Consultancy Services to Develop a Renewable Energy-based Off-grid Electrification Master Plan for Remote Islands of Vanuatu along the Example of Four Islands

Inception Report

8 April 2016

Peter Johnston
Environmental and Energy Consultants Ltd (Suva, Fiji)

and

Dr Herbert Wade
Renewable Energy Consultant

Prepared for

The Government of Vanuatu

and

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
(Project Number 81195891; GIZ Contract number: 13.9022.8-001.00)

Table of Contents

List of Figures

List of Tables

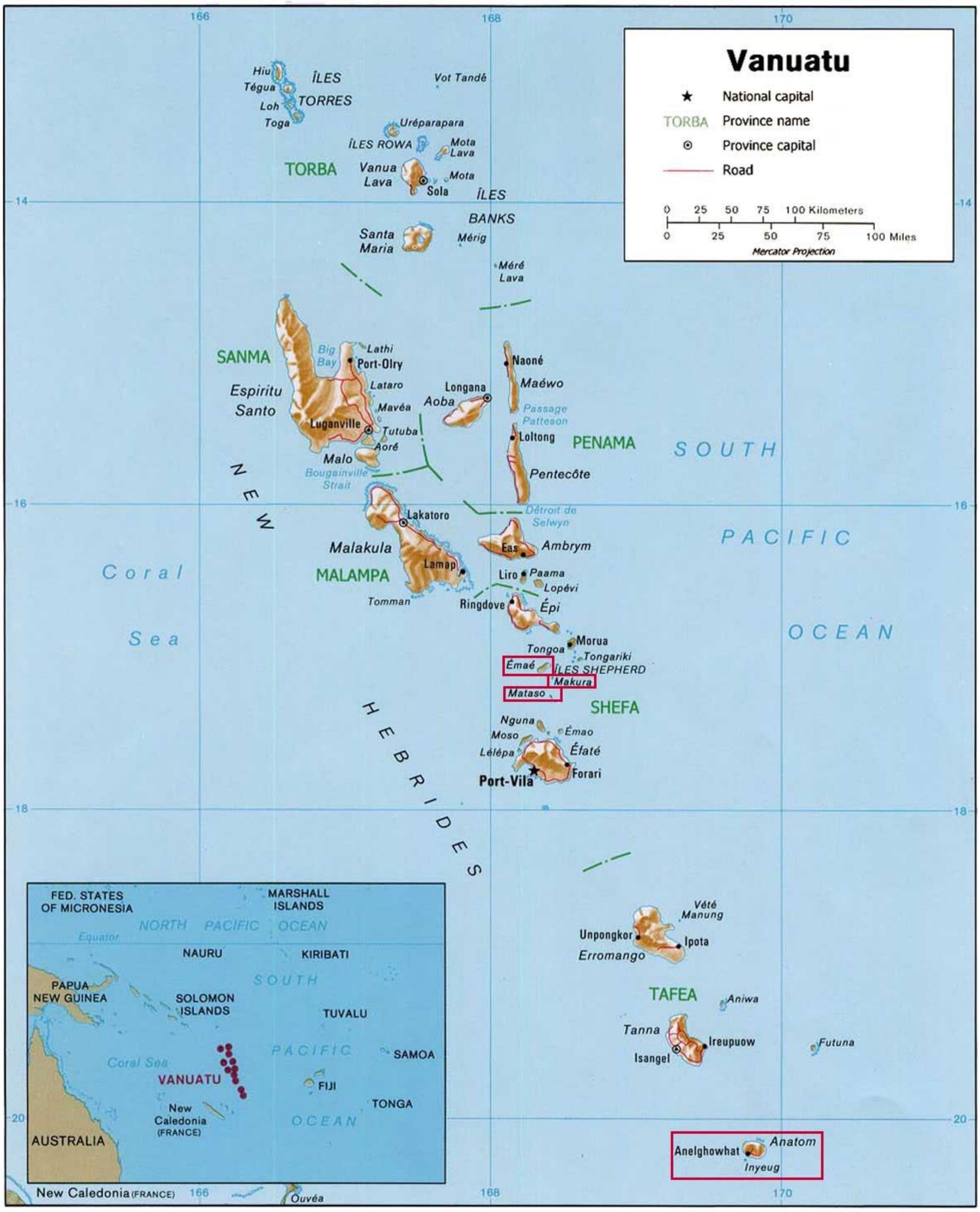
List of Annexes

Acronyms and Abbreviations

AC	Alternating current
ACSE	EU-GIZ Adaptation to Climate Change and Renewable Energy
ADB	Asian Development Bank
AFD	Agence Française de Développement
CGAP	Consultative Group to Assist the Poor
DC	Direct current
DFAT	Department of Foreign Affairs & Trade (Australia)
DoE	Department of Energy, Vanuatu
ESMAP	Energy Sector Management Assistance programme
EUEI	European Union Energy Initiative
FREPP	Fiji Renewable Energy Power project (UNDP Global Environment Facility)
GCF	Green Climate Fund
GGGI	Global Green Growth Institute
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GoV	Government of Vanuatu
INDC	Intended Nationally Determined Contributions (to GHG reductions)
IPP	Independent Power Producer
IRENA	International Renewable Energy Agency
JICA	Japan International Cooperation Agency
kWh	Kilowatt hour
LED	Light Emitting Diode
MCC*	Ministry for Climate Change and Natural Disasters (see note below)
MMO	Manage, Maintain and Operate
NAB	National Advisory Board for Climate Change and Disaster Risk Reduction
NAMA	Nationally Appropriate Mitigation Action
NERM	National Energy Roadmap
NGEF	National Green Energy Fund (proposed)
North-REP	North Pacific Renewable Energy Programme (EU/SPC)
O&M	Operations and Maintenance
PIC	Pacific Island Country
PPA	Pacific Power Association
PPP	public–private partnership
PV	Photovoltaic(s)
PV	Solar photovoltaic
RE	Renewable Energy
REP-5	Renewable Energy Programme for Five Pacific Island Countries (EU)
RESCO	Renewable Energy Service Company
SEIAPI	Sustainable Energy Industry Association of the Pacific Islands
SHS	Solar Home System
SPC	Secretariat of the Pacific Community

STEPS	Social, Technological and Environmental Pathways to Sustainability
TVL	Telecom Vanuatu Ltd
UNDP	United Nations Development Programme
UNELCO	Union Electrique du Vanuatu Limited
UNFCCC	United Nations Framework Convention on Climate Change
URA	Utilities Regulatory Authority
US$	United States dollars
USAID	United States Agency for International Development
USP	University of the South Pacific
VNSO	Vanuatu National Statistics Office
VREP	Vanuatu Rural Electrification Project
Vt	Vanuatu currency; also VUV
VUI	Vanuatu Utilities & Infrastructure Ltd
W	Watt(s)
WB	World Bank
Wp	Watts peak

* The ministry is usually referred to as the Ministry for Climate Change (MCC) or the Ministry for Climate Change and Natural Disasters. More formally, it is the Ministry of Climate Change Adaptation, Meteorology, Geohazards, Environment and Energy



Map of Vanuatu showing the location of the four target islands
Source: http://www.lib.utexas.edu/maps

1. Introduction

Vanuatu consists of eighty-six islands, about 65 inhabited, with over 12,000 km^2 of land area, and an April 2016 estimated population of 284,700 (http://www.vnso.gov.vu/ accessed 4 April 2016). Only four islands have urban/peri-urban electricity grid systems. There are grids in and around Port Vila on Efate Island, Norsup (Malakula Island) and Lenakel (on Tanna) all managed by Union Electrique du Vanuatu Limited (UNELCO) and a separate grid in Luganville plus a village mini-grid (on Espiritu Santo) managed by Vanuatu Utilities and Infrastructure Ltd (VUI). These systems are privately owned and operated through concession contracts with the Government of Vanuatu (GoV). They do not rely on donors for new and replacement generators, have no government subsidies other than duty-free fuel, and are regulated to operate in a financially sustainable manner. The remaining 61 inhabited islands have no grid electricity supply. The population without electricity access in rural areas (World Bank, 2014) ranges from 83-85% in Tafea and Shefa provinces (but much lower in the islands of these provinces where field trips for this project are planned), 89% in Sanma, 92% in Malampa and 97% in Torba.

This consultancy is to develop a renewable energy (RE) based off-grid electrification masterplan for the remote islands of Vanuatu. Off-grid is understood to mean away from the power utility grid networks of the two power utilities UNELCO (Efate, Malekula, Tanna) and VUI (Santo). Where practical there could rural electrification carried out with low-voltage DC installations on homes, such as solar home systems (SHS) to cover lighting, phone charging and small appliances such as radios, as well as grid voltage AC mini-grids for communities. Multiple communities powered by a single a mini-grid may be possible if the interconnection distances are not too great to be cost effective.

In the context of this study, ‘electrification’ refers to some agreed minimum standard of electricity services, which could be for a few hours per day (usually at night for lighting and other services) or a 24 hour supply. Generally rural electrification in the Pacific is understood to include SHS as they are permanent installations that require an institutional structure for their maintenance. However, portable solar lanterns and pico-solar installations are replacements for kerosene lighting and are not normally considered as rural electrification. The Acting Director of the Department of Energy (DoE) has confirmed that this study excludes solar lanterns/pico-solar systems.

The Rural Electrification Master Plan is understood to be a general long-term guide for electrifying those remote areas of Vanuatu that are off the power utility grids and are unlikely to be connected to utility grids for many years, if ever. The plan does not include detailed designs but will include design concepts and specifications that are considerations appropriate to Vanuatu (e.g. simplicity, cyclone resistance, robustness, and suitability for a tropical, salt air environment), an overall technical approach, mechanisms for financing wide-scale rural RE-based electrification, broad financial needs for capital costs, mechanisms for high-quality installations, mechanisms for sustainability (training, operations and maintenance, component replacement, user fees where appropriate, ownership, etc.) as well as the role of the Government of Vanuatu (GoV) and recommended legislative, regulatory and institutional changes needed for success.

This inception report is a desk-based study prior to the initial visit to Vanuatu in April 2016. It is based on: i) the prior experience of the authors with issues regarding renewable energy development in remote islands of the Pacific Island Countries (PICs) including Vanuatu); ii) a review of available relevant documentation; iii) discussions with Fiji-based experts familiar with Vanuatu and renewable energy issues facing Vanuatu; and iv) email exchanges and Skype discussions with stakeholders in Vanuatu, Pacific regional agencies dealing with renewable energy and others. A list of ‘People and

Organisations Consulted' is attached as Annex 1. A list of 'Documentation and Sources' relevant to this consultancy is attached as Annex 2.

2. Renewable Energy Resources Available for Vanuatu Rural Electrification

Renewable energy sources that are available in Vanuatu for small-scale electricity generation at the rural village or individual household level include:

1. **Solar Energy** – Solar photovoltaic generation is by far the most widely – and successfully – used renewable energy technology for rural electricity generation in the Pacific. With long life components used in the design, general maintenance is usually minimal and not difficult for rural dwellers to learn. The installations have no moving parts. They can be constructed at a reasonable cost to withstand the high winds and flooding that accompany tropical cyclones. Solar availability is very good in Vanuatu though there is sometimes reduced availability in areas where there are persistent clouds due to mountains.
2. **Wind Energy** – Large scale wind power is being used with reasonable success by several Pacific power utilities (currently installed in Fiji, Vanuatu and the French territories and planned for installation in US island territories) but to date there have been no small scale wind installations for rural electrification that have provided reliable power for the long term. Part of the problem is the large variability of the wind resource from place to place. Rural villages and isolated households tend to be located in low wind, sheltered areas for comfort and safety making it difficult to economically access the high level and consistent wind energy needed for low cost power generation. The tall coconut trees that are often associated with island villages also can greatly reduce access to adequate wind resources. The salt air, high humidity and high ambient temperatures found along the coast of the islands tends to increase maintenance problems with the tower-mounted mechanical and electrical components used in small wind generators. Cyclones are also a major problem for wind installations since towers must be designed to be easily and safely lowered and protected when a cyclone passage is expected.
3. **Hydro Energy** – Small-scale hydro energy may be practical at a few sites in Vanuatu where useable hydro sites are near enough to villages to allow an acceptable transmission line cost, but most small streams in the islands are seasonal and have very large variations in flow over the year. The heavy rains that accompany cyclones often seriously damage or sweep away the small run-of-the-river generation installations that are practical for village and individual use. The resource at the proposed site must be assessed and hydro systems must be designed specifically to fit that site, an expensive process. Also, stocking spare parts and training technical personnel to maintain a wide variety of installations can be quite expensive.
4. **Biomass Energy** – Although direct combustion or gasification of biomass for the generation of electricity is technically practical, the volume of biomass required is relatively large and the only economic electricity generation in the region based on biomass has been at forest and agricultural processing mills where large amounts of biomass waste products are available for burning or gasification. Small scale steam generation (Fiji) and small scale gasification (Onesua in north Efate, Vanuatu; French Polynesia; Papua New Guinea) for electrical generation have been attempted using harvested local biomass or the collection of coconut husks from a large number households, but the projects were soon abandoned as being too costly in time and effort.
5. **Biogas** – The conversion of biological materials, usually manure, to burnable methane through biogas digesters has been used with varying levels of success in the Pacific (Northern Marianas; Fiji). Although the gas produced can be used to fuel internal combustion engines, most biogas produced in the islands has been used for cooking, as that best fits the modest volume and quality of burnable gas available from the small scale Pacific dairy farms, piggeries and chicken farms. The

primary problems with biogas production is collection of the large quantities of manure and maintaining the conditions in the biogas digester conducive to gas production. To economically collect the manure there needs to be a number of animals which are confined so manure can be economically collected. Few remote farms have either the number of animals or easy access to their manure in order to make biogas sufficient for power generation.

6. **Biofuel** – In the Pacific Islands, coconut oil is a major resource for power generation and Vanuatu utilities are regional leaders in its use. However, the equipment needed to produce and refine the oil is relatively expensive and requires skilled maintenance and to date, coconut oil production in remote areas for power generation has not been very successful. Most remote island projects that have been designed for generation using diesel engines running on locally made coconut oil (e.g. Fiji) have, after a few years of operation, either been abandoned or have ended up operating on purchased diesel fuel, not locally made coconut oil. Nine coconut oil based biofuel systems have been installed in Fiji's remote islands (Cicia, Gau, Lakeba, Koro, Matuku, Moala, Rabi, Rotuma and Vanuabalavu) by Fiji's Department of Energy since 2007. These are dual fuel (diesel/coconut oil) with a capacity of about 170,000 litres of coconut oil each per year. The power systems run mostly on diesel fuel: in 2015, seven operational systems produced under 2,200 litres each per year on average, barely 1% of capacity. Because of low coconut oil output, insignificant diesel fuel savings, significant government investment with minimal return, inconsistent supply of copra, poor coordination between stakeholders and generally high costs, the government is arranging an independent review to decide if the programme should continue.

