Kingdom of Tonga

FY2018 Ex-Post Evaluation of Japanese Grant Aid Project

"The Project for Introduction of a Micro-Grid System with Renewable Energy for the Tonga Energy Road Map"

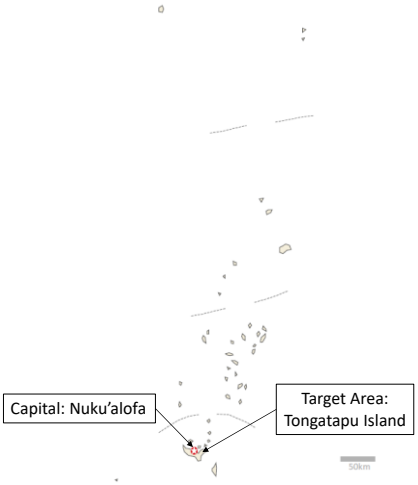
External Evaluator: Keisuke Nishikawa, Japan Economic Research Institute Inc.

0. Summary

Through this project, solar power facilities and a micro-grid system were introduced to achieve a balanced power supply of electricity supply from various sources and demand in order to contribute to the stable introduction of renewable energy and a reduced dependency on imported fossil fuel. The relevance of this project is high as the project was both consistent with the development plans and development needs of Tonga at the time of both planning and ex-post evaluation and was also consistent with Japan's ODA policy at the time of planning. As for implementation of the project, the project outputs were largely as planned, and the project costs and periods were within the plan. Therefore, the efficiency is high. With regard to project effects, except for the period during which Tongatapu Island, where this project was implemented, suffered severe damages caused by a super cyclone, target values for reductions in diesel fuel consumption volumes and carbon dioxide emissions as well as the amount of power generation through solar power generation were achieved. In addition, it was confirmed that system stabilisation had been achieved as expected by introducing a micro-grid system and that the level of recognition as to the necessity of large-scale electricity storage facilities to further introduce renewable energy generation facilities was raised among those concerned. With the inclusion of other solar power generating facilities, effects were seen in that 7 to 8% of diesel fuel needed for power generation in Tongatapu Island had been saved. Therefore, the effectiveness and impact of this project as a whole is high. Regarding operation and maintenance, there were no major problems in terms of all institutional/organisational, technical, financial aspects as well as the operation and maintenance status. Therefore, sustainability is judged to be high.

In light of the above, this project is evaluated to be highly satisfactory.

1. Project Description



Project Location

Solar panels installed in this project

1.1 Background

In Tonga, because of its geographical feature as an island country, petroleum-based fuel accounted for 25% of Tonga's whole imports, which was comparable to 10% of its GDP. Also, more than 98% of the electric power supply was delivered by diesel engine generators using imported diesel fuel. Therefore, Tonga was heavily influenced by international fluctuations of crude oil prices and was extremely vulnerable in terms of energy security.

The soaring global crude oil prices in 2008 forced Tonga's electricity rates to reach 1.00 Tongan Pa'anga/kWh (approx. USD 0.5/kWh), causing serious impacts on economic activities and the peoples' lives in the country[1]. Having learnt from this experience, the Cabinet of Tonga set 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: reductions in greenhouse gas emissions and improvements in energy security. The government also formulated the 'Tonga Energy Road Map 2010-2020' (hereinafter referred to as 'TERM') as an implementation policy to achieve the policy goal. However, Tonga still needed to adopt renewable energy systems to achieve the target of "50% of electricity from renewable sources". But it was expected to be difficult to stably supply electricity and to secure the quality of electricity because the output level of these renewable energy sources could fluctuate, if the introduction of wind and photovoltaic power generation etc., having output fluctuations, were substantially increased. In

[1] In Japan, the electricity tariff for household use soon after the surge of crude oil prices in 2009 was 22.8 US cents per kWh. Equivalent electricity tariffs in the same year were 20.6 US cents in the United Kingdom, 15.9 US cents in France, and 11.6 US cents in the United States. (Source: *FY2010 Annual Report on Energy* (*Energy White Paper 2011*))

order to deal with these circumstances, Tonga's electricity sector needed to promote the introduction of renewable energy sources while stably supplying electricity and minimizing fluctuations in frequencies of the grid system by adopting the micro-grid system.

1.2 Project Outline

The objective of the project was to stably operate a balanced power system of electricity supply from various sources and demand by establishing a micro-grid system in Tongatapu Island, thereby contributing to the stable introduction of renewable energy and the reduction of dependency on imported fossil fuels.

