Scaling Up Renewable Energy in Low Income Countries (SREP)

Investment Plan for Vanuatu

Government of Vanuatu

Climate Investment Funds

CLIMATE INVESTMENT FUNDS

SREP/SC.12/4
October 24, 2014

Meeting of the SREP Sub-Committee
Washington D.C.
November 18, 2014

Agenda Item 4

SREP INVESTMENT PLAN FOR VANUATU

PROPOSED DECISION

The SREP Sub-Committee, having reviewed document SREP/SC.12/4, *SREP Investment Plan for Vanuatu*:

a) endorses the investment plan as a basis for the further development of the projects and programs foreseen in the plan and takes note of the request for USD 14.0 million in SREP funding. The Sub-Committee requests the Government of Vanuatu, in the further development of the proposed projects and programs, to take into account comments made at the meeting and any additional written comments submitted by Sub-Committee members by December 3, 2014. The Government of Vanuatu is also requested to respond in writing to questions raised during the meeting, and in subsequent written comments.

b) re-confirms its decision on the allocation of resources, adopted at its meeting in November 2010, that all allocation amounts are indicative for planning purposes and that approval of funding will be on the basis of high quality projects.

c) approves USD 800,000 in SREP funding as a preparation grant for the project entitled, *Rural Electrification Project* (World Bank) to be developed under the investment plan.

d) takes note of the estimated budget of USD 500,000 for MDB project preparation and supervision services for the *Rural Electrification Project* (World Bank) and approves USD 250,000 as a first tranche of funding for such services.

e) further takes note of the estimated budget of USD 430,000 for MDB project preparation and supervision services for the *Small Hydropower Solar Project* (ADB), and approves USD 215,000 as a first tranche of funding for such services .

GOVERNMENT OF THE
REPUBLIC OF VANUATU MINISTRY OF CLIMATE CHANGE ADAPTATION, METEOROLOGY, GEO-HAZARDS, ENVIRONMENT & ENERGY
PMB 9054, PORT VILA
VANUATU

GOUVERNEMENT DE LA
RÉPUBLIQUE DE VANUATU
MINISTÈRE DE L'ADAPTATION AU CHANGEMENT CLIMATIQUE, LA MÉTÉOROLOGIE, LES RISQUES GÉOLOGIQUES, ENVIRONNEMENT & ENERGIE
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TEL : (678) 24 686 FAX : (678) 22 310

Your Ref:.................................
Votre Ref:

Date: October 22[nd], 2014

Our Ref: **301/18**
Notre Ref

Ms. Patricia Bliss-Guest
Program Manager
Administrative Unit
Climate Investment Fund
1818H Street NW
Washington DC 20433
USA

Dear Ms. Bliss-Guest,

Re: Submission of the Vanuatu Scaling-Up Renewable Energy Program Investment Plan to the SREP Sub-Committee and request for the provision of SREP resources on the basis of a grant

We hereby submit Vanuatu's Scaling-up Renewable Energy Program (SREP) Investment Plan to the SREP Sub-Committee for endorsement. The Government of Vanuatu highly appreciates the financial support provided by SREP and the technical support from the Multilateral Development Banks (World Bank Group and Asian Development Bank in particular) to develop the SREP Investment Plan for Vanuatu.

The Government of Vanuatu is committed to adopting an ambitious and responsive strategy to increase electricity access throughout the country by raising the share of renewable energy in the national energy mix. As expressed in the National Energy Road Map 2013-2020, the Government's objective is to energise Vanuatu's growth and development through the provision of secure, affordable, widely accessibly, high quality, clean energy services for an Educated, Healthy, and Wealthy nation. The objective has been translated into a target of increasing access to electricity from the current 27 percent of the population to up to 90 percent of the population by 2020. We believe the SREP resources will be critical to achieving this objective and catalyzing the scaling-up of renewable energy investments in the country.

The SREP Investment Plan identifies the renewable energy technologies and projects that will contribute positively to the sustainable development of Vanuatu. The Plan outlines the activities that must be carried out to realize the proposed projects and identified the financing modalities under which the projects can be realized.

In view of the immense development challenges facing Vanuatu and the competition among many priorities and sectors for the Government's limited resources, we would like to proceed in such a manner as would ensure as much investment towards these priorities as possible, but with a watchful eye on the level of debt we incur. In view of this, and the possibility for allocations under SREP being in the form of grant, the Government hereby requests that the allocation of SREP resources in Vanuatu be in the form of grants.

Please accept our thanks and appreciation for SREP's support to Vanuatu's program to facilitate a high level of access to electricity in our country.

Yours Sincerely,

REPUBLIC OF VANUATU
Director General of Climate Changes Adaptation, Meteorology, Geohazards, Environment & Energy
Directeur Général de Climat Change Adaptation, Météorologie, Géorisques, Environnement et Énergie
REPUBLIQUE DE VANUATU

Mr Jotham NAPAT
Director General

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Abbreviations and Acronyms

ADB	Asian Development Bank
CNO	Coconut Oil
DBO	Design-Build-Operate
DoE	Department of Energy (within MOCC)
GDP	Gross Domestic Product
GoV	Government of Vanuatu
GPOBA	Global Partnership on Output Based Aid
IPP	Independent Power Producer
LCOE, LEC	Levelized Cost of Energy
MDB	Multilateral Development Banks
MFEM	Ministry of Finance and Economic Management
MIPU	Ministry of Infrastructure and Public Utilities
MLNR	Ministry of Land and Natural Resources
MOCC	Ministry of Climate Change and Natural Disasters
NERM	National Energy Roadmap for 2013 – 2020
NGO	Non-Governmental Organization
PAA	Priorities Action Agenda 2006-15
PPA	Power Purchase Agreement
RE	Renewable Energy
RESCO	Rural Electrification Service Companies
SHS	Solar Home System
SREP	Scaling Up Renewable Investment Programme
UNELCO	Union Electrique de Vanuatu Ltd
URA	Utilities Regulatory Authority
USD	United States Dollar
VERD	Vanuatu Electricity for Rural Development Programme
VREP	Vanuatu Rural Electrification Programme
VUI	Vanuatu Utilities and Infrastructure Limited

Photo credit: Eguide Travel

1 Investment Plan Summary

This document contains the Investment Plan (IP) for Vanuatu. The IP is the result of extensive analysis led by the Ministry of Climate Change and Natural Disasters (MOCC), and a wide-reaching internal and public consultation process, also led by the Department of Energy (DoE), to identify priorities in the development of renewable energy technologies for electricity generation. The consultations included a wide range of government agencies, as well as representatives from the private sector, civil society, and academia.