   Diesel engines with small grids have long been heavily subsidised by the Fiji government and installed in many hundreds of villages. Long term success has been limited with frequent failures, power provided only a few hours a day and a high cost of generation due to the cost of diesel fuel in remote areas. In early 2016 (discussion with Fiji Department of Energy) over a third of about 600 village systems installed were non-functional. In the Pacific, conversion of village scale diesels to solar generation or diesel/diesel hybrids is either underway (Cook Islands, Samoa, Tonga, Fiji, Tuvalu) or is being seriously considered (Yap state in the Federated States of Micronesia, Marshall Islands).

7. **Geothermal and Ocean Energy** – Although Vanuatu has substantial geothermal resources, development of those resources for power generation is generally practical only for relatively large scale development such as the 4-8 MW system being considered for Efate. Although most of the rural population in Vanuatu lives along the coast, wave energy, tidal current energy and ocean thermal energy conversion (OTEC) are not technically proven for small scale power generation and would be at very high risk during cyclones.

3. Pacific Island Experience in Developing and Implementing Off-Grid Rural Electrification Based on Renewable Energy

For the majority of rural households, solar has been and is likely to continue to be the preferred choice as it has both technical and cost advantages over other renewable energy technologies available in rural Vanuatu. Types of solar installations intended for individual households include:

1. **Portable lanterns:** These are essentially an LED (Light Emitting Diode) light, sometimes including a phone charger, packaged with an associated rechargeable battery that can be carried from place to place and recharged by a separate, small solar panel. While they are particularly useful for walking at night around a village or a household compound, in general, the experience with portable lanterns has not been very good as their life has generally been short and their ability to operate reliably in the difficult Pacific Island environment has generally been poor, although many high-quality solar lanterns have also been sold in Vanuatu. Solar lanterns are not considered by

the Department of Energy as rural electrification and will not be proposed for inclusion in the Master Plan.

2. **Pico-solar.** Essentially a small solar home system (SHS), solar-pico-systems (SPS) typically include a fixed solar panel in the 10-20 watt range, a 12V sealed lead-acid battery and several low wattage but high efficiency LED lights. Often a phone charger is also included as part of the package. A fully charged battery can operate the lights for several hours but on cloudy days recovering a full charge may not be possible and lighting times are often substantially reduced until a sunny day can provide for full charge recovery. As noted in chapter 5 of this report, the New Zealand-funded 'Vanuatu Rural Electricity Project' (VREP phase 1) is to provide nearly 20,000 'plug & play' 5-30 watt pico systems to rural households, government posts and community facilities. Pico-solar is not considered as rural electrification and will not be included in the Master Plan.

3. **Battery Charging Stations.** A fairly large central solar station specifically designed for charging deep discharge lead acid batteries can be used to recharge individual batteries brought to the station by rural households. The concept has been tried in several South East Asia countries (Cambodia, Thailand) where carrying batteries on motorcycles for charging from a nearby grid connected village is a common practice. However, the solar charging stations have not been a success and after initial trials only a small percentage of households actually utilised each charging facility. The main reason was that the household cannot predict when the battery will be charged and ready for use. When the weather is cloudy, the charging rate slows to about 20% of the clear sky rate. As a result, customers' batteries may take several days to charge resulting in no household electricity for that period of time. In addition the slow charging causes a long queue of batteries awaiting charging further compounding the time it may take a customer's battery to be charged. In Thailand in the 1990s, over 1000 rural battery charging stations were constructed but customer response was so poor they were dismantled within a few years and the panels converted to SHS use. Battery charging stations are not considered as rural electrification and will not be proposed for inclusion in the Master Plan.

4. **Solar Home Systems**. By far, the majority of homes powered by solar energy in the Pacific Islands are using a solar home system (SHS). Since the first SHS were installed in the early 1980s, well over 10,000 SHS installations have been installed in the Pacific Islands with thousands more committed for future installation. Fiji plans over 3,000 new installations in 2016. The early installations, from about 1983-1992, had serious technical problems including inadequate panel capacity (usually 35Wp-50Wp), control units that did not properly manage battery charging, and batteries that were essentially upgraded car batteries that did not survive more than three or four years. The lessons learned during that first decade of their use were used in the design of the 1992-1994 EU Lomé II solar project that provided SHS for Tuvalu, Tonga and Kiribati. The project included a well-tested and rugged control unit designed specifically for Pacific Island conditions, an industrial grade deep-discharge 12V battery and 110Wp of solar panel capacity. Those installations performed well and their operational life far exceeded that of earlier installations with those in Tonga and Kiribati generally having a battery life in excess of 10 years, a result of both the high quality of the installation itself and the excellent quality of the long term support services that were included in the project design. Installations after 2000 have tended to include 150-200Wp panels totalling thousands of installations in Vanuatu, Tonga and RMI (PREFACE project, JICA project, Taiwan and EU projects). SHS are well suited to households with several small specialised structures in a compound since the energy is sufficient to simultaneously and reliably light several rooms from a single installation as well as provide energy for radio, phone charging and other small appliances such as "CB Radios" that can be used by households for two way communications between family members at home or fishing at sea. At this level of electrification, which is generally considered as true rural electrification, a support system for maintenance is essential and the quality of the maintenance, particularly with regards to battery replacement, becomes the primary determinant for success or failure over the long term.

Institutional Support arrangements for solar home systems

More than 30 years of trial and error experience is available for designing a workable system for sustaining SHS in rural households. Although the great majority of SHS have been provided through grant aid, the cost of maintenance – in particular battery replacement – is significant and generally is expected to be recovered from users through a modest periodic fee. Most analyses of O&M costs for SHS on outer islands have resulted in monthly costs of USD $10-$15, a cost generally less than that for the kerosene and batteries that are replaced by the SHS.

Individual and Community based management. It is clear that community or individual household based maintenance of SHS has not worked in the Pacific. A number of projects have been implemented in the Pacific that provided donor funded SHS and left maintenance to either the individual households or to the communities that were served. Early project failure has been uniformly the result. Examples are the 2002 PREFACE project in Vanuatu and the mid 1990's EU funded SHS project in Vava'u, Tonga. Experience has shown that the two primary reasons for the early failure of these technically satisfactory projects were user abuse (adding appliances that exceeded the delivery ability of the SHS, taking the battery out of the system and using it for night fishing, charging other batteries off the solar and using them externally, etc.) and lack of a system for accumulating the funds needed to replace the battery when it fails. With projects that include either community or individual maintenance, sufficient money for battery replacement has not been collected, accumulated and ultimately used for battery replacements. Although communities have levied charges for the use of the solar with the intent of accumulating a battery replacement fund, they have universally failed because i) people are essentially setting their own fees and invariably charge less than is sufficient to pay the actual maintenance costs; and ii) battery replacements for good quality SHS installations are not likely to be needed before 5 to 7 years pass and sometimes as long as 10 years. Individuals and communities have not managed to keep collecting the money for that long a period nor have they resisted the temptation to spend it on something else before the battery replacement is needed. As a result once the battery fails due to abuse or simply age, there is insufficient money available for its replacement. In the case of the Vava'u SHS project, the project failed in less than five years and the rural households were again without power for over 10 additional years before another donor (JICA) provided new SHS to the islands.

Kiribati's Solar Utility Concept*.* Kiribati was the first to establish a successful system for SHS installation, operation and maintenance. In 1989 the Kiribati Solar Energy Corporation (KSEC) was converted from a sales organisation (which had gone bankrupt) to a government-owned "solar utility" whereby the principles of conventional utility operation were applied to solar electrification. As with a conventional utility, KSEC owned the generation system (solar, charge controller and battery). The end-user owned the wiring and appliances and paid a monthly fee to KSEC for the power supplied to the house from the solar. KSEC hired and trained island-based technicians and maintained additional annual training programmes for at least one KSEC technician/agent on each island. Those agents were required to visit each installation at least once a month to confirm that the users were not abusing the system and to provide any maintenance (battery water, connection cleaning, etc.) needed to keep the system fully operational. In return for the electricity, a monthly fee of AUD $9 (Australian dollars) was charged – much less than the cost of kerosene for comparable hours of lighting. After an initial JICA funded installation of around 120 SHS operated successfully on North Tarawa for several years under the solar utility concept, the EU agreed to fund around 200 additional installations to expand the programme to two more islands. The three-island project operated successfully from 1994 to 2004 with on-time fee collection rates of over 85% and virtually 100% collections within 3 months of the due date. This high rate of collection, comparable to that of a conventional island utility, was due to the high level of user satisfaction that was the result of the frequent maintenance visits that in turn resulted in few power outages and a very long battery life. Unfortunately this success led to the EU agreeing to provide funding for an additional 1,600 home installations spread over all 18 islands of the Gilbert group. This sudden increase from about 325 on three nearby islands to about 2,000 installations spread over 18 islands was too much, too quickly for the KSEC administrative systems. Further, after 1998 the KSEC regularly lobbied government for a fee increase to accommodate the inflation that had occurred since the fee was set in 1992 but the government consistently refused to allow the increase. When there were only 325 installations on three islands, KSEC was able to make up the resulting cash shortfall by carrying out projects for the government and for the private sector but with 2,000 installations and 18 islands to manage, KSEC rapidly lost money and became unable to come up with the funds necessary to replace failed batteries in the older installations. Although the government has agreed to subsidise the KSEC to help cover the cost of replacement batteries, the project and KSEC itself still is in danger of failure due to outer island customers having lost confidence in KSEC's ability to keep services operating and therefore are failing to pay even the $9 fee.

Fiji's Renewable Energy Service Company (RESCO) concept. Early SHS projects in Fiji used community cooperative type management structures that failed within a few years. In the early 2000's, the Fiji Department of Energy (FDoE) wished to sustainably expand solar-based rural electrification and decided on a variant of the Kiribati solar utility concept that was then working well. The concept that evolved was called a Renewable Energy Service Company (RESCO) model with government owning the SHS and in essence renting them to rural households. The FDoE selected a set of components that included a solar pre-payment meter, essentially a device that turned on the power for 30 days when a purchased code number was entered into the meter. Since the initial SHS sites were accessible by road, rather than by training and hiring individual agents in each village, the FDoE contracted with a private company to travel to each village on a fixed schedule and perform maintenance on the systems as needed. Payments were made through the local Post Office. The fee was initially set at F$14.50 (about US$8) per month with F$0.50 going to the Post Office for their services. Though the approach functioned reasonably well for the first few years, when SHS installations were expanded to include outer islands, access to those sites by the maintenance company became difficult and expensive and has caused support problems. Another problem was that the collected fees went directly to the Government and the company doing the maintenance was paid a contracted amount that was not affected by the payment or non-payment of the fees by users. As a result, there was little incentive for the maintenance company to work with customers to get them to pay their arrears. An additional problem was that the South African company manufacturing and supporting the prepayment meters ceased production of the meters. An alternative supplier was found in New Caledonia but there too production and support of the meters ceased and by 2012 they had failed, worsening the problem of fee collection. FDoE ended up substantially subsidising the maintenance of the PV equipment even when the pre-payment meters were working and by the end of 2015 an additional F$0.7-0.8 million was owed by customers for prior services.

Tuvalu's Tuvalu Solar Electric Cooperative (TSEC). In the mid-1980's the Save the Children Foundation (USA) began trials of outer island electrification using SHS. The initial trials failed, partly because the systems were too small at 35Wp to provide the services desired and partly because the households were made responsible for maintenance, an approach that is now known not to work but seemed reasonable at the time. When neighbouring Kiribati established its Solar Energy Company, Save the Children was in the process of shifting their solar programme into local hands and modified the Kiribati solar utility concept to fit a national cooperative structure. The cooperative owned the SHS and hired and trained island agents to maintain the systems and collect fees that were considered sufficient to cover O&M costs. The cooperative was managed by a committee with representatives from each island and government, with oversight by the government. SHS equipment was provided mostly by the EU and installed by the cooperative. Once the installations were complete, the operation of the cooperative was much the same as the KSEC in Kiribati with outer island agents reporting to the central office on Funafuti (the capitol) regarding maintenance and fee collections. Unfortunately, the cooperative manager embezzled around AUD $40,000 from the cooperative leaving it without funds to replace batteries. Though the manger was caught, tried and jailed, the money was not recovered. The TSEC was essentially bankrupt and could not keep the SHS operational. In 2000, the Tuvalu government provided outer island electrification using diesel generators to replace the failing SHS and the TSEC closed down.

Tonga's Outer Island Solar Electrification Programme (TOISEP). The TOISEP has focused on SHS for those islands that are not large enough to justify the installation of a diesel powered grid. SHS installations began in the late 1980s and continues to the present with over 1,000 SHS installed overall. The hardware and designs matured in the mid-1990s and the management system has undergone several upgrades over the 30 year period. The initial management approach was for the Government Energy Unit to own the SHS and ensure that proper maintenance was carried out by local trainees. Battery replacements were expected to be funded through fees charged to the end users. That approach did not work well because of the difficulty and expense involved in accessing all of the islands. In the late 1900s, the solar TOISEP program in the Ha'apai group of islands was turned over to a committee that included national government, the Ha'apai government, and village government members. The committee was made responsible for hiring a renewable energy manager to hire, train and oversee local technicians on each island as well as to maintain a spare parts stock and interface with the oversight committee. The user fees are set by the committee and collected by the trained, island technicians who are required to periodically visit each installation and perform preventive maintenance, such as cleaning wiring connections, adding battery water, ensuring that shade is not encroaching onto the solar panels and helping the end users manage their power usage to best fit the capacity of the solar installation. If the technician does not perform his work well, end users are encouraged to report his poor performance to the village mayor who in turn has direct access to the oversight committee for action. With the recent JICA funded replacement of a failed SHS in the Vava'u group, the Ha'apai management model has been replicated in Vava'u since the multilevel committee approach has worked well over the long term and has resulted in thus far the most successful SHS program in the Pacific Islands. Although the Vava'u group of islands is compact and relatively easy to access, the Ha'apai group is a long volcanic island chain, similar to Vanuatu though smaller, and access is costly. Its electrification problems are similar to those of remote islands in Vanuatu.