Grant Limit/Actual Grant Amount	1,573 million yen/1,537 million yen
Exchange of Notes Date/ Grant Agreement Date	March 2013/March 2013
Executing Agency	Tonga Power Limited
Project Completion	March 2015
Target Area	Tongatapu Island
Main Contractor	(Equipment) Joint Venture of NBK Corporation and Fuji Electric Co., Ltd.
Main Consultant	Joint Venture of Yachiyo Engineering Co., Ltd. and West Japan Engineering Consultants, Inc.
Preparatory Survey	August 2012 – March 2013
Related Projects	[Grant Aid] The Project for Introduction of Clean Energy by Solar Home System (2010) The Project for Installation of Wind Power Generation System (2017) [Other International and Aid Organisations] (Asian Development Bank) Promoting Energy Efficiency in the Pacific: Phase 1 (2008 – 2011), Phase 2 (2011 – 2015) (The Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ)) Coping with Climate Change in the Pacific Island Region (2012 – 2013) (New Zealand Aid Programme) Renewable Energy-Meridian Solar Project (Popua

	Solar Farm) (2011 – 2012) Tonga Village Network Upgrade (2011 – 2013) (Renewable Energy and Energy Efficiency Partnership (REEEP)) REEEP TERM IU Support (2011 –) (World Bank) Tonga Energy Development Policy Project (2010 – 2011) TERM Implementation Project (2012 – 2013)

2. Outline of the Evaluation Study

2.1 External Evaluator

Keisuke Nishikawa, Japan Economic Research Institute Inc.

2.2 Duration of Evaluation Study

This ex-post evaluation study was conducted with the following schedule.

Duration of the Study: September 2018 – September 2019

Duration of the Field Study: 15 November, 2018 – 30 November, 2018

3. Results of the Evaluation (Overall Rating: A[2])

3.1 Relevance (Rating: ③ [3])

3.1.1 Consistency with the Development Plan of Tonga

Tonga's national development plan at the time of planning of this project was the 'Tonga Strategic Development Framework 2011-2014' (TSDF-I). One of the nine outcome objectives of the framework was 'infrastructure development', with one of its strategies being the maintenance and expansion of a highly reliable and economical electricity supply by introducing renewable energy. As for the energy sector, A long-term plan called TERM, targeting 2020, had been formulated, in which goals were set, including 50% of Tonga's electricity generation to be met through renewable energy and all people to have access to the electricity supply by 2020.

Tonga's development plan at the time of ex-post evaluation is the 'Tonga Strategic Development Framework 2015-2025' (TSDF-II), bearing the same name with a different target period. Five pillars are set out in the framework, one of which is 'Infrastructure and Technology Inputs'. One of the five outcomes for this pillar is to realise an appropriate mix

[2] A: Highly satisfactory, B: Satisfactory, C: Partially satisfactory, D: Unsatisfactory

[3] ③: High, ②: Fair, ①: Low

of energy through reduced dependence on fossil fuels and the expansion of renewable energy resources. With regard to the sector plan, TERM has remained effective, with the same target of catering 50% of power generation from renewable energy by 2020. Moreover, according to the TERM Implementation Unit[4] of the Energy Department of the Ministry of Meteorology, Energy, Information, Disaster Management, Climate Change and Communications (hereinafter referred to as 'the Energy Department'), the government of Tonga has set the target rate at 70% by 2030 in addition to the target set in TERM.

Based on the above, the direction to promote the introduction of renewable energy had been set out both at the time of planning and ex-post evaluation in the national plans of the 'Tonga Strategic Development Framework', and this project is consistent with the plans. Also, the target value of the sector plan of TERM remained unchanged at the time of ex-post evaluation, indicating that there has been an emphasis on the introduction of renewable energy.

In light of the above, it can be said that this project is consistent with the development plan of Tonga.

3.1.2 Consistency with the Development Needs of Tonga

At the time of planning of this project, Tonga had been dependent on imported fuel-based diesel power generation for more than 98% of its electricity supply. As a result, it was necessary to reduce dependency on the import of fossil fuels in terms of national energy security as it is heavily affected by external factors such as a surge in international crude oil prices. As a means of reducing dependency, the introduction of renewable energy facilities was promoted in the policy, but the facility for stabilising power voltages, which was crucial for its introduction, was left undeveloped.

In the ex-post evaluation, the renewable energy ratio after the completion of this project (March 2015), shown in Table 1, was captured.

[4] The TERM Committee was formed with 12 members, chaired by the prime minister, in order to achieve Tonga's sustainable economic development, reduce environmental burdens, and ensure energy security while reducing electricity tariffs. As an implementing team, the TERM Implementation Unit has been established.

Table 1: Introduction of Renewable Energy in Tonga

	2015	2016	2017	2018
Amount of diesel generation (MWh)	43,659	59,175	62,612	44,663
Amount of renewable energy generation (MWh)	3,971	5,072	6,622	5,058
Ratio of renewable energy generation (%)	8.34	7.89	9.57	10.17

Source: Data provided by the executing agency
Note: Data for March to December 2015 and January to September 2018 were adjusted to express annual figures.

As shown in Table 1, the renewable energy-based power generation ratio has risen to a level exceeding 10% in 2018. While it is considered difficult to 'raise the renewable energy ratio to 50% by 2020', as set out in TERM, several solar power generation projects, including this project, were implemented. Moreover, including 'The Project for Installation of Wind Power Generation System', whose construction was being implemented at the time of ex-post evaluation with support from Japan, efforts to reduce dependency on fossil fuels were being made, which indicates that the need to develop renewable energy facilities continued to be high.

