



Market and Industry Report

*Achieving the Sustainability of Distributed Energy Systems
in Pacific Island Countries and Territories*

August 2018



This Market and Industry report has been submitted to the United Nations Industrial Development Organization by One Energy Island Co., Ltd as the second report required under Contract No. 3000055492 - **Consultancy Services for the Design of a Sub-Regional Renewable Energy Mini-grid Program for Pacific Island Countries and Territories**

List of Acronyms

CVCF	Constant Voltage Constant Frequency
EE	Energy Efficiency
ES	Energy Storage
ESS	Energy Storage System
FDoE	Fiji Department of Energy
GHG	Greenhouse Gas Emission
ICT	Information and Communication Technology
IDB	Inter-American Development Bank
IGBT	Insulated Gate Bipolar Transistor
IRENA	International Renewable Energy Agency
KEA	Korea Energy Agency
OEI	One Energy Island
O&M	Operations and Maintenance
PCREEE	Pacific Centre for Renewable Energy and Energy Efficiency
PCS	Power Control System
PICT	Pacific Island Countries and Territories
PNG	Papua New Guinea
PPA	Pacific Power Association
PPP	Public Private Partnership
PQ	Power Quality
PRDR	Pacific Regional Data Repository for Sustainable Energy for All
RE	Renewable Energy
RETs	Renewable Energy Technology System
RFP	Request for Proposal
SIDS	Small Island Developing States
SIDS DOCK	Sustainable Energy Island and Climate Resilience Initiative
SPC	Pacific Community
SISEP	Solomon Islands Sustainable Energy Project
TOC	Top Operation Centre
UN DESA	United Nations Department of Economic and Social Affairs
UNIDO	United Nations Industrial Development Organization
VRLA	Valve-Regulated Lead-Acid

Executive Summary

The Pacific Community consists of 22 countries and territories (PICTs) with a total of about 10 million inhabitants and a total land area of about 553,409 km². By geographical location, they are divided into three sub-regional divisions, Melanesia, Micronesia, and Polynesia. Many PICTs are sparsely populated with a large proportion of residents living in rural areas and remote islands which lack modern infrastructure including a stable and reliable energy supply. The islands which comprise the PICTs are often isolated from each other both geographically, politically, and culturally. The isolation and the distance between the PICTs make establishing renewable energy systems difficult and expensive.

There are many existing barriers dealing with human capacity availability for governments, private enterprises, and citizens which restrict the full implementation of renewable energy technology within the PICTs to provide enhanced electricity access. These challenges can create a status quo which is difficult to change even if clean and renewable energy systems are in the best future interests of all stakeholders. Many of these barriers can be overcome through a shared capacity building process and collaborative effort between the public and private sectors. However, in order to be successful, challenges at various levels must be analyzed and addressed.

Due to financial, political, and technological factors, including the isolation and geography of the PICTs, large and integrated energy systems are limited in this region. Currently, many smaller islands rely on small scale or stand-alone diesel-powered generator systems which can be inefficient, costly, and pollute the local environment. On the other hand, decentralized renewable energy technology is becoming more prevalent because costs are decreasing while reliability is increasing.

As an alternative to existing diesel-based generation systems on small islands in the PICTs, a renewable energy-based hybrid mini-grid system comes into focus thanks to its technical advantages and environmental benefits. While the mini-grid market is trending upwards, many PICTs do not benefit from it. There are barriers to the implementation of mini-grid systems in the PICTs; Governments must often make tough choices when making funding decisions and the allocation of funding for energy is often limited, the current mini-grid market and industry is pre-mature and fragmented, resulting in the high cost and high risk of doing business, and local enterprises often do not have the organizational capacity to take on large projects.

Current practices of mini-grid projects are driven by the public sector with the financial support of international donor organizations. This process and structure is considered to be effective in opening a window to promoting mini-grid projects in PICTs as there is no viable commercial market for nurturing private business models. At the same time, the public model has certain limits. It creates the absence of local ownership and responsibility in the operation of mini-grid projects. In particular, considering the nature of mini-grid systems in PICTs whose locations are remote and dispersed over a wide range of distances and which require challenging O&M practices, the active participation of local enterprises is the most important in building and growing a sustainable mini-grid market in PICTs.

This market and industry report will analyze the factors which present challenges to the PICTs and will discuss the findings in order to make recommendations to improve the conditions for a more prosperous energy future for the PICTs. The study and analysis of this report will be focused on the pre-conditions and practical solutions for building a sustainable market and industry infrastructure which will lead to the active participation of local private enterprises as the key player in the mini-grid market in PICTs in the near future.

Key Findings

1. The market for mini-grid systems is trending upward across the Pacific, there are still many areas which can be improved. Generally, gaps arise which could be filled by increased private sector involvement, in the entire process of implementation of mini-grids, from the development, construction and operation and maintenance.
2. The dissemination of knowledge has greatly increased because of the involvement of organizations such as SPC's PCREEE and others, more could be accomplished through the systematic assessment of projects in order to create a database which identifies common mistakes and technical troubles that occur during the planning, installation and maintenance of mini-grids.
3. Governments must make tough decisions regarding the allocation of funding, especially in the energy sector. Renewable energy based mini-grid projects have very compelling socio-economic benefits but in order for mini-grid projects to be among the highest priority for the government's funding decisions, the operational performance of mini-grid projects must be proven to be reliable and satisfactory, and the anticipated socio-economic outcomes must be fulfilled through sustainable operation.
4. The existing hurdles and risks are high for private companies doing mini-grid projects in the PICTs. The remote nature of the islands in the PICTs and the harsh marine environment poses challenges due to accessibility issues, rusting and the lack of economies of scale. such unfavorable physical conditions result in a high cost and high risk of doing business and prevent private companies from actively coming in and pursuing business opportunities. As a result, there has been a vacuum of responsibility for the sustainable operation of mini-grid projects, which in turn results in unsatisfactory operational performance and unfulfilled socio-economic benefits of mini-grid projects.
5. Most PICTs announced ambitious goals of renewable energy contributions, from 20 to 50 percent by 2020 to 2025, however, those goals have not been achieved yet despite the rich renewable energy sources and promising potential benefits. In order for the active promotion of renewable energy in the PICTs, it is critical to encourage the active participation of private companies by reducing the hurdles and risks posed to private companies doing mini-grid business in the PICTs. It is believed that the mini-grid market and industry in the PICTs can grow and be nurtured only through the active participation of the private sector.

Recommendations

In the design of the PICT's mini-grid program, a stable and reliable electricity delivery system can be interoperated as an important step in building more resilient communities. The empowerment of the local community is interpreted in the design of a sustainable mini-grid system that is simple and easy to operate and manage by local people with governance and incentive models that encourage participation and invite the shared responsibility of all local stakeholders.

In order to enable more effective mini-grid programs across the Pacific, it is suggested that:

1. Categorizes islands into sub-groups based on similarities in geographical, economic and demographic conditions, and adopt different mini-grid technical and business models for each subgroup.
2. Develop a web-based database repository to access regional market information and trace, record, and accumulate performance and troubles of mini-grid projects in the PICTs. The database will be a repository to facilitate sharing operational data of mini-grid projects between countries and the SPC, and to build a comprehensive statistical data base of records of key troubles and operational performance of individual mini-grid projects. Such a data base will provide a critical knowledge base for market information and optimal design with best practices guidance for future mini-grid projects in the PICTs.
3. Design and operate an 'Integrated Mini-grid O&M (Operation and Maintenance) Platform in order to reduce the cost of operation and maintenance of individual mini-grid projects while providing timely and professional technical services to mini-grid projects in isolated locations.
4. Apply UNESCAP's "5Ps model" to the business practice of mini-grid projects. The main objective of the '5Ps model' is to help reduce the business and financial risks to private companies in the PICTs so that private companies may focus on their core activities—sustainable operation of mini-grid systems and the provision of a reliable energy supply.
5. Establish a capacity building program to upgrade their knowledge and skills on the advancement in technologies, impacts of changes in policies and legislations. In addition, organize, regular networking events to share experiences and develop strong partnerships to facilitate the development of mini-grid projects.

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1. Introduction

Based on extensive research and stakeholder consultations, this consultancy has produced a comprehensive Pacific Island Countries and Territories (PICTs) renewable energy (hybrid) mini-grid market and industry report. The report is written in a way which can be updated regularly by the Pacific Community's (SPC) Pacific Centre for Renewable Energy and Energy Efficiency (PCREEE) in the upcoming years. The document provides a thorough overview on the market potential, status and trends, existing barriers and opportunities, as well as concrete recommendations on how PCREEE can contribute through regional interventions, tools and methodologies.

The report is based on existing project information, statistics, stakeholder consultations and interviews, as well as updated assessment work of the past. The baseline report includes case studies from all three PICTs sub-regions – Melanesia, Micronesia and Polynesia. The assessment requires a strong partnership between the contractors and domestic partners in the PICTs with excellent knowledge of the mini-grid market. The report is expected to be widely disseminated through the PCREEE and the Pacific Regional Data Repository for Sustainable Energy for All (PRDR) <http://prdrse4all.spc.int/>. The consultant will provide all raw data to UNIDO and PCREEE to be included in the PRDR.

1.1 Objectives

This consultancy is to produce a report with a comprehensive overview on the market potential, status and trends, existing barriers and opportunities, as well as make concrete recommendations on how PCREEE can contribute to sustainable energy developments in the PICTs through regional interventions, tools and methodologies. This report will analyze the status of the current mini-grid market, opportunities and benefits of decentralized renewable energy solutions to PICTs, and barriers which prevent market and industry development at the government, industry, and community levels. It will also make suggestions to overcome barriers and foster successful public and private partnerships in order to facilitate decentralized renewable energy solutions in PICTs.

1.2 Market Research Methodology

The study employed a review of existing and requested literature in the PICTs and used market assessment questionnaires in Fiji and Tonga to identify factors influencing mini-grid market development. A qualitative analysis was carried out for the assessment of the region and each area was then developed further in detail to identify status, barriers, risks and potential. Through these areas of assessment, the study identified issues and determined best practices in order to achieve the expected outcome as deliverables. The assessment questionnaire is attached in the Annex I.

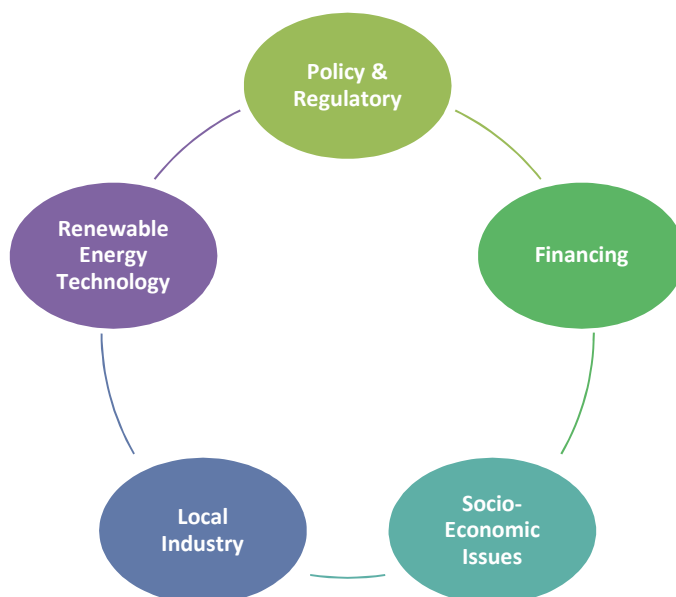


Figure 1: Areas of Market and Industry Assessment

The approach of data collection was made in the following steps;

Step 1: Gather existing statistics and data from international and national institutions

Step 2: Request data from national utilities, the private sector, and academia

Step 3: Interview governments, development partners and private operators

Step 4: Visit sites to production facilities, power plants, solar farms, and private industries

Steps 1 through 4 provide a basis to make further recommendations and move forward with mini-grid development in the PICTs. The basic knowledge acquired will help to identify common issues that arise in the development of the Energy sector in each country or territory and move towards shared solutions utilizing common resources. This market research is a necessary pre-condition towards more efficient energy utilization in the PICTs.

2. The Basics of Mini-Grids

For the purpose of this research, a mini-grid will be defined as a series of electricity generators and energy storage systems connected to an electrical distribution network which provides electricity to customers in a specific geographic area. Mini-grids, also known as “isolated grids” or “micro-grids” are usually small scale (10kW to 10MW) and operate separately from national electrical transmission networks.¹ Mini-grids are a cheaper option in rural or isolated areas where connecting to the national grid is often too expensive. Some systems may be designed so that they connect with existing networks assisting in the maintenance of power quality and stability.

Typically, mini-grids are utilized where national grid extension is too expensive, but demand is high enough that stand-alone systems are comparatively more expensive. This cost is influenced by several variables including, the size of the community, the distance from the existing national grid, and the relative population density and local geography. In the PICTs, the distance between islands and the remote populations make mini-grids in conjunction with stand-alone home solar systems the most economically feasible option for electricity supply.

As the distance increases from a central grid, so do the costs of construction, operation, and maintenance.² As central and national grids expand, existing mini-grids can be incorporated into the existing networks, help to provide stability, and store or transfer excess power to the network. As distribution networks continue to evolve, there has been a trend towards renewable and more sustainable local energy generation systems.³ Solar, wind, biomass and geothermal energy systems have seen increased use due to reductions in manufacturing costs, rising fossil fuel costs, and an increasing awareness of the environmental impacts of traditional energy generation methods.

The primary benefits of mini-grid implementation include economic, social, and environmental components. There is a positive correlation between access to energy and measures of human development. Particularly, the development of small and micro-enterprises can be linked with increased access to energy. In the Pacific, mini-grids represent the most attainable means of power. The necessity of energy access as a requirement for sustainable development can be based on three main arguments:

1. Access to affordable energy is a necessary component in several of the Sustainable Development Goals
2. Access to energy is a national development strategy which provides citizens an equal opportunity to foster new wealth-building.
3. Lack of access to energy resources is directly correlated with poverty.

¹Mini-grid policy toolkit: <http://www.mini-gridpolicytoolkit.euei-pdf.org/policy-toolkit>

² Electrification in Rural Areas: <http://iasir.net/AIJRSTEMpapers/AIJRSTEM13-239.pdf>

³ Energy Self Sufficiency: <https://www.sciencedirect.com/science/article/pii/S0306261915007758>

With this in mind, this market and industry report will define mini-grids as essential to the provision of power in Pacific Island Countries and Territories and a necessity for sustainable development in the region.

2.1 Technical Basics of Mini-grid

Mini-grids are utilized in remote areas and have a capacity below 10 MW. In the Pacific, mini-grids are typically in the 10 kW - 1MW range. Micro-grids are smaller than mini-grids and generally service smaller and more remote areas. Both micro and mini-grids connect a dispersed population to a source of energy and the distribution systems connect people living in close proximity to the energy network. Usually, renewable energies including solar, wind, hydro, and biomass are paired with a diesel generator and energy storage system (ESS) in order to maintain a reliable energy source for the users.

Standard configuration of mini-grid

A mini-grid will be defined as a series of electricity generators and energy storage systems connected to an electrical distribution network which provides electricity to customers in a specific geographic area. An example of technical design of a mini grid in Kiribati is shown in the following diagram.

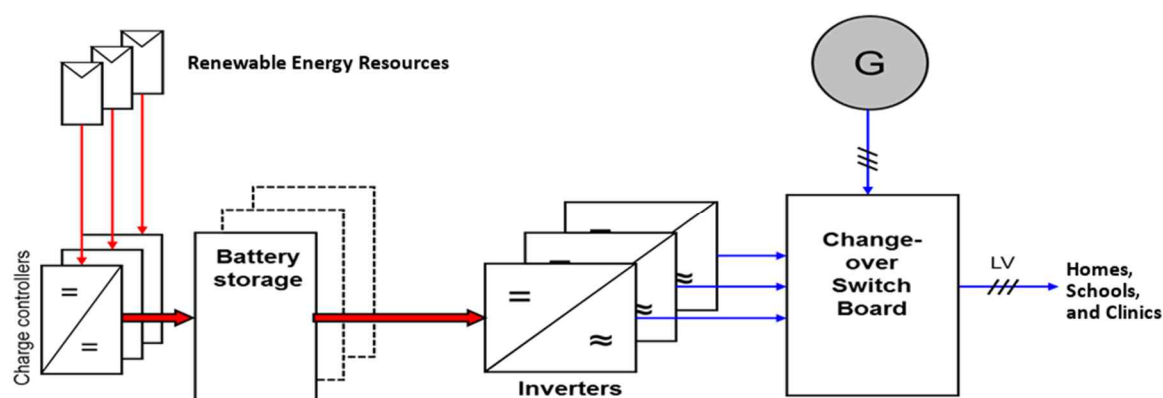


Figure 2 Standard Configuration of Mini-grid⁴

⁴ Tavita Airam Kribati Solar Company

Merits of hybrid mini-grid with renewable, ESS, and diesel

Hybrid mini-grid power systems have several potential advantages when compared with single technology power systems. For instance, the performance of a single renewable energy technology system can be impacted by the variability of the underlying energy resources and lack the consistency provided by hybrid systems. Multiple Renewable energy technologies can add value by diversifying supply across a number of different energy resources in order to expand the inputs to the mini-grid.

Adding energy storage such as battery systems with associated power electronics can greatly improve the reliability of supply. Adding a diesel generator set can further improve system performance because of their high controllability and significant energy storage (in terms of diesel fuel). Thus, when appropriately designed and implemented, hybrid mini-grid power systems should be able to serve a number of load points with adequate power quality and acceptable system reliability when compared with single technology systems.

Hybrid mini-grids have some limitations such as the high capital cost involved and a lack of experience and knowledge of these systems worldwide due to the limited understanding of their use to date. Natural resource availability and increased system complexity in terms of controls, requires professionals to carry out operation and maintenance which may be difficult in remote settings.⁵

Key Components of Mini-grids

Base-load generation represents the minimal power demand on a power grid over a given time. In most cases, diesel generators supply the base load. Diesel generators are most efficient when they are running at a constant speed at the optimal operational capacity.

Renewable Energies are technologies that collect energy from renewable resources which naturally replenish. Due to its intermittency, renewable energy must be designed in an integrated operational plan with other energy sources so that renewable energy can be utilized in a cost-effective manner.

ESS (Energy storage system) The functions of the ESS include load shifting and peak load reduction, as well as grid stability with frequency regulation and voltage support. The two most common batteries are Lead-Acid and Lithium Ion. Lead Acid batteries are the more reliable technology which is cheaper and better understood, while Lithium-Ion batteries feature faster discharge rates and a longer life span.

Power Control System (PCS) The Power Control System regulates the renewable energy generation and storage sources to maintain a stable supply of energy to the grid.

⁵ “Addressing some issues relating to hybrid mini grid failures in Fiji’ by Pranesh Kumar Dutt and Iain MacGill, School of Electrical Engineering & Telecommunications
University of New South Wales, Sydney, Australia.)

Design of Integrated Operation

There are three options for the design of an integrated mini-grid system.

1. **Diesel becoming the main generation component** responsible for CVCF (Constant Voltage and Constant Frequency) with RE supporting diesel with PQ (Power Quality) functions. The advantage of this option is that the governor system in diesel generators, a synchronization tool among different power sources, is able to utilize droop control, allowing synchronous generators to run in parallel. Therefore, the reliability of power system is well maintained. At the same time the speed of response of a diesel generator to a sudden change on the grid is slow and this option, therefore, is not considered to be appropriate when the level of fluctuation at the grid is high: for example, in case of a high penetration of RE sources.
2. **RE becoming the main generation component** responsible for CVCF with diesel the PQ function. When RE becomes the main power source, PCS should be responsible for the integration and synchronized operation among different energy sources. For this purpose, the PCS must be designed robust. The speed of PCS in emergency response is very fast, therefore, this system design allows the high penetration of RE sources into a grid. As mentioned above, PCS is fragile and easily malfunction when the activities of energy flow in the grid exceed the allowance of a designed system. When the PCS is broken, this leads to the failure of the entire grid system. Therefore, in order to achieve the purpose of this system, the design of PCS should be robust. On most of the remote islands, this system may not be appropriate considering weak O&M capability. One solution for this is to design redundant capacity of both ESS and PCS to respond to even less predictable events, but such redundancy causes cost increases for the mini-grid system users.
3. **One RE becoming the main generation component** responsible for CVCF with other Res supporting the main with PQ function. This system design is for a 'carbon free' mini-grid system. In this system, it is necessary for synchronization among PCSs linked to different RE sources. However, still there is no reliable PCS technology that allows droop control among PCSs. (Droop speed control is a speed control mode of a prime mover driving a synchronous generator connected to an electrical grid. This mode allows synchronous generators to run in parallel, so that loads are shared among generators in proportion to their power rating⁶). Due to this, the reliability of carbon free power system remains a challenging issue.

Considering the advantages and disadvantages of the each of the different options, the design of a mini-grid system should be based on a well conducted study on specific energy environment and need of community.

