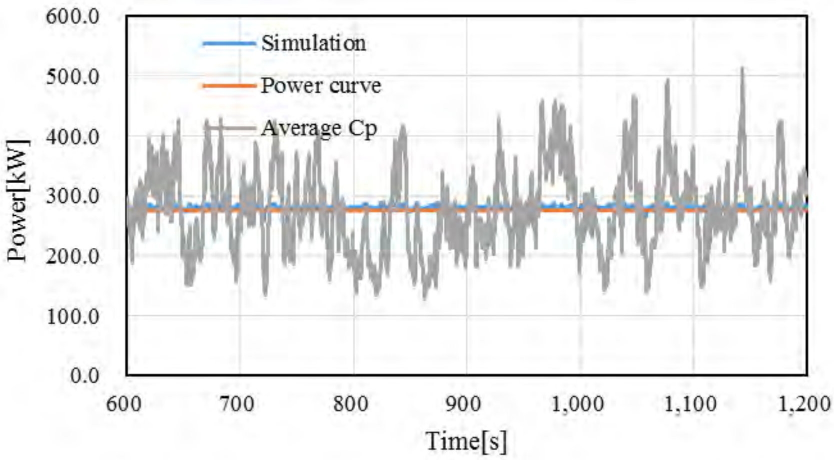

Time series graph of 25 m/s wind speed