This Investment Plan, if implemented, will be profoundly transformational for Vanuatu, changing a country with very limited access to electricity to one in which roughly 90 percent of the population has access and in which most of the energy consumed comes from renewable energy sources.

1.1 Vanuatu Context

Vanuatu is an archipelago of 82 volcanic islands in the South Pacific (65 inhabited) spread about 1300km north to south. It has a population of about 270,000 living in approximately 55,000 households. Roughly 28 percent of the population lives on the main island of Efate, while 75 percent live in rural areas.

Only four of the islands have grid systems (covering part of the island in each case), and these are operated under concession arrangements, where the local concessionaire undertakes generation, distribution, dispatch, billing and settlement for consumers within its area. The vast majority of customers outside concession areas do not have access to electricity, beyond perhaps pico solar lanterns.

Electricity generation on grid systems is primarily from diesel (approx. 77 percent in 2012), with smaller contributions from hydropower (10.7 percent), wind power (7.5 percent) coconut oil powered diesel generator units (roughly 4.4 percent), and solar PV (0.2 percent).[1]

1.2 The Context for SREP Involvement

Vanuatu's energy sector is characterized by low access[2], high relative prices, and significant reliance on imported fuels. Connections to the grids have increased over time supported by several donor-funded rural electrification projects. However, most rural households still do not have access to any permanent lighting source. Vanuatu has seen an increase in the use of renewable energy to supply demand in concession areas in recent years, from less than 10 percent in 2007 and 2008, to

[1] Calculated from: *Annual Technical Report 2012*. UNELCO, 2012.

[2] While many households now have handheld lanterns, this refers to access to electricity above this level, such as SHS, plug and play solar systems, or grid supply.

more than 20 percent in 2012[3]. This has primarily been driven by the private sector, with a smaller contribution by donors.

No domestic fossil fuel reserves

Vanuatu has no proven fossil fuel reserves and relies heavily on diesel generation, which made up 77 percent of grid-supplied generation in 2012. Diesel is purchased on world markets and transported by ocean shipping to the South Pacific, then distributed throughout the islands by local shipping.

Vanuatu's dependence on imported fuel creates security of supply risks (potential for fuel supply interruptions) as well as affordability problems for customers. World diesel markets have exhibited substantial price volatility in recent years, as well an increasing upward trend. Shipping diesel to Tanna and Malekula, which do not have deep water ports, adds a substantial margin to the already high cost. Fuel cost increases are passed through via an indexation formula applied to tariffs. The base electricity tariff in UNELCO's concession areas has increased by almost nine percent in the past four years. Investment in RE has an offsetting effect. The implementation of hydro, solar, wind, and even a CNO-fuelled diesel generator in the past 20 years has demonstrated how RE can reduce the issues resulting from diesel dependence.

Low access

The majority of Vanuatu households do not have access to a reliable source of power. Overall, just 27 percent of households have access to a permanent source of electricity. Even in concession areas where grid-supply is available a significant proportion of households are not connected to the grid, in part due to the cost of connection.[4]

Over several decades, donors have funded a number of solar panels and mini grid systems to supply schools, clinics, dispensaries and homes across Vanuatu, outside the concession areas. However, until pico-solar units became widely available in the past five years or so, the vast majority of rural households relied on kerosene, candles and gas lanterns for lighting. While pico solar is relatively cheap, the life of these solar lanterns is short and services provided by them limited. As such, they are seen as a 'stepping stone' to more permanent solutions for households.

1.3 Renewable Energy in Vanuatu

Vanuatu has considerable renewable energy potential, and significant past experience developing renewable energy projects. A summary of potential resources and past experience is presented below:

- **Hydropower.** Small hydropower contributes approximately 10 percent of Vanuatu's (and 80 percent of Santo's) annual grid-supplied electricity

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[3] The increase in renewable energy contribution is primarily driven by two factors: an increase in output from the Sarakata hydro plant; and commencement of operation of the Devil's Point windfarm.

[4] Household grid connection ranges from 31 percent for the Tanna concession to 76 percent in the Port Vila concession.

generation. Only one small hydropower plant is currently connected into a grid concession area, being the 1.2 MW Sarakata plant on Santo. Hydropower is, nevertheless, a proven and viable technology for Vanuatu. When connected to the grid, a single plant can make a significant contribution to baseload demand. There is likely also significant potential for pico hydro supplying mini grids, though no mapping of this resource is available.

- **Solar PV.** Currently, small grid-connected solar plants are installed on each of the main islands, with 40 kW on Santo (across three rooftop sites), 70 kW ground-mounted at Tagabe on Efate, and 20 kW on each Malekula and Tanna (all commissioned in the period 2011-13). Further solar PV is planned for Efate, including the committed ground and roof mounted UAE-funded 510 kW at Parliament/Meteo and the planned UNELCO/EU/Government funded 1.3 MW ground mounted plant at Devil's Point[5]. The available modelled data shows that Vanuatu has good solar resources. Estimates of average global horizontal irradiation (GHI) in various locations range from approximately 1,900 to 2,300 kWh/m^2/year. (By comparison, average annual GHI in Europe is 1,000 kWh/m$^{2/}$year). However, the modelled data has limitations and high uncertainty associated with this assessment,[6] and it will therefore be important to verify the resource with site-specific ground measurements.
- **Biofuel.** Coconut oil has the most potential for biofuel on Vanuatu, and can be used in existing and new diesel generating sets. While there is potential for expanding the use of CNO as a diesel replacement, the high (and highly variable) global price of CNO makes this a relatively high cost form of renewable energy, as well as being highly reliant on a sustainable source of oil. For some years, a number of UNELCO diesel generators on Malekula and Efate have been partially fuelled by coconut oil. In addition, the Port Olry microgrid utilizes a diesel/CNO generator. The coconut oil used in all these generators is produced and refined on Vanuatu, which has the significant benefit of avoiding the transport costs associated with importation of diesel. However, it is heavily reliant on sustainable production of CNO of the quality required for electricity generation, and exhibits significant price variability (due to being a commodity product traded on world markets). It is assumed that further supply of CNO could be developed if the price were sufficiently high relative to international market prices, currently about $1.25/litre.[7]

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[5] Funding of the Devil's Point solar farm by the EU is contingent on signoff of the Government contribution, which has not yet occurred.