⁶ https://en.wikipedia.org/wiki/Droop_speed_control

2.2 Mini-grid Business Model

Mini-grid systems take several forms and while the business models may be different, the final goal of providing affordable and reliable electricity remains the same. Mini-grid business models can be distinguished into four types:

1. The Utility Model
2. Private Enterprise Model
3. Community Model
4. Public-Private Model

Utility Model

Under this model, a state-owned company is responsible for the installation and operation of the mini-grid. The state-owned companies are usually subsidized by the government and it is the most common model for rural electrification in developing countries. Governments often levy tariffs and strictly regulate the cost per kilowatt hour.

Private Model

Under this model, a private company is responsible for the installation, operation and maintenance of the mini-grid. The grid generates electricity and sells it directly to customers. These private companies are mostly small or medium in size and unlike the utility model, do not operate the main grid. The private companies generate their investment capital from various sources such as grants, commercial loans and private equity to construct and operate the mini-grids.

Community Model

Under this model, the community owns and operates the mini-grid, however the design as well as installation is often done by a third party, contracted by the community or on its behalf by a non-governmental organization (NGO) or development agency. The investment capital generally comes from grants, supplemented by the local community.

Public-private Model

This model combines different aspects of the above models in order to maximize the effectiveness and efficiency of the grid. Hybrid business models are diverse and may involve different entities owning and operating different parts of the system. In general, the funding of mini-grids in many developing countries has been mostly through grants and subsidies from international organizations, in order to ensure that the upfront capital costs and the operational costs can be covered.

Building a sustainable financial structure can be challenging despite the vast and growing understanding of financial barriers in project development and an increase in financing tools. While mini-grids may stand out as being economically more attractive than grid connections especially in the remote islands of the PICTs, they are usually accompanied by high upfront costs. Renewable energy business models are designed in a way that they need to be able to be self-sufficient in order to be sustainable and that is achieved by setting realistic tariffs for the consumers despite potential financing limitations.

2.3 Mini-grids and Sustainable Development Goals

Mini-grids provide electricity which is a powerful driver for the provision of essential services such as education, healthcare, waste disposal and clean water while supporting income generation activities. The consumption of time associated with essential tasks may indicate energy-poverty; yet energy technologies can reduce the amount of time spent by poor households on basic activities. Access to electricity services can help communities meet basic needs and stimulate social, economic and environmental development. Mini-grids have many benefits which can be seen economically, environmentally, and socially. Mini-grids can help the Pacific Island Community accomplish the United Nations Sustainable Development Goal number seven (SDG 7), “to ensure access to affordable, reliable, sustainable, and modern energy for all” which has a set of cascading benefits effecting other sustainable development goals, including the effort to end poverty, hunger, improve health and education, improve economic growth, reduce inequality, and take action in the fight against climate change. In addition to goal number 7, the sustainable development benefits of RE based mini-grids include working towards SDG goals number 9 and 13. SDG 9 relates to renewing industry and infrastructure, while goal 13 concerns climate action; both of which require sustainable energy. Accomplishing these goals also is a step in the right direction for the Paris Agreement by dealing with greenhouse gas emission mitigation, adaption and finance. Mini-grids not only take on the task of international climate change, but they also have local benefits which can be seen in the environmental, social, and environmental realms. The potential benefits of mini-grid systems are depicted in figure 3 below.

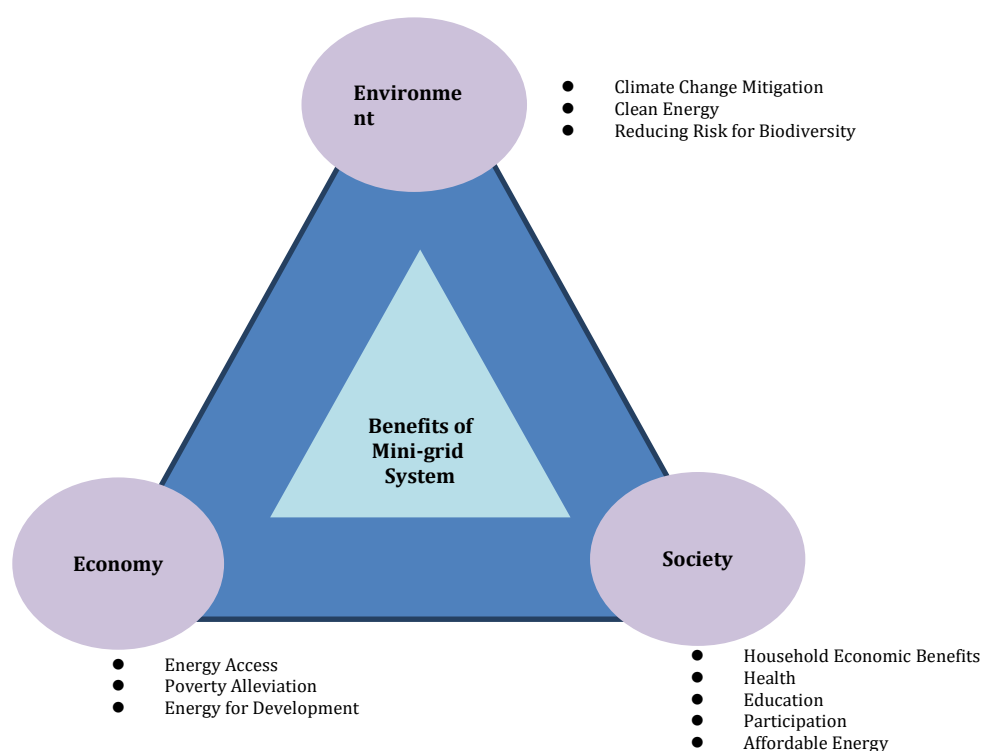


Figure 3 Benefits of Mini-grid Systems in Sustainable Development

Environmental Benefits

All energy sources (fossil fuels as well as renewable energies) have some effect on our environment. Even though renewable energy sources are considered environmentally preferable to conventional sources (and, when replacing fossil fuels, has significant potential to reduce greenhouse gas emissions) it is still important to understand the impacts linked to the production of power from renewable sources. The type and intensity of environmental impacts always vary depending on the specific technology used, the geographic location, and a number of other factors.

Economic Benefits

Energy access in itself is not a panacea to rural poverty issues. A successful intervention has the potential to stimulate development by modernizing existing needs and introducing new services. Individually, energy access has the potential to alleviate poverty through stimulating rural livelihood options. This can occur via the establishment of new energy-based industries, creating employment in manufacturing, construction and maintenance. Energy access can allow households to engage in a more diverse range of income-generating activities as well as make pre-existing activities more efficient. With the necessary infrastructure to ensure sustainability, new livelihoods developed via energy access can have a huge impact on long term poverty reduction.

Social Benefits

Building, operating, and maintaining mini-grids have generated positive social impacts in addition to economic benefits. They encourage integrated government cooperation and the participation of the private sector in all aspects of mini-grid implementation. Rural communities in developing nations stand to benefit greatly from electrification and the opportunities that come with it. Affordable and clean energy is a requirement in developing countries and inclusive implementation has been shown to generate a positive impact. The process of sharing power and resources to achieve a common goal helps to bring communities together to invest in future progress.

Modern energy access has the potential to improve health in rural areas both directly- by powering healthcare facilities- and indirectly, by providing cleaner fuel sources and reducing hard labor activities. The inefficient combustion of solid fuels combined with inadequate ventilation contributes to poor health in many households. These high levels of indoor air pollution often result in decreased pulmonary function, particularly amongst women and children. According to the WHO, approximately 2.6 million premature deaths are attributable annually to household air pollution, making it the second largest environmental health risk factor in the world.⁷

The impacts of energy access also have positive impacts on education. Improved energy resources can reduce the time and labor required to achieve certain tasks such as collecting fire wood and water as well as mechanizing many activities. This could lead to increased enrolment of children in schools, since they no longer have to spend so much time assisting with household duties. In addition, access to lighting in the home increases the time available for study and hence may

⁷ <https://ourworldindata.org/indoor-air-pollution>

positively impact achievement levels. Lighting at the schools themselves can remove restrictions on school times making night classes a viable possibility or allowing schools to double as community centers in the evenings. Electrification can also affect education infrastructure through the integration of modern resources such as computers and internet access.

A decentralized approach to energy interventions led by local needs and contexts is necessary, particularly with smaller communities and rural populations. Starting with the people and not the technology can lead to improved and more widely disseminated energy technologies. Even Principle 10 of the Rio summit on the environment states that "Environmental issues are best handled with the participation of all concerned citizens. Each individual should have information and the opportunity to participate in decision making processes." Employing a participatory approach is necessary in every aspect of ensuring the success of an energy project. In the Pacific, the Talanoa framework serves as a dialogue platform which encourages inclusive, participatory, and transparent communication between the stakeholders of a project and between nations in the Pacific.

3. Mini-grid Market and Industry in the PICTs

While there is an abundant supply of renewable energy resources, markets in the Pacific region often lack the capacity (human and technical) to harness and utilize them. In addition, high dependence on imported fossil fuels and fuel transportation issues are important concerns for energy security. Therefore, studies will be necessary to accurately examine the energy resources and energy markets in these countries. In order to better understand the mini-grid market in the PICTs, it is important to understand the socio-economic factors as well as the energy environment in the Pacific.

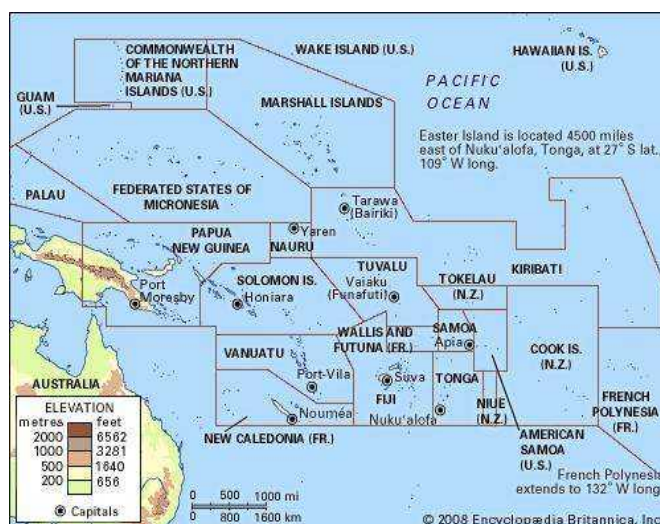


Figure 4 Map of PICTs⁸

⁸ Pacific Islands: <https://www.britannica.com/place/Pacific-Islands>

Socio-economic and Energy Environment

The Pacific Community (SPC) consists of 22 countries and territories (PICTs) with a total of about 10 million inhabitants and a total land area of about 553,409 km². By geographical location, they are divided into three regional divisions namely Melanesia, Micronesia, and Polynesia. Except Papua New Guinea, Vanuatu, Samoa and the Solomon Islands which contain mountain peaks over 1800 meters, the highest point of most of the islands are under 1000m and vulnerability to natural disaster and sea level rise has been a considerable concern for the entire Pacific Community.

PICTs vary in size considerably, with most having a number of small islands included in their land area. Many PICTs are sparsely populated with a large proportion of residents living in rural areas and remote islands which lack modern infrastructure. The islands which comprise the PICTs are often isolated from each other both geographically, politically, and culturally. This large amount of variance between the PICTs makes establishing a common energy system, based on renewable energy systems, difficult and expensive.

Table 1 and 2 depict the economic status of the Pacific Island countries and territories. While dependencies or territories have higher incomes, averaging over USD 18,000, most independent countries have GDP per capita averages of about USD 4,000. The SPC member countries and territories are highly exposed to extreme weather events and climate change impacts which would cause issues in conservation, flooding and sea level rise due to a lack of infrastructure and adequate capacity to respond quickly. Access to reliable, affordable and environmentally sound energy remains a key challenge to PICTs and the current paradigm constrain local capacities for sustainable development and growth.

Table 1 Economy and Population of Pacific Independent Countries

Country	ODA US\$ in millions	ODA Received per Capita	Population (2012)	Land area (km2)	GDP per capita (WB)		GDP growth rate per capita (WB)	
					US\$	Year	%	Year
Cook Island	8.09	536.22	15,087	237	15,002	2014	6.2	2014
Fiji	102.48	114.87	855,545	18,273	4,922	2015	5.56	2015
Kiribati	64.95	577.81	106,886	811	1,424	2015	3.5	2015
Marshall Is.	57	1,076.72	53,679	181	3,386	2015	0.63	2015
Micronesia (F.S.)	81.39	779.35	102,948	701	3,016	2015	3.77	2015
Nauru	31.25	2505	10,292	21	8,053	2015	2.81	2015
Palau	13.93	654.36	17,445	444	13,501	2015	9.36	2015
PNG	589.74	74.46	7,229,077	462,840	2,183	2015	8.53	2014
Samoa	93.72	483.69	187,610	2,785	4,149	2015	1.63	2015
Solomon Is.	190	323.47	587,068	30,407	1,922	2015	3.73	2015
Tonga	68.4	643.1	103,276	650	4,094	2015	3.71	2015
Tuvalu	49.65	4,513.23	10,732	26	2,970	2015	2.64	2015
Vanuatu	186.56	705.06	257,031	12,281	2,806	2015	-0.8	2015
Average	118.24	999.03	-	-	5,187	-	3.94	-

Source: Pacific Power Association. (2012), World Bank Data (2015), OECD (2015), UN data (2014)

Table 2 Economy and Population of Pacific Territories or Dependencies

Dependency or Territory	Population (mid-2012)	Land area (km2)	GDP per capita	
			US\$	Year
American Samoa	56,173	199	7,874	2007
French Polynesia	268,270	3,521	21,071	2006
Guam	169,719	541	23,134	2007
New Caledonia	255,645	18,576	37,993	2008
Niue	1,556	259	11,985	2009
Northern Mariana Islands	55,094	457	16819.9	2015
Wallis & Futuna	12,449	142	12,640	2005
Average			18,741	

Source: Pacific Power Association. (2012). Benchmarking Final Report 2012

Among the Pacific Community, 13 countries, considered small island developing states (SID) according to the United Nations Department of Economic and Social Affairs (UN DESA), have power access that relies on expensive diesel sources to generate electricity. According to the World Bank, Papua New Guinea (PNG) for example, only recorded 20.3% of power access for its nationals, just above 7 million. The Republic of Vanuatu reported a 34.5% of power access available to its citizens. Among those 13 developing states, the four countries including PNG, Vanuatu, Solomon Islands (35.1%) and Kiribati (48.1%), have less than 50% of power access available to the citizens. Although donors such as international organizations and bilateral aid agencies have provided financing for multiple energy generation projects to expand energy access, their remote location and a lack of institutional support has been a major challenge to overcome.

As it is shown in Table 3, a majority of countries have high access to power, but about 80% of the primary energy source is from fossil fuels which are used for transportation 75% and electricity 20% according to the IRENA report in 2012. Due to a high dependency on oil imports, energy security in the PICTs is a main concern for sustainable development, as well as exposed risks for oil transportation and future oil spills could pose a risk to the delicate ecosystems in the PICTs.

Table 3 Pacific Island Countries Power Access and RE Status

PICTs	Power Access (%)	Rate of RE (%)	CO2 emissions (metric tons per capita)	Renewable Electricity Targets by 2020 (%)
Cook Islands	-	-	-	100%
Fiji	100	59	1.3	100%
Kiribati	48.1	2.6	0.6	10%
Marshall Islands	90	<1	0.9	20%
Micronesia (F.S.)	71.7	-	1.4	30%
Nauru	99.2	<1	4	50%

Palau	99.8	<1	12.3	20%
Papua New Guinea	20.3	35	0.8	No Target
Samoa	97.9	41	1	+10% ⁹
Solomon Islands	35.1	<1	0.4	50%
Tonga	95.3	<1	1.1	50%
Tuvalu	98.5	3	1	100%
Vanuatu	34.5	19	0.6	65%

Source: World Bank Data (2014), Power Access and CO2 Emission. World Bank Data (2015), PPA (2011), RE rate, IRENA (2013), Pacific Lighthouses, French Development Agency (2014), Renewable Energy in Pacific Islands.

PCREEE was established as a knowledge hub with a focus on information exchange regarding regional interventions, tools, and methodologies in a partnership with the private sector, international donors, and the Pacific Island Countries and Territories. PICTs have growing attention and a need for RE development and many have set forth ambitious goals, but they still must contend with restrictions in the region for RE to grow due to policies, capacities, finance, market environment, social awareness, and other related barriers. To be able to promote the natural development of RE, a strategic approach in public private partnership (PPP) is needed for the energy market on the islands to reach a sustainable level.

Aligned with the Sustainable Energy Island and Climate Resilience Initiative (SID DOCK) setting up a goal to increase energy efficiency by 25%, and meet 50% of electricity from RE, each island country has established RE goals in order to meet the Sustainable Development Goals, including goal 7, ensure access to affordable, reliable, sustainable, and modern energy for all, goal 9, to build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation, and goal 13, to take urgent action to combat climate change and its impacts.

In order to accomplish the goals, set forth regarding Renewable Energy and Energy Efficiency, it was acknowledged that there was a need for regional organizations to pool together their resources in order to more efficiently work towards a more prosperous energy environment in the Pacific. The major organizations working to this end are:

1. **The Pacific Community (SPC) and its Pacific Center for Renewable Energy and Energy Efficiency (PCREEE)** - The SPC was established in 1947 by the Australian, France, British, and US governments with colonial experience in the Pacific countries. The SPC provides technical assistance, training and research services to the member countries in areas such as health, fisheries, human development and agriculture and many other areas including energy. Especially in recent years, sharing and promoting regional cooperation. PCREEE was established as a regional vehicle for the accelerated adoption and implementation of feasible renewable energy and energy efficiency technologies in the island countries in the Pacific. It is a partnership between the SPC, the Sustainable Energy Island and Climate Resilience Initiative (SID DOCK) and the United Nations Industrial Development Organization (UNIDO) and the government of Austria. .

⁹ 10% increase of RE consumption.

2. **The University of the South Pacific (USP)** – Is a Public research organization with locations in Fiji, Samoa, Vanuatu, the Cook Islands, Kiribati, Marshall Islands, Nauru, Niue, The Solomon Islands, Tokelau, Tonga, and Tuvalu. As a public organization owned by the 12 previously mentioned governments, the USP promotes various programs and research grants regarding the Pacific Community and its members.
3. **Pacific Power Association (PPA)** – Is an inter-governmental agency that promotes technical training, the exchange of information, and dissemination of technical expertise in order to benefit member countries in energy sector.

3.1 Country Level Market Analysis

Case studies through site visits, market surveys, and focused research has allowed for a better analysis of the mini-grid market on a local level. Project reviews have established a baseline of existing projects and determine where there are potential future needs. Community and Stakeholder interviews are necessary to determine which areas need to be addressed when it comes to developing mini-grid projects in the PICTs. Financing methods and sources of funds for previous projects will guide future developments which can be improved upon. Technological capacity and capability of the PICTs must be determined to establish where areas of need are and help fill the gaps. Finally, key commercial and operational deficiencies must be examined to help generate private sector development and public-private partnerships. The following four Countries were selected as case studies to identify typical issues and possible solutions to RE development in the PICTs:

1. Vanuatu (Melanesia)
2. The Solomon Islands (Melanesia)
3. Tonga (Polynesia)
4. Kiribati (Micronesia)

3.1.1 Melanesia – Vanuatu, Solomon Islands

- **Vanuatu**

Geography

Vanuatu is a Y-shaped archipelago consisting of about 83 relatively small, geologically younger islands of volcanic origin (65 of them inhabited), with about 1,300 kilometers (810 mi) between the most northern and southern islands.

Energy Mix

It is estimated that about 75 percent of Vanuatu's citizens have no or low access to electricity. Vanuatu imports all petroleum products and the demand is expected to increase. Based on

expected demand increases, imports are expected to double (to 100 million liters) by 2022.¹⁰ Because of the high demand for imports and the importance of petroleum products to the economy, Vanuatu has a very high level of exposure to shocks and price volatility. In addition to reliance on imported fuels, the average cost for diesel is higher than other PCREEE countries. Therefore, cost-competitive renewable energy has a role to play in both meeting future demand and decreasing the consumption of traditional fossil fuels.

In terms of renewable energy, Vanuatu has increased generation in recent years. Coconut oil is a locally available renewable energy source and 21.8% of total production. Wind turbines add another 12.8% to the mix with hydropower at 8.7% and solar at 0.3% for a total of 43.6% renewable energy sources at peak production. The primary reasons for the increased contribution of renewables has been the increased cost of imported fuels and the decreasing cost of RE technologies.