With regard to the introduction of the power system stabiliser, which is indispensable for the introduction of renewable energy facilities, according to the executing agency and the Energy Department, it was confirmed at the time of ex-post evaluation that a plan to introduce a power storage system was being formulated through support from the 'Green Climate Fund[5]' and the Asian Development Bank.

Therefore, it can be said that this project is consistent with the development needs at the time of planning and ex-post evaluation.

3.1.3 Consistency with Japan's ODA Policy

At the time of planning of this project, Japan expressed its policy to support the promotion of introducing renewable energy at the sixth Pacific Islands Leaders Meeting (2012). In the Country Assistance Policy for the Kingdom of Tonga (2012), 'Environment and Climate Change' was a focus area, and a support for TERM efforts was planned to be provided.

Therefore, this project can be said to have been consistent with Japan's assistance policy for the entire Pacific region and Tonga at the time of planning.

[5] A fund tasked with the operation of a financing mechanism based on the United Nations Framework Convention on Climate Change (UNFCCC) to support the efforts of developing countries toward reducing (mitigating) greenhouse gas and dealing with the effects of climate change; Japan decided to make a contribution in May, 2015. (Source: Ministry of Foreign Affairs website)

It was confirmed that this project was consistent with the development and sector plans as well as the development needs of Tonga at the time of both planning and ex-post evaluation, and with Japan's ODA policy for the Pacific region and Tonga at the time planning. Furthermore, it was considered that there were no issues in terms of project planning and approach.

In light of the above, the relevance of this project is judged to be high.

3.2 Efficiency (Rating: ③)

3.2.1 Project Outputs

Through this project, it was planned to introduce a solar power system and power system stabilisers on Tongatapu Island. Details of the planned and actual outputs (implemented by the Japanese side) are shown in Table 2, and it was confirmed that these outputs were all implemented as planned.

Table 2: Planned and Actual Outputs of This Project

		Plan	Actual
Procurement and Installation	1. Micro-grid system at Popua Power Station 1.1 Micro-grid controller 1.2 Power system stabiliser 1.3 House electric facility board	 1 set 8.3 kWh or more 1 set	 1 set 8.3 kWh or more 1 set
	2. Micro-grid system at the Vaini project site 2.1 Micro-grid controller 2.2 Power stabiliser 2.3 PV system 2.4 Grid-connected switch gear for 11-kV system 2.5 House electric facility board	 1 set 8.3 kWh or more 1,000 kWp 7 boards 1 board	 1 set 8.3 kWh or more 1,000 kWp 7 boards 1 board
	3. Optical cable communication system	15 km	Approx. 15 km
Procurement	1. Grid-connected switch gear for 11-kV system (at the Popua Power Station)	4 boards	4 boards
	2. Replacement parts	1 set	1 set
Construction	1. Building for inverters and power storage system (at the Vaini project site)	Approx. 190 m^2	201.50 m^2
	2. PV array bases (at the Vaini project site)	1 set	1 set
	3. Building for inverters and power storage system (at the Popua Power Station)	Approx. 100 m^2	117.70 m^2

Source: Preparatory Survey Report, Documents provided by JICA and information provided by the executing agency

11kV high voltage receiving panel (at the Vaini project site)

New electrical room at Popua Power Station

Through this project, it was planned that the Tongan side was also to implement the following tasks, and it was visually confirmed during the site survey of the ex-post evaluation study that they had actually been implemented as planned.

- Clearance of trees, and exterior wall and gate work at the Vaini project site
- Work to increase the size of the 11kV distribution wire and connection work at the Vaini project site
- Expansion work for an 11kV switch board room at the Popua Power Station
- Installation work for grid-connected switch gear for 11kV system at the Popua Power Station
- Remodelling work for the existing power generating facilities at the Popua Power Station.

In addition to this procurement and construction work, it was planned as a soft component of this project to provide (1) instructions on operation and maintenance methods of the micro-grid system and facilities to be introduced to Tonga for the first time and (2) instructions on stable operation methods of distribution systems where the system is connected. These instructions were provided as planned from November 2014 to February 2015. According to the executing agency, while the implementation period was short, lectures and actual practices were provided intensively, leading to the acquisition of basic skills.

3.2.2 Project Inputs

3.2.2.1 Project Cost

This project was planned at a total cost of 1,630 million yen, composed of Japan's project cost of 1,573 million yen and Tonga's project cost of 57 million yen.

The actual project cost was a total of 1,609 million yen[6], composed of Japan's 1,537 million yen and Tonga's 71 million yen, as shown below.