[6] The Meteonorm 7 database, used to develop solar maps for Vanuatu, uses available "measured" data sites from ground-based weather stations and geostationary satellites and interpolates to estimate what solar resource would be at a specific location. The quality of available datasets and the interpolation algorithm have limitations, and the uncertainty of the modelled solar resource data at a specific site is high.

[7] The cost of diesel for electricity generation in Efate was 110 VT in 2012 (USD1.18/litre), 132 VT (USD 1.41/L) delivered to Malekula and 146 VT (USD 1.56/L) to Tanna. *Annual Technical Report 2012.* UNELCO, 2012.

- **Geothermal.** Vanuatu has no installed geothermal power plants. KUTh Energy prospected three potential sites on Efate, and selected the Takara site in North East Efate as the best candidate for geothermal power. A pre-feasibility study was undertaken in 2012, and a two stage development (2 x 4 MW net) proposed. This study assessed geothermal power from Takara to be the least-cost power supply addition for Efate under a broad range of conditions.[8]
- **Wind.** Only one wind farm is currently in operation in Vanuatu, being the Devil's Point wind farm on Efate, commissioned by utility UNELCO in 2008. It has eleven turbines at 275 kW each for total capacity of 3.025 MW. UNELCO has proposed plans to extend the site, with short-term plans of installing an extra two turbines and eventually expanding the farm to double the current capacity. While in general wind resource data shows few good locations for wind energy, several sites have been identified with good capacity factors, as well as being close to roads and transmission.

Barriers to renewable energy in Vanuatu

There are a number of barriers to the expansion of renewable energy in Vanuatu. These include (i) the process to ensure that land can be used for renewable energy projects and reticulation of electricity from them given the many landowners, and often unclear ownership, (ii) existing regulatory framework does not provide for IPPs to have PPAs with concession holders, or for concession holders to include the cost of power purchased under these PPAs in tariff calculations, (iii) high upfront capital costs for most renewable energy projects, and (iv) uncertainty regarding Santo concession, and limited term remaining for several of UNELCO's concessions. In future, a key consideration will be a careful analysis of the issues around integrating new renewable capacity into the grids where more sophisticated control systems may be required to manage variability over a variety of timeframes.

With regard to off-grid supply specifically, additional barriers include (i) equipment maintenance and fee collection for very remote locations, (ii) limited working capital for local suppliers of individual solar systems to maintain adequate inventories, and (iii) limited local capacity for undertaking installations and maintenance.

The future of renewable energy in Vanuatu

The Government's renewable energy strategy is driven by the overarching goals of improving energy security, ensuring the affordability of electricity, and increasing access to a much greater proportion of the population, particularly in rural areas. The National Energy Roadmap for 2013 (NERM) establishes targets for RE as a way forward in achieving these objectives. This SREP IP is consistent with the strategies and targets established in the NERM.

Table 1.1 shows the Government's targets for access to electricity by 2020. In addition, the GoV has established targets for the proportion of electricity to be

8 *Vanuatu: Efate Geothermal Power and Island-Ring Grid Development Framework.* The World Bank Group, October 7, 2011.

provided from renewable sources: 40 percent by 2015 and 65 percent by 2020. Renewable energy generation represented roughly 15 percent of total grid-connected generation capacity (and produced 23 percent of energy output) in 2012, and contributed approximately 22 percent in kilo-watt-hour terms.

Table 1.1: Electricity Access Targets to 2030

	Current	2015	2020	2030
Households within grid-concession areas (approx. 18,500 HHs)	68% (12,500 HHs)	75%	90%	100%
Households close to grid-concession areas (approx. 3,000 HHs)	0%	33%	90%	100%
"Off-grid" households* (approx. 31,500 HHs)	<10%	TBD	100%	100%
Public Institutions (grid and off-grid)	50%	90%	100%	100%

Source: NERM.

*Electricity supply via individual systems (solar panel installations and basic internal wiring that can supply several lights and charging facilities for phone, radio, TV, etc.) or basic power products (cash-and-carry pico-lighting and charging products sold through retail shops and other establishments).

The Government remains strongly committed to developing renewable energy (RE). This includes commitment to RE projects funded by concessionaires, independent power producers (IPPs) and donors, development of sustainable models for rural electrification, and regulatory arrangements to develop an energy sector that encourages and facilitates RE investment.

1.4 The Proposed Investment Programme for Vanuatu

Each of the potential renewable energy resources were evaluated against national and SREP criteria, and prioritized accordingly. The criteria reflect the Government's strategic objectives, and the clear recognition that SREP funding should be used to overcome barriers to technologies that will have the potential to have a transformative impact on the energy sector.

The national criteria considered were: Affordability and cost of the technologies, the likelihood that projects could go forward in the near-term, socio-economic benefits of each of the technologies, recognition of social and cultural realities in Vanuatu, consistency with demand profiles, the existence of a "hurt factor" which ensures customer "buy-in", and the sustainability of the investment. In addition, the investments were assessed against the SREP criteria, which included increased access to energy through renewable energy sources, low emission development, leveraging of additional resources, and gender impacts.

Two investment priorities emerged from the analyses and the discussions with stakeholders. These are as follows:

1. Individual solar systems and micro/ mini-grids for rural electrification;
2. Support for proposed base load 'run of river' hydro generation on Malekula and Espiritu Santo;

Table 1.2 presents a plan for financing the projects described in Section 5. It shows the proposed contributions or grants from SREP as well as estimates of the amounts anticipated from MDBs and the private sector.

As the table shows, roughly US$ 14 million of SREP funding is expected to catalyse roughly 1.4 times as much investment, most of it from the private sector (as equity or debt), and the public sector lending windows of the MDBs.

Table 1.2: Financing Plan

<u>SREP Project</u>	SREP	MDB Responsible	Government of Vanuatu	MDBs	Private Sector (Equity)	Other	Total
Rural Electrification Project							
Plug and play solar systems		WB			3.1	3.1*	**6.2**
SHS, micro and mini grids	5.0		1.5	2.0	2.0		**10.5**
Technical assistance and project management	1.2					1.6*	**2.8**
Feasibility studies and preparation	0.8						**0.8**
Subtotal: Off-Grid Solar and Micro-grids	**7.0**		**1.5**	**2.0**	**5.1**	**4.7**	**20.3**
Small Hydropower Project							
Investment in Sarakata and/or Brenwe	7.0	ADB	1.9	5.0	0.0	0.0	**13.9**
Subtotal: Small Hydropower Projects	**7.0**		**1.9**	**5.0**	**0.0**	**0.0**	**13.9**
Grand Total	**14.0**		**3.4**	**7.0**	**5.1**	**4.7**	**34.2**
SREP Leverage	**1.4**						

*Government of New Zealand

The investment programme proposed for Vanuatu will have a profoundly transformative impact on the country. It will result in most households in Vanuatu having access to electricity, and allow one of the four islands with grid supply to satisfy most energy demand with renewable energy.