Policy & Regulation

The National Energy Roadmap was established for the years 2013-2020. In October 2011 the Government of Vanuatu launched the development of the Vanuatu Energy Roadmap 2013-2020. The roadmap was passed by the Vanuatu government in June 2013. It has the overall vision to “energize Vanuatu’s growth and development through the provision of secure, affordable, widely accessible, high quality, clean energy services for an Educated, Healthy, and Wealthy nation”. The roadmap focuses on the following five key energy priorities:

1. Achieving access to secure, reliable and affordable electricity for all Citizens by 2030 through connection to electricity of 75% of household within concession areas by 2015, 90% by 2020 and 100% by 2030; for households close to concession areas the corresponding figures are 33%, 90% and 100%, respectively, while for off-grid areas the target is 100% of households having access to modern electricity via individual homes systems and basic power products by 2020.
2. Achieving energy security for Vanuatu at all times through diversifying energy sources and providing the enabling framework for investments in energy. The target to diversify energy sources includes increasing the share of renewable technology in the power generation mix by 65% by 2020.
3. Mitigating climate change through enhanced deployment of renewable energy technologies and energy efficiency.
4. Ensuring that energy services in Vanuatu are affordable and low-cost.
5. Reducing reliance on imported fossil fuels and ensuring that needed petroleum supply is reliable, secure and affordable throughout Vanuatu.

¹⁰ Vanuatu National Energy Road Map 2013

Stakeholders

Vanuatu is undergoing a process of rural electrification which is ongoing.¹¹ There are several key players in the electricity market including:

Union Electrique du Vanuatu Limited (UNELCO)	A privately-owned utility that has been providing electricity to Port Vila and Luganville for several decades and has recently extended its services to parts of East Malekula and Tanna.
Vanuatu Utility Infrastructure (VUI)	A US-based company and in January 2011, through competitive bidding the company won the concession for power generation and supply for Luganville, on the island of Espiritu Santo - VUI's installed capacity in 2011 was 4.1 MW and generation was approximately 8,570 MWh. Demand was 7,600 MWh and forecast to grow at 2–3% annually. There are currently over 2,500 customers with around 300 additional customers each year.
Utilities Regulation Authority (URA)	Established in 2008 as a semi-autonomous body to mediate between the Government and electricity and water utilities. The URA also acts as a regulator for pricing, energy access, standards and monitoring of concession agreements
Pacific Energy	This company imports petroleum products from New Caledonia and sometimes Fiji.
The Government of Vanuatu	Retains the legal right to control fuel prices however it has allowed the market to determine pricing since 1989. The Government has considered tendering for the supply of petroleum fuel products – using an approach similar to Samoa's – and in 2012 the World Bank began a detailed study of the opportunities, costs and benefits of such a scheme.
Vanuatu Renewable Energy and Power Association (VANREPA)	A non-governmental organization has been active since 2003 in bringing wind power to rural areas, managing renewable energy projects for donors and selling solar lighting kits and energy efficient stoves through Green Power, a retail spinoff. Through Green Power, VANREPA has teamed up with the Vanuatu Women's Development Scheme (VANWODS) to provide micro-finance for pico-solar kits. VANREPA also provides renewable energy generating systems to communities under its Community Powerhouse model. Solar-generated electricity is stored in batteries at the charging station from where it is made available through a mini-grid to schools, health centers, community centers and commercial enterprises that pay a monthly fee for their electricity.
Community Powerhouse	This company is a supplier of solar kits and solar electrification of community facilities.

¹¹ Vanuatu Rural Electrification Project: <http://prdrse4all.spc.int/data/resettlement-policy-framework-vanuatu-rural-electrification-project-stage-2vrep-ii>

- **The Solomon Islands**

Geography

The Solomon Islands are comprised of six major islands and over 900 smaller islands covering a land area of more than 28,000 square km. It lies east of Papua New Guinea and has extremely humid weather throughout the year. The islands are widely dispersed over a large area and the Santa Cruz Islands are especially remote from main islands. The capital, Honiara, is located on the island of Guadalcanal.

Energy Mix

The Solomon Islands is almost completely dependent on imported petroleum for its commercial energy needs although biomass still accounts for about 40% of gross national energy production, with other renewable representing about 1% with the rest coming from petroleum sources. The relative share of fossil fuels in the country's energy consumption has increased from 47.5% to 52.7% mainly at the expense of biomass, the share of which fell from 47.4% to 43.1% and electricity which fell from 5.1% to 4.2%. Virtually all of the Solomon Islands' electricity is generated from imported diesel.

The forecast for 2020 predicts a continuing trend of increased oil consumption (up to 56.3%) and decreasing biomass consumption (down to 39.5%) while the share of electricity remains unchanged. There are two small hydropower plants in provincial centers totaling 182 kW of capacity but all the rest of SIEA generation is diesel. Guadalcanal accounts for over 80% of total generation in the Solomon Islands and is therefore the primary target for RE development. Although hydro-projects were initiated in the past on the Lungga and Komarindi rivers, the current focus is on hydro development on the Tina River where it is hoped to provide around 60 GWh each year for the Honiara grid, which would cut diesel use by about half.

Under ADB funding, feasibility studies commenced in January 2013 for the development of small-scale hydro power schemes for provincial out-stations under the "Outer Islands Renewable Energy Development Project in Solomon Islands". Japan recently funded 38 million USD in improvements to the Honiara power system including a new genset and upgraded distribution facilities which were commissioned in 2008. In 2007, AusAID began a rural electrification project focusing on provincial power supplies. AusAID also provided funding for the rehabilitation of the Lungga and Honiara power stations and the installation of a 4.2 MW Wartsila engine that had been purchased by SIEA in 2002.

With support from the World Bank, AusAID and other agencies, the Solomon Islands Sustainable Energy Project (SISEP) began operations in 2009. SISEP aims to improve the operational efficiency, system reliability and financial sustainability of SIEA through improved financial and operational management, reduction of losses, and increased revenue collection. Technical project implementation support to SIEA will also be provided, along with consultancy services, a technical training program for engineering staff, and the establishment of a technical partnership with the Fiji Electricity Authority.

Components of SISEP include:

1. Strengthen SIEA management, including engaging two professional utility line managers (a general manager with a technical background and a commercialization manager) and an overseas director, and provide training for key management staff.
2. Strengthen financial operations, including the implementation of a commercialization program including new financial management and billing systems and preparation and implementation of a new finance accounting manual with a staff training program.
3. Improve technical operations, by implementing a loss reduction program, a planned maintenance program for generation facilities in Honiara, and a distribution reinforcement program to increase the availability of existing generation and improve system reliability.

Policy & Regulation

The Solomon Islands are powered through a cooperative of utilities which are regulated by the government.¹² Thanks to considerable donor assistance, numerous draft energy policies have been developed since the 1980s. A National Energy Policy Framework was endorsed by the government in 2007. The National Energy Plan aims to promote education on imported fossil fuel dependence, increased use of renewable energy resources and energy efficiency for the sustainable development of the country. Although developing renewable energy and rural electrification policies is a priority for the Energy Division, no such policies are currently in place. In 2010, in its support of clean energy development for sustainable rural development, the Cabinet of the Solomon Islands approved the exemption of imported solar power equipment from import duty tax and goods tax.

There are also several important pieces of legislation related to electricity in the Solomon Islands:

1. The Electricity Act of 1969 created SIEA and gave it exclusive rights for power generation in Honiara and provincial centers. Exclusions were later added which allowed private generation of less than 50 kW capacities for certain purposes without the need for an SIEA license. This allowed rural villages to generate their own electricity without government approval.
2. The River Waters Act of 1981 impacts on hydro development and is intended to prevent upstream water uses to adversely impact on downstream populations.
3. The Provincial Government Act of 1981 allows provincial governments to provide electrical services within their jurisdiction.
4. The Environmental Act of 1998 includes environmental impact assessment requirements that could affect some future energy sector investments.
5. The Land Tenure Legislation attempts to sort out some of the many issues surrounding the use of land in the Solomon Islands. About 87% of land rights are based on Customary Land

¹² Solomon Islands Electricity Authority Annual Report 2016: <http://prdrse4all.spc.int/data/solomon-islands-electricity-authority-annual-report-2016>

terms, the traditional approach to land transfer and use, and the rest is Alienated Land, which was procured and given freehold title during the colonial era. Regulation of electricity systems does not go beyond basic licensing of private generation by SIEA and a number of different agencies have some impact on how SIEA and other electricity suppliers operate.

Stakeholders

There are several important stakeholders in the Solomon Islands energy market:

The Ministry of Mines, Energy and Rural Electrification	The Energy Division within the Ministry of Mines, Energy and Rural Electrification is responsible for energy policy, renewable energy development and project implementation. The Energy Division's roles are extensive but staffing levels and budgetary allocations are reportedly inadequate to carry out these functions, though there has been improvement since 2008.
The Solomon Islands Electricity Authority	The Authority is government owned and responsible for the provision of electricity to Honiara, as well as eight provincial centers: Auki, Kirakira, Lata, Tulagi, Buala, Gizo, Malu'u and Noro in Western Province. SIEA has around 220 employees but has a long history of under-investment, insufficient resources and limited staff capacity. ¹³
Markwarth Oil Ltd. and South Pacific Oil Ltd.	They are two national oil companies which supply the Solomon Islands with petroleum products. Both companies have storage depots in central Honiara. Petroleum and gas prices are regulated by a Price Control Unit within the Ministry of Commerce, Industries, Labour and Immigration.
The Department of Commerce	The Department of Commerce regulates electricity tariffs and petroleum prices through its Price Control unit.

3.1.2 Polynesia-Tonga

Geography

Tonga comprises five main island groups—Tongatapu, 'Eua, Ha'apai, Vava'u, and Niua— with a total of 176 islands. On 11 January 2014, the most powerful storm ever recorded in Tongan waters passed directly over the northeast islands of Ha'apai, directly affecting about 5,000 people, or 66% of the local population. The cyclone is estimated to have caused USD 53 million in damage and losses, with the majority of damage levied against housing, business, agriculture, power

¹³ Irena Pacific Lighthouses: Renewable Energy opportunities and challenges in the Pacific Region: Solomon Islands

Infrastructure, and education facilities.¹⁴ The state-owned electricity utility—Tonga Power Ltd.—estimates that 90% of Ha’apai’s distribution lines, 40%–70% of electricity poles, 65% of transformers, 90% of transformer structures, and 95% of streetlights were damaged. Ha’apai was left almost completely without power. In response facilities were rebuilt, including the main electricity network and damaged school facilities. The Cyclone Ian Recovery Project restored access to electricity and increased the power system’s resilience to future weather events. In 12 February of 2018, a category 4 cyclone swept through Tonga and caused significant damage to the Tongatapu and ‘Eua islands. While the upgraded grids suffered damages amounting to 4.7%, compared with the damage of 45.9% to the grids that had not been upgraded.¹⁵ The upgraded grids are under the Outer Islands Renewable Energy Project (OIREP)³ in ‘Eua, and the Tonga Village Network upgrade Project (TVNUP)⁴ in Tongatapu. The experience from the cyclone was a good lesson how a resilient grid is important to secure the energy stability from extreme weather events.

Energy Mix

In terms of energy sources, well over half of Tonga’s national energy needs are met by imported petroleum. Photovoltaics (PV) currently account for less than 4% (May 2013) of the total energy used however, rapid expansion is currently underway. In 2012, imports of gasoline totaled about 12.7 megalitres (ML) while diesel fuel amounted to about 27 ML, with around half of the imported distillate being used for electricity generation. Although 89% of Tonga’s households enjoy access to grid electricity, 90% of power generation relies on imported diesel. Renewable energy and improvements to energy efficiency provide opportunities to lower cost, enhance energy security, and decrease emissions.

All electricity on the islands of Tongatapu, ‘Eua, Lifuka (Ha’apai) and Neiafu (Vava’u) is generated and distributed by the government-owned national utility, Tonga Power Limited. Small grid systems for the larger Ha’apai islands (‘Uiha, 168 customers; Ha’ano, 106; Ha’afeva, 69; and Nomuka) were constructed in cooperation with the Australian Agency for International Development. The systems are powered by diesel generators and operated by an electricity cooperative on each island. Hours of operation vary by island but typically are less than 12 hours a day. The cost per kilowatt-hour (kWh) of operation has been higher than predicted, largely due to the actual load being substantially lower than estimated for the design, causing the engines to operate with poor fuel efficiency.

An Asian Development Bank (ADB) project has been proposed to address the difficulty with these small grid systems and determine the feasibility of integrating solar generation with them in order to reduce the use of fossil fuels. Private electricity generation, particularly on church and commercial properties in the outer islands is typically provided by diesel generators with some PV systems supplementing them.

¹⁴ Tonga 2016 census: <http://prdrse4all.spc.int/node/4/content/tonga-2016-census-population-and-housing-volume-1-basic-tables-and-administrative>

¹⁵ ADB. (2018). Summary Assessment of Damage and Needs: Energy Sector.

Solar home systems provide power for almost all of the homes on the smaller outer islands with the most recent installations each providing 160 watts-peak (Wp) of solar PV capacity. The systems provide 24-hour power (using batteries) for lighting and small communications and entertainment appliances. Consumer service standards are regulated and cover the rights and responsibilities of both TPL and its customers. These include the rights and responsibilities to provide proper customer service, good quality power and for disconnection for non-payment of fees.

With the exception of three small island cooperative operated grids, all grid-supplied electricity in Tonga is generated and distributed by TPL. Around 15,000 customers are being served on the four larger islands with over 90% of them on Tongatapu. By Pacific standards, TPL is a mid-sized utility. During the past few years there has been little change in generation with sales remaining in the 40 to 44 gigawatt-hours range, a result of economic stagnation and the rising cost of electricity.

Policy & Regulation

The Government of Tonga has set a target of reducing fossil fuel imports for power generation by 50% by 2020 and defines a strategy for achieving this goal in the Tonga Energy Roadmap 2010–2020. Renewable energy and energy efficiency improvements are key elements of this strategy¹⁶ There are several important stakeholders in the Tonga energy environment:

As far as policy is concerned, the chief legislation(s) are:

1. National Renewable Energy Policy was established in 2006 with the aim of assisting renewable energy development in the Kingdom. This was followed by the Government adopting the Tonga Energy Roadmap in 2009 for 50% of electricity generation to be from renewable resources by 2012.
2. The Tonga Energy Road Map is a ten-year work plan for 2010-2020 intended to reduce oil imports and Tonga's vulnerability to oil price shocks; increase access to modern energy services in an environmentally sustainable manner; and meet international requirements for reducing carbon emissions. The Tonga Energy Road Map Agency was created under the authority of Cabinet as a Government Agency. The Department of Energy under the Ministry of Energy, Information, Disaster Management, Environment, and the Climate Change is the central single Agency responsible for Energy, among others. The key principles are:
 - a) Least cost approach to meet the objective of reducing Tonga's vulnerability to oil price increases and shocks;
 - b) Managing risk with respect to the sequencing and timing of new investments and to the extent feasible development of a portfolio of options to meet the demand for electricity;
 - c) Long-term financial sustainability in the electricity sector;

¹⁶ Tonga power limited annual report 2015: <http://prdrse4all.spc.int/node/4/content/tonga-power-limited-annual-reports-2009-2010-2011-and-2015>

- d) Social and environmental sustainability; and
- e) Clear, appropriate and effective definition of roles for government, TPL and the private sector.

Other key legislation and regulations relating to energy in Tonga include:

1. Renewable Energy Act (2008)
2. Electricity Act (2007)
3. Price and Wages Control Act (1988)
4. Environment Impact Assessment Act (2003)
5. Cooperative Societies Act (Cap118)
6. Petroleum Act (Cap134)
7. Forestry Act (Cap126)
8. Lands Act (Cap132)
9. Foreign Investment Act (2002)

Stakeholders

The following contains a list of major stakeholders in Tonga:

Ministry of Meteorology, Energy, Information, Disaster Management, Environment, Climate Change and Communications (MEIDECC)/ Energy Planning Unit (EPU)

The EPU (now the Department of Energy) was instrumental in developing rural electrification through solar energy. It is currently monitoring the JICA-funded Vava'u solar home systems project, overseeing solar on the Tonga outer islands and also working in the area of energy efficiency in parallel with programs being carried out under the Tonga Energy Road Map Implementation Unit (TERM-IU).

Tonga Power Ltd (TPL)

A government owned corporate entity that operates under a concession agreement monitored by the Tonga Electricity Commission, the electricity regulator. The rural areas in Tongatapu have TPL-operated diesel grids, while the outer islands have either solar power or community managed diesel mini-grids. TPL acts as a commercially operated business, with a board consisting of local and foreign members appointed by the government.

The Electricity Commission

The Electricity Commission was introduced under the Electricity Act of 2007 to reflect the best international practices for public utility regulation and, since privatization of the utility remains a long-term government goal, to facilitate a possible future sale of the government's interest in TPL. The Electricity Commission is legally required to regulate tariffs, consumer service standards and electrical safety. The regulatory framework employed is of the concession-contract type. Tariffs, tariff adjustment formulas, operational efficiency benchmarks, consumer service standards and penalties for non-achievement are all specified in a contract between the Electricity Commission, representing the government, and the electricity provider.

Kingdom Energy

A business supplier and maintenance provider for Solar Home System in Tonga.

3.1.3 Micronesia-Kiribati**Geography**

Kiribati consists of 32 atolls and one solitary island, Banaba, for a total of 33 land masses.

According to the Pacific Regional Environment Programme (previously South Pacific Regional Environment Programme), two small uninhabited Kiribati islets, Tebua Tarawa and Abanuea, disappeared underwater in 1999. The United Nations Intergovernmental Panel on Climate Change predicts that sea levels will rise by about 50 cm (20 in) by 2100 due to global warming and a further rise would be inevitable. It is thus likely that within a century the nation's arable land will become subject to increased soil salinity and will be largely submerged.¹⁷

Energy Mix

In terms of energy supply and demand, since the rural islands depend on solar and biomass for energy, the growth of petroleum imports is almost entirely due to the increased population and growth in services on Tarawa and Kiritimati Islands. Petroleum is supplied from Fiji by ExxonMobil and BP while the Kiribati Oil Company imports petroleum fuels to its depot in Tarawa and Kiritimati Island with an annual import volume of around 23 million liters.

Electricity from the grid serves about 44% of the total households, with another 17% supplied by solar PV and 3% by electricity from Island Council and church mini-grids. In general, around 64% of Kiribati households have access to some form of electrical power. The grid power system on Tarawa

¹⁷ Pacific Islands Regional Organization: <http://dfat.gov.au/international-relations/regional-architecture/pacific-islands/pages/pacific-islands-regional-organisation.aspx>

was upgraded under the Japan International Cooperation Agency (JICA) funding in 2005–2006. About 5.45 Megawatts of generation is now installed with 4.2 MW in Bikenibeu and 1.25 MW in Betio. The Public Utilities Board maintains by far the largest grid with 4 108 residential meters, 556 commercial meters and 277 government meters in 2012. There are also 151 street lights on Tarawa.

On Tabiteuea North, all of the 49 staff residences, associated with the new southern island hospital, are connected to the hospital mini-grid. In Kiritimati, village grids in total had 525 residential meters, 53 commercial meters and 102 business meters excluding the mini-grids serving the two church secondary school campuses and the motel at the far end of Tabwakea village. The National Space Development Agency of Japan's (NASDA) down range satellite tracking station and its business sectors (motels and shops) in Main Camp have their own power systems. On the outer islands, mini-grids are also present in public and church boarding schools, church communities and island council headquarters. Although details are not available, these are known to serve only a small fraction of all households.

Electricity in rural areas comes from solar home except for Island Council offices and some housing immediately around the Island Council compounds where a small generator is usually operated for a few hours each day. These generators serve a total of about 3% of Kiribati Island residences. In the outer islands, petroleum use is mainly restricted to kerosene that is used for lighting or cooking, and petrol is used to operate a few motorcycles, outboard powerboats and a truck and/or tractor owned by the Island Council for island transport use. Traditional sailing canoes are used extensively for subsistence fishing, which help to keep petrol use low on outer islands. Traditional biomass energy sources continue to contribute around 25% of the overall energy used in Kiribati and biomass very much dominates energy use on the outer islands, although this has been somewhat offset by “modern” fuels such as kerosene and LPG. However, biomass use on the outer islands has changed little over the years compared with its usage on Tarawa, which has fallen significantly as kerosene and LPG have become more widely used in the cash economy.

Copra production usually produces more biomass waste than is used, so there does not seem to be any biomass supply problem caused by scarcity or deforestation, although the premium firewood species, such as mangrove, have become scarce in some areas. Although it is very difficult to get precise information about household biomass usage, estimates suggest it is about 4 000 tonnes of oil equivalent per year, roughly comparable to the amount of fuel used for electricity production.

Tarawa electricity demand in 2011 was about 6.6 Gigawatt-hours for government customers, 7 GWh for domestic customers and 3 GWh for commercial sectors. It may be noted that there is a slight decrease in the level of electricity consumption from the domestic and government and industry consumers which may be related to the increasing tariff as well as some efforts at improving the efficiency of energy use in government. Electricity generation on Tarawa in 2011 was approximately 17.3 GWh requiring usage of around 5.8 megalitres (ML) of diesel fuel. Electricity production for Kiritimati is a small fraction of that of Tarawa.