Table 3: Breakdown of Actual Project Cost of Japan

(Unit: million yen)

Item	Project cost
Construction	0
Equipment	1,474
Design and supervision	63
Total	1,537

Source: Documents provided by JICA

Table 4: Breakdown of Actual Project Cost of Tonga

(Unit: thousand Tongan Pa'anga)

Item	Project cost
Bank commission	39
Clearance of trees, and exterior wall and gate work at the Vaini project site	150
Work to increase the size of the 11kV distribution wire and connection work at the Vaini project site	82
Expansion work for 11-kV switch board room at the Popua Power Station	103
Installation work for grid-connected switch gear for 11kV system at the Popua Power Station	197
Remodelling work for the existing power generating facilities at the Popua Power Station	175
Land lease for the PV system at the Vaini project site for the first year	450
Total	1,196

Source: Documents provided by the executing agency

Note: 1,196 thousand Tongan Pa'anga = 71 million yen, calculated based on the period-average exchange rate (1 Tongan Pa'anga = 60.03 yen)

While the project cost for Tonga exceeded the planned amount due to some items slightly exceeding the expected amounts, the total project cost was within the plan at 1,609 million yen (99% of the plan).

3.2.2.2 Project Period

The planned project period[7] of this project was 24 months, including the detailed design and bidding period. The actual project period was 23 months, from May 2013 till March 2015. All the installation of equipment and operation instructions were completed within the planned period, showing that the actual period was within the plan (96% of the

[6] Not matching the total value of Japan's and Tonga's individual project costs due to rounding off

[7] As the Ex-ante project evaluation paper and the preparatory survey report did not indicate a specific period from the Grant Agreement signing date till the commencement of detailed design, the project period was regarded as the period between the commencement date of detailed design and the construction completion date.

plan).

The outputs necessary for the generation of project effects were as planned. The project costs and periods were also within the plan. Therefore, the efficiency is high.

3.3 Effectiveness and Impacts[8] (Rating: ③)

3.3.1 Effectiveness

3.3.1.1 Quantitative Effects

At the time of planning of this project, reduction in diesel fuel consumption and CO_2 emissions, and the amount of annual power generation by the photovoltaic system were set as quantitative effect indicators. In the ex-post evaluation, the percentage of power generated by the facilities developed through this project in relation to all power generated in Tongatapu was captured to verify the degree of contribution of this project, as there are several renewable energy generation facilities in Tongatapu.

Table 5: Quantitative Effect Indicators of This Project

	Baseline	Target	Actual			
	2011	2018	2015	2016	2017	2018
		3 Years After Completion	Completion Year	1 Year After Completion	2 Years After Completion	3 Years After Completion
Reduction in the amount of diesel fuel (kℓ/year)	—	327	389	342	373	273
Reduction in the amount of CO_2 emissions (t-CO_2/year)	—	886	1,062	934	1,018	744
Amount of annual power generation by 1MWp photovoltaic system (MWh/year)	0	1,308	1,556	1,369	1,492	1,091
(Reference) Percentage of power generated in Tongatapu (%)	—	—	3.2	2.5	2.5	2.0

Source: Calculated from the Ex-ante evaluation paper and documents provided by the executing agency
Note: Estimated annual adjusted values calculated by multiplying the values of March-December by 1.20 for 2015 and the values of January-September by 1.33 for 2018

Since the completion of this project till 2017, a reduction in the amount of diesel fuel, reduction in the amount of CO_2 emissions, and the annual amount of power generated all

[8] Sub-rating for Effectiveness is to be put with consideration of Impacts.

stayed at the level above the target values. The values in 2018 did not reach the target figures, but it was due to the occurrence of a large-scale outage throughout Tongatapu Island after the super cyclone Gita, the size of which had not been seen for the past 60 years, hit the island in February 2018. After the direct strike of the cyclone, six weeks were required for temporary restoration, during which power generation was also limited. However, it was judged that the declines of figures in Table 5 were due to peculiar factors caused by the natural disaster. On a different note, the amount of power generated by the facilities developed through this project account for 2 – 3% of the total power generated in Tongatapu Island.

In Tongatapu Island, large-scale solar power generation facilities, other than the one developed through this project (1.0-MW size), are a 1.3-MW-scale facility (commissioned in July 2012) installed with assistance from New Zealand and a 2-MW-scale facility (commissioned in September 2017) by an independent power producer with Chinese capital. As shown in Table 6, the three facilities in total account for 8.6% of the power generated in the whole island of Tongatapu (2018), indicating a certain degree of contribution.

Table 6: Effects of the Three Photovoltaic Facilities on Tongatapu Island

	2015	2016	2017	2018
Reduction in the amount of diesel fuel (kℓ/year)	799	836	1,041	1,199
Reduction in the amount of CO_2 emissions (t-CO_2/year)	2,182	2,282	2,841	3,273
Amount of annual power generated by 4.3MWp photovoltaic system (MWh/year)	3,197	3,343	4,163	4,796
(Reference) Percentage of power generated in Tongatapu (%)	6.6	6.1	7.1	8.6

Source: Calculated from the data provided by the executing agency
Note: As in Table 5, annual adjusted values were for March-December 2015 and January-September 2018.