Rural electrification Project

The rural electrification project would target 80 percent of the roughly 22,000 dispersed off-grid customers in Vanuatu, which include approximately 17,500 households, not-for-profit community halls, and aid posts. The Project will fund some portion of the capital costs of stand-alone solar systems, and where feasible micro- or mini-grid systems. Franchise, concession or management contract models may be used to design, build and (as necessary) maintain the systems.

The results of the project would be to increase electricity access in Vanuatu from roughly 27 percent to 90 percent. Nearly all customers outside existing concession areas could be connected, allowing Vanuatu to meet its ambitious NERM targets.

The co-benefits of the investments will be far-reaching in terms of creating opportunities for income generating activities, improving health (by, for example, allowing for refrigeration of vaccines and medicines, and avoiding the deleterious health effects of kerosene and traditional fuel use), and educational outcomes (by, for example, allowing for more hours of study under better lighting). The programme will also provide jobs for Ni-Vanuatu to undertake installation, maintenance and collection of revenue under the Design-Build-Operate (DBO) business model proposed for micro-grids.

On-grid hydropower Project

The small hydropower projects would ensure that the Islands of Malekula or Espiritu Santo generate most of their electricity from renewable energy. The existing Sarakata hydro plant illustrates the potentially transformative impact hydropower can have in providing a stable source of electricity for a community, and reducing its reliance on imported diesel for electricity generation. The plant has been doubled in capacity since the initial plant was installed, but this has been more than matched by growth in demand, as the population of Luganville has embraced this stable and lower cost source of electricity.

Either the Brenwe or Sarakata projects would have substantial transformative impact. If the Brenwe plant is selected for funding, generation from it will displace output from the largely CNO-fuelled diesel generators which currently provide the vast majority of power needs to the Malekula network.[9] The project will produce almost 100 percent of energy demanded in the early years, reducing to some 80 percent by 2040. With the associated transmission, the project will also support the future connection of nearly 2,000 more households to secure grid supply.

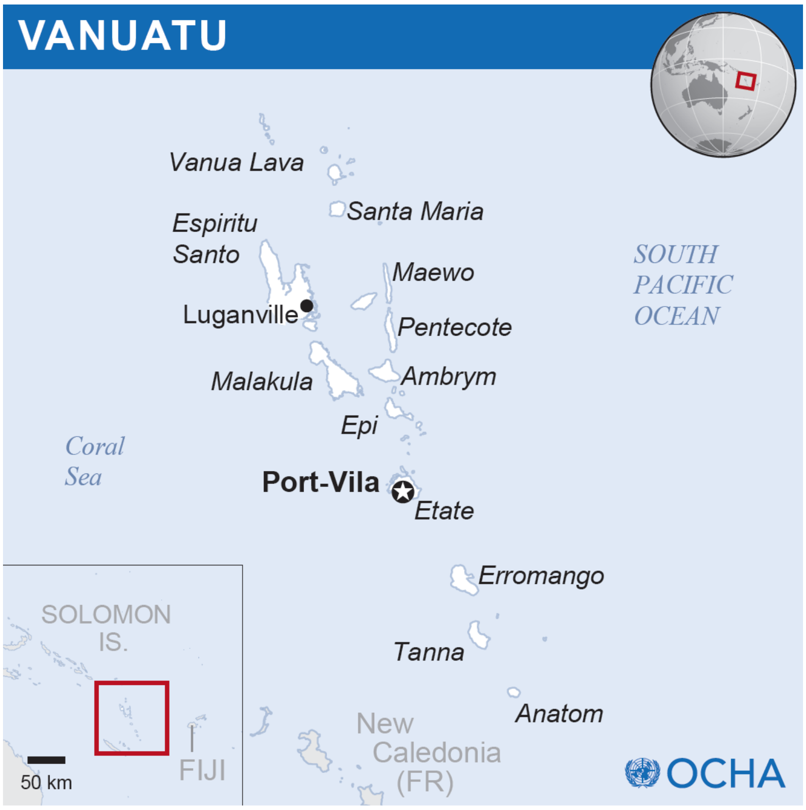
[9] While CNO is a renewable resource, it has a high value on global markets, and is a more costly source of electricity than hydro plant.

If the Sarakata plant is selected for funding, it would enable the near complete displacement of diesel generation on Santo. Santo already has close to 80 percent of its demand met from the Sarakata hydro plant, supported primarily by diesel generation. Extending the plant to utilize currently surplus water could enable the full displacement of diesel generation, and maintain the same high level of energy from renewables through to 2035 and beyond.

2 Country Context

Vanuatu is an archipelago of 82 volcanic islands in the South Pacific with a total area of 12,300m^2, and about 1300km north to south distance between the outermost islands. Some 65 of the islands are inhabited. The Republic of Vanuatu was founded in 1980 from the New Hebrides, upon independence from the British and French administration.

Figure 2.1: Map of Vanuatu



Source: ESRI, Gov't. of USA, UNCS. Map provided courtesy of the UN Office for the Coordination of Humanitarian Affairs.

Disclaimer: The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

Vanuatu has a population of about 270,000 living in approximately 55,000 households. Roughly 84 percent of the population lives on the largest eight islands (including 28 percent on the island of Efate, where the capital city Port Vila is located), while the remaining 57 populated islands are each home to an average of 137 households. Overall population density averages 19 people per km^2; however, this varies significantly by province and village.[10]

The majority of the population lives in rural areas (75 percent), though growth figures for the past decade show a rural-urban shift.[11] From 1999 to 2009, the population of Vanuatu increased by an average 2.3 percent annually. The World Bank projects that the population will continue to grow, to 322,000 by 2025, an average of 2 percent per annum.[12]

2.1 Climate Change

Vanuatu is ranked as the world's most vulnerable country to climate change, on the Commonwealth Vulnerability Index of 111 countries. This index takes into consideration propensity for natural disasters and extreme events associated with climate variability (including sea level and temperature extremes, and droughts), together with its limited technical and financial capacity.