By 2011, at least 2,100 outer island households had installed solar energy for lighting, operating radios and other small appliances. The government-owned KSEC essentially operates and maintains all of them. Typical installations include a 100 Wp panel and 100 Ah battery with three compact

fluorescent (CF) light bulbs and a multi-voltage adapter for a radio connection. High reliability charge controllers are manufactured locally by KSEC for these systems with a few exported for use in SHS.

Policy & Regulation

Energy policies in Kiribati include:

1. The Public Utilities Ordinance which provides the legislative basis for the formation of the Public Utilities Board.
2. The Prices Ordinance includes price controls for petrol and kerosene. Diesel is not under price control.
3. The Petroleum Act regulates safety, storage, rationing, and customs inspections.
4. The Environment Act provides for the protection, improvement and conservation of the Kiribati environment. It is supplemented by Environmental Regulations of 2001.

Although the Kiribati Government has had an unwritten policy of allowing only renewable energy for outer island electrification since the 1980s, an overall energy policy was formally established in 2009. The Energy Policy was established in association with the Kiribati Development Plan 2008–2011 and has since been expanded through the revised energy policy (KIER 2017-2025.) The plan supports the following primary goals: human resource development in the energy sector; development of livelihoods; energy security; and energy access. Its guiding principles are sustainability, gender equity, environmental compatibility, stakeholder participation, good governance, and cultural/traditional compatibility.

Renewable energy policies include:

1. promoting sustainable renewable energy access
2. Ensuring that the limited biomass resources are used in an economic, environmental, and culturally sustainable manner
3. Strengthening collaboration with development partners for the advancement of renewable energy programs
4. Promoting and encouraging the use of appropriate renewable energy technologies
5. Expediting the replication of successful solar programs.

Kiribati has introduced a number of appropriate incentive packages to encourage the use of renewable energy technologies including reduced taxes, duties and tariffs. The energy policy also requires the local utilities to establish a regulatory framework for the energy sector, coordinate the implementation of climate change mitigation activities by using renewable energy resources, and ensure the coordination of energy requirements for any major infrastructure development.

The Kiribati Adaptation Program (KAP) is a USD5.5 million initiative that was originally enacted by the national government of Kiribati with the support of the Global Environment Facility (GEF), the World Bank, the United Nations Development Program, and the Japanese government. Australia later joined the coalition, donating USD 1.5 million to the effort. The program aims to take place over six years, supporting measures that reduce Kiribati's vulnerability to the effects of climate change and sea level rise by raising awareness of climate change, assessing and protecting available

water resources, and managing inundation. At the start of the Adaptation Program, representatives from each of the inhabited atolls identified key climatic changes that had taken place over the past 20–40 years and proposed coping mechanisms to deal with these changes fewer than four categories of urgency of need. The program is now focusing on the country's most vulnerable sectors in the most highly populated areas. Initiatives include improving water supply management in and around Tarawa; coastal management protection measures such as mangrove re-plantation and protection of public infrastructure; strengthening laws to reduce coastal erosion; and population settlement planning to reduce personal risks.¹⁸

Stakeholders

There are several important stakeholders involved in the provision of electricity including:

The Ministry of Public Works and Utilities	Responsible for the planning, management and coordination of the energy sector
The Energy Planning Unit	Coordinates the implementation of energy policies, providing advice and assistance on all energy-related matters and activities
The Public Utilities Board	Responsible for provision of power, water supply and sewage services for South Tarawa
The Kiribati Solar Energy Company	A government-owned corporation is responsible for the provision of electrical services for rural areas through the operation and maintenance of solar photovoltaic (PV) systems. It currently manages 224 kilowatts peak (kWp) of solar PV for outer island residences, 47.6 kWp of solar systems for community buildings, 7.5 kWp for street lights and 6.4 kWp for communications. In the past it has also been contracted to maintain solar water pumps for the Public Works Department, solar PV for health center buildings, school solar systems for the Ministry of Education and solar PV for schools of various church groups. ¹⁹
The Kiribati Oil Company	Involved in the distribution of petroleum products throughout Kiribati
The Ministry of Line and Phoenix Islands Development	Responsible for all government services on Kiritimati Island as well as the Line and Phoenix Islands.

¹⁸ Climate Change in Kiribati:

https://web.archive.org/web/20120202020502/http://www.climate.gov.ki/Kiribati_climate_change_strategies.html

¹⁹ Irena Pacific Lighthouses: Renewable Energy opportunities and challenges in the Pacific Region: Kiribati

3.2 Case Studies of Existing Mini-grid Projects

A total of eight cases of mini-grid projects/programs are reviewed in order to determine what methods are best and how challenges can be avoided in the future. All the cases presented similar issues including financing, maintenance, and transportation challenges to the local community. Table 4 includes detailed outlines of cases.

- **Case 1** is part of the European Union's development Funding (EDF 10) which supported electrification of 6 outer island schools in Kiribati. Prior to these installations, the schools were using only DC power. IRENA has identified a number of issues with the RE projects in Kiribati including²⁰:

 - Total dependence on donor agencies resulting in long lead times and implementation complexities.
 - Lack of trained personnel
 - Difficult environment for renewable energy equipment
 - Transportation challenges for equipment and replacement parts
- **Case 2** is part of the European Union's development Funding (EDF 10) which supported electrification of 6 outer island schools in Kiribati. The system is designed to provide entire electricity requirement for the village with the diesel generator acting as backup.
- **Case 3** is part of the UAE –Pacific partnership LaKaRo (Lakeba, Kadavu and Rotuma) mini grid projects comprising a total of 555 kW PV. The three projects commissioned in 2015, are expected to save 722 tons of CO₂ each year and save 259,000 liters of diesel fuel worth USD 497,000 annually. Prior to this installation, the system was operating fully on diesel.
- **Case 4** is a hybrid system which was first of its type and was installed in 1997 by Fiji Department of Energy (FDoE) with assistance from Pacific International Centre for High Technology Research (PICHTR). According to the FDoE the intention of the project was to demonstrate the technical and financial viability of Hybrid Power Systems in Fiji to supply 24-hour electricity to a rural and remote community. The system was designed to provide power to the whole Nabouwalu Government Station and Nabouwalu Village. The Government Station includes a Government Hospital, Post Office, Provincial Council building, Agriculture and Fisheries Department, Public Works Department depot and its staff quarters, Police Station and its staff quarters and three shops and other Government Departments, altogether totalling about 100 customers.²¹ Unfortunately, this hybrid system did not last for its expected life and for the last several years has been running only on diesel generators. FDoE analysis has shown that the failure was due to lack of maintenance leading to neglect. The department responsible for the Operations and

²⁰ IRENA. (2013). Renewable energy opportunities and challenges in the Pacific Islands region, Kiribati.

²¹ <http://www.fdoe.gov.fj/index.php/power-sector/nabouwalu-village-hybrid-power-system>

Maintenance (O&M) did not meet all the maintenance requirements. There have been attempts to rehabilitate the system, but these attempts are ongoing.

- **Case 5** is solar/diesel hybrid system funded by the Korean government and implemented through the Korean Institute of Energy, Technology, Evaluation and Planning. This was the first co-financed project between the Korean and Fiji governments. The project is expected to provide 24-hour reliable electricity to the recipient community.
- **Case 6** is supported by the UAE Partnership Fund to build solar-diesel hybrid mini-grid in Neiafu, on the island of 'Utu Vava'u, the largest island in the Vava'u archipelago. 500 kW solar array PV is added to the diesel generators using the SMA Fuel Save technology. The system achieves fuel savings of approximately 170,000 litres of fuel per year and avoids the emission of 500 tonnes of CO₂-equivalent greenhouse gas emissions. The 500-kW array provides up to 70% of the energy demand at mid-summer noon.²² This system together with other solar projects has helped reduce Tonga's electricity tariffs by 1-1.5 %. The system is monitored remotely.
- **Case 7** is an ADB funded project to help install 4 solar mini grids in Atiu, Mangaia, Mauke and Mitiaro, of the Cook Islands. The mini-grids will supply each island with about 95% of their electricity needs, with an installed capacity of 1.3 MWh of solar and 7.3 MWh of battery storage.²³ These systems will reduce Cook Islands' diesel consumption by 350,000 litres annually and hence reduce carbon emissions by 960 tons of CO₂/year. The project is expected to provide reliable power to the islanders and the contractor, Infratech, has involved recipient communities in installation activities also building human capacity.²⁴
- **Case 8** is funded by ADB grant loan (concessionary lending) to install 1.25 MW_p of grid connected solar PV on Tonga outer islands.²⁵ The main objective of this project is to demonstrate a method for reducing Tonga's heavy reliance on imported fossil fuels for power generation.²⁶ Phase 1 on grid generation installations on Ha'apai and Eu'a has been commissioned and is currently under operation. The funding model for this project is different from most other projects. This work is funded through a concessional loan offered by ADB to the government of Tonga. This project is funded under ADB's strategic agendas: environmentally sustainable growth and Inclusive economic growth. It will also assist in Gender Equity and Mainstreaming Partnerships.

²² Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. (2016). Off-Grid Solar Installations in the Pacific Region, A Workshop Report.

²³ <https://www.infratec.co.nz/projects/cook-island-pv-mini-grids-southern-group>

²⁴ A detailed analysis for case 7 is in the annex II.

²⁵ Case 7 is not a standalone mini-grid project and detailed list is in the annex II.

²⁶ <https://www.adb.org/projects/43452-022/main#project-pds>

Table 4 Cases of Mini-Grid Project in PICTs

Classification	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8
Project Type	Solar PV mini grid	Solar PV mini grid with Diesel back up	Solar PV/ Diesel hybrid mini grid	Solar PV/ Wind / Diesel hybrid mini grid	Solar PV/ Diesel hybrid mini grid	Solar PV/ Diesel hybrid mini grid	Solar mini-grid	Solar PV/ Diesel hybrid mini grid OIREP ²⁷
Location	Kauma (Abemama), Kiribati	Kiritimati island, Kiribati	Kadavu island, Fiji	Nabouvalu , Fiji	Kadavu island, Fiji	Vava'u island, Tonga	Cook Islands	Islands of 'Eua, H'aapai and Vava'u , Tonga
Business Year	2014	2014	2015	1997	2017	2013	2016	2017 (Project agreement signed)
Scope and Major Composition	42.525 kW _p sola PV (180 x 235 W _p) + 3488.3AH C ₁₀ Battery + 18 kW inverter (3 phase) with Diesel backup.	16.215 kW _p solar PV + 2150AH C ₁₀ battery + 12 kW inverter	249 kW _p solar PV + 2 x 23 kW Hatz twinpacks low load diesel generators	37.4 kW _p solar PV + 8 x 6.7 kW Bergey wind + 50 kW battery + 2 x 100 kVA diesel generators	30 kW _p solar PV + 32 kVA diesel generators -	420 kW _p Solar PV+ 930 kW Diesel + 100 kW Battery	Solar Photovoltaic plants under Cook Islands Renewable Energy Sector Project(COO46 453-002) Phase 1	9 islands, Solar PV 1.25MWp in total and ESS
Funding	A component of EU 10 th European Development Funding (EDF)- Total 4.1 Million Euros	A component of EU 10 th European Development Funding (EDF)- Total 4.1 million Euros	UAE Pacific Partnership Fund (Total 5 million USD for 3 projects in Fiji)	MOFA, Japan (F\$ 800,000) + FDoE , Fiji F\$ 230,000	Korea Government (1.5 M USD) + Fiji Government (500, 000 FJD)	UAE partnership Fund	NZD 30M(USD 20M), ADB Loan	ADB concessional lending
Target location	Kauma High School, Approximately 400 students and staff	Poland Village, Population 441 people (2010 census). The village also has a primary school.	Vunisea government station, hospital, school and two neighbouring villages	Nabouwalu Government station, hospital, other government departments and Nabouwalu village totalling 100 customers.	Namara Village, 68 households	Vava'u island, 850 homes	Atiu, Mangaia, Mauke and Mitiaro	'Uiha Island, Eua, Ha'afeva, Ha'ano, Ha'apai, Niuafo'ou, Niuaotupapu Island, Nomuka Island, Vava'u
Operation	School Technicians are responsible for regular maintenance with backup service offered by KSEC providing an after-sale service, KSEC also keeps stock of spares.	KSEC provides maintenance service and also keeps stock of spares. Villagers pay a maintenance fee.	The Public Works Department operates and maintains the power station., The consumers pay the national electricity tariff.	The Public Works Department was responsible for maintenance and operation.	Managed by Fiji Department of Energy under its Rural Electrification Programme. Electricity is fully subsidized.	Tonga Power Limited	Managed by the local public works	Tonga Power Limited
Performance and Impacts	The system has been operating well since installation and has been able to provide electric power to lights, computer lab, office equipment and a kitchen with freezers/refrigerators	The system is operating well since installation and has been able to provide electric power villagers do their daily requirements.	The system has faced some challenges in the form of controlling the variable solar supply. More importantly, the recent cyclone Keni devastated a large part of transmission and distribution system.	This is an example of failed project. Two years after commissioning the system fell into neglect and disrepair. With no maintenance, the project was soon defunct and now the electricity supply is solely using diesel generators.	Some technical challenges have been encountered and are currently being resolved.	The system is working fine since installation with no major problems reported. The PV can satisfy 70% of the electricity demand during a sunny mid-day.	The Hybrid mini-grid is working as expected	Contractor was selected through a tender, 2017

²⁷ OIREP, Outer Island Renewable Energy Project, Kingdom of Tonga

3.3 Major Findings of Past Practices

An analysis of past practices and selected case studies has yielded the various status, barriers, risks and potential that currently affect the mini-grid market in the PICTs. These factors are discussed below in terms of policy and regulation, financing, socio-economic, local industry, and renewable energy technology.

Policy & Regulation

Although most of the government in the PICTs announced RE penetration goals by 2020, the actual progress of renewable energy promotion falls far behind the announced goals. As seen in Table 5, the Electrification ratio is high in most PICTs with the notable exceptions of Papua New Guinea (20.3%) Vanuatu (34.5%) The Solomon Islands (35.1%) and Kiribati (48.1%).

In terms of renewable energy contribution percent and the stated 2020 goals, all countries have established goals for 2020 with the exception of Papua New Guinea. However, it remains unlikely that any of the listed countries will reach their stated goals with the possible exception of Fiji.

Setting targets for generation is an important step in prioritizing clean and renewable energy as a priority for local governments and setting a high standard proves just how important this priority is for the PICTs and conveys a commitment to future of the energy market in the PICTs.

National governments must make tough decisions when prioritizing strategies to formulate consistent and enforceable sustainable energy policies and few governments require minimal energy performance requirements for private properties because of the burden these places on land owners. Policies and Regulations which may help to reach the stated RE targets but place a heavy burden on citizens remain unpopular and governments must endeavor to find a balance between beneficial regulations and policies and a healthy business environment.

Table 5 Goals of RE and actual RE penetration of PICTs²⁸

Country	Electrification Ratio (%)	RE Contribution (%)	2020 RE Goal (%)
Cook Islands	-	-	100%
Fiji	100	59	100%
Kiribati	48.1	2.6	10%
Marshall Islands	90	<1	20%
Micronesia (F.S.)	71.7	-	30%
Nauru	99.2	<1	50%
Palau	99.8	<1	20%
Papua New Guinea	20.3	35	No Target
Samoa	97.9	41	10%
Solomon Islands	35.1	<1	50%
Tonga	95.3	<1	50%
Tuvalu	98.5	3	100%
Vanuatu	34.5	19	65%

²⁸ Data from different sources. World Bank Data (2014), Power Access and CO2 Emission. World Bank Data (2015), PPA (2011), RE rate, IRENA (2013), Pacific Lighthouses, French Development Agency (2014), Renewable Energy in Pacific Islands

Financing

In terms of financing, there are two main financial reasons for the delay in transition to renewable energy technology in the PICTs:

1. Limited financial resources from the public sector and citizens often prevent the actual implementation of the announced RE goals.
2. The absence of private investment to fund RE and mini-grid projects, especially in remote areas within the PICTs is a critical to implementing the targets.

These issues are often tied to the isolated geography and limited market for RE development in the PICTs however, international organizations have been incredibly generous in providing concessional loans and grants which provide the capital necessary for the construction of mini-grid projects throughout the PICTs. When reviewing past case studies, the issue that often arises is the financing of ongoing operations and maintenance costs. Financing the ongoing costs of mini-grids is possible through the creation of public private partnerships or independent government agencies to oversee operations. A successful example can be seen in the establishment of Tonga Power Limited which has successfully adapted market driven mechanisms in order to set tariff rates and provide electricity at a fair price while maintaining operational budgets. A well designed and coordinated transition from the current donor funded RE and mini-grid financial model must include the increased participation of private companies and market-based fee collection and operational cost practices.

Socio-Economic

The socio-economic benefits of electricity best provided by localized mini-grid systems has been proven. Access to affordable, reliable and sustainable electricity has created the opportunity for a higher quality of life for citizens in the PICTs. The provision of electricity to small and remote islands in the PICTs has allowed for the use of freezers to keep food fresh which reduces the number of trips to larger islands to deliver goods and return with necessary provisions. Lighting in homes has allowed for increased education opportunities and helped to maximize the time available for study. Electricity has also allowed for increased communication by radio, phone, and internet so that public safety can be better maintained, and medical emergencies are addressed more quickly. Finally, by addressing issues in education, and making tasks such as gathering water and preparing food easier, the gender gap has been reduced in remote areas allowing more opportunities for women in the PICTs.

A successful mini-grid project must take into account the needs of the local community and actively engage them so that the system is designed in a way that best meets their needs. In the PICTs, mini-grid systems must provide the opportunity to participate in the operation of the mini-grid itself and allow citizens to develop their own enterprises through the provision of a reliable electricity supply.

Local Industry

Among private enterprises, several factors may prevent PICTs from promoting a market which encourages the development of the RE industry. This includes a lack of policy support from relevant

governments in the form of grants and loans, a monopolistic or unprofitable energy generation sector and a lack of local workers with the required technical skills. Many enterprises are apprehensive in making new infrastructure investments due to the effects of market instability and extreme weather events on the highly volatile tourism sector, which is very important to the economies of many of the PICTs. Additionally, RE technology tends to have a high upfront cost and this often prevents entrepreneurs from entering the market and starting a business. In addition, a lack of incentives and market system to encourage participation of private companies in particular local ventures and community development has hindered their entrance into the market. Finally, the small and isolated markets of PICTs do not allow for economies of scale which can help to provide more affordable energy at a lower cost.

Typically, projects have been heavily reliant on external sources of funds, technology, products, and human capital. The high dependency of mini-grid projects and practices on external sources of funds and an external supply of products and technology has created “mismatch problems.” This mismatch occurs between the standardized, mass production of key mini-grid components—solar PV module, wind turbines, energy storage systems, and power control systems—and the need to customize components to fit into local weather and geographical conditions, remote and challenging logistics conditions, and operational and maintenance requirements. In addition to the mismatch problem, there is also a discrepancy between the process of ODA funding, which is led by international donor organizations, and the foregone potential synergy from local communities in the possible participation, and shared ownership and responsibility. Some of the local industry and human capital issues include:

1. Decisions in design and implementation are made and driven by outside professionals who may not have a full understanding and knowledge of socio-economic needs of the local community
2. Less opportunity than what could be possible for local enterprises and community to be actively participating in design and construction
3. Products and technology design and functionality that may not match local socio-economic needs and geographical conditions
4. Inadequate training for operation and maintenance to local engineers or managers

Renewable Energy Technology

In order for renewable energy technology to be utilized to maximum effectiveness in the PICTs, several lessons have been learned from past projects; future endeavors should take into account the following:

1. Ensure that existing infrastructure is suitable for the new installation.
2. Remotely monitor the systems, using external expertise if this is not available in-house.
3. Work out full maintenance, repair and replacement cost structures at the planning stage, and know what method of funding the replacement of batteries and other equipment will be used at the end of their life.
4. When trying new equipment, be second or third, not first off the block. Learn from other installations around the world, not only Pacific Island installations.

5. The high humidity and salt in the air can create malfunctioning in the critical components like inverters. There are reports of solar inverters failing within a short time despite having a warranty for 10 years. Replacement is time consuming and expensive.²⁹
6. It is also important that all the technical and operation manuals are in English so that they can be followed by the PICT technicians. There are cases where the manufacturer/installers instructions are in a different language creating difficulties for the people on the ground.
7. Some of the mini grid systems have failed where the system was designed for a lower demand, but availability of electricity makes the recipients buy and connect more loads (freezers/refrigerators for example) making the whole system fail.
8. Harmonization and establishment of component standards for mini-grids is crucial.

Generally, many of the potential technical issues can be solved through increased coordination with local authorities and adapting the foreign technology to local conditions keeping in mind that operations and maintenance will typically be addressed by the local community. If the planners of future installations take heed of the lessons learned from past projects and take into account the potential issues in the policy and regulation, financing, socio-economic, local industry, and renewable energy technology arenas, then the program will have a much higher probability of long term success.