***The Republic of the Marshall Islands (RMI) outer island solar program*.** A number of outer island SHS projects, usually focussing on a single atoll, were funded by donors in the 1980s and 1990s but none included a system for adequate maintenance and none could be considered a long term success. That began to turn around in 2000 when the PREFACE project (Australia/France funded) provided 150Wp installations for several islands and the Marshall's Energy Company (MEC), the Majuro based utility, agreed to provide support to the project. The MEC hired and trained one or more local technicians on each atoll receiving SHS and after calculating the O&M cost, set a monthly fee of US$12 for the SHS service. Following PREFACE, Taiwan and EU projects expanded MEC's role to most of the outer islands, installing SHS of between 150 and 200Wp. The projects have resulted in several thousand SHS installations spread over the 29 atolls with over 80% of outer island households now having access to electricity through a SHS. Unfortunately the Nitjela, the RMI legislature, arbitrarily decided that the $12 fee was too high – even though that was generally less than the kerosene and dry batteries that were replaced by the SHS – and required the MEC to drop the fee to $5 with promises to provide subsidies to cover the additional cost of maintenance. With the promised subsidies slow to materialise, the maintenance services to the outer islands have had to be greatly reduced and there are concerns that the available funds will not be enough to replace batteries in the older installations that are expected to fail in the next year or two.

Solar Micro-Grids, Mini-Grids and Solar-Diesel Hybrid Mini Grids

Solar micro-grids and mini-grids. Although there is no specific line separating a micro-grid and a mini-grid, in general a micro-grid is smaller and is assumed to serve a single facility, such as a school or hospital, while a mini-grid typically serves a number of individual households and small businesses in a village. The mini-grid design concept is very similar to a micro-grid but is typically made up of multiple micro-grid type modules that are operated in parallel to increase the level of power availability and overall system reliability. The use of micro-grids for schools and remote government buildings in the Pacific dates from about 2003 with projects by the EU and UNDP electrifying some remote schools with AC distribution instead of the 12V DC lighting and fans installed in schools in earlier years. The use of AC distribution was mainly requested by the countries to make it practical to include computers, audio-visual equipment and, in some cases, the Internet, in their schools. The first village electrification by solar mini-grid went on-line in 2006 to power the 10 household village of Apolima, Samoa. The solar installation completely replaced the existing diesel generation and there is no diesel backup for the solar. That installation has operated reliably with no major maintenance thus far though batteries are ageing and can be expected to require replacement soon. In 2008 two additional 100% solar village installations were constructed on outer islands of Yap State of the Federated States of Micronesia through an EU project. Those installations for the village of Asor and the village of Fadrai both have operated reliably since their installation and both survived the 2015 category 5 cyclone (called a Typhoon in the North Pacific) with no significant damage to either installation.

Solar-Diesel Hybrid Mini Grids. In the rural electrification context, a solar-diesel hybrid is typically a solar mini-grid with an associated diesel engine with generation by solar until the battery charge is depleted and then generation shifts to diesel. Some more complex designs operate the diesel and solar simultaneously but for long term reliability, such installations need well trained operators and good technical support. An example of such a failure is a solar/wind/hybrid installation at Nabouwalu on the island of Vanua Levu in Fiji in the year 2000. Although it initially worked well, the Public Works Department operators who were trained in the operation of the system were soon replaced and problems with the wind system and with the control system tying the three technologies together resulted in its failure after less than five years of operation. Its generation then reverted to 100% diesel operation.

A small solar/diesel system has been operational at the Vaitupu high school in Tuvalu for a number of years but the diesel and solar do not operate simultaneously. In Tokelau, there is nearly a megawatt of solar mini-grids with diesel back-up that has been operating satisfactorily since 2012. Fiji has converted three outer island provincial centre diesel powered grids to solar/diesel hybrids, Tuvalu and the Cook Islands are currently converting outer island diesel systems to solar/diesel hybrids and the

Tonga utility has announced a project to convert all small diesel generation on the outer islands to solar diesel hybrids. It is important to note that all of the diesel/solar hybrid installations to date are being managed and maintained by the same organisation that operated the diesel grid, usually the national utility or (in Fiji) the Public Works Department. Thus far, they have adequately maintained the installations and the solar generation has generally provided better quality and more reliable power than the diesel mini-grids they replaced.

Institutional Arrangements for Micro and Mini Grids. Most of the micro-grids in the Pacific are associated with government facilities, though some eco-tourist facilities have solar mini-grid power (e.g. Fafa Island, Tonga). Typically the facility owner (often the Department of Education or Department of Health) is expected to arrange for system maintenance. The quality of maintenance varies from good to non-existent and of course so does the reliability of the installation. Those facilities that have contracted with the national utility or a local solar company for maintenance have generally had good results but self-maintenance has not worked well.

Lessons Learned in the Pacific Regarding Solar Energy for Rural Electrification

From over 30 years of Pacific experience with solar PV systems, the following lessons have been learned (or in some cases should have been learned):

1. Individual and community maintenance has not worked and cannot be recommended. (Pacific Region)
2. The often quoted concept that there needs to be a financial investment (a portion of the initial capital and installation costs) by the end user or they will not respect the investment has not been demonstrated to be true. Indeed, when the end user owns the system, whether as a gift or as a purchase (as was the case for solar in Kiribati in the 1980's), there has been a history of user abuse and lack of maintenance that has caused short battery life and unreliable power even with good quality end user training. The most successful programmes have had the equipment owned by the government or a 'solar utility' company with no investment by end users other than the appliances that are connected to the power system. Users are charged a fee to cover O&M costs and, if appropriate, to amortise over a 10-15 year period any capital costs that were not covered by a donor or a government subsidy. If the fee is not paid within a reasonable time (often three months in arrears is allowed) power access is cut off. This is the same system that is used for conventional grid based power generation and is proven to work well. (RMI, Kiribati, Tonga, Fiji, Tuvalu, Yap State)
3. Installations must be designed and installed in a manner that will withstand the harsh, often corrosive environment of Vanuatu and the passage of violent storms. (Yap State)
4. Both SHS and mini/micro grids should be modular in design, utilise standardised, well proven components and follow strict standards for their design, installation, operation and maintenance. (Palau, Cook Islands, Tokelau, Tuvalu, Tonga, RMI)
5. To provide rapid repair of rural electrification sites, an easily accessed inventory of spare parts for the standardised systems needs to be maintained in locations easily accessible by technicians from those sites. (Tonga)
6. Hybrid mini-grids that operate 24/7 need a trained operator on duty 24/7. (Nabouwalu, Fiji)
7. Only energy efficient appliances and lights should be allowed for connection to renewable energy installations. (Tokelau, Yap State)
8. Unless disconnects can be made for non-payment, it has been shown that the rate of user payments quickly falls to a level that will not allow sustainability (Fiji, Kiribati, Tuvalu). Prepayment

systems that automatically shut off power if payment is not made can help, but locally hired technicians have been known to bypass the pre-payment meters to benefit friends, relatives and neighbours (Tuvalu, Fiji). Village based technicians should be made clearly responsible to an external organisation, not to village leadership. It is almost impossible for a technician who is responsible to his/her own village leadership to disconnect customers who fail to pay for an extended time. However, if they are officially responsible to an external organisation for their work (and their pay), bypassing meters or not disconnecting households for non-payment may result in the loss of their job and public disgrace. This seems to be understood by the village and the technicians have been able to disconnect as needed. (Kiribati)

9. Oversizing the panels in SHS installations as much as 30% over the size needed for their expected load has been found to be cost effective. The better quality of service that results, especially in cloudy weather, and higher system reliability improves customer satisfaction and in those projects where systems are somewhat oversized, much less abuse and customer tinkering has been seen with those systems than with installations that are marginal in size. With panel prices less than USD $1.00 per Wp, adding 30 Wp to a 100Wp SHS is an excellent investment for remote installations. (RMI, Kiribati, Tuvalu, Palau)

10. For remote sites, the cost of replacing components is very high and only high quality, well proven and reliable components should be used. For the most economic operation of both SHS and micro/mini-grid systems battery sizing that provides at least 5 days of autonomy (a 20% average, daily battery discharge level) has been found to be the minimum with an automatic disconnect that cuts off power when the charge level falls below 50%. (Kiribati)

11. Replacement of batteries in remote sites can end up more than double the cost of the replacement battery itself due to high import duties and the transport costs, both to take in the new battery and to take out the old one for recycling. Therefore it is usually cost effective to use very high quality, industrial grade deep discharge batteries in order to reduce the frequency of battery replacements. (Yap State, Kiribati, Solomon Islands)

12. Open cell lead-acid batteries are longer in life and lower in cost than comparable quality sealed batteries. But they require adding distilled or properly collected rain-water to the cells about once every two months for SHS batteries and every six months for mini-grid batteries. If there is no externally managed maintenance, water replacement is rarely done properly and the life of the batteries is seriously shortened. In that case sealed batteries are a better economic choice. (RMI)

13. Repetitive training of local technicians, preferably at least annually, has been found to be important to attain and keep a high level of maintenance quality. (Kiribati).

14. For good quality maintenance with well-trained local technicians to be cost effective for a solar utility, around 75 electricity customers (SHS and/or mini-grid) per island appears to be around the minimum with around 125 customers the maximum that can be reasonably maintained by one technician. (Kiribati). For smaller customer bases, periodic visits by external technicians and high quality installations that use somewhat oversized pole mounted panels with a sealed battery and controller in an outdoor, weatherproof enclosure appear to be the best approach (RMI).

15. Newly elected governments are often unaware of the ongoing costs. Informal discussions with high level government officials (especially members of the parliament, ministers and staff of the head of government) should be held after each change of government to help them understand that, although renewable energy sources are free and donors may donate equipment for free, there is a real and substantial on-going cost for maintenance, particularly the large periodic cost of battery replacements. The need to recover these costs from end users should be explained so there are sufficient funds to sustain the installations for the long term. Explain that those costs are generally less than the cost of using petroleum fuel and batteries for rural lighting and small appliances. If those costs are not met, the renewable energy systems will fail and rural households

will have to return to more expensive kerosene lights and dry batteries and an inferior service. (Many PICs)

16. Finally, Governments should work closely with donors that wish to sponsor the expansion of renewable energy based rural electrification to make sure that the proposed equipment is appropriate, fits the needs of the recipients, and can be maintained satisfactorily through local resources. If standards are in force for the type of installation to be used, donors should be strongly encouraged, and preferably required, to provide materials and designs that meet those standards. Expanding coverage through new installations should be staged over time so that the national management system can gradually adapt to the increased responsibilities that additional installations and new locations for equipment will entail. (Kiribati, others)

A recent critical review of mini-grids (UN Foundation, 2014) is largely based on south Asian experience, with only one island case study (Haiti) but its conclusions – and those of other reviews – are broadly consistent with the lessons learned from PIC experience.

1. Electricity demand is extremely hard to predict, especially in a village that has never had access to electricity. It is best to look at similar villages as a starting point. (For Vanuatu this could be users in Malekula or Tanna, though their consumption is likely to be higher than the target islands.)
2. The case studies do not support the notion that income-generating activities will necessarily lead to high revenues, or that they are necessary at all for fully recovering operating costs. Furthermore, developing income-generating activities is no simple task. Electricity is not necessarily linked in the minds of villagers to productive activities – mainly lighting, mobile phones and entertainment appliances.
3. Community cohesiveness varies drastically, and developers were often disappointed by a community's inability to work together to keep the system running due to conflicts, lack of motivation, or other reasons. The strength and cohesion of the community, generally due to strong village leadership, was the greatest determinant of success of the system.
4. The institution responsible for maintenance must be monitored and feedback provided by the monitoring agency as to actions to be taken. An inadequate maintenance contractor, and long-term maintenance contracts without adequate performance incentives, along with infrequent interactions with villagers partly explain why many micro-grids fall into and stay in a state of disrepair."
5. A key to success is tariff and penalty design. Having an independent and/or paid user fee collector usually increases the likelihood of payment collection, as does clearly defining and strictly enforcing penalties.
6. A fixed monthly fee allowing unlimited energy use within the customer's load limit works best for systems that provide lighting and mobile phone charging only.
7. Firm but flexible payment rules are important. A successful approach has been monthly collection with flexibility allowing for non-payment of up to three months Strictly enforced penalties and shutting off service to non-paying customers soon after a violation occurs tend to maintain high collection rates and a higher quality of service.
8. Most tariffs were in some way power-based, and require some mechanism for restricting customer demand, such as over-use penalties, efficient appliances and load limiters. These are, effectively demand-side management measures.

4. VANUATU'S ENERGY SECTOR INSTITUTIONAL ARRANGEMENTS, LEGISLATION AND REGULATIONS RELEVANT TO REMOTE ISLAND ELECTRIFICATION

The institutional and legal framework relevant to remote island electrification is summarised below and illustrated in Figure 4.1.

- ***Department of Energy***. A new Ministry for Climate Change and Natural Disasters (MCC) was established in 2013 including the Department of Energy (DoE), the Department of Environment and Conservation (DEC), the Project Management Unit (PMU) and others. The DoE has responsibility for energy sector planning and administration and has long had a key role in assessing rural energy resources, identifying rural energy supply projects, and developing and implementing these projects, nearly always donor-funded. The PMU works closely with DoE in developing project proposals and managing donor funds as it has the authority to act as Financial Management Agent for externally funded programmes and projects on behalf of the ministry. Considering its mandate, the DoE is small and under-resourced financially. In 2015 (GoV/NAB, 2015) it had only six professional staff (Director, Program manager, On-grid electrification officer, Off-grid electrification officer, Energy efficiency & conservation officer, petroleum officer), two support staff (Finance & procurement, administrative assistant) and three project staff on temporary contracts. The off-grid position is currently unfilled as the incumbent was promoted to Acting Director in early 2016.
- ***The Utilities Regulatory Authority***. The Utilities Regulatory Authority (URA), established in 2008, provides oversight for electricity supply in 'concession' supply areas (currently held by UNELCO and VUI), is responsible for provision by utilities of safe, reliable and affordable electricity (and water) services, deals with consumer complaints and advises the government on matters related to electricity. It also reviews and sets the maximum level of retail tariff for each concession, with provision for binding arbitration in the vent of disagreements.
- ***Other Ministries***. The Ministry of Infrastructure and Public Utilities (MIPU) is responsible for all the public infrastructure of the government and the Ministries of Education and Health have been involved providing small solar PV systems for remote schools and health centres. The ministry of Finance will be involved in any arrangements for financing remote energy systems.
- ***The power utilities***. Neither UNELCO nor VUI currently work outside the concession areas of the four islands indicated. However, they each manage (or soon will manage) coconut-oil based biofuel generation systems near their grids under GoV contracts. In principle they could manage remote island RE-based electricity supply systems under similar contracts, although costs are likely to be high.
- ***NGOs and private sector service providers***. Several local and regional NGOs have been involved in implementing remote energy projects (e.g. VANREPA, IUCN, ACTIV), and some could have a role in providing equipment and/or managing RE systems. This is also true of local companies. About 5 years ago, a now-discontinued Australian assistance programme (Vanuatu Electrification for Rural Development or VERD) identified eleven potential Renewable Energy Service Companies (RESCOs) that could be involved in remote electrification: Cloud Zero Power Supplies, Energy 4 All, GreenTech, Jem Solar, Pacific Power Products, Solar Communication, VanGlobal, VANREPA, Vanuatu Son Solar, Vate Electrics, and White Sand Engineering. At the time, these had an average of five employees each and were all headquartered in Port Vila. VANREPA is apparently now inactive but some of the others are still operating.