Vanuatu is already experiencing the consequences of climate variability and change, including sea level rise, increased intensity of extreme events, and changes to agricultural productivity and water availability. Such impacts are likely to increase in the future, for example, projections for 2050 include:

- A 1.6-2.2 degree C increase in the average maximum temperature for January to March, relative to the long term normal, and more frequent occurrence of extreme temperatures
- Dry season rainfall is likely to increase in the northern half of the country, and decrease in the southern half, but in each case by only a few per cent; however, wet season rainfall is likely to increase across the entire country, by at least 10 percent. Drought events will occur more frequently
- Relative sea level rise will increase from the current 5.5mm/year to 49.7mm/year in 2050

In 2012, the World Bank initiated a project to increase resilience of communities in Vanuatu to climate change and natural hazards.[13]

2.2 Affordability of Energy

The costs of electricity production and distribution in Vanuatu are high by world standards. As with many island nations, this is caused by factors such as high reliance

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[10] Density by province ranged from 11 people per square km in Torba, to 52 in Shefa. *2009 National Population and Housing Census*. Vanuatu National Statistics Office, 2009.

[11] Population growth from 1999 to 2009, as measured by Census was 2.3%, broken down to 3.6% growth in urban areas and 1.9% in rural areas.

[12] *Health Nutrition and Population Statistics: Population estimates and projections Database*. The World Bank Group. Accessed June 2014.

[13] *Increasing Resilience to Climate Change and Natural Hazards in Vanuatu.* The World Bank Group. Accessed September 22, 2014. http://www.worldbank.org/projects/P112611/increasing-resilience-climate-change-natural-hazards-vanuatu?lang=en.

on diesel generation, remoteness, geographical dispersion, and low customer density. Connection costs are highly subsidized[14], as are tariffs for very small domestic consumers; however higher use households and businesses pay very high tariffs, and for many households in concession areas electricity may remain unaffordable.

Table 2.1 below displays the average and lowest quintile monthly household incomes and electricity demand in the four concession areas, along with the estimated proportion of income spent on electricity.

Table 2.1: Average Monthly Household Demand and Incomes in Concession Areas

Concession area	average HH electricity demand / month (kWh)	average HH electricity cost / month (Vatu)	average HH income / month (Vatu)	% average income spent on electricity	average HH income/ month (lowest 20%) (Vatu)	% low income customers spend on electricity
Port Vila	54	1001.54	104,100	0.96%	18,400	3.0%
Luganville	49	876.12	74,100	1.18%	21,500	2.6%
Malekula*	30	556.41	60,200	0.92%	20,700	2.7%
Tanna*	37	686.24	53,500	1.28%	24,200	2.3%

Monthly expenditures calculated as (kWh demand * current rate for usage up to 60 kWh per month). Low user demand assumed 30kWh/month.

*Tanna and Malekula average income data was unavailable; Tafea and Malampa averages used as a proxy.
Source: *Vanuatu National Energy Road Map,* 2013.
Household Income and Expenditure Survey, 2010.
UNELCO monthly base price adjustments.

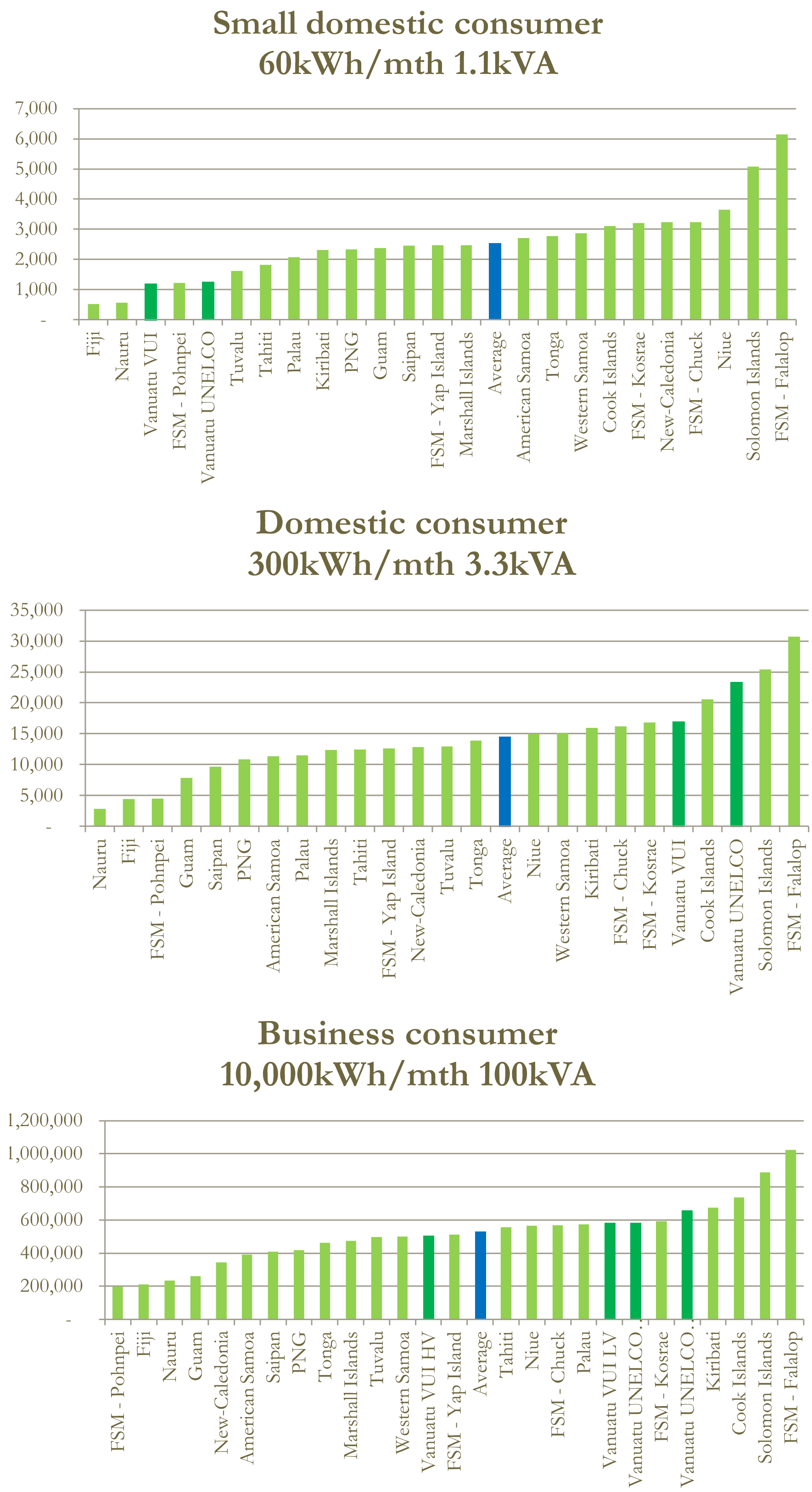
While these proportions of total monthly income spent on energy appear reasonable, households typically have a very small budget for household operations. They can spend only about 10 percent of their monthly income on expenses such as fuel, lighting, communications, household supplies, appliances, equipment, and furniture.[15] Taking these constraints into account, the average on-grid household in Vanuatu spends between 9 and 13 percent of their household operations budget on electricity, while for the average lowest quintile income household this can be up to 30 percent.