²⁹ EU-GIZ ACSE: Off-Grid Solar Installations in the Pacific Region: A Workshop Report

4. A Comprehensive Design of the Mini-Grid Program in the PICTs

In the Pacific Island Countries and Territories, the provision of electrification to rural islands and remote communities throughout the region has been a policy objective for several decades. However, the progress has been rather slow for various reasons. In some cases, the policies are not so clear, ineffective and are not well coordinated and implemented. The cost of rural electrification tends to be high and many governments subsidize the cost of energy. Clear policies, better institutional arrangements, consistent and transparent subsidy arrangements and reconsideration of tariff policies would contribute towards improving the rate of rural electrification substantially in some PICTs. Increased access to energy services at affordable prices can only be effectively achieved through tailored approaches and mechanisms. Therefore, a comprehensive approach that takes into account socio-economic conditions, and an integrated technical and business model is necessary to establish a successful mini-grid program in the PICTs.

Design Approach of the Mini-grid Program

The issues surrounding a mini-grid program in the PICTs are multi-dimensional—technological, socio-economic, geographical and demographical—and the solutions to the issues also need knowledge and collaboration with different fields as previously reviewed in the major findings. Creating a prosperous energy environment is a multi-sectoral problem that needs an integrated solution.

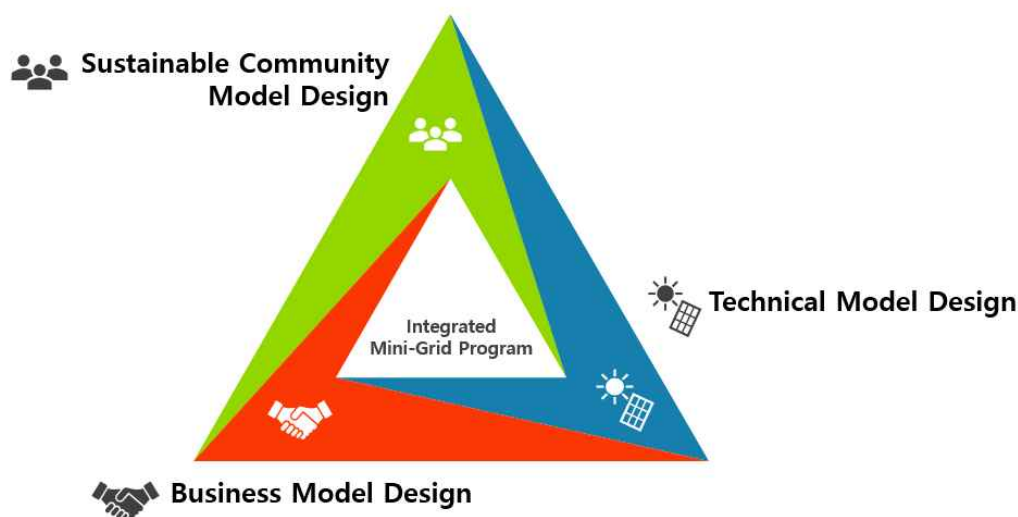


Figure 5 Design Approach of the Mini-grid Program

The first step is to design a model for mini-grids, according to the principles of Design for Good, and identify the specific socio-economic needs of the local community for an energy system and understand the geo-physical constraints and resources to deliver, construct, and operate an energy system.

The PICTs contain a diverse array of communities varying in size and population, demographics, characteristics, energy consumption behavior, features of existing power systems, and physical access. Different sets of needs and conditions require different design solutions.

After an assessment of a community's socio-economic needs for a mini-grid, the next step is to design technical and business models that match the identified needs and conditions of a community. The principles of social impact and empowerment must apply to the design of technical and business models.

In the design of the PICT's mini-grid program, the social impacts on technical and business model design could be interpreted as addressing the practical needs of the community for a reliable, accessible and affordable supply of electricity. The empowerment of people is interpreted in design as an aspect of a sustainable mini-grid systems that are simple and easy to operate and manage by people in community, and governance and incentive models that enable agency and invite active participation and the shared responsibility of the community.

4.1 A Sustainable Community Mini-grid Model in PICTs

The mini-grid program in the PICTs will be addressed as a social problem in this chapter and the concept of 'Design for Social Good' will be applied. The concept of 'Design for Good' has been borrowed from Emily Pilloton, who founded Project H Design³⁰ in 2008 and has been promoting the concept and practices of design for social impact instead of design for commercialism.

The "Design for Good" focuses, unlike commercial designs, on the needs of the community, on social impact, and on the empowerment of people. The needs of the community mean not only the underlying interest of human beings for consuming more, but the desire to do better and to improve community's living conditions. Social impact means being mindful of the consequences of a design rather than the artificial aspects of it; empowerment sees the users not as consumers but as co-designers and partners.

The key players of a sustainable socio-economic environment include:

Self-governing, Interrelated Economies that

- Contributes and collaborates to mitigate carbon emissions and climate change impacts
- Enables improved livelihoods and productivity of the communities

Resilient and Self-reliant Energy System that

- Utilizes locally available renewable energy resources with designs that withstand extreme weather events and natural disasters
- Makes electricity supplies stable and affordable to the local community
- Empowers the local community to be responsible for the management and operation of their energy systems

³⁰ <http://www.projecthdesign.org>

Green Entrepreneurs that

- Fosters and drives sustainable growth of the region and community
- Creates jobs and business opportunities for local people and local investors
- Empowers users and community to participate in establishing distributed energy systems and industry infrastructure

Under the guiding principles of social design-- identify needs of community, consider social impacts as the highest priority, and empower people—the following design principles are suggested to apply to the implementation of technical and business models for a mini-grid program in the PICTs.

People need reliable, clean and affordable energy

1. The first thing to do in order to design a working model for mini-grids is to identify specific socio-economic needs of local community for an energy system, and geo-physical resources and constraints to deliver, construct, and operate an energy system.
2. PICTs are diverse communities varying in size of population, demographics, characteristics of community, energy consumption behavior, features of existing power systems, and physical access. A different set of needs and conditions require different technical and business model solutions.
3. Based on socio-economic needs and geo-physical constraints, to classify islands of PICTs into three groups for each of which a different set of technical and business models are recommended these classifications include: i) main islands, ii) outer islands with potential for a commercial scale grid, iii) outer islands which are very remote and hard to access with little potential for a commercial scale grid.

To design mini-grid systems which fulfill the identified needs and conditions, and meet the basic design principles they must be:

▸ Accessible

1. Design mini-grid technical models that are easy to deliver and assemble, easy to install, and simple and easy to operate.
2. To achieve “Simplicity,” complex parts or functionality of an energy system should be integrated into a simple package, and/or should be handled by a separate entity in an integrated way.
3. Achieving “simplicity” may result in higher system costs due to customization requirements. Therefore, it is necessary to find solutions that achieve “simplicity” without additional cost or even in a less expensive way.

▸ Affordable

1. Utilize locally available renewable energy resources.
2. Utilize locally available materials and human resources. A “win-win collaboration model” with foreign companies based on comparative advantage: Core technologies and training

from foreign companies with localization and customization, and construction and operation by local enterprises.

3. Proper funding and adaptable tariff schedules to make a mini-grid project financially affordable and sustainable.

► Socio-economic Sustainability

1. Empower community and/or a local enterprise to be an active agent and owner of the system; Governance models that empower community ownership.
2. Design and implement proper technical training programs for local engineers and community to have operation and maintenance capability.
3. To design business models that enable and foster the participation of the local community and private enterprises.

Categorization of PICTs

Different conditions of Islands in different categories are expected to determine different ways to institute energy infrastructure change. Accordingly, islands in different groups need different sets of technical and business models for mini-grid program design. The following table provides a tentative grouping and characteristics of each island group and proposes different technical and business model for each group.

Table 6 Categorization of PICT islands

	Main Islands (Group A)	Outer Islands (Group B)	Remote Islands (Group C)
Existing power system and environment	Centralized grid operated by a public utility corporation Size of average load larger than 10MW in most main Islands Still majority of power generation based on diesel	Small grid operated by a public utility or a private company Size of average load varies in the range of several hundred kW to several MW Mostly diesel-based generation	No reliable power system, or small independent power system on diesel base Size of average load in most cases less than one hundred kW
Constraints and conditions for commercial scale mini-grid projects	Dominant and monopolistic position of existing utility	High demand of mini-grid with RE and ESS Economies of scale needed to make a bankable commercial project	Challenging logistics conditions for delivery and construction Poor local capacity for construction and O&M
Feasible technical model	Grid tied RE systems utilizing local RE sources ESS for voltage support and frequency regulation as RE increases	Hybrid of mini-grid systems with RE, ESS and diesel to reduce the dependency of diesel	SHS (Small Solar Home System), or Hybrid mini-grid system

Feasible Business model	IPP with private funding	Community or private business model with a blended funding that includes concessional loan from public sector	Public program
Technical System Design	Diesel as the main power source responsible for CVCF with RE supporting PQ function	RE as the main power source responsible for CVCF with diesel supporting PQ function	Small solar home system, or mini-grid with RE as the main source but with: no CVCF or PQ functions. Black out or supply interruption allowed
Key problems and solutions	Grid stability as RE penetration increases	High level of engineering requirements for mini-grid design Effective O&M platform Incentives to attract private participation Innovative business model to achieve economies of scale of a project, and Blended financing model for risk sharing between public and private companies	
Recommended tasks	Determined capabilities of local communities Data base of mini-grid projects, including record of troubles, for knowledge accumulation and knowledge sharing Integrated O&M platform Effective Public and Private Partnership (PPP) model to encourage private participation (to modify and apply UNESCAPE's "5Ps Model") Blended financing and incentive tools for risk sharing between public and private companies Win-win collaboration between foreign technology companies and local enterprises for customization and localization of key equipment, and local capacity building		

4.2 Design of Technical Model

As discussed in previous parts of this study, there are key problems that constrain mini-grid promotion in PICTs. Solutions to those problems must be invented, therefore, if an effective mini-grid program should be designed and implemented. In order to analyze problems and find proper solutions, reliable data and knowledge is necessary. Without reliable knowledge and data, any attempt to find and provide solutions will be short-sighted and ineffective.

Currently, there are growing numbers of mini-grid projects in operation and under-implementation, and there are as many numbers of technical problems observed or reported. However, those activities and observed problems are not presented in an organized way, and do not provide reliable

data base and knowledge in studying and analyzing mini-grid technical problems in depth. There are issues that must be addressed in the design, operation and maintenance phases.

Problems in Design Phase

The design phase is critical in implementing successful projects, in the PICTs; mini-grids must take into account the following issues:

1. Application of the most relevant data or statistics to be referred concerning technical troubles and system performance. Without such data and knowledge, the designing of a robust and reliable mini-grid system is not possible.
2. Need of an optimal design of integrated operation of a mini-grid system based on the specific energy environment of target community. Design without such consideration will lead to frequent technical troubles and system failures.
3. Need of design of package of imported equipment for challenging logistics - Systems are installed in remote areas where communication/travel is difficult and expensive. Therefore, key equipment must be packaged so that it is easy to transport and install.
4. The high humidity and salt in the air can create malfunctioning in the critical components like inverters. There are reports of solar inverters failing within a short time despite having a warranty for 10 years. Replacement is time consuming and expensive. Therefore, a design and customization of key equipment to match local climate and operational conditions.
5. There are currently No standard technical protocols of mini-grid systems.
6. Inadequate design of key equipment for delivery, construction, and operation - One of commonly occurring technical issues concerning mini-grid systems in PICTs is that inadequacy of imported products or packages of key mini-grid components. For example, the quick deterioration or depreciation of ESS in the hot and humid weather, and frequent failure of PCS including inverters are among those complaints. The causes of such problems may be rooted to several underlying problems—products with bad quality, products designed for different weather or geo-physical environment, and products with complex design for a local engineer to understand and operate (local staff must be involved right from the beginning).

Problems in Operational and Maintenance Phase

1. Need of effective and cost-efficient O&M practice to deal with the challenging geographical condition and requirement of skilled experts in PICTs.
2. Operational Manual - Often it is difficult to communicate the proper method of mini-grid operation, therefore the manual should be easy to read, understand, and practice. Such an operational manual should be written in a commonly communicated language at the local community, and the content, description, and interface of the operation manual should be simple and easy for local O&M staff to understand and practice.
3. Adequate management of key components and spare parts - There are varying qualify of key components of a mini-grid. Frequent and unpredictable troubles of key components and challenging condition of timely repair and replacement require proper management of key components and spare parts. Often the cost and benefit of keeping inventory of necessary

spare parts for emergency becomes a trade-off. Even a small technical trouble may lead to system disruption due to delayed repair or replacement. At the same time, the limited availability of fund for O&M allows no redundancy in component and spare parts management.

4. Updated System Specifications – Operational manuals should be regularly updated to keep up with changing conditions.

Practical ideas or guidelines include:

1. To build a database of technical troubles of key components from different suppliers. Such data base will be useful in tracing root causes of frequently occurring technical problems.
2. To design and implement an integrated O&M platform which connects multiple mini-grid systems to a TOC (Total Operation Center) through available wireless communication.
3. To set up an independent board of experts for monitoring and supervising product quality and technical standards.
4. To organize a collaborative R&D task force of foreign manufacturers and local enterprises to study and test customization and localization of key components of mini-grid system. Establishment of a regional testing and certification laboratory will be helpful in this aspect.
5. To provide incentives to attract long-term commitment of key manufacturers to the mini-grid market in PICTs.

Therefore, the first task for design of mini-grid program in PICTs should be the construction of mini-grid data-base which collects, records, and categorize all of mini-grid project activities, performance and troubles in PICTs. The data base will become a key asset that provides practical and detailed guidelines and ideas for mini-grid program to PICTs. PCREEE in conjunction with Pacific Data Repository can work in this direction.

4.2.1 Database of Mini-grid Projects in PICTs

It is crucial to record the performance of a system and troubles of key components of a mini-grid project in a specific community. Tracing the history of performance and frequently occurring troubles of all mini-grid projects and building an accumulated collection data and the history of troubles and performance issues will allow for the optimal design and sustainable operation of a mini-grid system in the future. An example that could be expanded upon is that of PacTVET which has compiled a significant amount of data which can be regularly updated by the PICTs. An accessible web-based database of mini-grid systems in the PICTs should be designed to include the following items for recording:

- System configuration
- Community environment and change of it in which a system is built and operated
- Status of system operation and performance
- Record of breakdowns by components and makers

Building a database will require challenging workload and participations of experts from different fields and stakeholders from different institutions. It is recommended that a further discussion and plan for mini-grid project database be initiated as a following project after this report. To address the possible issues mentioned above, this consultancy is recommending an “Integrated Mini-grid O&M Platform” which attempts to streamline the issues that may occur in the day to day operation of a mini-grid.

4.2.2 Integrated Mini-grid O&M Platform

Mini-grid systems in small islands should have a different O&M approach than normal renewable energy systems. Most mini-grid systems in outer islands or remote communities are being monitored by local staff. Some of those systems have remote monitoring connected wirelessly to O&M staff. However, most mini-grid systems are operated independently by local staff.

This type of O&M creates problems. Under-skilled or under-qualified local staff, and no timely communication and direction from a qualified O&M manager at a distant location fail timely response to system troubles. As the number of mini-grid systems increases in the PICTs, there will be growing need for an integrated O&M platform which is linked wirelessly to each of the mini-grid systems in distant locations and provide timely and adequate direction or advices to local O&M staff at remote locations. By doing so, the quality of O&M services can be assured and costs for O&M can be saved. Therefore, the basic idea for an integrated O&M platform is that mini-grid systems scattered on different islands should be controlled through a central operations hub. To prepare for smooth operation and further expansions, a technical standard should be established. A detailed explanation can be found in the Annex.

The Integrated Mini-grid O&M Platform should be comprised of the following components:

1. Standard O&M Manual
2. Platform Structure Design
3. Energy Management System
4. Component Management
5. Communication Infrastructure

Standard O&M Manual

A Standard O&M Manual is safety procedure and equipment protocol that will help ensure the safety of system operation and maintenance. It is more important than typical power plant, since the TOC (Top Operation Centre) controls the entire site.

Platform Structure Design

Since mini-grid sites are often isolated and difficult to reach, a TOC (Total Operation Center) should be established to control the sites. The TOC is located on a main island where full-time experts are available 24 hours a day. Full-time experts educate local engineers (site managers, or local O&M staff) to maintain equipment at the dispersed mini-grid sites. On these sites, local engineers are

responsible for daily operation, routine system check-up, and emergency response to technical troubles. Roles & Responsibilities between the operation center and the sites should be designated by the O&M manual.

Energy Management System

EMS is hardware and related software to be located at sites for monitoring, collecting data, and some features of auto-operation. With an EMS, it becomes possible for a mini-grid to communicate real time with TOC on system operation and technical troubles. Moreover, if abnormal events happen, the EMS determines which specific parts are malfunctioning and sends data to the TOC server.

Component Management

The TOC oversees component management. The main challenge for component management is that immediate orders should be minimized through accurate demand forecasts. Also, centralized component management will help save the cost of keeping an inventory of spare parts for emergency replacement at each individual site. There should be a proper design of inventory allocation of spare parts and components-between the TOC and sites.

Requirements of Communication Infrastructure

Wireless telecommunication infrastructure in PICTs varies country to country and region to region.³¹ In designing an integrated O&M platform, wireless communication infrastructure should be carefully investigated. The existing wireless communication infrastructure in the Pacific offers only limited capacity for an integrated O&M relationship between a TOC and dispersed remote project sites. However, considering the speed of evolution in wireless communication technologies and expanding coverage of services, such a limit is expected to be resolved in the near future.

4.3 Design of Mini-grid Business Model

The purpose of business model design is to attract participation of private enterprises and to encourage shared risk and ownership, and responsibility of mini-grid projects. Sustainability of mini-grid projects is expected to be enhanced through shared ownership and responsibility with private enterprises including community-based organizations.

4.3.1 5Ps Business Model

5Ps (Pro-poor Public and Private Partnership) model was designed and initiated by UNESCAP in order to incentivize and encourage private participation in rural electrification in Asia. To accelerate electrification project in poor areas, a 5Ps model was created with focus on “Pro-Poor” to the Public

³¹ UNESCAP (2018) Broad Band Connectivity in pacific islands, Asia pacific Information Superhighway Working Paper Series

and Private Partnership (PPP) model. It was first applied to construction and operation of a small hydro power facility in the village of Cinta Mekar in Indonesia in 2004. In order to provide valuable energy access to rural and remote island communities, public and private partnerships which vitalize the local industry can play a significant role in PICTs. Figure 6 describes how the 5P model works. The mini-grid project is jointly owned by private sector and community for sustainable operation.



Figure 6 Pro-Poor Public Private Partnership (5Ps Model)³²

Public

The major roles of public sector are setting the standards of quality of projects, promoting projects and monitoring the performance of projects. Also, the public funds capital investment for equipment and construction in form of grants, loans, or shared equity investments, when there is no viable financial market for funding mini-grid projects. The concept of 5Ps includes the establishment of SPV (Special Purpose Vehicle). As a result, this system provides an opportunity for local private enterprises and communities-based organizations to experience and learn as the active player of a rural electrification project.

Private

The core of the 5Ps model is the private sector players (companies and individuals) participating in rural electrification for profit purpose. These private companies are the entities of investment, ownership and operation of rural electrification projects. They are responsible for the operation of projects and share the benefits and risks from operation.

³² UNESCAP (2018) Brochure: 5P Project.

Cooperation between Public-Private sectors

Unlike large infrastructure projects where PPP model is applied, off-grid electrification projects are characterized by extremely poor business environment with challenging logistics, and high risk and low stability of cash flow generation. In this condition, the important role of public sector is sharing the business risks with private companies while supporting and monitoring the process of business operation. The public and private risk allocation in PPP (Public and Private Partnership) model is shown below.