3.3.1.2 Qualitative Effects (Other Effects)

At the time of planning of this project, the qualitative effect through implementing this project was expected to be the 'stabilisation of the power grid with the use of power storage equipment and micro-grid controllers[9]', and it was anticipated that the instability of power generation by photovoltaic facilities would be mitigated.

According to the executing agency, power generated by the facilities made under the

[9] Equipment to maintain the output increases/decreases of power source equipment at a certain level in response to sudden fluctuations in the amount of power generation

assistance of New Zealand and by the Vaini project site, made through this project, has been stabilised after being incorporated into the transmission grid on Tongatapu Island by using the power storage equipment and micro-grid controllers developed through this project[10]. By the equipment installed through this project, instability of the volume of power generated by photovoltaic facilities, that had previously fluctuated significantly, was mitigated, and diesel power generation at base load[11] has been controlled. Power voltages and frequencies have been controlled within the standard values set by the executing agency, indicating that the qualitative effects of this project have also been generated.

However, the system installed through this project cannot capture the power generation status of the facilities of the independent power producer, developed and operated after this project was implemented, nor control them. It is considered important to ensure the introduction of the power storage system expected to be installed through the 'Green Climate Fund', especially when promoting the construction of renewable energy facilities by independent power producers in the future.

3.3.2 Impacts

3.3.2.1 Intended Impacts

At the time of planning, the following impacts were expected to be generated through the implementation of this project.

- Alleviation of the fluctuation risks of diesel fuel prices
- Improvements in energy security through the reduction of dependency on diesel fuel imported from overseas.

According to the information provided by the executing agency, through power generation by the photovoltaic power generation facilities developed through this project, financial effects of fuel reduction in the amount of 404 thousand Tongan Pa'anga in FY2015/16, 438 thousand Tongan Pa'anga in FY2016/17, and 436 thousand Tongan Pa'anga in FY2017/18 were achieved. These amounts are the equivalents of 2.6%, 2.3%, and 2.0% of the fuel costs the executing agency paid out respectively. While these ratios are not necessarily high, it can be said that impacts of reducing price fluctuation risks and dependency on importing diesel fuels have been generated as expected.

[10] Hours of power outages on Tongatapu Island were 1,252 minutes in FY2015/16 and 1,560 minutes in FY2016/17. While the number of minutes increased because of an ongoing project to rehabilitate distribution networks and because of the inclusion of planned power outages, stability had increased according to the executing agency.
[11] The minimum amount of power supplied all the time regardless of season and/or time period

With regard to the situation of the entire country of Tonga, the annual reports of the executing agency show that the amount of diesel fuel reduced by power generation through renewable energy facilities, including the ones of this project, were 1,110 thousand litres in FY2015/16, 1,180 thousand litres in FY2016/17, and 1,500 thousand litres in FY2017/18. The impacts on prices were 1.29 million Tongan Pa'anga in FY2015/16, 1.44 million Tongan Pa'anga in FY2016/17, and 1.63 million Tongan Pa'anga in FY2017/18, accounting for 8.4%, 7.5%, and 7.6% of the fuel costs the executing agency paid in respective years.

A calculation based on the data provided by the executing agency and Tonga Statistics Office shows that the percentages of import values of the executing agency in relation to the fuel import values of the whole of Tonga were 22% - 29% per year (FY2012/13 – FY2017/18). It indicates that the introduction of several renewable energy facilities (Table 6) has generated the reduction effect of approximately 2%[12] of the entire imports of Tonga (As this project accounts for the saving of about 2 - 3% of the fuel consumed by the executing agency, the ratio of contribution to the entire country of Tonga is estimated to be approximately 0.6%). According to the Energy Department of Tonga, Tonga's energy security refers mainly to the mitigation of the effects of fuel price fluctuations (surge). Therefore, the realisation of imported fuel reduction can be said to be leading to the improvement of energy security of the country.

3.3.2.2 Other Positive and Negative Impacts

(1) Impacts on the Natural Environment

At the time of planning of this project, undesirable impacts to environment and society through project implementation were estimated to be minimal or very little, and there were no issues in relation to *the JICA Guidelines for Environmental and Social Considerations* (April 2010). In Tonga, implementation of an environmental impact assessment was required in accordance with the Environmental Assessment Act 2003 and the Environmental Impact Assessment Regulations 2010.

Checked with the executing agency at the time of ex-post evaluation, the environmental impact assessment was conducted as planned and the following conditions were imposed against the implementation of the project.

- Mitigation of noise disturbance, and avoidance of landscape changes caused by ground levelling work as well as soil runoff

[12] The percentage of power generated by several renewable energy facilities is 7 to 8%, and the percentage imported by the executing agency is 22-29% of the entire fuel imports of Tonga. As 7-8% of 22-29% is approximately 2%, it was calculated as the 'reduction effects of approximately 2%'.

- Mitigation of air pollution by construction machines and transport vehicles
- Appropriate use of chemicals and electric devices
- Avoidance of soil contamination and dust
- Avoidance of effects by reflection of solar panels (light and heat)
- Prevention of electrical leakage.