Figure 2.2 below shows indicative electricity tariffs paid in a number of Pacific countries, for various consumer sizes. While prices for the smallest consumers in Vanuatu are among the lowest in the Pacific region, prices paid by larger domestic consumers are among the highest. The electricity bills faced by Vanuatu business consumers were found to be close to the average for the region. Refer to section 2.6for more detail regarding tariffs charged to different customer groups.

[14] 80 percent of the service connection cost is subsidized, but connection costs have remained a barrier for consumers.

[15] Castalia, *Global Partnership on Output-Based Aid: Improved Electricity Access in Vanuatu – Final Report*, September 2012, p.27.

Figure 2.2: Electricity Prices in the Pacific (Vatu/kWh)

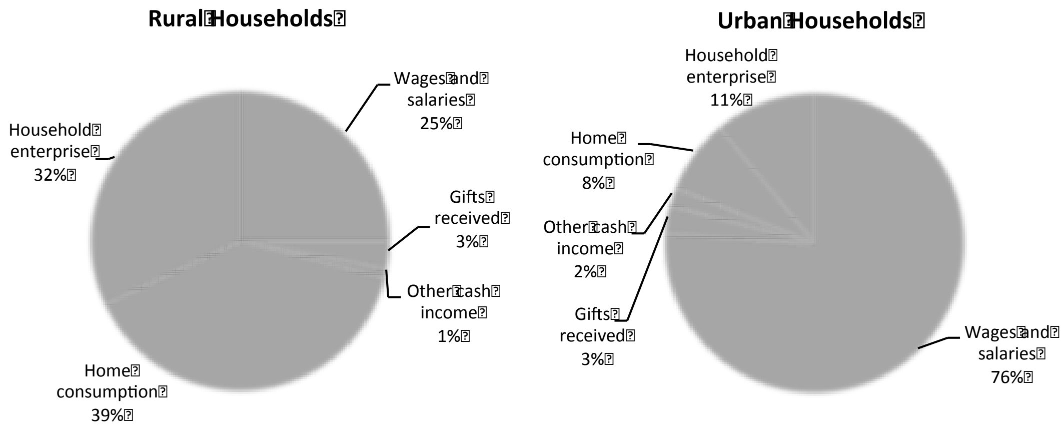


Note: Small domestic consumers are assumed to use 60 kWh of electricity per month on a 5 A connection; Domestic consumers 300 kWh per month on a 15 A connection; and business consumers 10,000 kWh per month on a 100 kVA connection.

Source: *Comparative Report – Pacific Region Electricity Bills*, URA, July 2014

Off-grid consumers face additional challenges with regard to affordability of electricity. In addition to low average monthly household incomes, a high proportion of their income is from non-cash sources as shown in Figure 2.3. Cash incomes can often also be irregular due to the seasonal nature of much of their work.

Figure 2.3: Proportion of Aggregate Household Income from Cash and Non-Cash Sources



Source: *Vanuatu Household Income and Expenditure Survey*,VNSO, 2010 (December 2012)

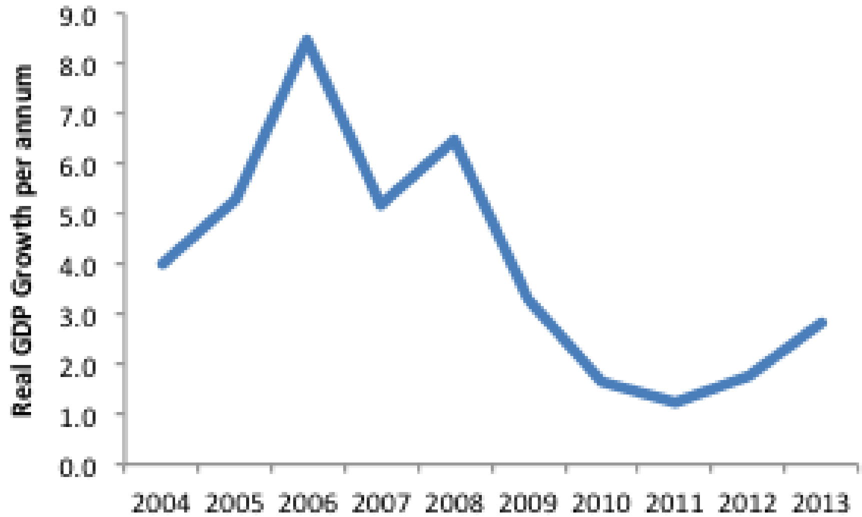
2.3 Economy

Vanuatu is classified as a Small Island Developing State (SIDS). The economy of Vanuatu is comprised of a mixed subsistence sector on which the majority of the population is dependent, and a small high cost modern sector.

Vanuatu has experienced positive economic growth over the period 2004-2013, with GDP growing from USD 364 million in 2004, to over USD 800 million in 2013, an average real growth rate of about 4 percent. As shown in Figure 2.4, strong growth (driven by construction activity, tourism and other service industries) was tempered in 2009 and 2010 by the impact of the global financial crisis. In 2012, agriculture, services (including tourism) and industry contributed 20.6 percent, 67.7 percent and 11.7 percent of GDP, respectively. Primary agriculture sources are copra, beef, cocoa, and kava.

Other economic indicators show that the economy is relatively stable. Inflation remains slow, and Vanuatu’s balance of payment stable. In addition, public and external debts are low. The fiscal position is sound with fiscal deficit at 1.5 percent of GDP in 2012.

Figure 2.4: Annual Change in Real GDP, 2004-2013



Source: *Vanuatu GDP at Constant Prices, % Change*. IMF, accessed June 2014. https://www.quandl.com/ODA/VUT_NGDP_RPCH-Vanuatu-GDP-at-Constant-Prices-change.

Like most Pacific Island nations, Vanuatu has no known indigenous fossil fuels, and as it has yet to fully develop its renewable energy resources, the economy relies heavily on imported petroleum products and has felt the impact of recent volatile and high world petroleum prices. Electricity prices are high for most consumers as a result, and access rates are low. These issues in the energy sector restrict the progress that can be made in areas of economic and social development, such as in the education and health sectors.