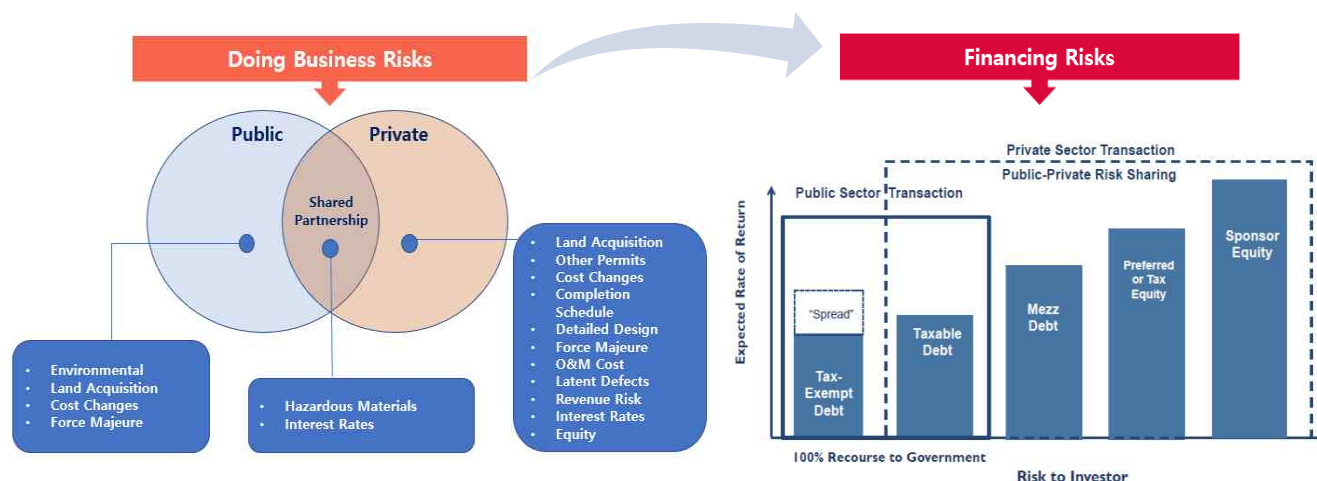


Figure 7 Business Risk Allocation Example

The above PPP model is based on the market environment of advanced countries with stable business environment and developed financial markets.³³ In this environment, the roles and risks sharing of the public sector include mitigating the risk from political environment, for example regulation and business permits, securing business sites, and sharing risks from budget overrun from a design modification. On the other hand, in general, the exclusive business risks associated with implementation of a project, including financing, and profit realizations are taken by the private companies. Another role of the public sector in financing and business implementation may include tax breaks and exemptions, and low interest loans in some cases. However, considering underdeveloped financial market, and poor business environment and industry infrastructure surrounding mini-grid projects in remote islands in developing countries like PICTs, it is unrealistic for private businesses to take the entire business risks such as implementation of project, financing and realizing profits as shown in the above PPP model. Therefore, the public sector needs to share those risks with private businesses.

³³ *How to Structure a 3P Deal*, National Counsel for Public and Private Partnership, 2015

4.3.2 Application of the 5Ps Model to Mini-grid Program in PICTs

One of the key challenges of mini-grids in the PICTs is related to economies of scale. The dispersed and remote locations of small islands make it very difficult to develop a mini-grid project on a commercially feasible scale. Such fragmented market structure also makes project development and management very costly. In addition, the uncertainty of charging and collecting tariffs from users, poses risk to any private company that may want to enter this market.

The private sector, too, is not well organized for doing mini-grid business in the PICTs. Lacking the adequate human resources and engineering knowledge necessary for designing, building and operating mini-grid projects becomes a major barrier to a local company. In many countries, local enterprise is at a disadvantage in the industry value chain: They are not given opportunities to play an active role in the process of design and development of mini-grid projects driven by donor funding. Most of the key technologies and products are from external sources. Local enterprises can hardly accumulate core knowledge and create value added in doing business. However, a local mini-grid business—small in size and understanding of local conditions--may be best suited to meet the O&M needs of the grid.

Considering the existing market and industry barriers and constraints, in order for successful transition to the 5Ps model in PICTs for private participation, the following preconditions are required.

1. Designing and institutionalizing a clear political process necessary for the implementation of the 5Ps model
2. Proper allocation of roles and responsibility, and risk sharing between public and private sectors
3. Establishing investment fund dedicated to mini-grid financing with private partners
4. Fostering human resources for capacity building necessary for stable system O&M and business operation
5. Establishing case studies, knowledge, and statistics of mini-grid operations

Design of bridge model for transition to 5Ps-based model

Based on the above-mentioned hurdles and required preconditions, it may not be realistic to achieve full-phased 5Ps model mini-grid program in PICTs. As the 1st phase, therefore, it could be reasonable to set a bridge step for transition to 5Ps model and building necessary preconditions for transitioning to full-phased 5Ps model implementation.

The preconditions for transferring from public (general Official Development Assistant model) sector to 5P model accompanying investment in private sector are i) competency of local communities and enterprises, ii) risk sharing and joint investment of public and private sector, iii) restructuring of related policies, iv) availability of funds for execution of loan and equity financings, and v) securing purchasing power of users (residents).

The mini-grid program in PICTs has significance in i) cultivating the operational capacity of local community and private companies through implementation of proper training and reinforcement program, ii) establishing a cooperative system between private and public sectors and iii) contributing to growing purchasing power and economic ability of residents through virtuous cycle of stable supply of electricity and income generation activities. In this regard, it seems significant and valid for mini-grid program to set, as the 1st phase, a 'bridge model' between ODA model and 5P model in the mid to long term way to full-fledged 5Ps model which, in the end, aims to advance to 'market driven' mini-grid program. The detailed bridge model design is shown in the table 7 below.

Table 7: Design of Mini-grid Business Model in PICTs as Preliminary Model of 5Ps

Task	Party	Public Model	Bridge Model	5Ps Model	Market-driven Model
Project Development	Public	Public, with foreign experts, leads project design and development	Public involvement in securing sites, and permit and license	Public involvement in securing sites, and permit and license	Public involvement in securing sites, and permit and license
	Private	No involvement	Private leads development	Private leads development	Private leads development
Operation	Public	Government responsible for operation	Monitoring Tariff scheduling and guarantee	Monitoring Tariff scheduling, and guarantee	No involvement
	Private	No involvement	Through training, transfer operation to professional local company and community	Private responsible for operation and maintenance	Private responsible for operation
Investment	Public	Provide ODA grant to beneficiary government	Provide concessional loan or grant to projects (through a public intermediary)	Concessional loan or grant from public	No involvement
	Private	No involvement	Private participants generate cash income for operation and maintenance	Private participation in investment	Funding from financial market

The main goals of the preliminary model of the 5P's when applied to the development of mini-grids in the PICTs include:

1. Build a successful case to demonstrate competency of private enterprise
2. Build data base of mini-grid projects in PITCs
3. Testing risk sharing model between public and private
4. Build local industry infrastructure for transition to market-driven system

By accomplishing these goals, RE based mini-grid systems will have a solid foundation for private sector participation in the PICTs.

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Annex I Market Assessment Questionnaire(s)

Subject	Questionnaire	Expected Outcome
Policy & Regulation	What RE policies are currently in effect in the PICTs? Which related regulations and incentives to mini-grid development can be included? Major policy challenges in mini-grid project development. Who are the key stakeholders and decision-makers in individual PICTs? What is the energy policy in the PICTs?	Concrete recommendations for institutional improvement including the development of the mini-grid market at the government level
Renewable Energy Technology	What are the key energy technologies to be adopted? What is the accessibility to key technologies? What are the major challenges or hurdles to wide-application of key renewable energy technologies: cost, sourcing channel, and local industrial capacity?	Assessment of availability and accessibility of key renewable energy technologies and what is the current capacity to maintain such technology?
Financing	Which types of financing models can be applied to mini-grid projects? What is the available source of funds; private and public? How can gaps between funding needs and availability be addressed?	Identification of financial needs, appropriate financing model, and strategy of mini-grid financing
Local Industry	What is the local capacity to develop mini-grid projects? What are the expected roles and contributions of local players? What is the current regional plan for local industry building? How can hurdles to local players in taking active participation and contribution be addressed?	Evaluation of current industrial capacity and challenges, and strategy for local industry building
Socio Economic Issues	What are the socio-economic benefits of mini-grid projects? What is the current level of participation of the community in mini-grid projects? What are the challenges to sustainable community development through facilitation of community based mini-grid projects?	Assessment of potential benefits of and challenges to community-based mini-grid projects, and recommendations for sustainable mini-grid project development and operation

Annex II Cases of Mini-grids in Cook Islands and Tonga

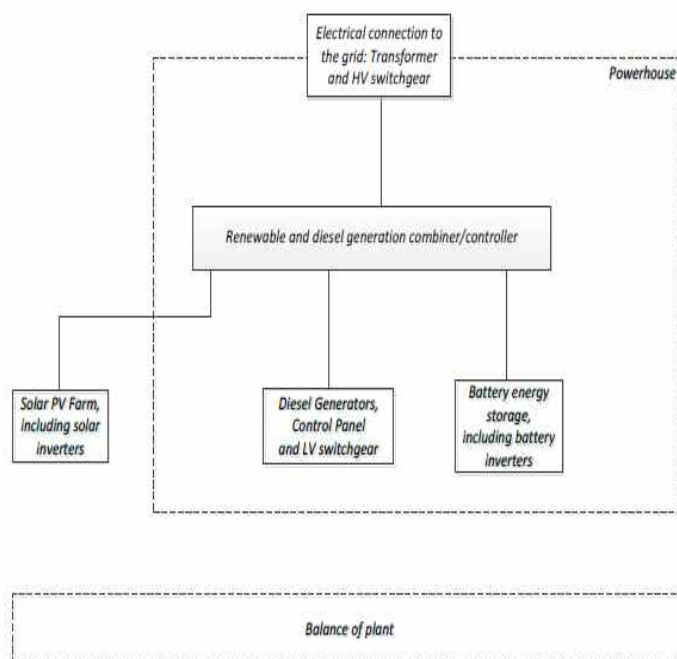
[Energy Environment of Project Islands in Cook Islands, 2012]

	Atiu	Mangaia	Mauke	Mitiaro
Annual Demand	382MWh	454MWh	230MWh	149MWh
Peak Demand	105kW	176kW	75kW	60kW
Solar Resource (GHI)	Average 4.7kWh/day			

[Solar Photovoltaic plants under Cook Islands Renewable Energy Sector]

Scope Item	Atiu	Mangaia	Mauke	Mitiaro
Solar PV Array	400kWp	460 kWp	225 kWp	150kWp
Solar PV Inverters	325 kW	375 kW	200 kW	125 kW
Array Mounting	Ground Mount-Driven/Floating	Ground Mount - Floating	Ground Mount - Driven/Floating	Ground Mount - Floating
Battery Inverters (continuous)	162kW	216 kW	90 kW	72 kW
Battery Bank	2500 kWh @ C120	3400 kWh @ C120	1400 kWh @ C120	1100 kWh @ C120
Generators	Utilise Existing inc controllers 1x180kVA, 2x132kVA, 1x100 kVA	Utilise Existing inc controllers 2x 180 kVA + 1 x 37.5 kVA	New Gensets inc controllers 2x60 kVA	New Gensets inc controllers 2x60 kVA
Power House	Utilise Existing Diesel Power Station Build new Renewable Energy Powerhouse	Utilise Existing Diesel Power Station Build new Renewable Energy Powerhouse	Build new Renewable Energy Powerhouse including generators	Build new Renewable Energy Powerhouse including generators
LV Switchgear	Provide new LV Manual Transfer Switch within existing Diesel Power Station Provide all new LV switchgear for RE Power system as required	Provide new LV Manual Transfer Switch and new LV station services switch board within existing Diesel Power Station Provide all new LV switchgear for RE Power System as required	Provide all new LV switchgear for RE Power System as required	Provide all new LV switchgear for RE Power System as required
HV Switchgear	Utilise Existing - currently 3.3 kV soon to be upgraded to 11kV	Provide new HV Switchgear within existing Diesel Power Station	Provide all new HV switchgear for RE Power system as required	Provide all new HV switchgear for RE Power system as required
Transformers	Utilise Existing - currently 3.3 kV soon to be upgraded to 11 kV	Utilise Existing - 11kV	Provide all new step-up transformers as required to suit existing HV distribution - currently 3.3 kV soon to be upgraded to 11 kV Provide new step-down transformer as required to suit existing HV distribution - currently 3.3 kV soon to be upgraded to 11kV	Provide all new step-up transformers as required - new 11 kV distribution
Grid Connection	Connection to existing LV feeder at existing diesel power station Utilise existing step-up transformer adjacent existing diesel power station	Connection to existing LV feeder at existing diesel power station Upgrade of existing HV switchgear Utilise existing step-up transformers adjacent existing diesel power station	Provide new step-up transformers and new HV feeder from new RE Power House to existing substation Upgrade existing HV switchgear and transformer at existing substation Provide new step-down transformer at existing Diesel Power Station	Provide new step-up transformers and new HV feeder from new RE Power House to existing Diesel Power Station. Provide new step-down transformer at existing Diesel Power Station. Reconnect existing LV distribution at existing Diesel Power Station

[System Design of Project in Cook Islands]



[System location analysis in Tonga]

Island	Solar PV Capacity (kW)	Type of System
Eua	200	Grid connected
Vava'u	400	Grid connected
Ha'apai	550	Grid connected
Ha'apai, Uiha	70	Community mini-grid
Ha'apai, ka	70	Community mini-grid
Ha'apai, Ha'ano	70	Community mini-grid
Ha'apai, 'afeva	70	Community mini-grid
Niuatoputapu	150	Grid connected
Niuafo'ou	100 Units of 200W	SHS (Small Home System)

Annex III Selection of Key Components of Mini-grids

Base-load generation

Although there are several options for base-load generation, in a small island energy environment where a large scale, centralized power generation system does not command an economy of scale, diesel generators may meet current needs but in the long term, hybrid systems have been shown to be cost effective. The advantages of diesel generators include low capital investment requirements, and simple and controllable operation. On the other hand, diesel fuel is costly and environmentally hazardous (as shown in the figure below); regular delivery of diesel fuel to a remote island often becomes very challenging, and the diesel fuel prices are fluctuating in accordance of the ups and downs of the international oil market. The fluctuating oil prices leave an island community or country financially vulnerable. Nevertheless, as discussed in the previous section, diesel generators, combined with RE and ESS, offer an affordable and manageable energy option to most of island communities, like the PICTs.

Renewable Energies

There are several types of renewable energy technologies available for PICTs: solar PV, wind (small and large), small hydro, geothermal, and biomass. Each of the renewable energy technologies has advantages and disadvantages. A brief description of advantages and disadvantages of available RE technologies in PICTs is provided in the following table which determines if they are appropriate for implementation in the PICTs.

[Grading of the Advantages and Disadvantages of RE Technology]

	Solar PV	Small Wind	Wind> MW	Small hydro	Biomass	Geothermal
Resource availability	A	B	B	C	B~C	C
Space availability	B	A	B	B	A	A
Seasonal fluctuation	A	B	B	C	A	A
Technology reliability	A	C	B	B	A	B
Cost per kWh	B	C	A	A	A	A
Quality of energy (Intermittency)	B	C	C	B	A	A
Environmental impact	A	A	C	A	B	B

(A: favorable availability, B: available with some restrictions, C: limited or restricted availability)

According to the analysis, Solar PV and Biomass appear to be the most feasible renewable energy options. However, unlike solar PV, biomass has constraints in terms of resource availability. Solar PV, too, has constraints in space availability. Many islands in the PICTs are covered with mountains forests, and agricultural land which are not appropriate for land development for solar PV. However,

thanks to its modular and scalable features, solar PV can overcome such disadvantages. In terms of resource availability, technology reliability, and cost competitiveness, solar PV is by far, the most feasible RE option for mini-grid implementation in the PICTs.

ESS (Energy storage system)

There are a number of ESS technologies on the market. Each of the technologies has different characteristics and applications. The following figure displays a brief summary of available ESS technologies and features.

[Features of different storage technologies]³⁴

Storage Type	Power (MW)	Discharge time	Efficiency (%)	Lifetime (yr)	Overall storage cost (USD/MWh)	Capital cost (USD/kw)
Pumped Hydro	250-1000	10h	70-80	>30	50-150	2000-4000 (100-300)b
CAES	100-300 (10/20)	3-10h	45-60	30	-150	800-1000 (1300-1800)
Fly Wheels	0.1-10	15s-15m	>85	20	Na	1000-5000d
Super Capacity.	10	<30s	90	510 ⁴ Cycles	Na	1500-2500 (500)d
VRB	0.05-10	2-8h	75/80DC 60/70AC	5-15	250-300d	3000-4000 (2000)d
Li-ion battery	-5	15m-4h	90DC	8-15	250-500de	2500-3000 (<1000)de
Lead battery	3-20	10s-4h	75/80DC 79/75AC	4-8	Na	1500-2000
NaS battery	30-35	4h	80/85DC	15	50-150d	100-2000d
SMS	0.5+d	1-100s/hd	>90	>510 ⁴ Cycles	Na	Na

The following table shows different applications of ESS, and detailed characteristics of each application.

³⁴ ENERGY STORAGE, IDB, December 2017

[Key characteristics of storage systems for particular applications]³⁵

Application	Output electricity (e), Thermal (t)	Size (MW)	Discharge duration	Cycles (typical)	Response time
Seasonal storage	e,t	500 to 2000	days to months	1 to 5 per year	Day
Arbitrage	E	100 to 2000	8 hours to 24 hours	0.25 to 1 per day	>1 hour
Frequency regulation	E	1 to 2000	1 minute to 15 minutes	20 to 40 per day	1 min
Load following	e,t	1 to 2000	15 minutes to 1 day	1 to 29 per day	<15 min
Voltage support	E	1 to 40	1 second to 1 minute	10 to 100 per day	millisecond to second
Black start	E	0.1 to 400	1 hour to 4 hours	<1 per year	<1 hour
Transmission and Distribution (T&D) congestion relief	e,t	10 to 500	2 hours to 4 hours	0.14 to 1.25 per day	>1 hour
T&D infrastructure investment deferral	e,t	1 to 500	2 hours to 5 hours	0.75 to 1.25 per day	>1 hour
Demand shifting and peak reduction	e,t	0.001 to 1	Minutes to hours	1 to 29 per day	<15 min
Off-grid	e,t	0.001 to 0.01	3 hours to 5 hours	0.75 to 1.5 per day	<1 hour
Variable supply resource integration	e,t	1 to 400	1 minute to hours	0.5 to 2 per day	<15 min

Considering different ESS technologies and applications, and specific requirements of ESS functions in an island environment, it discusses two ESS technologies, lead-acid and Lithium-ion batteries for ESS applications. Advantage and disadvantages of lead-acid battery and Li-ion ESS include:

Lead-Acid Batteries

Lead-acid batteries are the most common energy storage(ES) technology. They have low capital costs, reasonable roundtrip efficiency, and are well-understood—therefore, easily serviced. This makes them attractive technologies for use in small systems that do not have the technical capacity to service advanced ES technologies, or where cost minimization is an important factor. The drawback of lead-acid batteries is their short lifespan. Because of their shorter lifespan, lead-acid batteries have a higher cost.

³⁵ ENERGY STORAGE, IDB, December 2017

Lead-acid batteries are defined by their use of lead plates to form the two electrodes of the battery. There are two types of configurations for lead-acid batteries: wet cell and valve regulated (VRLA) batteries. A wet cell uses distilled water as part of its electrolyte, and the distilled water has to be replaced on a regular schedule (typically about twice a year). Wet cell batteries must also be oriented upright to prevent spilling electrolytes. VRLA batteries require less maintenance and are less sensitive to non-upright orientations than wet cells. Finally, some lead-acid batteries use a gel as an electrolyte, which makes them less sensitive to non-upright orientations.³⁶

Dry cell batteries are an innovation on a technology originally developed in the 1990s, which uses metal-coated fiber mesh as part of the battery. This type of battery has recently been installed in several large installations in Hawaii. In these installations, which range in size from 1.25MW to 15MW, the advanced dry cell batteries have been paired with wind and solar energy.³⁷

Ultra-batteries are hybrid ES devices that combine VRLA batteries with electrochemical capacitors. Electrochemical capacitors store power physically between a high surface area carbon electrode and a liquid electrolyte. Physically storing the power means that there is no chemical reaction taking place. This greatly extends the lifespan of the battery, because, as mentioned above, chemical reactions greatly reduce the life of batteries.³⁸

Since lead-acid batteries can be drawn upon quickly, they are appropriate for energy management and power quality regulation purposes, as well as for backing up power in small RE installations. Lead-acid batteries can also discharge for moderate periods of time; this makes them reasonably useful for transmission and distribution investment deferral. Lead-acid battery installations are generally too small for large conventional generation plants. They are ideal for systems where physical space is not a major concern, and low up-front costs are preferred.

One disadvantage of lead-acid batteries compared to Li-Ion batteries is in power quality control and the limited capacity of discharging power versus capacity of storing energy. The ratio is called the “C ratio.” The C ratio of lead-acid batteries is 0.1 to 0.2 which means that lead-acid batteries are able to discharge instant power of 10 to 20 percent of its designed capacity of energy storage. On the contrary, Li-Ion batteries are able to discharge stored energy to the full capacity instantly. The instant discharging capacity is very critical in controlling fluctuating energy flows from RE sources.

The following example of an island grid on Baltra Island, Galapagos, Ecuador shows how the low C ratio of a lead-acid battery shows limited performance when it is connected to a wind power system. (The case was surveyed and included in Feasibility Study of Mini-grid in Santa Cruz and Baltra Islands, Galapagos, Ecuador, by One Energy Island, 2017.) On Baltra Island, a 4,000kWh lead acid battery with 500kW PCS was connected to three units of 750kW wind turbines in operation. The C-Rate of the battery was 10% and DoD was 50%. This meant that the actual capacity of the lead-acid battery in fast response to the wind turbine volatilities was just 400kW. A problem occurred when the

³⁶ IRENA 2012: Renewable Power Generation Costs in 2012: An Overview

³⁷ DOE 2012: Hawaii Energy Facts and Figures

³⁸ Cantec Systems, 2012

power generation from the wind system suddenly dropped more than 400kW. Such an event was observed occurring several times even in a single day. Since the lead-acid battery was not able to control the fluctuations of the wind turbine, the intermittency of the wind power system caused voltage and frequency changes in the grid beyond the normal range.