According to the executing agency and the Department of Environment, these items were all observed during project implementation. Also, no negative impacts to the natural environment had been reported during or after the implementation of this project, and there have been no complaints lodged from nearby residents.

Therefore, it is considered that there are no problems at all as no negative impacts to environment or to local residents have occurred in association with project implementation.

(2) Resettlement and Land Acquisition

The Vaini project site, one of the sites of this project and the location of the photovoltaic generation facilities to be installed, was the property of a noble (Minister for Land, Environment, Climate Change and Natural Resources), and the implementation of the project was planned upon signing a 50-year lease agreement[13]. The lease agreement for the site was signed as planned, and no procedural issues were observed. Also, provision of land by the noble seems to be regarded by residents of nearby villages as one based on non-expensive lease fees for a project with high public benefits, and it was confirmed that there were no issues caused.

Through this project, no resettlements of residents occurred.

Therefore, it can be said that there were no problems as a whole as the procedures for the use of land for this project were adequate and no resident resettlement occurred.

(3) Other Impacts

As other impacts of this project, the executing agency expressed that the Vaini project site, where solar panels were installed, is located along the main street connecting the city centre and the airport and has played a significant role in raising people's awareness of renewable energy.

In addition, this project realised the mitigation of power generation fluctuations of the photovoltaic facilities implemented with support from New Zealand prior to this project by introducing the power stabilisers. Also, among those concerned, such as the executing

[13] In Tonga, land is owned by the royal family or nobles and is not traded.

agency, recognition of the importance of power storage equipment associated with the introduction of renewable energy facilities was raised through realising for the first time that the system would enable stable operations of the entire power generation system. Based on this experience, a notion that incorporating large-scale power storage equipment would be necessary in further introducing renewable energy facilities was formed, and it was confirmed at the time of ex-post evaluation that an application to cover the introduction cost was submitted to the 'Green Climate Fund'. The application was approved, and it was decided that the power storage equipment would be introduced after 2019.

With regard to effectiveness, the target levels of the quantitative indicators of this project were achieved, except for the period when Tongatapu Island was heavily damaged by the super cyclone in February 2018. Moreover, it was observed that system stabilisation was realised by the introduction of the micro-grid system through this project and that recognition of the importance of a large-scale power storage system for further introduction of renewable energy was raised and that the efforts to introduce it independently were being made after completion of this project.

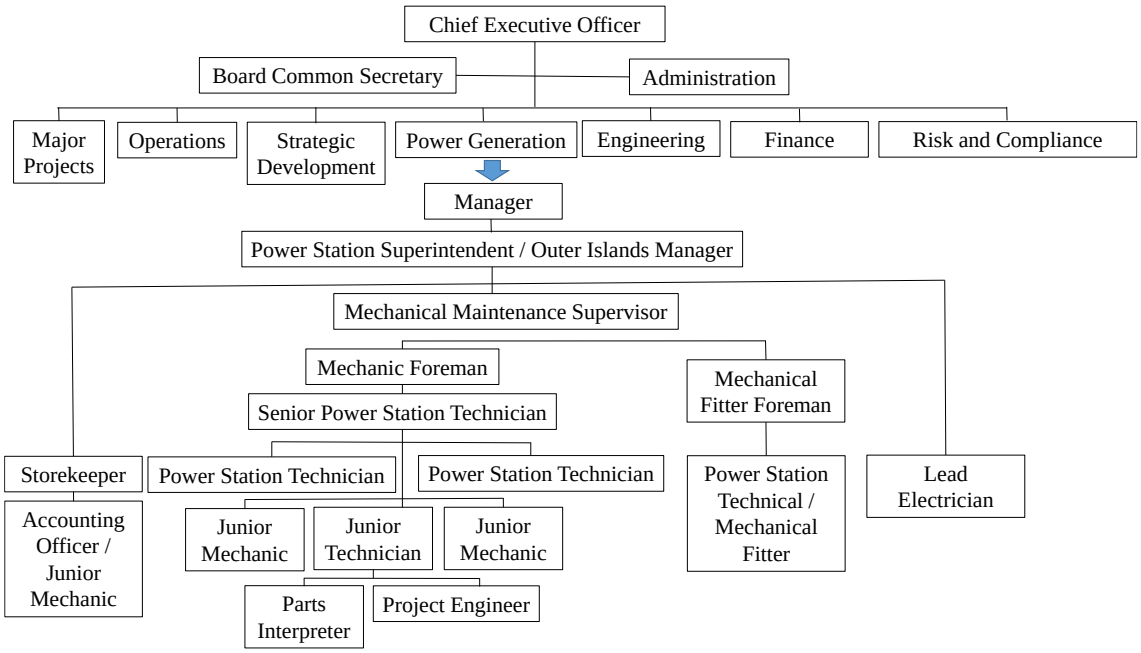
As for the impact, together with other renewable energy facilities introduced before and after this project, Tongatapu Island as a whole has realised a 7 to 8% reduction of diesel fuel for power generation, which has led to the improvement of national energy security by reducing fuel imports. There were no environmental or social problems observed as there were no occurrences of negative impacts on the natural environment or resettlement/land acquisition cases.