Legislation and regulations governing the oversight of the electricity sector include the following:

- **The Electricity Supply Act** [Cap 65] governs the granting of concessions, with the Minister of Infrastructure and Public Utilities responsible for monitoring performance and addressing access to private land. The Act permits independent power producers (IPPs) to generate electricity and supply it outside the concession areas, or to the concession grids although concessionaires are not obliged to purchase power. There is also no framework for Independent Power Producers (IPPs) to access existing networks and for the concessionaires to pass through costs incurred under Power Purchase Agreements (PPAs) with the IPPs.

- **The Utilities Regulatory Authority Act** (URA Act of 2007; amended in 2010 and 2013) established the URA. URA has developed guidelines and issued a Commission Order regarding the implementation of feed-in tariffs and net metering for renewable energy, but thus far only in Port Vila (July 2014). These apply to small-scale installations like solar generators on residential rooftops, and larger-scale Independent Power Producers (IPPs) that operate under a Power Purchase Agreement (PPA) with the utilities. The URA could (and should) establish regulations for licensing service providers. As noted in a recent Renewables Readiness Assessment for Vanuatu (IRENA, 2015), "In future … diesel mini-grids may be converted to solar power. The proliferation of many different types of designs for these mini-utilities would make maintenance costly, as it must then be tied to the company that sold and installed the equipment. To avoid this problem, technical standards and design guidelines for mini-grids, particularly those powered by solar, may need to be created and enforced. This will help ensure the installations are consistent in design, and thereby also in maintenance, and will use components known to function satisfactorily and reliably in the Vanuatu environment. Furthermore, standards and guidelines of this kind help training institutions focus maintenance training on common design approaches across Vanuatu. This would make maintenance less costly and more readily available." RRA may establish conditions for provision of rural water supply (e.g. outside of concession areas) and could presumably do the same for electricity, for example establishing guidelines and rules for Renewable Energy Service Providers (RESCOs). According to one study (BizClim/EU, 2012) URA has the power to set tariffs and standards for rural electrification, although it has not done so. However, there have been discussions between the DoE and the URA regarding the development of a joint DoE-URA mechanism for establishing tariffs for a planned solar PV system to be established by GIZ under the EU-GIZ 'Adaptation to Climate Change and Sustainable Energy programme' (ACSE), which is currently being designed. The RESCO concept and mechanisms for establishing tariffs for off-grid remote electricity supply are relevant to this project and will be discussed with the URA, as will the status of the PPA/IPP guidelines.
- **The Environment Management and Conservation Act** (2010) requires most developments to carry out an environmental assessment. Order Number 102 under the Act (2013) establishes procedures for a Preliminary Environmental Impact Assessment (PEIA) of any project, proposal or development activity. The PEIA is an assessment that indicates whether or not the development requires a full EIA prior to development. If, following a determination by the Department of Environment and Conservation (DEC), the project requires full EIA then ToR are provided by the DEC and the EIA Review Committee for discussion with the project proponent. Public engagement and landowner consultation is required and the EIA must be carried out by a consultant registered with DEC. From the text of the Act it is not clear whether small-scale rural electrification/access to energy projects must carry out a full EIA or whether a Preliminary EIA is sufficient. The Act lists (clause 12) a number of environmental impacts (water resources, air quality, unsustainable use of renewable resources), which require an EIA. In many cases, small-scale rural electrification projects will have no appreciable negative impact on the environment and a PEIA should suffice.

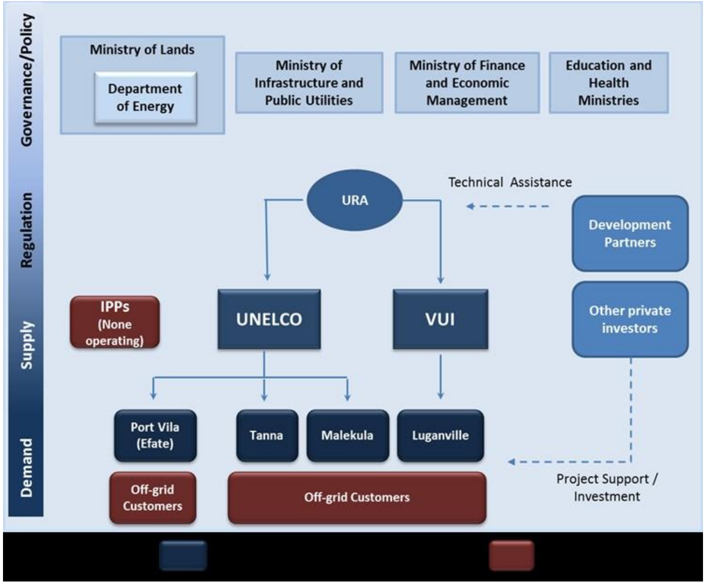


Figure 4.1: Overview of Electricity Supply Stakeholders
Source: Figure 2.8 of Vanuatu's NERM: 2013-2020 (GoV, 2013)
(The DoE has since come under the Ministry of Climate Change)

5. Current or Proposed Activities Relevant to this Study

The *National Energy Roadmap: 2013-2020* or NERM (GoV, 2013) is the framework for Vanuatu's energy sector development and was endorsed by the Council of Ministers (Cabinet) in early 2014. The NERM identified five priority areas: access, petroleum supply, affordability, energy security, and climate change with specific objectives, targets and actions within each area. According to a draft *Updated Vanuatu National Energy Road Map: 2016-2030* (GoV, 2016), for peri-urban households in or near electricity supply concession areas, the target for electricity access by 2015 (69%) has nearly been met (63% achieved). For both on and off grid public institutions, such as schools and health centres, the goal was 90% but only 54% access has been attained. For off-grid areas, there has been essentially no progress. The goal was 55% by the end of 2015 with only 9% achieved, a slight decrease from 10% several years ago because of an increase in the number of households in off-grid areas. The overall national goal for electricity production from renewable resources was 40% by 2015 but 29% was achieved using a mix of coconut oil, hydro and wind energy.

About 83% of rural households do not have electricity services compared to 20% of urban households. The NERM goal of 100% access to electricity in rural off-grid areas by 2020 seems highly likely to be delayed until 2030. Even so, a substantially enhanced effort will be required to meet the goal. Considering firm financial commitments, the draft NERM Update expects off-grid access to be no more than 30% of households by 2030.

Table 5.1 below indicates ongoing and proposed activities to increase rural access to electricity in areas with no grid access.

Table 5.1: Ongoing and Proposed Actions to Increase Rural Energy Access in Off-Grid Areas

Investment or action	**Priority**	**Status**	**Funding source**
Rural Biofuel Project (Ambae, Vanua Lava)	Immediate	underway	EU/GoV
Solar & biogas community RE project	Immediate	being designed	GEU-GIZ ACSE
Vanuatu Rural Electricity Project (VREP) Phase 1 plug & play solar PV for off-grid households & public facilities	Immediate	Underway from 2014	NZMFAT (via WB)
Talise Hydro Project, Maewo (Phase 2—installing distribution lines)	Immediate	underway?	?
Whitesands solar PV micro-grid, Tanna	Highest	proposed	
National Green Energy Fund to support investments in renewables-based electricity access & energy efficiency, especially in rural areas	Highest	In draft	GGGI
Vanuatu Rural Electricity Project (VREP) Phase 2 (solar home systems; mini PV grids	Highest	proposed	?
Reform import duties, tariffs and VAT to encourage imports of renewable energy equipment (solar PV, wind, biomass) and spare parts.	Highest	proposed	GoV
Develop an electrification plan for renewable energy in remote islands (this study)	Immediate	from 3/2016	GIZ
Commission a national study on biomass resource and use in Vanuatu, and develop a national biomass strategy (with Departments of Forestry and Agriculture)	Highest	proposed	?
Explore mini-grid RE systems in communities with potential to develop agriculture, fisheries, and/or tourism businesses	Highest	proposed	?
Encourage systematic implementation of standalone RE systems within communities with strong governance, track record of maintaining infrastructure, and well-established community plans linked to provincial and national plans; not prioritising implementation of standalone RE energy projects in communities likely to have problems maintaining systems in the future	Highest	proposed	?

Source: Adapted & revised from Table 0.1 of *Updated Vanuatu National Energy Road Map: 2016-2030* (draft, March 2016)

In addition, the International Finance Corporation (IFC) is undertaking a 'Regulatory Assessment for Pacific Renewable Energy for Pacific Island Countries' during 2016. However, this is primarily to develop bankable renewable energy projects for the commercial and industrial sector, and is unlikely to directly address access in off-grid areas.

Arguably, the above table quite substantially overestimates the extent of likely rural electrification (in off-grid areas) considering the funding already committed. For example, the New Zealand Aid/Pacific Region Infrastructure Facility *Vanuatu Rural Electrification Project* (VREP phase 1) plans to electrify 17,500 rural households, 230 aid posts and 2,000 community buildings, using subsidised individual 'plug and play' solar PV systems of 5-30 peak watts (Wp). The goal is to reach 85% of off-grid households. These pico-solar systems provide lighting and mobile phone charging but do not constitute electrification as defined for this project. A VREP Phase II, which is yet to be funded, is proposed for developing and implementing larger solar home systems (SHS) and rural micro-mini-grids, which are more costly, and will require some form of maintenance and user fees to be sustainable, but will provide a real, if basic, electrification service.

In brief:

- Under current plans and confirmed funding, Vanuatu will come nowhere near achieving 100% electrification in off-grid areas by 2030;
- Even the 30% access projected under the revised (but still draft) NERM Update includes a large percentage of small 5-30 wp pico PV systems which don't really constitute electrification; and
- The planned and proposed high priority activities appear to exclude any substantive institutional development necessary for wide-scale electrification of off-grid communities and households.

The initial NERM of 2013 argued that "Continuing with past policies and investment strategies will not achieve what the Government and people of Vanuatu expect from the energy sector. Historically, the Government has pursued fragmented policies to develop the energy sector and has largely been content to respond to individual project proposals from development partners and private investors. This approach has failed to realize efficiencies across the sector, and is unlikely to unlock all sources of available financing to achieve sector goals." This remains the case for off-grid electrification. A break from the past is needed to build the type of energy sector that Vanuatu aims to achieve.

6. RECENT GOVERNMENT STUDIES AND POLICIES RELEVANT TO OFF-GRID ELECTRIFICATION

Various studies and strategic plans have been developed, or are being prepared, which include recommendations, objectives and/or actions relevant for off-grid electrification.

The NAMA report. The *Nationally-Appropriate Mitigation Action Design Document: Rural Electrification in Vanuatu* report (GoV/NAB, 2015) notes that "outside the UNELCO and VUI concession areas, a coordinated public system to provide off-grid electricity is completely lacking. Communities are small, remote, and widely dispersed, and the low population density drives up both the capital cost of off-grid electricity installation, and the costs of on-going maintenance." The GoV report recommends a national renewable energy based off-grid electrification effort. The NAMA accepts the NERM (2013 version) targets of "100% electrification for "Off-grid" households through micro-grids and individual solutions (Solar Home Systems)."

The NAMA report proposed five mini-grids (Table 6.1), each to supply electricity from solar photovoltaics (PV) to a single village (or two contiguous villages) and nearby facilities through a 230 VAC distribution network. The investment cost was estimated at about US$1.8 million for an installed PV capacity of 174 kW (peak) including diesel backup costs, providing electricity for 1,509 people in 298 households in six communities on five remote islands plus electricity service for nearby facilities such as health centres and schools. The cost is about US$6,100/household ($1,200/capita) with an installed PV capacity of 115 watts/capita. Estimated consumption was 69 kWh/household/month, varying somewhat by community depending on the other facilities connected. The design and component specifications were to be "based on proven cyclone-resilient power systems used in other Pacific Island energy projects, but modified for Vanuatu conditions as/if required. These five communities were selected as priorities based on alignment with the NERM and the Government's Priorities and Action Agenda (PAA), sufficient household density to make the investments economically feasible, expressed interests of local governments in supporting the implementation, potential for income generating activities, and equitable distribution among different islands. During the detailed project design, feasibility assessments of the sites were to be carried out."

Table 6.1: NAMA Off-grid electrification proposal: Five PV Mini-Grids* for Six Villages

Province	Tafea	Tafea	Malampa	Penama	Tafea
Island	Tanna	Tanna	Malekula	Pentecost	Aniwa
Village	Ipikel	Ipkangien	Unmet & Uri	Loltong	Ikaukau
Population	358	127	662	237	125
Households	61	27	130	51	29
Installed capacity (kW peak)	34.5	22.2	62.1	28.5	26.7
Consumption (est) (MWh/year)	49	31	88	40	38
Investment (est) (US$ millions)	0.363	0.234	0.653	0.300	0.280
* The NAMA described these as micro-grids but village grids are usually considered 'mini'					

In 2015, UNDP Bangkok worked with the DoE to develop, and expand, the NAMA mini-grid recommendations as part of a proposed submission to the Green Climate Fund (GCF). A draft GCF proposal expanded the project to include an additional seven PV-based mini-grids for 36 villages in seven islands (including Aneityum). However, the proposal was never completed, although there have reportedly been tentative discussions to reconsider it (discussion with T Jensen, UNDP, March 2016). If so, the team will liaise with UNDP to stress the desirability of common standards.

INDC report. The *Intended Nationally-Determined Contribution* report (INDC; GoV, 2015) prepared for the UN Framework Convention on Climate Change (UNFCCC), is a commitment (voluntary, not legally binding) to substantially reduce Vanuatu's energy sector greenhouse gas (GHG) emissions, much of this by increasing the share of electricity from renewable sources. Based in part on the *NERM: 2013-2020* goals, it sets a 2030 target of reducing business-as-usual GHG emissions from electricity by 100% and the energy sector as a whole by 30% "conditional, depending on funding commensurate with putting the transition in place being made available from external sources."

Renewables Readiness Assessment. The *Vanuatu Renewables Readiness Assessment* (GoV/IRENA, 2015) assesses the opportunities for greater use of renewable energy, and recommends strategies and actions to facilitate this. It concludes that "for off-grid renewable energy systems, sustainable operations pose perhaps the biggest challenge." The RRA recommends a number of actions which are necessary for wide-spread RE implementation. These include the following:

- Review enabling legislation and policies that relate to the powers and duties of the URA and DoE, particularly for standard designs and institutional oversight of off-grid SHS and solar mini-grid installations;
- Design and implement an institutional approach for sustaining micro/mini-grid electrification of residences and public buildings;
- Develop standard modular designs for solar mini-grids, with various-sized installations using the same components to help ensure that end-users receive installations sized to meet their needs and allows maintenance at the lowest cost possible. The design should include a specified set of panels, batteries, charge controllers, and inverters, with components selected as appropriate for

use in Vanuatu. Development partners and private investors should be required to meet these standards;

- Enhance the capacity for sustaining micro/mini grid solar technology, with courses at local institutions for PV installers and maintenance personnel;
- Develop a strategy for increasing access to electricity in rural areas in a programmatic and rational manner, working closely with the World Bank and others;
- Conduct a market study for micro-grids for remote tourism facilities, in conjunction with tourism authorities; and
- Develop financial mechanisms for increasing private investment in renewable energy and energy efficiency. Once the technical and institutional aspects for development of private investment in renewables are addressed, then access to finance will be necessary to support the heavy front-loaded investment needed for installing the equipment.