Vanuatu currently sits at 124 out of 187 countries on the Human Development Index (HDI), a composite index published by the UNDP that incorporates life expectancy, education and income indices.[16] Analysis indicates that among Pacific nations, HDI rankings are higher for those with higher levels of access to electricity.

Land access remains one of the more complex issues in Vanuatu. All land in rural areas is under customary ownership, and there are often disputes regarding land ownership.

2.4 Energy Sector

The energy sector has a critical role to play in achieving the strategic objectives of the GoV in the coming years. Section 2.4.1 describes the GoV's strategic objectives for the energy sector and the importance of the energy sector in achieving national development objectives. Sections 2.4.3 and 2.4.4 describe the institutional and legal framework of the energy sector of Vanuatu.

[16] "Table 1: Human Development Index and Its Components | Data | United Nations Development Programme." UNDP Open Data. Accessed June, 2014. https://data.undp.org/dataset/Table-1-Human-Development-Index-and-its-components/myer-egms.

2.4.1 Strategic objectives of the Government of Vanuatu

The SREP IP was developed to be consistent with the GoV's vision for a more diversified economy and more equitable social and economic development, and with key GoV objectives and priorities.

The GoV's Priority and Action Agenda (PAA) 2006-2015 set out the following objectives for Vanuatu's energy sector, to:[17]

- Reduce the cost of services
- Extend the coverage of rural electrification
- Promote the use of renewable energy.

The 2012 National Energy Road Map (NERM) continues this focus. It establishes three strategic action directions:

- Government leadership and commitment – establishing a consistent set of enabling policies and a strong legal and regulatory framework
- Empowering and holding accountable key institutions
- Implementing a sector wide approach.

The NERM focuses on five priority areas – petroleum supply, access, affordability, energy security, and climate change – and identifies priorities, proposed actions and initiatives to achieve the priorities. Targets were associated with each of the priority areas, and include least cost generation expansion, target connection levels by customer group, and increased investment in renewable energy. Access and RE targets are set out in Table 2.2.

The objectives for energy established in the NERM are based on the premise that access to modern energy is a fundamental enabler and catalyst for economic development, and enhancing the livelihoods and wellbeing of all Vanuatu citizens. In addition, modern energy is central to achieving progress on almost all dimensions of human welfare and development, including: education, health care, access to water, essential communications, and income generation.

[17] Preparation of the NERM was supported by the World Bank as the lead development partner, and has incorporated input from other development partners who are active in Vanuatu. The NERM is consistent with the draft Vanuatu Infrastructure Strategic Investment Plan (VISIP) (2012), which is a medium term plan for economic infrastructure investment, and included the following priority projects in the energy sub-sector: Takara geothermal power plant (incl. transmission and distribution), extensions of the power grids on Santo and Efate, the Brenwe hydro project on Malekula and the Wambu hydro project on Santo. Note that the ADB has more recently decided not to proceed with the Wambu project.

Table 2.2: Targets for Electricity Access and Renewable Energy

Target Category	Current	2015	2020	2030
Electricity Access Targets				
HHs with grid concession areas (~ 18,500 HHs)	68% (12,500 HHs)	75%	90%	100%
HHs close to concession areas (~3,000 HHs)	0%	33%	90%	100%
"Off-grid" HHs (~31,500 HHs)	<10%	TBD%	100%	100%
▪ Individual home systems permanent electricity solutions* ▪ Basic power products**				
Public institutions (grid and off-grid)	50%	90%	100%	100%
Renewable Energy Targets				
% renewable energy	19%	40%	65%	
Diesel efficiency*** improved by:		10%	20%	
Energy efficiency	By 2014: ▪ Comprehensive data collection established ▪ Set realistic targets ▪ Begin EE initiatives			

Total # of Households (HHs) is ~53,000 based on 2010 census update, and average 4.5 persons per HH.

**Individual home system refers to solar panel installations and basic internal wiring that can supply several lights and charging facilities for phone, TV, radio, etc.

**Basic power products refer to the cash and carry pico lighting and charging products sold through retail shops and other establishments.

****Diesel efficiency refers to meeting the Pacific benchmark for diesel generation units operated by the utilities. No diesel efficiency estimations are available for private generators used in the manufacturing and industrial industries.

Source: NERM

2.4.2 National and international policy frameworks

In addition to NERM and the GoV's PAA, there are several national and international policy frameworks relevant to the energy sector of Vanuatu. These are summarized in Table 2.3.

Table 2.3: National and International Policy Frameworks

Framework	Organization(s)	Description
Vanuatu Infrastructure Strategic Investment Plan (VISIP) (2012)	GoV	The VISIP is a medium term plan for economic infrastructure investment for Vanuatu, following on the work of the FAESP, and the IRENA RE Roadmap. The VISIP is currently in draft form.
World Bank Country Partnership Framework (CPF)	World Bank	The World Bank CPF for Vanuatu is being developed which supports government objectives to reduce the cost of services, extend coverage of rural electrification and promote the use of renewable energy.
ADB Vanuatu Partnership Strategy 2010 - 2014	The Asian Development Bank	ADB's country partnership strategy prioritizes the energy, transport, information and communication technology, water supply, and other municipal infrastructure and services sectors. http://www.adb.org/countries/vanuatu/strategy
The Secretariat of the Pacific Regional Environment Programme (SPREP)	SPREP	SPREP has been charged by the governments and administrations of the Pacific region with the protection and sustainable development of the region's environment. http://www.sprep.org/about-us
Framework for Action for Energy Security in the Pacific (FAESP) 2010 - 2020	Secretariat of the Pacific Community	The FAESP is a regional framework for the provision of technical assistance to the energy sectors of Pacific Island countries and territories. http://www.spc.int/edd/section-01/energy-overview
Pacific Islands Greenhouse Gas Abatement through Renewable Energy Project (PIGGAREP)	GEF, UNDP, and SPREP	PIGGAREP is a project of SPREP charged with reducing the growth rate of GHG emissions from fossil fuel use in the PICs through the removal of the barriers to the widespread and cost effective use of feasible RE technologies.
Pacific Infrastructure Advisory Centre (PIAC) and Pacific Region Infrastructure Facility (PRIF)	ADB, AusAID, EC, EIB, WB, New Zealand Ministry for Foreign Affairs	PIAC operates under the coordination of the Pacific Region Infrastructure Facility (PRIF), a partnership for improved infrastructure in the Pacific Region between ADB, the Australian Agency for International Development (AusAID), the European Commission (EC) and the European Investment Bank (EIB), the New Zealand Ministry for Foreign Affairs and Trade and the WB.
Pacific Power Association (PPA)	PPA, PRIF, PIAC	The Pacific Power Association (PPA) is the regional organization representing 25 electric power utilities in 20 Pacific Islands Countries and Territories (PICTs). Amongst other activities, the