Lead-acid batteries, although they perform well in load shift and peak shaving, do not match well with an energy environment where the penetration of intermittent RE sources is high.

Li-Ion Batteries

Lithium (Li)-ion batteries are smaller than lead-acid batteries, but they are more expensive. They also can be charged and discharged more reliably and can handle deeper discharges from their stated capacities without being damaged—giving them higher duration, efficiency, and lifespan. Despite their benefits, Li-ion batteries have the highest long run marginal cost (LRMC) of all the technically viable ES technologies.³⁹

As a result, Li-ion batteries are only desirable as a higher end alternative to lead acid batteries where reliability is prized, and physical size is constrained. This explains why small electronic devices—such as mobile phones, handheld game systems, and laptops—typically use Li-ion batteries. Li-ion batteries function in a similar manner as lead-acid batteries. The electrodes are made of carbon and metal oxide. The lithium is in the form of a salt, placed in an organic solvent that forms the electrolyte. If the battery is discharging, the carbon is the negative electrode and the metal oxide is the positive electrode. The roles of the electrodes reverse when the battery is being charged.

Li-ion technology has been steadily improving over the past decade as mobile devices have drawn more heavily on the technology. For small mobile applications, Li-ion may be considered a mature technology; however, in electrical grid applications, Li-ion is still developing. The most important development perspective is the addition of new Li-ion chemistries that can reduce costs, improve safety, and increase lifetime while maintaining the efficiency and compact size of Li-ion batteries.

Li-ion batteries are very versatile. Similar to lead-acid batteries, they can be drawn upon quickly, making them appropriate for providing power management and backup power for renewable and conventional generation plants. They can also be used for power quality regulation and transmission and distribution deferral purposes. They also can discharge for longer periods of time than lead-acid batteries, and can therefore be more useful for energy management for small grids using RE.

Li-ion batteries are most appropriate for installations where physical size and weight need to be minimized. In addition, Li-ion batteries are more durable and have greater efficiency than lead-acid batteries, so they may be more attractive than lead-acid batteries wherever durability is a major concern.

³⁹ IRENA, 2012: Renewable Power Generation Costs in 2012: An Overview

However, Li-Ion batteries are reported to become vulnerable in high temperature and humidity. No actual case of such a problem was identified in this study, but this issue needs to be investigated further through a comprehensive survey of mini-grid projects in field operation.

Power Control System (PCS)

Despite sharing about 5 percent of the budget of a power system, the PCS plays a key function in mini-grids. Also, the PCS is the origin of most frequently occurring problems in a mini-grid. An Insulated Gate Bipolar Transistor (IGBT) fails frequently when the fluctuations of a grid exceed the designed capacity of the PCS. The replacement of an IGBT board is not a solution and the integration of the system should be redesigned in order to accommodate the level of fluctuations in the grid. In solar inverters, the IGBT performs key functions to convert direct current from the solar cells to alternating current.⁴⁰ When volatility in the power system goes beyond the controlled level, the IGBT fails. This issue becomes a serious and most frequently occurring problem in particular in a power system which has a high penetration of RE sources.

⁴⁰ <http://www.solarmango.com/scp/igbt-the-core-of-the-solar-inverter/>

Annex IV Design of an Integrated O&M Platform

1. Standard O&M Manual

A Standard O&M Manual is necessary to keep your system operating at peak levels with minimum downtime. Safety procedures and special equipment that will help ensure the safety of system operation and maintenance personnel: Example O&M manual is presented below.

[Example O&M Manual⁴¹]

Weekly	Clean PV array from dust and bird drop. Use clean water and avoid hard water
	Observe battery state of charge(SOC) In case of VRLA battery use voltmeter to measure voltage to check corresponding SOC
Monthly	If flooded, check electrolyte level of lead acid batteries and top up if required. Wipe electrolyte residue from the top of the battery
	Inspect all terminals for corrosion and loosened cable connections. Clean and tighten as necessary. After cleaning, add anti-oxidant to exposed wire and terminals
	check if new loads have been added and system is over-loaded
	Inspect array for broken modules If any, replace with appropriate module
Annually	Check array wiring for physical damage and wind chafing
	Check array mounting hardware for tightness
	Inspect inverter-remove dust or dirt, inspect system wiring for poor connections for signs of excessive heating, inspect controller for proper operation
	Verify output from the array

When designing standard O&M manual, it is necessary to consider the following issues.

- Manual needs to be concise and correct in a proper language so that local operators read, understand, and practice without difficulty
- Manual needs to be designed for training purpose of local O&M staff
- A clear definition and assignment of responsibility of the management of manual to local O&M staff

⁴¹ GSES (global sustainable energy solutions), CLEAN(Clean Energy Access Network)(2015) "Installation, Operation and Maintenance of Solar PV Microgrid-A handbook for technicians",

2. Platform Structure Design

Total Operation Center (TOC) and site: the TOC is located on a main island. Full-time experts are available 24 hours a day. Experts at the TOC educate site managers or operators. On the sites, local engineers are responsible for daily operation, routine system check-up, and emergency response to technical troubles. Roles & Responsibilities between the operation centers and sites should be designated by the O&M manual.

The roles and responsibilities and scope of communication between the TOC and local sites should be designed in consideration of level of skill and expertise of site operators and available wireless communication infrastructure between TOC and a local site.

The number and location of TOC covering mini-grid projects in PICTs should be determined based on the study of economies of scale of the proposed integrated O&M platform project, workloads of physical coverage to a TOC dealing with a number of remote projects, and the most cost-efficient way of configuration of the platform network.

3. EMS (Energy Management System)

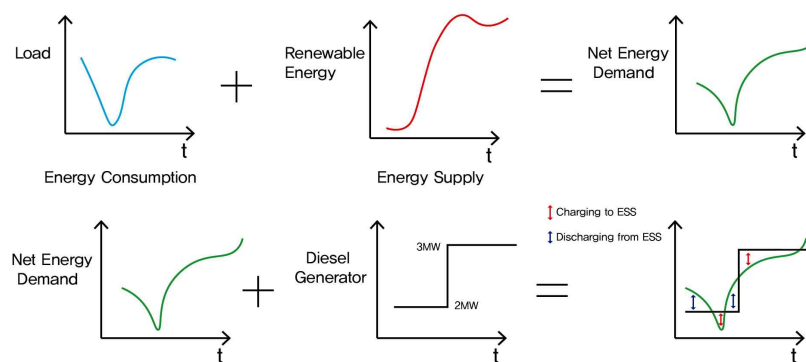
EMS is a critical part of mini-grid operation. It is software for monitoring, collecting data, and some features of auto-operation. With an EMS, it becomes possible for a mini-grid to communicate in real time with the TOC about system operation and technical troubles and set alarms in the case of emergencies.

[Operation Configuration]

Category	Details of activity
Monitoring	weather information (temperature, radiation)
	real-time generation
	alarming when abnormal event happens
	DC voltage, current, I/O condition
	AC voltage, current, I/O condition
	power factor, active power, reactive power
	battery operation management
	diesel operation management
	operation of other devices
Data collection	collecting data and recording technical troubles
	output of data in text or excel format
Auto-operation	conferring a degree of security and operational authority to site managers and operators
	directing manual or auto stop by devices in case of troubles
	auto configuration of operation

	assigning major parameters to devices
	retrieving user data from AMI
	Real-time electricity bill calculation

The most challenging parts of the EMS are the auto-configuration of operations. The definition of auto configuration is “The auto-configuration function is defined as the capability of the mini-grid system to automatically optimize its operation followed by any change in the system activities and configuration”.⁴² According to demand, the operation of components should be decided. For example, if demand is 50kW but solar generation is 20kW, diesel/battery must be operated. If demand is 10kW, but solar generation is 20kW, the battery should transfer to store electricity. All of this decision-making is done in real time in an auto-configuration.⁴³



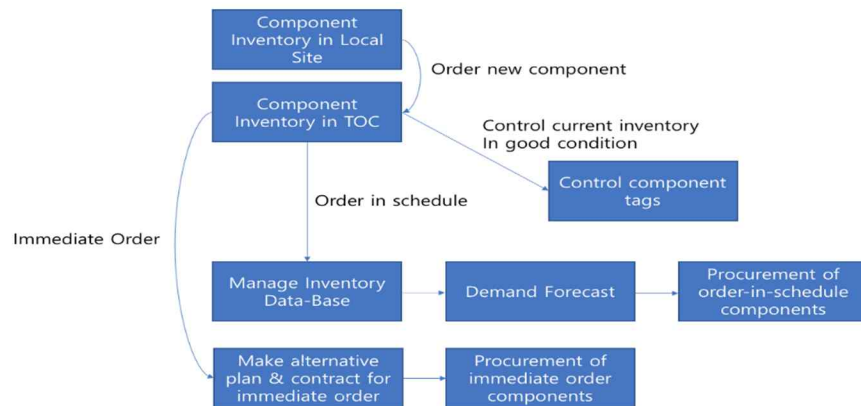
[Simplified EMS Algorithm]

4. Component Management

For O&M of mini-grid, various components are needed (see the example below) Therefore, component management is one of the key factors in O&M. The TOC is in charge of component design and management.

⁴² Van-Hai Bui, Akhtar Hussain, and Hak-Man Kim (2017), Optimal Operation of Microgrids Considering Auto Configuration Function Using Multiagent System

⁴³ Van-Hai Bui, Akhtar Hussain, and Hak-Man Kim (2017), Optimal Operation of Microgrids Considering Auto Configuration Function Using Multiagent System



[Diagram of Component Management]

There are 3 main roles for TOC in component management

- Control current inventory
- Orders in schedule
- Immediate orders

The main challenge for component management is that immediate orders should be minimized through accurate demand forecasts. To forecast demand accurately, a well-constructed record of previous troubles and replacements of parts and components is essential.

As the diagram shows, some components and spare parts are stored in local sites and some components and spare parts are stored in the TOC. The quantity and location of components and spare parts should be carefully determined based on the following standards:

- How expensive are components?
- Is special training needed to handle components?
- How often will components be replaced?
- How often will the components fail?

5. Communication Infrastructure

Telecommunication infrastructure plays a key role in designing the mini-grid operation and maintenance platform. As wireless telecommunication technologies evolve, the communication infrastructure for O&M platforms are expected to advance. The following table shows the different generations of wireless communication protocols and the speed of data transmission⁴⁴

⁴⁴ <http://katiparla.com/4g-features-comparision-1g2g3g-5g/>

[The Evolution of Wireless Communication]

Protocols	Examples	Speeds
1G	brick phones, bag phones	2kbps
2G	GSM/CDMA/GPRS	14.4~64kbps
3G	WCDMA	2 Mbps~
4G	LTE	200Mbps ~ 1 Gbps

Wireless telecommunication infrastructure in PICTs varies country to country and region to region.⁴⁵ In designing an integrated O&M platform, wireless communication infrastructure should be carefully investigated. According to the above graph, the prevailing protocol is 3G in the PICTs. With 3G coverage, real-time large data transmission, which needs sophisticated smart-grid technology, is not possible. Therefore, on-site monitoring is the best available option in many areas.

For example, Woojin IS, a Korean company which installs and operates a mini-grid system in Fiji, installed a data-server to collect real-time data at the project site in Fiji. The monitoring center at Woojin's office in Korea monitors through wireless communication collected data from the server and if necessary, retrieves data in an excel format. The process of data collection at the site, monitoring collected data and retrieving them at the center is reinforced due to the low speed of data transmission and is limited by the available telecommunication infrastructure. The existing infrastructure is not enough for real-time data transmission. Although Fiji' 3G coverage is known to be good compared to other PICTs, nevertheless, it was found in a visit to Woojin's monitoring center that the real time data transmission was very limited, only allowing the transmission of simple text messages. The following table shows the required level of wireless communication infrastructure and feasible scope of data transmission.

[Tiers of Data Transmission]

Level of data transmission	Purpose	Specific protocols	Speed requirement
Simple message transmission and monitoring	To alert error message	-	2G
Video communication	To communicate between O&M center and site	Webrtc	200 kbps ⁴⁶ (3G)
Real-time Data-Transmission	To collect and transmit real-time data.	Open ADR 2.0	Higher than 3G

The existing wireless communication infrastructure offers only limited capacity for an integrated O&M practice between a TOC and dispersed remote project sites. However, considering the speed of evolution in wireless communication technologies and expanding coverage of services, such a limit is expected to be resolved in the near future. Therefore, in designing integrated O&M

⁴⁵ UN ESCAP (2018) Broad Band Connectivity in pacific islands, Asia pacific Information Superhighway Working Paper Series

⁴⁶ <https://stackoverflow.com/questions/29854622/webrtc-bandwidth-requirements>

platforms, it is recommended to have contingency option in preparation for future upgrades to the platform.

Once completed and put into operation, the integrated O&M platform is expected to prove to be a very useful tool not only for effective O&M of mini-grid systems, but for the building and improving of mini-grid databases, an important knowledge asset which will serve a critical role of the mini-grid program in the PICTs.

Annex V 5Ps Business Model

Purpose

Going beyond the limitations of Public Private Partnership (PPP) projects that were mostly focused on large infrastructure projects, 5Ps model was designed in order to promote the participation of the private sector in relatively small rural electrification projects

Previous rural electrification models were led by the governments in business development, construction and operation. In this process, due to lack of expertise within government departments, and restrictions and limitations to private sector participation in implementation procedure, there were difficulties in the dissemination and timely distribution of rural electrification model in developing nations in Asia. As a measure to overcome this, the participation of private businesses was actively sought in collaboration with the government. To this end, there are roles for both the public and private sectors.

Key Success Factors of 5Ps model

For the success of 5Ps model, the suitable roles allocation and setting between public and private participants are important. In particular, it is imperative to implement active utilization of public funding in the form of concessional loan or grant, designing proper electricity tariff schedule for profit realization for private companies, and assurance of affordability of electricity to users and communities. It is the key roles to be taken by the public sector in order to facilitate private participation.

Based on these roles setting, (i) autonomous participation of community and local enterprises (ii) establishment of clear policy program, and support and monitoring by central and local governments, (iii) participation of private businesses with experiences and competency, (iv) coordination among stakeholders, and proper governance structure for smooth collaboration between private companies and government, are the success factors of 5Ps model. *5P Model Example: IDCOL's Solar Home System (SHS) Distribution Project, Bangladesh*

[IDCOL Example]⁴⁷

Background

A good example of 5P (Pro-Poor Public Private Partnership) model-based project would be Solar Home System (hereinafter SHS) in Bangladesh.

The business started with the support from the World Bank and GEF (Global Environment Facility) to supply electricity to remote villages in Bangladesh using renewable energy since January 2003. In line with the governmental goal of Bangladesh to supply electricity to all citizens by 2021, this project was implemented by IDCOL (Infrastructure Development Company Limited). IDCOL was responsible for implementation of the project under cooperation with NGOs and private sector

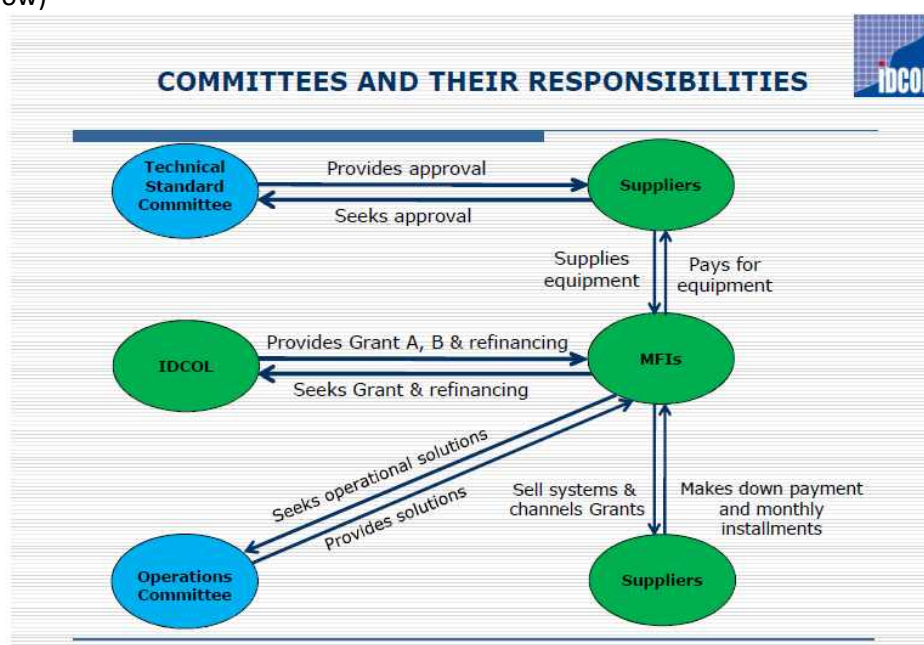
⁴⁷ IDCOL and World Bank websites

companies.

Since initiation, the program has consistently expanded its coverage by securing additional fund from multiple donor organizations; GIZ (German Federal Enterprise for International Cooperation), KfW (Kreditanstalt für Wiederaufbau), ADB (Asia Development Bank), IDB (Inter-American Development Bank), GPOBA (Global Partnership on Output-Based Aid), JICA (Japan International Cooperation Agency), USAID (United States Agency for International Development) and DFID (Department for International Development).

Until 2016, the investments to SHS summed up to BDT 52.2 billion (USD 696 million), of which USD 600 million was provided as concessional loans and the remaining USD 96 million was offered in the form of grant.

IDCOL, under the vision of “sustainable and environment-friendly investment”, was established in May 1997 by the Bangladesh government, and was approved as ‘non-bank financial institution’. IDCOL financed mid to large sized infrastructure projects including renewable energy projects. (Figure below)



Structure

Approximately 56 partner organizations (PO) were participating in distribution of SHS with IDCOL. Roles & Responsibilities of IDCOL and PO is shown in the following diagram.

IDCOL	Partner Organization
- Grant & soft loan management - Selection of contractors and monitoring performance - Technical standards and performance evaluation	- Customer and site survey - Selection and contracting with customers - System installation and O&M - Fee collection and loan payback

Performance

As of October 2016, total 4.1 million units of SHS were installed and supplied electricity to approximately 18 million people. This is approximately 12% of total population of Bangladesh. With electricity supply, approximately 1.14 million tons of kerosene was consumed. The value of the

saved kerosene was approximately USD 411 million. IDCOL expected that the 4.1 million units of installed SHS would save additional 3.6 million tons of kerosene and save USD 1,3 billion over the next 15 years.

Goal

IDCOL plans to supply 6 million units of SHS by 2021 and to supply total 220MWh of electricity per year.

Improvements

According to the SHS Impact Evaluation report published by World Bank in 2013, the major areas of consistent improvement included quality assurance through technical audit, system upgrade for minimizing technical issues, and selecting target customer groups for maximizing the utilization of electrification.