National Green Energy Fund. A draft report has been prepared (Castalia, 2016) with options and recommendations for a National Green Energy Fund (NGEF) for supporting green energy investments at various scales, including remote renewables-based off-grid power. The report considers sources of funding, management of the fund, ensuring maximum impact, etc. As the NGEF report has yet to be finalised, or the concept endorsed by the GoV, it is premature to consider its potential impact on off-grid electrification. However, this study team will discuss the report and its status with the DoE and, to the extent practical, consider its effect on project finance.

New national plan. The *National Strategic Development Plan* (currently being finalised by the Office of the Prime Minister) will establish GoV objectives for social, environmental, and economic development over the next 15 years. It will include objectives related to access to reliable and affordable energy that increasingly comes from renewable sources, environmentally-responsible economic growth, and sustainable natural resource management.

***Climate Change strategy*.** The *Vanuatu Climate Change and Disaster Risk Reduction Strategy 2016-2030* (GoV/SPC, 2015) focuses on resilient development in the context of external events such as climate change and natural disasters. It recognises the importance of developing energy infrastructure that is highly resilient to climate change and disasters, including the need to develop appropriate standards.

7. Overview of the Selected Target Islands

The target islands selected by the DoE and GIZ for assessment are Emae, Makira and Mataso in the Shepard group of Shefa Province north of Efate (Figure 7.1) where the capital Port Vila is located, and Aneityum – sometimes called Anatom – in Tafea Province to the far south (Figure 7.2). A map of Vanuatu showing the locations of these islands is shown on page iv. Satellite images of the four islands are attached as Annex 3. (More detailed images will be in the final report.)

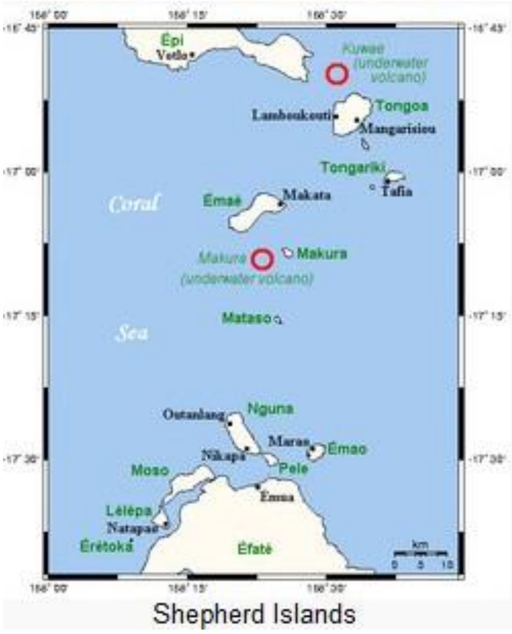


Figure 7.1: Location of Emae, Makira & Mataso

Figure 7.2: Location of Aneityum (southernmost island of Tafea province)

As shown in Table x, Makira and Mataso are very small, with about 100 people or less mostly living in a single village and with land areas under 2 km^2. They are south of Emae with a population of over 700 people living in about six villages mainly in the northern half of the island. Aneityum is by far the largest of the four, with populations scattered along the coast but concentrated in the southwest. Although most ni-Vanuatu are Melanesian, the people of the islands to be visited are Polynesian.

Table 7.1: Overview of the Selected Islands

Island	Population (Census)		AAGR:	Area	Comments
	1999	2009	1999-2009	km^2	
Emae	850	743	-1.34%	33.2	About 6 scattered villages, mostly in North and Northeast
Makira	132	106	-2.17%	1.79	One village: Malakof
Mataso	101	74	-3.06%	1.55	One village: SE part of main island
Aneityum	821	915	+1.09%	160.48	Most population in SW coast near airport; scattered population along North coast

Note: Populations at time of 1999 & 2009 Census (11 November)
Source: www.citypopulation.de AAGR = average annual growth rate of population

Emae has an airstrip but is not well developed. Travel between villages is reportedly mainly on foot along a coastal road and by coastal boats. There are no visitor's facilities except one small traditional-style bungalow near the airstrip. Makira and Mataso are reached by boat from Emae. Literature searches and discussions have provided no information on energy resources or electricity generation for any of those islands.

In Aneityum, an EU-funded project approved about 2008 was meant to provide electricity to one community, Anelcahuat, from six small wind generators. The project was managed by a local NGO, the Vanuatu Renewable Energy Power Association (VANREPA). A monitoring report (EU, 2009) reported that "a powerhouse will deliver alternating low tension current (AC) to institutions (schools, dispensaries, etc.) through small grids, and will allow households to recharge their DC lighting kits (to be supplied to each house) on the battery banks charged by the wind systems." A VANREPA report (UNDP, 2012) refers to 2008 study carried out for Aneityum on community-based renewable energy, and a planned 2013 follow-up to prepare a community profile, assess community interest in the RE project and its basic suitability, gather information regarding local energy needs; assess local capacity; and assess the energy potential of the geographic location. The DoE (communication with Leo Moli, 4 April 2014) is aware of the 2008 study carried out under the EU project, but has no copy. It appears that the 2013 survey may not have been carried out. According to Mr Dick Matenekea of the Area Council (as reported in the Daily Post, 31 August 2013), wind turbines were installed but "did not provide service for long on the island as winds damaged it and the structure was dismantled and stored at the local school compound." As the island is generally very sunny, VANREPA apparently decided to switch from wind to solar photovoltaics (PV), and purchased some PV equipment, but the project was cancelled by the EU.

In 2015, the DoE worked with UNDP Bangkok on a draft proposal to the Green Climate Fund (see chapter 6). Although the proposal was never finalised, it tentatively included a PV mini-grid for Anelkauhat, covering 404 people in about 85 households. DoE provided a map (Figure 7.3) for the abandoned proposal, which shows village and school locations:

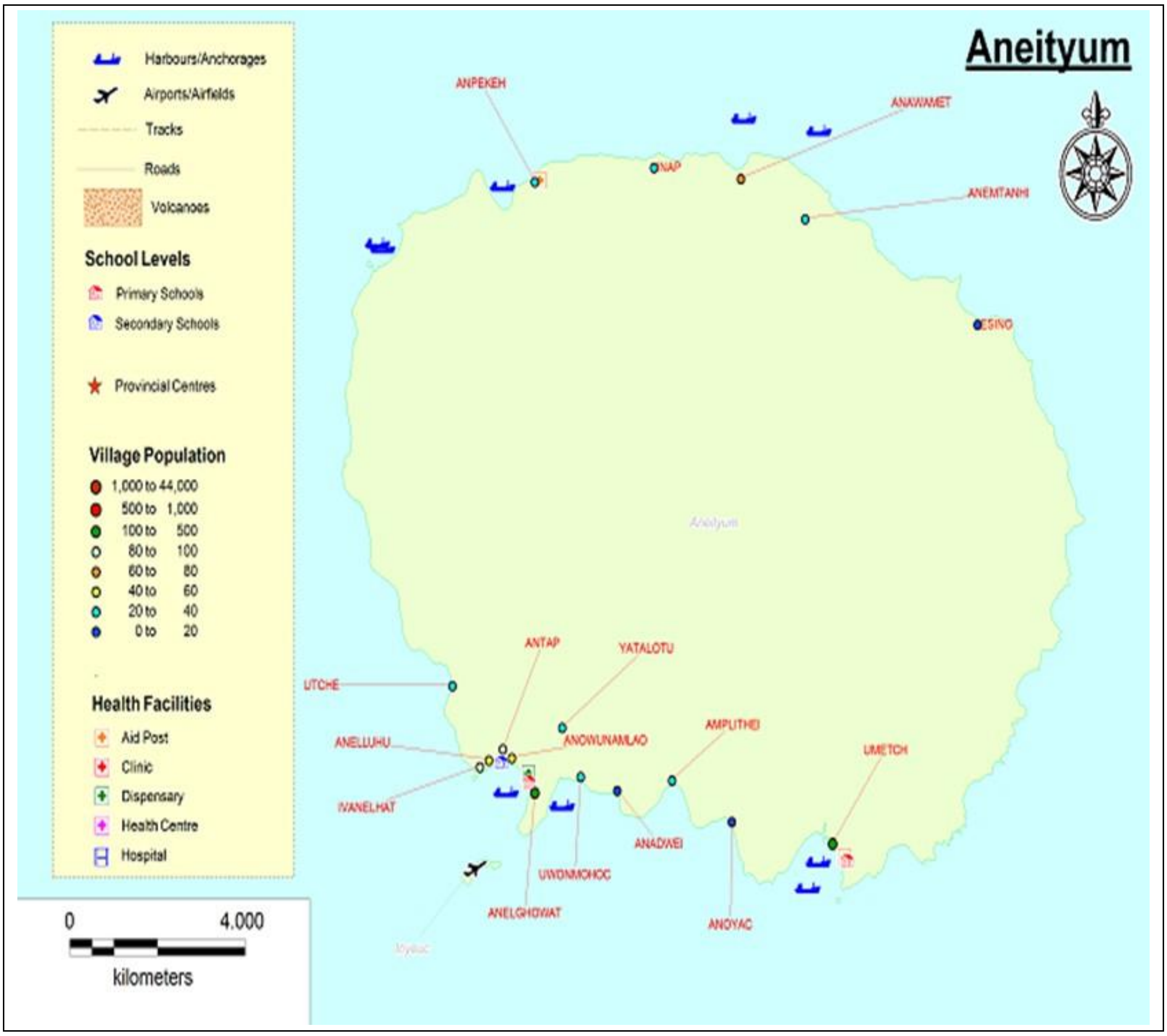


Figure 7.3: Aneityum island communities and facilities

Renewable energy resource data. Very little data have so far been found on energy resources for the islands. There is no historical data on wind or sunshine hours available online from the Vanuatu Meteorological Service (http://www.meteo.gov.vu/HomeClimate/tabid/147/Default.aspx) but some older charts were found. NASA satellite data provides an indication of solar and wind availability for the general oceanic area of the islands and can be used as the basis for rough mini-grid and SHS designs, though it is likely that the conditions on the islands include less solar and wind resources than are available in the surrounding ocean. Annex 6 provides sunshine hours for Tanna, north of Aneityum, indicating an 18 year average of 5.62 hours per day from 1981-1998. Bauerfield on Efate (probably the closest site to Emae with long-term weather data) has slightly less sunshine, at 5.48 hours per day. Unfortunately the correlation between sunshine hours and solar energy availability is weak so it cannot be reliably used for solar design purposes, though it does indicate a generally good solar resource.

Communications. One option for payment of user fees for rural electrification is through mobile phones. A poverty analysis (VNSO 2013) estimated that in 2010, 82% of all rural households had mobile phones, and this has no doubt increased considerably since then. The Digicel website, accessed on 4 April 2016 (http://www.digicelvanuatu.com/assets/uploads/VTU_map.jpg) suggests (Figure 7.4) that Emae and nearby islands are covered. According to Telecom Vanuatu Ltd, "TVL has extended its network coverage within the archipelago covering Banks, Mota Lava, Vanua Lava, Port Olry, Big Bay, Thion, North Maewo, Gaua, Paama, Epi, South East Malekula, Pentecost, Ambrym, East and West Erromango, East and West Tanna including **Aneityum** and Futuna" (http://www.tvl.vu/en/mobile/coverage/) also accessed on 4 April 2016. The coverage, and quality of coverage, will be verified and discussions held with TVL and Digicel regarding how their systems can be used for payment of electrical services.

Figure 7.4: Digicel Mobile Coverage

8. INCOME AND EXPENDITURE IN RURAL VANUATU

Before results are available from surveys to be carried out in April-May 2016 in the four islands on ability and willingness to pay for electricity, there is very little information available for preliminary estimates.

The most recent information on household cash expenditure patterns in Vanuatu is for 2012 (VNSO, August 2013) when households spent 54,700 vatu (US$ 590.90)[1] on average per month. 76% of the total was for food (41%), housing (19%) and transport (16%), leaving one-quarter for all other household expenses. Communication, education and transfers were around 5% each. Rice and kava were the most popular items bought in the household food and drinks category, accounting for one-third of total expenditure on food and drinks. Outside of these three broad categories, school fees and cell phone top-ups were the two largest single expenditure items, accounting for 40% of all other expenditure. Cash expenditure for energy accounted for 3,020 vatu/month on average, of which

[1] Based on June 2012 exchange rate of 92.57 vatu/US$ from www.exchnagerate.com

electricity charges were 1,780, LPG 490, liquid fuels 470 and solid fuels (wood, charcoal) 290. One in three households were grid-connected, incurring an average of monthly electricity bill of 5,500 vatu (US$59.41). Unfortunately, the report did not provide urban-rural disaggregation or expenditures by province or island.

The *Vanuatu Household Income Expenditure Survey Report 2010* (HIES, VNSO 2012) based on a sample of 10% of the population, and an analysis of poverty based on HIES data (VNSO 2013) provides the most recent data on incomes and expenditures for rural Vanuatu. Results (Table 8.1) are available at provincial level, but not for specific islands.

Table 8.1: Income and Expenditure: Vanuatu 2010

Key results	Vanuatu overall	Rural overall	Rural Shefa	Rural Tafea
Household monthly income (average)	83,800	79,500	131,800	53,500
% of income from cash [1)]	68%	59%	81%	30%
Household monthly expenditure (average)	76,200	69,300	86,300	65,100
% of expenditure by cash [2)]	36%	30%	38%	23%
Household monthly cash income (rounded off)	57,000	46,900	106,800	16,100
Household monthly cash expenditure (rounded off)	27,400	20,800	32,800	14,973
% of households with wage or salary income	36%	20%	42%	7%
% of households with other cash income	20%	19%	33%	22%

1) Excludes subsistence income & gifts of goods received. 2) Excludes subsistence consumption & gifts.
Shefa province includes Makira, Emae and Mataso; Tafea includes Aneityum.