In light of the above, it is judged that the effectiveness and impacts of this project are high.

3.4 Sustainability (Rating: ③)

3.4.1 Institutional/Organisational Aspect of Operation and Maintenance

The executing agency for this project is Tonga Power Limited (hereinafter referred to as 'TPL') under the Ministry of Public Enterprises and has been positioned as the public corporation in charge of power supply in Tonga. TPL is comprised of eight divisions (three divisions of management and administration and five technical divisions), with a total of 229 staff members, out of which 29 are trainees.



Source: Prepared based on the documents provided by the executing agency

Figure 1: Organisation Chart of TPL (Partial)

The Power Generation Division, in charge of operation and maintenance of photovoltaic generation equipment and micro-grid controllers, etc., is composed of 28 staff members (16 on Tongatapu Island and a total of 12 on the outer islands). The Power Generation Division has five technicians holding qualifications, such as those for electricians, etc. (including the manager and the superintendent in charge of power stations) and the executing agency judged that the division had a structure with sufficient staff numbers.

After TPL was corporatised in 2008, the organisational structure has not undergone major changes, and it can be judged from the operation and maintenance status that the Power Generation Division is well structured, including technicians with adequate qualifications. Also, while the staff of the Power Generation Division had been in charge of diesel power generation, they received training through this project, and operation and maintenance of renewable energy generation was carried out by the staff with sufficient knowledge at the time of ex-post evaluation.

3.4.2 Technical Aspect of Operation and Maintenance

Since the time of planning of this project, TPL has had sufficient experiences in operation and maintenance of power plants. While the experiences of those operating and maintaining photovoltaic generation facilities are relatively few, they have learned about operating the power stabilisation system, responding to breakdowns, and so on through the implementation

of the soft component of this project, and they have said that there are no issues they cannot technically handle. Moreover, the operation and maintenance manuals on the photovoltaic generation and micro-grid system prepared through this project were being stored at their respective sites, Popua Power Station and Vaini, and are referred to when necessary. At the time of site surveys during the ex-post evaluation, the power stabilisation system was being operated in conjunction with the existing diesel power generation management system based on the instructions provided in the soft component, and no technical problems were observed.

Regarding the maintenance and improvement of technical capacities, there were sometimes opportunities to participate in training programmes provided by donors such as JICA, New Zealand, Australia, and others, but there was no systematic training programme. While no technical problems in particular on routine operation and maintenance were identified, an issue TPL should tackle is considered to be the implementation of training programmes for technicians on a regular basis so that they can always acquire new technological know-how.

3.4.3 Financial Aspect of Operation and Maintenance

The TPL's financial balance in recent years is shown in Table 7, showing a continuation of sound operations.

Table 7: Operating Balance of the TPL

(Unit: thousand Tongan Pa'anga)

Item	FY2015/16	FY2016/17	FY2017/18
Revenue	43,374	48,457	46,451
Cost of sales	-26,243	-28,955	-33,305
Gross profit	17,130	19,501	13,146
Sales expenses	-4,896	-5,301	-6,277
Administrative expenses	-6,516	-8,129	-10,207
Other income	2,225	2,860	10,426
Results from operating activities	8,144	8,931	7,088
Net financial costs	-818	-1,173	-1,027
Profit before tax	7,326	7,759	6,062
Corporate tax/Subsidies, etc. (25%)	-1,831	-2,233	-1,354
Total comprehensive income	5,494	5,526	4,708

Source: TPL Annual Report (respective years)

Notable items in relation to the operating balance in recent years are as follows:

- Although 'Other income' increased significantly in FY2017/18, it is due to receipt of a subsidy of 6 million Tongan Pa'anga from the Cyclone Gita Network Recovery Donor Fund;
- Maintenance expenses of power generation facilities are included in the 'cost of sales', which were 2,663 thousand Tongan Pa'anga in FY 2015/16, 1,350 thousand Tongan Pa'anga in FY 2016/17, and 3,157 thousand Tongan Pa'anga in FY 2017/18. The amount needed for stable operation of the power supply system seems to have been sufficiently allocated;
- The electricity tariff has been 0.3420 Tongan Pa'anga/kWh since July 2017. It was heard that the electricity tariff had been heavily affected by fuel prices for diesel power generation, which accounts for the majority of the total power generation, and that it had been fluctuating regularly in response to the price trends.

As a whole, the financial status of TPL in recent years has been a surplus for all of the gross profits, results from operating activities, and the total comprehensive income, showing a sound financial status. The electricity tariff is adjusted in response to international fuel prices, so that excessive impact to the financial condition is considered to be curbed. The necessary amount of expenses for maintenance had been disbursed without delay, and there were no problems observed.