Annex VI Meeting Minutes

One Energy Island (OEI) Meetings in Fiji and Tonga for the

Design of a sub-regional renewable energy mini-grid program for Pacific Island Countries and Territories (PICTs) delivered by the Pacific Centre for Renewable Energy and Energy Efficiency (PCREEE)

Date & Time	Name of Officer	Venue	Participants
April 23 1400-1600	Acting Director of the Fiji Department of Power and Energy	Fiji Department of Power and Energy	- Mr Taeil Kang - Mr. Chris Curington - Ms Jinkyung Oh - Dr. Atul Raturi
April 23 1700-1900	Mr. Ravinesh Nand Technical Advisor Energy German Cooperation Agency (GIZ) Email: ravinesh.nand@giz.de	GIZ Fiji office	- Mr Taeil Kang - Mr. Chris Curington - Ms Jinkyung Oh - Dr. Atul Raturi - Mr. Ravinesh Nand
April 24 0900-1000	Mr. Rupeni Mario Team Leader – Renewable Energy and Efficiency Project – Economic Development Division South Pacific Community (SPC) Email: rupenim@spc.int	SPC office	- Mr Taeil Kang - Mr. Chris Curington - Ms Jinkyung Oh - Dr. Atul Raturi - Mr. Rupeni Mario
April 24 1100-1300	Mr. Amit Singh General Manager/ Director CBS Power Solutions Email: amit@cbspowersolutions.com	CBS Power Solutions	- Mr Taeil Kang - Mr. Chris Curington - Ms Jinkyung Oh - Mr. Amit Singh - Dr. Atul Raturi
April 24 1400-1600	Mr. Bruce Clay General Manager Clay Energy. Inc. https://clayenergy.com.fj/	Clay Energy, Fiji	- Mr. Chris Curington - Mr. Bruce Clay - Mr. Kini Koroi - Dr. Atul Raturi
April 25 1000-1200	Mr. Rupeni Mario Team Leader – Renewable Energy and Efficiency Project – Economic Development Division South Pacific Community (SPC) Email: rupenim@spc.int	SPC office	- Mr. Chris Curington - Mr. Rupeni Mario
April 25 1700-1800	Katerina Syngellakis Pacific Regional Representative Green Growth Planning and Implementation Global Green Growth Institute (GGGI) Email: katerina.syngellakis@gggi.org	GGGI Fiji office	- Mr. Chris Curington - Ms. Katerina Syngellakis

April 25 1000 - 1100	Mr. Solomon Fifita Manager -PCREEE Pacific Centre for Renewable Energy and Energy Efficiency (PCREEE), Geoscience, Energy and Maritime Division, Secretariat of the Pacific Community (SPC) Email: SolomoneF@spc.int	PCREEE Office	- Mr Taeil Kang - Ms Jinkyung Oh - Mr Solomon Fifita - Mr Peceli Nakavulevu - KEA Chunsuk Byun - KEA Eunyoung Park
April 26 0900 – 1000	Ms. Mafile'o Masi Chief Environmentalist and Head of Division Waste Management and Pollution Control Division- Department of Environment, Ministry of Meteorology, Energy, Information, Disaster Management, Environment, Climate Change and Communications (MEIDECC) Email: mafileo.masi@gmail.com	Department of Environment – MEIDECC	- Ms Mafile'o Masi - Mr Taeil Kang - Ms Jinkyung Oh - Lesieli Tu'ivai- Environmental Monitoring and Compliance Division - Kosilio faka'osi
1000 - 1100	Dr. Tevita Tukunga Director -Department of Energy Ministry of Meteorology, Energy, Information, Disaster Management, Environment,Climate Change and Communications (MEIDECC) Tevita Tukunga Email: ttukunga@gmail.com Feauini Veikoso Laumanu Email: feauini@gmail.com	Department of Energy - MEIDECC	- Ms Feauini Veikoso Laumanu - Ms Jin Kyung Oh - Mr Taeil Kang - Dr Tevita Tukunga - Mr Sione Misi
1100 - 1145	Mr. Fe'ao Teutau Manager – Kingdom Energy Email: kingdomenergy@gmail.com	PCREEE Office	- Mr Taeil Kang - Ms Jin Kyung Oh - Mr Fe'ao Teutau
1200 - 1430	PCREEE Anniversary	PCREEE Office	
1500 - 1600	Ms. Jeanette Tuionetoa Australian Department of Foreign Affairs and Trade Email: Jeannette.Tuionetoa@dfat.gov.au	Australian High Commission	- Ms Jeanette Tuionetoa - Ms Jinkyung Oh - Mr Sione Misi
1600 - 1700	Mr. Semisi Fukofuka Development Programme Coordinator New Zealand Ministry of Foreign Affairs & Trade Semisi Fukofuka Email: Senisi.Fukofuka@mfat.govt.nz Elena Procuta Email: Elena.Procuta@mfat.govt.nz	New Zealand High Commission	- Mr Semisi Fukofuka - Ms Elena Procuta - Ms Jinkyung Oh - Mr Sione Misi
April 27 1030 - 1130	Mr. Paula Tupou Acting CEO Tonga Electricity Commission, Nuku'alofa.	Electricity Commission	- Mr Paula Tupou - Ms Jinkyung Oh - Mr Chris Curington - Mr Sione Misi

1200 - 1345	Site Visit (Solar Farms) Mr Matapa Havea Tonga Power Limited Email: mhavea@tongapower.to	- Matatua 2 MW Solar Farm (Chinese Singyes Company - IPP) - Maama Mai 1.3 MW Solar Farm (NZ AID)	- Ms Jinkyung Oh - Mr Chris Curington - Mr Sione Misi
1400 - 1500	Mr. Alfred Vaka Programme Officer Japan International Cooperation Agency (JICA), Tonga Email: alfredvaka.to@jica.go.jp	JICA – Office, Nuku'alofa	- Mr Yasushi Hayashi - Mr Alfred Vaka - Ms Jinkyung Oh - Mr Chris Curington - Mr Sione Misi
1600 - 1700	Ms. Estrellita Fulivai Social Gender Development and Safeguards Monitoring & Evaluation Specialist Ministry of Meteorology, Energy, Information, Disaster Management, Environment, Climate Change and Communications (MEIDECC) Email: esefulivai@gmail.com & Mrs. Andrea T Tola Strategic Development Manager Tonga Power Limited, Nuku'alofa, Tonga Email: ataliauli@tongapower.to	PCREEE Office	- Ms Andrea Tora - Ms Estrellita Fulivai - Ms Jinkyung Oh - Mr Chris Curington - Mr Sione Misi
1700 – 1800	Mr 'Ofa Sefana Energy Specialist, (PEC-Fund Project Coordinator) Ministry of Meteorology, Energy, Information, Disaster Management, Environment, Climate Change and Communications (MEIDECC) Email: ofasefana@yahoo.com & Mr Peceli Nakavulevu Private Sector Expert – Pacific Centre for Renewable Energy and Energy Efficiency (PCREEE), Geoscience, Energy and Maritime Division, Secretariat of the Pacific Community (SPC) Email: peceli99@hotmail.com	PCREEE Office	- Mr Ofa Sefana - Mr Peceli Nakavulevu - Ms Jinkyung Oh - Mr Chris Curington - Mr Sione Misi

1. Depart of Environment Meeting on April 26 at 9:00

- a. Major Role of Department of Environment
Minimize environmental contribution through the environmental impact assessment by legislation. Government of Tonga is committed to achieve 50% RE by 2020.
- b. Challenge to assist RE
 - End of Life Equipment for Solar and Wind Turbine (Battery disposal)
Concept is new to Tonga. RE is regarded to end of life especially with the solar battery. (Circulation) Remote island does not have facility to dispose solar batteries -> causing problem. Recycling companies' capacity is also challenging.

Dept. of Energy storing in the container and Environmental Division takes over to ship it to Singapore & South Korea. Only way to dispose solar batteries due to no facility in Tonga.

- Land Use (Location)

Even if the location is desirable, communities not necessarily want it in the designated location. Hard to negotiate with land owner and communities. Hard for community to accept RE installment due to this land use matter. Agriculture base industry, so RE would affect community's economy. Dept. of Environment would support RE, but land use is an issue due to limited size of islands.

- Cost Benefit should be analyzed and need to see if it is better to install solar PV in their household and environmentally benefitted in a long run.

- c. Step of EIA (Environmental Impact Assessment)

- Form to be submitted by owner of the project. RE is considered major project and has to go through EIA and Minister of Environment is authority to determine. Waste disposal and ecological aspects to look at and community consultant is covering the social aspects before it is finally approved.

2. Department of Energy on April 26 at 10:00

- a. Major Role of Department of Energy

RE management of off the main central grid. Yet to be connected to mini-grid, but so far Solar Home system has been promoted.

- b. Current Operation of Solar Home System

All the projects are through government, but it is run by incorporative society (gov-community, Business Cooperative Society) Outer island has own local government. DOE legalize the incorporative society to run the solar home system. Each community employ 2 people designated to report to DOE. Ownership belongs to society later.

- c. Challenges for DOE

Solar Home System has been established for past 10 years. Capacity and management has to be developed to move to Mini-grid. Not just technology, how to monitor and build capacity is an issue. Operation and Maintenance parts are important matters. (O&M)

Although there is guideline for standardization, Tonga has not run mini-grid yet, so it has not followed any guideline yet.

- d. Potential Challenge to Mini-grid

Move to mini-grid, everything (Tech, Cap, Income, Economic Scale) has to be scaled up and it will be challenging. It will be advantage in electricity bill and efficiency, but Attractiveness for investors will be also challenging.

Mini-grid is not pilot, DOE is already approaching mini-grid.

- e. Follow up (Solar Home System experience from DOE and specific follow up questions)

3. Kingdom Energy and Electrical Supply/Services on April 26 at 11:00

- Business Supplier for Solar Home System in Tonga
- a. Main Role – Solar Home System in remote areas. Any type of solar maintenance is main role. Mainly contract with DOE. Energy cap is 10kW ish.
- b. Challenges as a private sector
- c. Finance/ Capital - Finding local finance is challenging. Mostly overseas companies finding local companies. Official tender comes from TPL on newspaper of internet and oversea companies (Suppliers) are bidding. (Japan is main model)
- Current Finance – by counterpart as main contractor (Suppliers and foreign countries) and sub contract with them as a local company.
- Transportation to remote islands is challenging
- Challenges to work with oversea companies are communication (Technician does not speak English)
- d. Cooperation with Incorporative – make sure the solar home system works (Installation in houses)
- e. Follow up – Pictures and other info. to share with OEI Government is looking for 6MW Installation by Tonga Power Limited.

4. Mr. Solomone Fifita, Manager -PCREEE on April 26 at 14:30

- a. SPC works on data mainly and policy & petroleum. PCREEE is focusing on RE& EE special mandate.
- b. Business opportunity provided by energy target & NDC, what ppl should do in order to start business. Provided seed funding. Trainings for bids, proposal trainings, and managing contract.
- c. Local business challenges – Criteria is too high for locals and access to the capital. Preparing competitive proposal is challenging and PCREEE is providing some training for that.
- d. Mini-grid opportunities are great as certain areas need electricity, so that is market for mini-grid. Subsidy is necessary as that is the way to get electricity 24 hours in outer islands.
- e. Sustainability – ADB is looking into it for recycling and collect used batteries. As long as it is collected, it would not cause any problem. Working on Marshall Islands to collect batteries to send main islands.
- f. Community matter – Socialist has to analyze the impact. Energy would provide income generation and for better livelihood.
- g. Standardization of RE is adopted at the regional level, but not implemented to national level. Local legislation and additional changes will be needed. PPA will be going to update for regional level.

5. Australian High Commission on April 26 at 15:00

– Ministry of Foreign Affairs and Trade

- a. OIREP – outer island renewable energy project
Australian government is funding with ADB for OIREP. AusAID is an extension of the Foreign Ministry in ODA, mostly partnering with the ADB.
- b. Challenges as a donor's perspective
– local capacity and private sector
International contractors subcontracting with local industries. But mostly handled by ADB. Local does not have capacity to maintain the hardware. Part of it is managed by local/ part is managed by TPL. Japan, Spain etc, all different hardware for TPL to maintain. Maintenance is challenge in Tonga.
- Gender balance is also challenging. Energy field is male dominant area.
- Community does not see the cost effectiveness of RE.
- Infrastructure in the outer islands
- c. Excited for PCREEE in Tonga how it can help local industries and support PCREEE through SPC by Australian government.
- d. National level there is donors meeting and communication channel to cooperate. Not regularly but by the subject once a month or so. Once a year there is high level talks and donors together for the next year. Tonga major donors: AUS, NZ, Japan, China (Big 4 donors), EU, ADB, WB.

6. NZ High Commission on April 26 at 16:00

– Ministry of Foreign Affairs and Trade

- a. NZ solar farm: is located where the main power generator is. It is easy for them to control as it is directly connected to the power generation. It was NZ public private partnership (fully funded). Funded for 5 years and last November it is fully handed over to TPL. It has been running very well. TPL has been very well managed so far and not so much problem so far. Very little issues between NZ company and locals.
- b. Successful factors: Minor problem with some cables buried but quickly identified due to lagoon. Electronic maintenance issue has occurred, but TPL itself has capacity to maintain themselves. 5 years funding for TPL to manage themselves well and having the right people and managing project made it possible. Communication of TPL is pretty good with donors and responsible.
- c. Reinvest needed: Tariff regulator said expectation to reduce tariff is good, but power tonga need to re-investing in the grid. (Second part of NZ support) Huge project NZ upgraded main program and all of rural part of Tonga from 17 villages to 55 villages to update the electricity network. No damages to what TPL worked on so it was really good. A couple of years ago, NZ supported feasibility studies, 5 areas for 5 years and 30 ish villages to support. There were significant line losses. Some areas line loss is 33% some of the area, so it needs to be re invested. Also, Cyclon needs to be considered for the electricity network to be resilient underground.
- d. Challenge: Pacific regional infrastructure facility (PRIF) to look at. (Supported by NZ DFAT)

- e. TPL has well organized with getting parts and NZ supported enough funding for procurement and did not have much problem with getting some parts and supply issues. NZ is monitoring closely to make sure how they spend money and maintenance.
- f. Donor coordination cases: F/S study, NZ was sharing info with Japan and coordination approach for wind turbines such as using same one with Japan. However, priority changed than wind, so it did not work. (50mil project) Challenge to coordinate with other donors: Expectation and requirements by donors are also difference.

7. Tonga Electricity Commission on April 27 at 10:30

- a. Electricity Commission regulate the price of electricity. It has an agreement with TPL for regulating tariff based on oil generation. Basic formula every 5 years. Last one was 2015 and next 2020.
- b. Commission Tasked by law, Customer Service Standard – how many minutes customers out of electricity. Maintaining electricity standard, license and major investment ex.) solar farms. Commission complies with new project to follow basic guidelines. Monitor the electricity price is charged fare not only for the consumer but also shareholders.
- c. Electricity price is subsidized by the government. Hold the price for 100 kWh by subsidy and after commercial unit and cost could be regionally different by the difficulties.
- d. There is one flat price and it is sort of subsidized between consumers to make the flat price.
- e. License: Electrical workers. NZ has 13 types of licenses. And Electrical Inspector. Electricians to be trained 4years in NZ. Training is depending on the system of supply. Tonga has same system with NZ and AUS system. Tonga has adapted the standard of NZ. It has provided total of 38 licenses were provided.
- f. Regulator under the government might be dangerous. It has to be independent or above the government. Regional association has a meeting end of next month. PPA (Power Producing Agreement)
- g. Local industries challenge: numbers have to be correct. Cost/Benefit analysis and cost effectiveness need to be calculated to look what is profitable. Whether Business side of renewable is correctly understood. In addition, Australia is subsidizing solar panel. If it is less subsidized, it will be less attractive for industries.

8. JICA on April 27 at 14:00

- a. JICA has worked in Tonga has been more than three decades. (Interviewee is relatively new and has been in Tonga for a month)
- b. Wind power planning: Eastern part of Tongatapu, JICA is planning to construct 1MW Wind power. Construction will start this coming august. It plans to be connected to main headquarter and will be monitored every second to monitor diesel generation to minimize for reducing GHG emission.
- c. JICA also has solar farm located in Tongatapu. It is connected to main grid and every second, it sends record of how much energy is provided. Currently, due to Cyclone, system is a bit damaged.
- d. Process of project: Request comes from Tonga government. And between government, those projects are agreed. There have been no issues raised so far. Under the scheme of grant system, Japanese government announces the tendering to Japanese companies for solar, wind, data systems etc. Japanese companies are constructed by

Japanese government and consultant company monitor whole construction cooperating with TPL. TPL is responsible for maintenance. After 5 years, there is final inspection to fully hand over to Tonga.

- e. TPL training – Few weeks to few months. Either in Japan or Tonga.
- f. Solar Home System: JICA also participated in a solar home system program. – Challenges: transportation due to weather condition to remote island. Requirement for households (household pays certain amount to government for the future maintenance) Minor issues with procurement issues, but TPL is in charge.
- g. JICA PEC fund: JICA has funding for pacific regional fund including outer islands. DOE is looking after the off grid for communities. (MEIDECC)
- h. JICA library has information for Tonga Solar information.
- i. Future direction: Tonga government is very committed to RE. Majority of people live in Tongatapu, so probably JICA will stay the focus on Tongatapu. Outer islands will be choices by JICA.

9. Department of Energy and Tonga Power Limited on April 27, 2018 at 16:00

- a. OIREP started 2001 for outer islands and it has already lesson learned. It has electricity committee there to report government if there are any issues. (if they do not have enough fund to take care of their own system)
- b. Incorporative society, they are made for profit based (cooperative).
- c. 3.2% of 50% of RE commitment from OIREP. 1.4% is covered so far.
- d. Government is looking into upgrading the current system. Also consider gender issues for female to be more included such as collecting payments, looking after the demand as they are using the electricity home.
- e. TPL has a fixed price, but rural area has their own prices, designated by committees. Some households cannot afford it. Community size is approx. 200 people.
- f. Challenges in rural area to implement. Committee is one issue, determining the price (majority is depending on fishing and agriculture and due to the capacity, they do not have much income, so ability to pay is an issue) that's why current profit-based system has an issue.
- g. TPL is sole power utility in Tonga. As government has the ambitious commitment, TPL is into upgrading system and looking into expanding more to work with DOE for Tonga Energy Road Map. 2008 RE act has been passed. Currently less than 20 % so it has long way to go.
- h. All detailed information can be sent by emails. (Proposal to GCF etc. and information can be sent, Tonga Energy Roadmap etc.)
- i. Local industries challenges: capital cost is main issue. It has been with the donors, but nobody has ability to afford. Bank has some loan program for RE with a little interest rate to encourage people.
- j. Donor funded project challenges: Trying to integrate with other plants and data. Trying to find the people to upgrade etc. It is not an issue, but not enough capacity to handle. Suppliers have all different models. Integration is issues for maintenance. Maintenance itself is fine.
- k. Capacity building area: Rural area needs establishing private business for income generations for locals to pay. Training on various business skills. RE integration is main issue from TPL. Oversea companies are not sharing enough information when it comes to upgrading.

10. Ministry of Meteorology, Energy, Information on April 27 at 17:00

- a. PEC fund- part of Japanese fund about 60 mil dollars for PIC region. And 4 mil dollars is allocated to each country.
- b. Ideas for funding is *Tech solar dissemination plan open to other application, * Biz opportunity for women in remote island community * Solar farm system & put off the diesel water pumping system.
- c. Currently diesel pumping has been used due to the high electricity cost from main grid.
- d. 22 solar water pumps so far in 17 villages. Size 20 households to 100s. Energy cap about 6kWh to 11kWh. Maintenance is important part. Water pumping system's cost of operation has significantly reduced (half) Solar pumping has been promising project. So far, current plans are Solar Home, Street Light, Pump, Freezer, Solar Mini-grid. Goal is to reach 100% solar in off grid.
- e. Government design these systems and set design first and announce for suppliers to provide. Trying to contract with multinationals to get the most suitable designs.

11. Mr. Peceli Nakavulevu, Private Sector Expert (PCREEE) on April 27, 2018 at 17:30

- a. Private companies have been successful in Suva. The thing is companies want bigger market places. Challenges are local companies only contract through tendered project. Also, financial capacity is challenges with banking loans and etc. PCREEE also supports these companies. Technological parts are also an issue.
- b. MOU association of development finance institution to facilitate small companies to help.
- c. Price of electricity is matter. Ex. Solomon Island – electricity bill is too high.
- d. Strength of local industries- knowledge and network, experience in local resources.
- e. PCREEE direction: not every island has the energy access like PNG and Solomon Is. There have been a lot of initiatives, but it has not worked well. Mini-grid where PCREEE wants to focus as outer islands are not connected.

Annex VII Market and Industry Report Survey

One Energy Island Co., Ltd.

This survey is designed to assist One Energy Island Co., Ltd. In conjunction with PCREEE and UNIDO in identifying the strengths, weaknesses, opportunities, and threats related to establishing an effective mini-grid program in the Pacific Community. These programs relate to Renewable Energy and Energy Efficiency (RE and EE) project development. We request that you take a few minutes of your time to answer these following questions. This will be of great help in identifying the key factors that influence the establishment of renewable energy and energy efficient systems in the Pacific Community. Please complete the survey and send it back to _____ with survey in the subject line.

1. Personal Information

a. Name

b. Name of your organization (Company, department, or civic group)

c. Position in organization

d. What is your Country or Territory of residence?

2. Strengths of the Energy Market

a. What makes your country or territory a good candidate for RE and EE development?

- b. Are there any energy projects currently under development in your Country or Territory? If yes, can you describe them?

Location:

Capacity:

Type:

Project Budget:

- c. What positive steps has your Country or Territory made towards RE and EE development?

- d. Are there any specific regulations or incentives that you believe help to promote RE and EE development in your Country or Territory?

3. Weaknesses of the Energy Market

- a. Which issues (Regulatory, Business, Environmental etc.) have most negatively influenced RE and EE development in your Country or Territory?

- b. Have any energy related projects failed to meet expectations or were not completed in your Country or Territory? Please explain why.

4. Opportunities in the Energy Market

- a. Do you believe that there is a high level of awareness of the need for RE and EE projects in your country or territory?

- b. Do you believe that there is a role for a mediator (consensus building) in developing RE and EE projects in your Country or Territory?

- c. Are there any potential energy development projects being pursued by your organization?

5. Threats in the Energy Market

- a. Which factors (environmental, institutional, regulatory, etc.) do you believe presents the greatest threat to RE and EE development in your Country or Territory?

- b. Do local businesses have all the resources they need to develop RE and EE projects? If no, which resources are necessary?

- c. Do local governmenternments have all the resources they need to develop RE and EE projects? If no, which resources are necessary?

- d. Are there any other additional barriers which may hinder RE and EE development in your Country or Territory?

Thank you for taking the time to complete our questionnaire, your input is valuable to us and we appreciate your contribution.