As shown, the bulk of income and expenditure throughout the country in 2010 was the imputed value of subsistence activities. Unfortunately, for cash income and expenditure, rural Shefa province is not indicative of Emae, Makira and Mataso islands as it includes rural Efate where there is considerable rural cash employment in government, the private sector, farming and the tourism industry and other relatively large islands. Similarly, Tafea is not indicative of Aneityum Island, as Tafea includes Tanna, with a reasonably well-developed tourism industry and income from coffee growing. Even at a provincial level, the data provide little guidance on discretionary cash expenditure and the data are six years old. Nonetheless there is a bit of useful information from the HIES:

- Assuming that rural Vanuatu overall is more representative of Makira, Emae and Mataso than rural Shefa, under 20% of households in 2010 had some wage and salary income and about 20% (some of whom would be the same households) had other cash income. Aneityum households may have less cash income than Tafea in general (as there is considerably more tourism in Tanna). Possibly 7% or less had wage and salary income and about 20% other cash income. This might suggest limited ability of many households in the selected islands to be able to pay, or pay much, for electricity services.
- In Tafea, cash expenditures are (or were in 2010) almost the same as cash incomes so there may be limited discretionary income.
- 45% of all rural households relied on kerosene or candles for lighting which suggests a possible area of cash savings if electric lighting is used. However, It is estimated that over 55,000 solar lanterns were distributed in Vanuatu between 2010 and 2013 (DFAT, 2014) and many thousands have been provided since then, particularly after Cyclone Pam in early 2015. Kerosene and battery expenditures may therefore already be low.

- In 2010, in all rural areas except rural Shefa, over three-quarters of household income was derived from household subsistence activities and the sale of agricultural, forestry and fisheries produce and other home-produced items like bread, processed kava etc. There could be scope for increasing income from such activities after electrical services are introduced, although evidence on energy systems for cooling and storing fish from other Pacific Islands (and elsewhere) suggests that this is unlikely.

9. Technical Concepts Appropriate for Remote Island RE Electrification in Vanuatu

Based on the material from the earlier sections of this Inception Report, what has worked and failed elsewhere in the region, and our understanding of the situation in Vanuatu, the following approach is likely to be recommended for Vanuatu:

- Solar PV as the most appropriate option (technically, economically) for electrifying most communities and for the provision of electricity for stand-alone household and community facilities;
- Depending on the local context, other RE technologies will be considered. PV/diesel hybrids may be alternatives for larger communities (although Pacific experience suggests that these may become diesel-only over time). Small wind electric systems or wind/PV hybrids might be alternatives in especially favourable sites (although the limited experience in the Pacific with small, rural wind systems has been generally poor). Some islands have a reasonable coconut resource and coconut oil based biofuels may be an alternative (but it is likely that this will be too complex except where a power utility manages the system for remote island operation and maintenance as is the current approach in Vanuatu with both UNELCO and VUI managing biofuel systems);
- Standardized, modular designs will be specified based on high-quality components that can be adapted for a range of sizes of installations and have been proven to be sustainable in PICs or similar environments;
- Designs, panel mounting systems, power houses, etc. should all suitable for remote tropical island conditions, specifically including cyclone and flood resistance;
- Specifications for bidding for designing and installing renewable energy (off-grid systems should include design and installation certification by a reputable body or at the minimum good-quality practical training in design and installation.
- For SHS & mini grids, energy efficiency measures will be incorporated into the system design, as efficient lights and appliances allow a smaller, less expensive generating source and lower O&M costs; and
- There will be discussions with donors or suppliers of other similar RE systems to encourage compatibility with the standardized design approach.

10. Mechanisms for Government Oversight, Finance, Management and O&M

At the inception phase, it is premature to suggest an overall financing and management approach, as the team has yet to meet with DoE, financial institutions, service providers, utilities, etc. In brief:

- **Institutional development**. It is anticipated that the Department of Energy would retain overall responsibility for development and implementation of RE based off-grid energy. At present DoE has about six professional staff (excluding several funded by donor projects) of whom only one position is for off-grid electrification. It is not possible to manage a large-scale and sustainable remote island rural electrification programme (i.e. one with a goal of 100% electrification or even 50% by 2030) without substantially more staff and a budget to support those staff. Even Fiji, with about triple Vanuatu's population, has struggled to keep community and household systems (diesel and PV) operating with over 40 staff devoted to off-grid electrification. It is premature to suggest the institutional changes needed; these will be assessed during the visits to Vanuatu.

- **Financial mechanism**. Until the GoV finalizes and approves the proposed National Green Energy Fund (NGEF), and decides on its priorities, operations and management, it is too early to consider off-grid financing in any detail. The team will assess the NGEF, the World Bank ESMAP 2015 report on sustainable energy financing for island states, and a 2015 GIZ report on financing green energy that includes recommendations for small-scale rural renewable energy systems such as SHS and mini-grids. There will be discussions with Vanuatu's financial institutions on financing remote island systems, although their interest rates may be too high. (The 2015 GIZ report deals largely with strengthening financial institutions for offering green energy loans.)

  An interesting example in the Pacific is the Palau Development Bank Solar Finance (off grid) mechanism. In 2008, the National Development Bank of Palau (NDBP) initiated a programme for the finance of grid-connected solar and off-grid solar for residences and commercial buildings. The programme was mainly directed toward urban dwellers and grid-connected solar since Palau has a relatively small off-grid rural population. For off-grid solar, a modular approach was used with the smallest size about 400 Wp of solar charging an industrial grade 12V deep discharge battery. A charge controller and a 300 Watt sine wave inverter were also included along with a selection of lights, fans and other small DC appliances. The second level uses two modules and doubled the array to 800Wp of solar and connected two of the 12V batteries in series making it a 24V DC installation with the inclusion of 300 Watt inverters, a charge controller and a selection of 24V lights. The third level again doubled the solar capacity to 1,600 Wp and used four of the 12V batteries connected in series for a 48V supply. An SMA 1500 Watt Sunny Island inverter was specified for the four module system. There was no subsidy provided for off-grid solar; the systems were marketed as a way to avoid the very high cost of running the grid to a rural home (which in Palau is mostly charged to the customer) while having access to electricity at a basic level, an intermediate level or a near urban level of electrification. Loan periods could be 10 to 20 years. The first 10 years of maintenance was included in the loan (which included one battery change expected at about 5 to 7 years after installation). Although the grid-connected programme was considered a success, the off-grid programme had few takers. At the time the program was put into place, the cost of an off-grid installation was over USD $6 per installed Wp of solar and the relatively high cost was an obstacle. Today the same installation has about half the cost compared to 2008-2010 making such a package more attractive to the more affluent off-grid Vanuatu household or to small rural commercial establishments such tourism in off-grid areas of Vanuatu. Although Vanuatu lacks a national development bank, the Agriculture Bank has in the past expressed interest in programmes similar to those of Palau.

- **Charges to end-users.** Considering the low rural cash incomes in Vanuatu, there needs to be a mechanism for a considerable upfront subsidy of capital costs, an approach which is almost universal in PICs, usually based on donor support but also government capital budgets. For sustainability, experience everywhere strongly supports the need for an ongoing users' fee that is sufficient to cover at least O&M costs, including programmed equipment replacements, especially batteries and inverters. There are various mechanisms for collection and administration and these will be explored during the island trips.

- **The four targeted islands**. Whatever management mechanism is recommended for the four islands to be visited must be scalable/applicable for application for a broader wide-scale government remote island RE programme. Experience in the region suggests that there must be a reliable mechanism for O&M and this requires an ongoing O&M training programme as part of the Master Plan.

11 Workplan and Timing

A timetable for Deliveries and Key Activities is attached as Annex 4.

Initial meetings and site visits

1. Review Internet-sourced satellite images of the four selected islands, other documentation available in Port Vila, and available population and socio-economic data of the islands, with an initial comparison to other remote islands of Vanuatu to determine if they appear to be sufficiently similar to possibly allow replication of the same model widely within the country.
2. Meet with stakeholders to discuss their experiences with remote renewable energy in Vanuatu. These will include but not be limited to: Ministry of Climate Change (Director General, DoE, Department of Environment & Conservation, Programme Management Unit), financial institutions, development agency staff who may be in Port Vila (ADB, Australian DFAT, GGGI, GIZ, New Zealand MFAT, World Bank, etc.), power utilities (UNELCO, VUI), the URA, and NGOs and private energy suppliers (as listed in section 3 of this report).
3. Through discussions with DoE (week of April 11), agree on a mechanism to oversee work undertaken under this consultancy, determine the appropriate frequency of briefing of DoE and the committee, determine the key stakeholders to be met, etc. Agree on a questionnaire (and Bislama translation) for survey use during visits to the selected islands.
4. Following discussions (particularly with DoE), revise this implementation plan / methodology / timing as necessary.
5. From the Vanuatu National Statistics Office, Department of Health, Department of Agriculture, etc. the team will obtain for the selected islands whatever updated information is available on populations, economic activity, agricultural production, etc. This will be followed by two visits to each island. The first in April and the second in May with each visit to include one international consultant and the local consultant.
6. During site visits, the team will travel to as many villages as possible during the time available and update information on village population (household interviews, health centre statistics, etc.), carry out surveys on their desire for electrification and services wanted and carry out surveys of ability and willingness to pay for electrical services using techniques compatible with the earlier 2010 HIES report. The interview format, attached as Annex 5, will be translated to Bislama prior to the island visits.
7. During the initial visit, the team will begin the preliminary design of appropriate RE based electrification systems for the islands based on measurements of selected villages, supplemented by satellite imagery, and discussions with residents. During the second visit, the team will refine and collect additional information as required. Draft survey reports will be completed by early May and if necessary revised and finalized by early June.

Draft project design and implementation for the four selected islands

Provided all island visits can be carried out and completed according to the proposed schedule, a draft RE electrification master plan for the selected islands will be completed by early June. Included in the draft master plan will be:

1. Technical design for electrifying selected islands using renewable energy: SHS, micro-grids, mini-grids. Designs will be modular in nature with each module capable of stand-alone generation. Increased capacity will be through the addition of more modules in parallel. This approach provides for simplicity of implementation, standardized components to minimize spare parts requirements and standardized maintenance and system operation to permit training to be consistent and transferable among all installations. Designs will focus on simplicity, robustness sufficient to survive cyclones, reliable operation in the coastal Vanuatu environment, and the use of high quality components to maximize their life in order to minimize the high cost of component replacement in remote areas.
2. Likely costs and methods of funding projects. Cash incomes are generally low so a high subsidy is likely to be needed at least for the capital investment. For most renewable technologies, the primary cost of generation is that of the capital investment. O&M is typically modest, at least compared with generation using diesel fuel and the very high fuel costs in remote areas. Therefore the primary financial support needed will generally be for the initial investment with operational and maintenance costs borne primarily by users. Where there are productive uses involved (e.g. tourism facilities), some long term, low interest loans may be practical but for residential use capital investments will need to be mostly borne by donors and government.
3. Technical alternatives. The renewable alternatives to be considered will be biomass (typically agricultural or forestry waste), biofuels (most likely coconut oil), solar PV and wind. Small hydro is very site specific and many smaller streams in Vanuatu are seasonal, making it impractical for wide spread rural electrification use. As confirmed by DoE, solar lanterns and pico-solar applications will not be considered.
4. Capacity building. The master plan will include the design for institutional change and capacity building within DoE and other relevant government agencies, capacity building within the rural communities being served and capacity building for the private sector where there is to be an interface with the rural electrification programmes (e.g. the utilities or other O&M contractor).
5. Management for the selected islands. Approaches to rural electrification management in other PICs will be considered and a system appropriate to Vanuatu will be proposed. By utilising modular type installations that are the same throughout Vanuatu, it may be practical for a central organisation to manage O&M and consumer interactions for all rural electrification that takes place under the master plan. The primary problem will be financing of the O&M system with user fees, by far the preferred approach, since long-term subsidies for O&M are unlikely to be possible. It is expected that local persons will be trained in basic O&M and made responsible to the central rural electrification management organisation for their work. Various fee collection systems will be considered and pros and cons provided. These will include payment through the mobile phone network, payment through provision of locally grown produce instead of cash (as in some Solomon Island projects), payment by urban relatives (as in some Marshall Islands projects), prepayments through smart meters/pre-payment meters (as was the case in some Fiji projects), etc. Consideration will also need to be given to the loss of income due to cyclone passages and how emergency funds for repairing cyclone damage can be used for covering rural electrification costs during the recovery period.

6. Institutional, legal and regulatory changes needed. Through discussions with DoE, the URA and other stakeholders, an outline of the legal and regulatory changes that are needed to carry out the master plan will be prepared and submitted to DoE for their consideration.
7. Workshop in Port Vila to discuss draft technical and management approaches. A workshop is to arranged by DoE, not the consultant team. After completion of the draft master plan, the DoE will organise a stakeholder and donor agency workshop to review the draft master plan for the target islands and invite discussions and comments for its improvement.

Project design and implementation for wider master plan

The latter half of June will be spent revising the draft RE electrification master plan for the selected islands based on the discussions and comments from the workshop, and preparing a draft of the broader RE masterplan for remote island electrification using renewable energy.
In general, the draft national master plan will be an expansion of the plan for the target islands and its development will follow the same approach as the target island master plan but with added flexibility to allow for the diversity that exists over the nation as a whole. The first step will be to analyse the census and other demographic data to determine the distribution of areas where the remote island installations will be appropriate. The team will then determine the differences in the availability of renewable resources in different parts of Vanuatu and revise the plan to fit the broader requirements of all remote areas of Vanuatu both with regards to the renewable technologies proposed and the O&M management system to be used. Breaking the country into rural electrification regions will be an option to be considered with regions possibly based on geography, renewable resource availability, user density, local technical and management skills, and inter-island transport systems.
The draft master plan will be revised as necessary and completed by the end of June 2016. The report will be finalised at the office of Environmental & Energy Consultants, Ltd in Suva, Fiji.

Keeping the Department of Energy Informed

1. *Consultation.* The team will be in frequent communication with the DoE (daily when in Port Vila), and DoE will be invited to actively participate in any discussions of interest to them. The Acting Director will have a schedule of meetings and will be encouraged to discuss progress anytime at his convenience. The Director General will also be kept informed throughout the consultancy. A brief weekly progress report will be provided to the DoE covering general progress, any delays and issues encountered, and how these are being addressed.
2. It is important to share knowledge with colleagues in Vanuatu. The consultancy team will provide a list of all materials consulted during the work undertaken to the DoE, along with electronic copies of all such materials. At the convenience of the DoE, in addition to regular progress reports, the team will be available to provide a briefing or briefings (probably Power Point presentations) to staff, the steering committee and others on issues, constraints, opportunities, etc. regarding remote island electrification in Vanuatu through renewable energy.

Annex 1: People and Organisations Consulted

The list below excludes consultations by email with the Vanuatu Climate Change Ministry (Director General Jesse Benjamin) or the Ministry's Department of Energy (Acting Director Chris Simelum, Project Manager Leo Moli, GGGI consultant Paul Kaun, and World Bank consultant Jerry Lapi).