3.4.4 Status of Operation and Maintenance

The facilities and equipment developed in this project were inspected and recorded at least once a week and were operating in good condition as a whole. However, the optic fibre cables (connecting the Vaini project site and the Popua Power Station) cut by Cyclone Gita, that hit Tongatapu Island in February 2018, had not been restored at the time of ex-post evaluation and the power generation data could not be instantly captured remotely. TPL had been carrying out work in the ongoing grant aid project by JICA, 'The Project for Installation of Wind Power Generation System', to enable data transmission at a shorter distance and without any influence from heavy storms by connecting cables from the Vaini project site to the submarine cable, connecting the installation site for the wind power generation facilities and the Popua Power Station.

As for the procurement of parts, none of them in particular were needed by the time of ex-post evaluation. When the solar panels were damaged by Cyclone Gita, the spare parts provided through this project were used. Also, when a purchase of spare parts is required, it

is considered that there will be no issues in procurement judging from their past operation and maintenance conditions of the entire power supply system.

Based on the above, it was confirmed that the facilities and equipment developed through this project are all in good operating condition, except for the optic fibre cables, and regular inspections have been conducted and records have been kept. There are no problems as a whole.

While no regular training system for technicians about maintenance has been established, there were no problems in terms of institutional/organisational aspects, technical aspects, financial aspects as well as operation and maintenance status as a whole, and it can be said that operation and maintenance has been sufficiently conducted. Therefore, it can be judged that the sustainability of the effects generated in this project is high.

4. Conclusion, Lessons Learned and Recommendations

4.1 Conclusion

Through this project, solar power facilities and a micro-grid system were introduced to achieve a balanced power supply of electricity supply from various sources and demand in order to contribute to the stable introduction of renewable energy and a reduced dependency on imported fossil fuel. The relevance of this project is high as the project was both consistent with the development plans and development needs of Tonga at the time of both planning and ex-post evaluation and was also consistent with Japan's ODA policy at the time of planning. As for implementation of the project, the project outputs were largely as planned, and the project costs and periods were within the plan. Therefore, the efficiency is high. With regard to project effects, except for the period during which Tongatapu Island, where this project was implemented, suffered severe damages caused by a super cyclone, target values for reductions in diesel fuel consumption volumes and carbon dioxide emissions as well as the amount of power generation through solar power generation were achieved. In addition, it was confirmed that system stabilisation had been achieved as expected by introducing a micro-grid system and that the level of recognition as to the necessity of large-scale electricity storage facilities to further introduce renewable energy generation facilities was raised among those concerned. With the inclusion of other solar power generating facilities, effects were seen in that 7 to 8% of diesel fuel needed for power generation in Tongatapu Island had been saved. Therefore, the effectiveness and impact of this project as a whole is high. Regarding operation and maintenance, there were no major problems in terms of all institutional/organisational, technical, financial aspects as well as the operation and maintenance status. Therefore, sustainability is judged to be high.

In light of the above, this project is evaluated to be highly satisfactory.

4.2 Recommendations

4.2.1 Recommendations to the Executing Agency

Immediate restoration of optic fibre cables

The optic fibre cables damaged by the impact of the super cyclone Gita in February 2018 are an essential facility to instantly capture the volume of power generated by the photovoltaic facilities at the Vaini site and to control diesel power generation accordingly. While the preparatory work for restoration was ongoing at the time of ex-post evaluation, it is necessary to complete it immediately so that the effects of the execution of this project will be sufficiently generated at all times.

To consider installing power storage equipment and a control centre

TPL was planning to install large-scale power storage equipment through the assistance of the Green Climate Fund as it is difficult for the power stabilisation system of this project to capture and control the conditions of renewable energy facilities installed after the execution of this project. When various renewable energy facilities are introduced in the future, it is desirable to emphasise the viewpoint of the importance for system stabilisation and to consider the installation of power storage equipment and a comprehensive control centre.

4.2.2 Recommendations to JICA

Japan has played a significant role in introducing renewable energy in Tonga through this project and through the wind power generation project being implemented at the time of ex-post evaluation. For the overall stabilisation of the power system, which was a point of challenge for the country at the time of ex-post evaluation, it is considered to be important to keep exchanging information with the executing agency and to support the development of equipment and to provide technical assistance as necessary.

4.3 Lessons Learned

Cooperation toward the stabilisation of the entire power system

In this project, while the equipment to stabilise the power system for the power generated by the photovoltaic facilities developed through the preceding project supported by New Zealand and through this project were introduced, no equipment to stabilise the additional power generated by the independent power producer was not considered. As Tonga's policy had a target to raise the ratio of renewable energy to 50% by 2020, it was considered important to draw an overall picture as to what kind of equipment would be further needed for system

stabilisation. As a large cost is required for the introduction of large-scale power storage equipment and power stabilisation systems, it is thought difficult to implement them within a single project. However, in introducing renewable energy, it is important to ensure consistency between individual projects and, for the government in the country of project implementation, to consider the entire system when aiming to achieve long-term goals. Under the overall picture, it is also important to implement the projects sequentially to enable stable operations of the entire system in the future.

(End)