Amlesh Kumar Din amlesh@powerlite.com.fj Managing Director, Powerlite, Shalimar street, Suva; phone: 3384088/9922268. (Supplies installs and maintains remote Fiji DoE solar PV systems)

Bruce Clay bruce@clayenergy.com.fj Director, Clay Energy, Fiji (part of the Sunergise solar group)

Craig Bohm craig.bohm@giz.de Technical Adviser and Country Manager for Vanuatu, EU-GIZ Adaptation to Climate Change and Sustainable Energy (ACSE) Programme, Suva, Fiji

Deepak Chand deepak.chand@moit.gov.fj Fiji Department of Energy rural electrification programme

Joeli Valemei joeli.valemei@moit.gov.fj Senior Energy Officer, Fiji Department of Energy rural electrification programme

Katerina Syngellakis katerina.syngellakis@gggi.org Fiji and Vanuatu Country Representative, Global Green Growth Institute (GGGI), and former energy specialist with GIZ, Fiji

Ofa Sefana, Acting Energy Planning Specialist, Tonga Energy Road Map Implementation Unit

Paula Katirewa Paula.R.Katirewa@moit.gov.fj Current Director of Energy, Fiji

Peceli Nakavulevu, peceli99@hotmail.com Former Director of Energy, Fiji; author of 2015 UNDP GEF study on the status of Fiji's village solar PV programme

Pranil Singh Pranil.SINGH@eeas.europa.eu Energy specialist, EU Pacific Office, Fiji

Ravinesh Nand ravinesh.nand@giz.de Energy Officer, EU-GIZ Adaptation to Climate Change and Sustainable Energy (ACSE) programme, Suva , Fiji; former Acting Director of Energy, Fiji

Srikanth Subbarao srikanth@subbaraoconsulting.com GIZ ACSE renewable energy consultant, Vanuatu (by Skype)

Thomas Jensen thomas.jensen@undp.org Energy Specialist, UNDP, Fiji

Annex 2: Documentation and Sources

For those reports which were downloaded, the web sites are provided. A full electronic set of all of the reports listed will be provided to the Vanuatu Department of Energy.

ADB, 2015	Handbook for Rooftop Solar Development in Asia; http://www.adb.org/sites/default/files/publication/153201/rooftop-solar-development-handbook.pdf
AFD, 2014	Renewable Energy in the Pacific Islands: An overview and exemplary projects (Agence Française de Développement; October)
BizClim, EU, 2012	Private-Public Partnership for access to renewable energy in rural areas of Vanuatu (Final Report; 16 August)
Castalia, 2016	Designing a National Green Energy Fund for Vanuatu (Draft Comprehensive Report; Castalia Consultants for GGGI & Government of Vanuatu; January)
CGAP, 2014	Access to Energy via Digital Finance: Overview of Models and Prospects for Innovation (Jacob Winiecki, et. al. for the Consultative Group to Assist the Poor); http://www.cgap.org/sites/default/files/DigitallyFinancedEnergy_FINAL.pdf
CGAP, 2015	Promoting Competition in Mobile Payments: The Role of USSD (Brief; Michel Hanouch & Greg Chen for the Consultative Group to Assist the Poor; 13 Feb); http://www.cgap.org/sites/default/files/Brief-The-Role-of-USSD-Feb-2015.pdf
CGAP, 2016	Understanding Consumer Risks in Digital Social Payments (Brief; Jamie Zimmerman & Silvia Baur for the Consultative Group to Assist the Poor; 2 March); http://www.cgap.org/sites/default/files/Brief-Understanding-How-Consumer Risks-in Digital-Social-Payments-March-2016.pdf
Climate Investment Funds, 2014	Scaling Up Renewable Energy Program in Low Income Countries (SREP) Investment Plan for Vanuatu (revised version; October)
Daily Post, 2013	Article on EU-funded rural energy projects (Vanuatu Daily Post 31 August)
DFAT, 2014	Independent Completion Report: Lighting Vanuatu (prepared for DAT/Australian Aid by David Kelly and the Energy Cultures Group of Otago University; January)
ESMAP, 2014	Commercially Operating Mini-Grid Systems (workshop report); https://www.esmap.org/sites/esmap.org/files/DocumentLibrary/Commercially Operating Mini Grid 2014 Workshop Report .pdf
ESMAP, 2015	Financial Mechanisms for Clean Energy in Small Island Developing States (Background Paper; January) http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2015/11/09/090224b0831a0b6c/1_0/Rendered/PDF/Financial0mech0nd0developing0states.pdf
EU, 2009	"The answer is blowing in the wind" - Improving access to energy services for the communities of Futuna and Aneityum (Vanuatu) using wind technology (Monitoring report MR-126180.01 13 November)
EUEI, 2014	Mini-grid Policy Toolkit: Policy and Business Frameworks for Successful Mini-grid Roll-outs (EUEI, REN21, etc.; September); http://www.minigridpolicytoolkit.euei-pdf.org/policy-toolkit
EUEI, 2014	Mini-grid Policy Toolkit: Support Tool: financing, PPA, retail tariff setting, etc.; http://www.minigridpolicytoolkit.euei-pdf.org/support-tools

Fiji govt, 2003	Draft Bill on Renewable-energy based Rural Electrification (RESCO)
Fiji govt, 2015	Fiji Solar Home System Project: Awareness Information Paper
GIZ, 2015	Financing Green Growth (energy): A review of green financial sector policies in emerging and developing countries; http://www.greenfiscalpolicy.org/wp-content/uploads/2015/07/GIZ_Financing-green-growth.pdf
GIZ, 2015	Outer Islands Solar Electrification in Tonga: a Case Study (Ofa Sefana for Government of Tonga, Secretariat of the Pacific Community & GIZ, October)
GIZ, 2016	Solar and Biogas based Rural Electrification with the Implementation of a Sector-specific Climate Early Warning System (CLEWS) 'Dashboard' (Project Design Document for Vanuatu under 'Adaptation to Climate Change and Sustainable Energy' programme; EU-GIZ; March)
GoV, 2011	Electricity supply act No. 21 of 2000 (amended 2011)
GoV, 2011	Utilities Regulatory Act No. 11 of 2007 (amended 2011)
GoV, 2013	Vanuatu National Energy Roadmap: 2013-2020; http://grein.irena.org/UserFiles/casestudies/Vanuatu_National_Energy_Roadmap.pdf
GoV, 2015	Intended Nationally Determined Contribution Report to UNFCCC; http://www4.unfccc.int/submissions/INDC/Published%20Documents/Vanuatu/1/VANUATU%20%20INDC%20UNFCCC%20Submission.pdf
GoV, 2015	Vanuatu Infrastructure Strategic Investment Plan (Summary) http://www.theprif.org/components/com_jomcomdev/files/2015/08/34/121-VISIP%204%20page%20summary%20paper.pdf
GoV, 2015	Vanuatu Rural Electrification Project (VREP) Request for Expressions of Interest
GoV, 2016	Updated Vanuatu National Energy Road Map: 2016-2030 (Castalia draft; March)
Gov/IRENA, 2015	Vanuatu Renewables Readiness Assessment (prepared by Herb Wade & IRENA; June); http://www.irena.org/DocumentDownloads/Publications/IRENA_RRA_Vanuatu_2015.pdf
GoV/NAB, 2015	Nationally-Appropriate Mitigation Action Design Document: Rural Electrification in Vanuatu (NAMA; prepared by the Vanuatu National Advisory Board for Climate Change and Disaster Risk Reduction); www.undp.org/content/dam/undp/library/Environment%20and%20Energy/MDG%20Carbon%20Facility/NAMA%20Final%20Vanuatu%202.pdf?download
GoV/SPC, 2015	Vanuatu Climate Change and Disaster Risk Reduction Strategy 2016-2030 (prepared by SPC and others); http://www.spc.int/pafpnet/attachments/article/476/Vanuatu%20Climate%20Change%20and%20DRR%20Policy%202016-2030.pdf
Grue + Hornstrup, 2015	Income Generating Activities and Tariff Structure for Bukuya Public Private Partnership (Fiji Renewable Energy Power Generation Project, August)
GSES, 2015	Installation, Operation & Maintenance of Solar PV Microgrid Systems: A Handbook for Technicians; Global Sustainable Energy Solutions; December) https://drive.google.com/folderview?id=0B7kbXdZp5ahhaXAwSWoxMnZ3aFE&usp=sharing
IRENA, 2015	Off-Grid RE Systems: Status & Methodological Issues

JICA, 2015	Pacific Power Sector Study: Survey to Gather and Verify Information for Aid Measures to Improve Energy Security in the Pacific Region Power Sector (includes micro-grids; Vanuatu)
Lighting Global, 2015	Off-Grid Power and Connectivity: Pay-As-You-Go Financing and Digital Supply Chains for Pico-Solar (Lighting Global Market Research Paper; May); https://www.lightingglobal.org/wp-content/uploads/2015/05/Off_Grid_Power_and_Connectivity_PAYG_May_2015.pdf
Mario, Rupeni, 2009	PIC experience with mini-grids: toolkit for legislators Prepared for SOPAC, Secretariat of the pacific Community)
Minigrid newsletter, 2015	SparkMeter brings smart grid functionality to underserved utility customers (Clean Energy Mini-grids Newsletter; December) http://www.globalproblems-globalsolutions.org/site/MessageViewer?current=true&em_id=71359.0
Nakavulevu, Peceli, 2015	Design and Establishment of an Effective and Least-Cost Tariff Collection System for Fiji Department of Energy's Solar Home Systems Projects; Final Report (prepared for UNDP-GEF Fiji Renewable Energy Power Project; October)
Nakavulevu, Peceli, 2015	Literature Review of Effective & Least Cost Solar Home Systems Tariff Collection System (prepared for UNDP-GEF Fiji Renewable Energy Power Project; August)
Polack, Anthony, 2010	Drivers & Barriers RE electrification Vanuatu Polack (MSc thesis for MSc in Renewable Energy; Murdoch University)
PPA, 2010	Port Olry Biofuel project Vanuatu: Pacific Case Study (prepared by I Toimoana
SEIAPI & PPA, 2012	Grid Connect PV Guide Vanuatu
SPC, 2015	Barriers to effective adaptation & resilience planning in the Pacific: information management perspective with specific reference to Fiji, Tonga & Vanuatu (with Griffiths University, Australia)
Spiegel-Feld, Danielle, 2015	Deploying Solar Powered Microgrids on Small Island Developing States: Breaking Through the Barriers (Guarini Center, New York University; December); http://guarinicenter.org/wp-content/uploads/2015/12/Deploying-Solar-Powered-Microgrids-on-Small-Island-Developing-States-20151.pdf
SPREP, 2005	Vanuatu National Report: Pacific Islands Renewable Energy Project (Johnston, et. al. for SPREP/Global Environment Facility)
Stein, David, 2014	Community Powerhouse: A Rural Electrification Model for Vanuatu (Green Power Concept Note)
STEPS Centre, 2014	Community-based Micro Grids: A Common Property Resource Problem (Lorenz Gollwitzer; 31 July); http://steps-centre.org/wp-content/uploads/Rural-Electrification.pdf
STEPS Centre, 2014	Financing Sustainable Energy for All: Pay-as-you-go vs. traditional solar finance approaches in Kenya (Rolffs, P., Byrne, R. & Ockwell, D.); http://steps-centre.org/wp-content/uploads/Financing-Energy-online.pdf
Szabo, Tyler, 2010	Prospective Impacts of Improved Energy on Income Generating Activities in Rural Vanuatu (May)

Thwaites, Mikaila, et. al, 2014	Cost-Benefit Assessment for PV Mini-grids (CAT Projects & Univ of New South Wales); https://www.researchgate.net/publication/273945854_COST-BENEFIT_ASSESSMENT_FRAMEWORK_FOR_PV_MINI-GRIDS
UN Foundation, 2014	Microgrids for Rural Electrification: A critical review of best practices based on seven case studies (Daniel Schnitzer et.al. for United Nations Foundation, Energy4All, University of California & Carnegie Mellon University; February) ; http://energyaccess.org/wp-content/uploads/2015/07/MicrogridsReportFINAL_high.pdf
UNDP, 2012	Modern Energy for A Traditional Society: Applying a community-drive model in Vanuatu (prepared by VANREPA and David Stein, January)
UNELCO, 2006	Vanuatu Rural Electrification Plan
URA, 2011	Electricity Reliability Standards in Relation to a Regulated Service
URA, 2014	Feed In Tariff & Net-Metering – Final Decision and Commission Order (July)
URA, 2015	URA Decision and Guidelines on Power Purchase Agreements
USAID, 2011	Hybrid mini-grid for rural electrification, Lessons Learned; http://pdf.usaid.gov/pdf_docs/PNADX679.pdf
VNSO, 2010	Vanuatu National Population and Housing Census 2009 (Volume 1; Basic Tables Report) http://www.vnso.gov.vu/index.php/census-and-surveys/household-income-expenditure-survey-hies#hies-archived-reports
VNSO, 2012	Vanuatu Household Income & Expenditure Survey Report 2010 (2010 data): http://www.vnso.gov.vu/index.php/census-and-surveys/household-income-expenditure-survey-hies#hies-archived-reports
VNSO, 2013	Household Expenditure Patterns in Vanuatu (Vanuatu Hybrid Survey from Pacific Living Conditions Survey; 2012 data; August); http://www.vnso.gov.vu/images/Special_Report/Expenditure_Patterns/2013HybridSurveyFactSheet.pdf
VNSO, 2013	Vanuatu Hardship and Poverty Report (based on 2010 Household Income & Expenditure Survey); http://www.vnso.gov.vu/index.php/census-and-surveys/household-income-expenditure-survey-hies - hies-archived-reports
VNSO, 2015	Statistical Pocket Book Vanuatu 2015
Wade, Herbert, 2012	Renewable Energy Mini-Grid Common Design Principles and Specifications (for New Zealand Ministry of Foreign Affairs and Trade
WB, 2014	Vanuatu Rural Electrification Project (VREP; 5-30w PV)
WB, 2014	Vanuatu sustainable energy readiness: Brief
Websites, 2016	LiDar maps: Vanuatu globe; Google Earth images

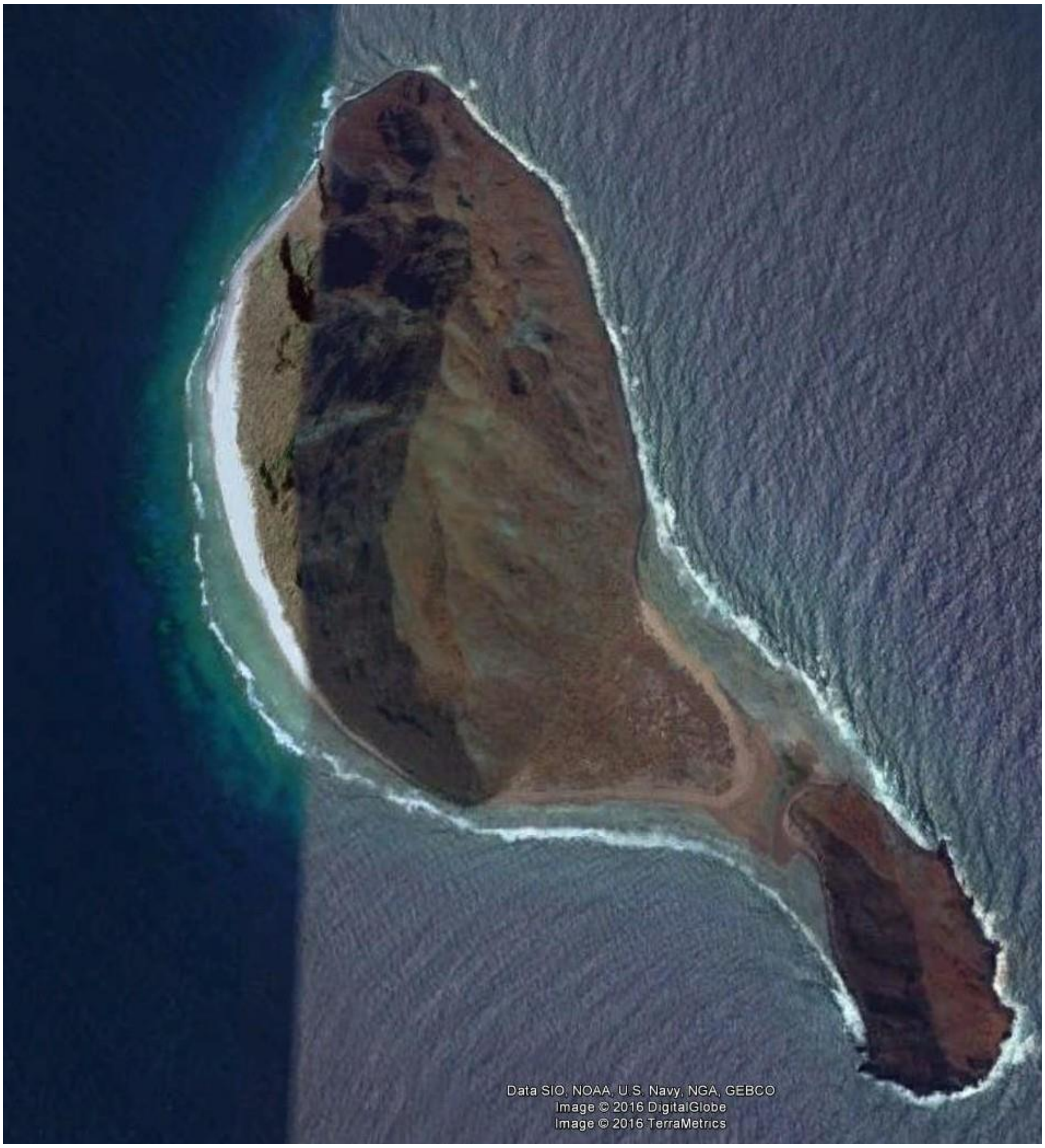
Annex 3: Images of the Target Islands

(Source: Google maps)

Emae and Makira Islands, Shephard Group, Vanuatu

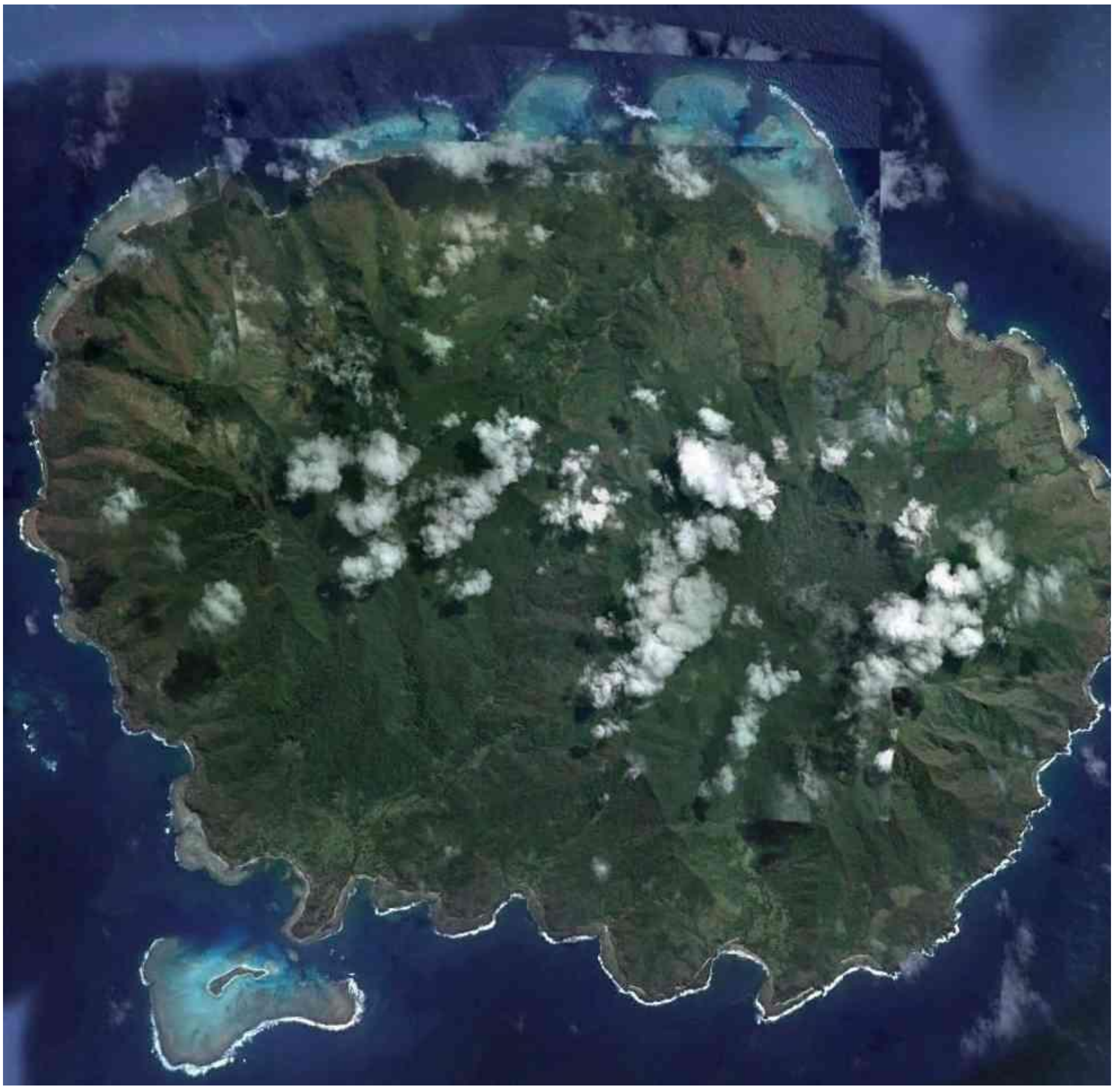
Emae is the larger island above. Makira is at the bottom right

The Emae airstrip is at the bottom of the larger island to the southwest



Mataso Island, Shephard Group, Vanuatu

The only village is at the flat land at the southeast of the larger portion of the island



Ameityum Island, Tafea, Vanuatu

The airstrip is on the small island off the peninsula on the south of the main island.
Most settlements are along the southwest coast of the island.

Annex 4: Timetable for Deliverables and Key Activities

This is the post Inception Report timetable

Deliverables	**Timing**			
	March	April	May	June
Inception report (deliver to DoE on 11 April))	--	--		
First site visit: Emae, Makira & Mataso * (Wade, Salong: 11-15 April)		--		
First site visit: Anetyum * (Wade, Salong: 21-26 April)		--		
Draft survey report (following first visit to all 4 islands)			--	
Second site visit: Emae, Makira & Mataso * (Johnston, Salong: 16-20 May)			--	
Second site visit: Anetyum * (Johnston, Salong: 24-26 May)			--	
Revised survey report following second site visits			--	-
Prioritized renewable energy projects & applicable technologies for the selected islands		---	--	
Preliminary technical design of identified potential RE projects for selected islands			--	--
Financing requirements & recommendation of workable business and institutional models & financing schemes for identified projects				---
Draft RE electrification master plan for the selected islands				----
Final approved RE electrification master plan for selected islands				----

***** Site visit timing is for international consultants (Wade, Johnston) ; local consultant (Salong) will extend stays as required

Timing of Key Activities	**Timing**			
	March	April	May	June
Complete Inception report		10 April		
Initial site visits : Makira, Emae & Mataso Initial site visit: Aneityum		11-15 April 21-26 April		
Includes i) work on verification of populations; ii) income & willingness to pay survey; iii) demand surveys.				
Complete draft site survey reports			6 May	
Complete report on prioritized projects and technologies for selected islands			13 May	
Second site visit: Aneityum Second site visit: Makira, Emae & Mataso			16-20 May 24-26 May	
Local consultant may travel earlier &/or later as needed				
Revised site survey report as required				3 June
DoE Stakeholder consultation workshop. (*See note*)				June
Preliminary technical design for 4 islands				3 June
Report on financing, business, institutional model				15 June
Draft RE masterplan				17 June
Final RE masterplan				30 June

Note: *Content & timing of workshop to be determined by DoE.*

Annex 5: Household Survey Form

LOCATION____

MEMBERS OF THE HOUSEHOLD (do not count persons who will only reside in the household temporarily)

1. Name____Age_____Sex_____
2. Name____Age_____Sex_____
3. Name____Age_____Sex_____
4. Name____Age_____Sex_____
5. Name____Age_____Sex_____
6. Name____Age_____Sex_____
7. Name____Age_____Sex_____
8. Name____Age_____Sex_____
9. Name____Age_____Sex_____
10. Name____Age_____Sex_____

CASH INCOME SOURCES (estimate the income from each source for each month of the year)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Gifts received												
Wages and salaries												
Agriculture												
Handicrafts												
Fishing												
Part time work												
Other_______________												
Other_______________												
Other_______________												
Other_______________												

HOUSEHOLD EXPENDITURES OF CASH (Include only estimated CASH expenditures, not barter or in-kind)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Kerosene (for lighting)												
Batteries (for lights, radios, or other battery operated equipment)												
Food purchases												
Clothing purchases												
Mobile phone payment												
Transport cost (includes fuel purchased for boats)												
Alcohol, tobacco, kava												
Housing (including repairs and purchase of items for use in the house but not including batteries or kerosene)												
Other cash payments _____________________												
Other cash payments _____________________												
Other cash payments _____________________												

How much is the household willing to pay in cash each month to have access to enough electricity for good quality lighting, radio use and phone charging? _________________

How much would the household be willing to pay each month for electricity to operate good quality lighting, radio use, phone charging and to operate a video player for about four hours a week?

____

Please show below how important you feel each of the listed electrical services is to your household by putting an X in the box showing the level of importance of each service. If a service important to your household is not listed, please name the service by writing its name in one of the "Other" boxes.

	Very Important to have	Important for the household	Ok but not essential	Not very important	No need at all
Electric lights					
Radio					
Video					
Refrigerator					
Freezer					
Washing machine					
Phone charger					
Other _______________					
Other _______________					

Does someone in your household have a mobile phone (Yes or No)___________

If Yes, what company provides the mobile phone service (DIGICEL or TVL)___________________

If someone in your household has a mobile phone, how is it charged (put an X in the box that is correct)?		
Solar charger		
Charged by a shopkeeper		
Community charging location		
Charged by a battery in a boat, tractor, truck or car		
Other____ __________		

If there is a fee for charging, how much does it cost to charge the phone?___________________________

Does your household have a solar powered portable lantern or other solar lighting unit? (Yes or No) _________________ (if No, skip the following questions about solar powered lighting)

Do you use the light every day? (Yes or no)________________

About how many hours a day do you use the light? (if less than 1 hour per day write “less than 1”)______________________

Can the light be easily moved from room to room (Yes or No)? ___________________________

If yes, is it a light that can be taken outside for walking at night? (Yes or no)______________

If your household accepts electrical services, which of the following approaches to payment would you prefer (put an X by each one you feel is a suitable way for your household to pay for electrical services):

Pay a small amount every day or two	
Pay by the week	
Pay by the month	
Pay in advance when you have the money	
OTHER MODE OF PAYMENT ____	

Annex 6: Sunshine Hours, Tafea Province

(Source: Vanuatu Meteorological Service)

This is for Tanna, the island closest to Aneityum for which sunshine hour data could be found. If required, more recent data for Aneityum will be sought from Meteo.

Station: BURTONFIELD A/P, Tanna					Monthly Sunshine Data				19.32s 169.15e				
Province: TAFEA					(in hours)				74m above msl.				
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1987	241.1	134.9	177.5	163.4	172.1	184.4	138.9	220.8	173.6	284.3	224.6	240.6	2356.2
1988	152.3	157.3	38	63.5	137.2	77	180.9	176.8	208.5	208.5	218.8	136.3	1755.1
1989	115.2	116.4	142.1	170.8	174.1	122.3	148.3	149.9	226.2	234.3	253.6	198.2	2051.4
1990	167.7	166	178.9	197.1	228.8	175.1	205.8	202	159.4	197	238	167.3	2283.1
1991	219	152.5	68.7	106.9	159.5	115.1	178.6	176.5	182.9	223.5	221	214.7	2018.9
1992	129.9		180.9	107	93.7	123	139.4	209.4	182.5	267.1	256.9	249.9	1939.7
1993	132.1	195.2	154	162.6	148.8	123.2	169.1	191.6	202.4	236.2	204	161.5	2080.7
1994	164.3	162	180.2	188.4	169.7	85.6	115.7	157.6	215.4	233.8	217.3	163	2053
1995	234.9	217.6	171.5	186.2	63.2	133.4	149.4	184.2	189.1	219.3	212.2	178.8	2139.8
1996	203	230.7	144.9	217.6	191.6	111.2	136.2	230.2	211.6	263.2	221.3	189.7	2351.2
1997	184.4	234.4	220.3	185	154.8	102.7	36.7		120.3	188.2	253.1	181.7	1861.6
1998	176.3	206.5	196.9	201.2	179.1	135.1	190	213.6	193.7	11.6			1704
	176.6833	179.4091	154.4917	162.475	156.05	124.0083	149.0833	192.0545	188.8	213.9167	229.1636	189.2455	2049.558
1981 - 98	185.0722	176.7529	166.3105	160.8368	158.8526	127.1111	155.8556	186.4556	192.3294	213.6778	217.4938	194.65	1985.779
Ave 18 yrs	5.699462	6.407468	4.983602	5.415833	5.033871	4.133611	4.969444	6.195308	6.293333	6.900538	7.638788	6.104692	5.615228