		PPA undertakes a regional benchmarking exercise for all member Utilities, in partnership with the PRIF and Secretariat for the Pacific Community (SPC).
Sustainable Energy for All (SE4ALL)	The United Nations, The World Bank	A global initiative with the objective of: i) providing universal access to modern energy; ii) doubling the global rate of improvement in energy efficiency; and iii) doubling the share of renewable energy in the global energy mix by 2030. www.se4all.org
IRENA RE Roadmap	IRENA	IRENA is a multi-governmental organization and a hub for knowledge sharing and activities for advancing of the use of renewable energy. www.irena.org

2.4.3 Institutional framework in the energy sector

The Ministry of Climate Change and Natural Disasters (MOCC) and the Utilities Regulatory Authority (URA) are the key entities regulating the energy sector. The Department of Energy within MOCC has a central role in coordinating energy sector development, including identifying and implementing rural electrification projects. It is specifically tasked with development, implementation and review of the National Energy Road Map 2013-2020 (NERM), under direction from the Energy Taskforce (which has broad government representation). The MOCC is also responsible for coordinating (with the National Advisory Board) all government and non-government initiatives addressing climate change and disaster risk reduction in the country, and coordinating rural electrification programmes. Since its establishment in 2007, the URA has provided price, quality, and regulatory oversight of the electricity and water sectors.

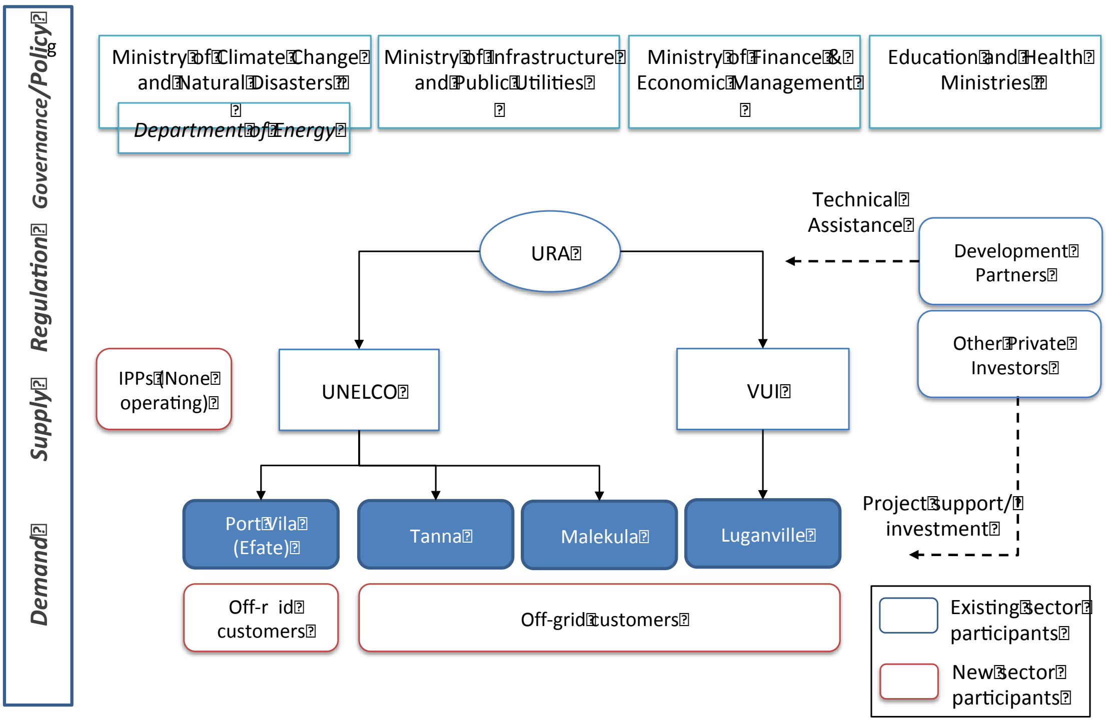
Other government Ministries involved in the electricity sector include:

- Ministry of Land and Natural Resources (MLNR) – responsible for administering the Geothermal Energy Act [Cap 197] under which the government grants licenses for geothermal prospecting and production,
- Ministry of Infrastructure and Public Utilities (MIPU) – responsible for all the public infrastructure of the government,
- Ministries of Education and Health – which are involved in a programme of solar energy packages for social institutions, and
- Ministry of Finance and Economic Management (MFEM) which, with the Prime Minister's Office, oversees the Vanuatu Infrastructure Strategic Plan.

The electricity sector consists of two private operators, Union Electrique de Vanuatu Ltd (UNELCO) and Vanuatu Utilities and Infrastructure Limited (VUI), each of which undertakes generation, distribution, dispatch, billing and settlement for consumers within its area. UNELCO, which has been operating in Vanuatu's electricity sector since 1939, was the sole concessionaire prior to expiry of the Luganville concession in December 2010. At that time, the Government of Vanuatu decided to operate a competitive tender process for the concession. The Government entered into negotiations with VUI (its preferred concessionaire), and to ensure continuity of supply to consumers, signed a Memorandum of Understanding (MoU) with VUI to operate the Luganville network. Subsequent legal action by UNELCO over the tender process has meant that a new concession agreement has not been signed and the MoU remains in place pending a Court decision on the matter.

Figure 2.5 shows the institutional structure of the electricity sector in Vanuatu.

Figure 2.5: Structure of the Electricity Sector of Vanuatu



Source: NERM

2.4.4 Regulatory Framework in the Energy Sector

The key elements of the regulatory and legal framework for the energy sector are:

- The Electricity Supply Act (1972, plus amendments), which provides for granting of concessions, protection of the rights of concessionaires, and recognizes the role of the URA;
- The Utilities Regulatory Act (2007, amended 2011) established the URA and defined its role, function and authority, including assigning it specified powers under the Electricity Supply Act and concession agreements.[18] The purpose of

[18] Prior to the Act, service standards and rules for tariff setting were defined in individual concession agreements.

the Act is to ensure the provision of safe, reliable and affordable regulated services, maximize access to regulated services throughout Vanuatu, and promote the long term interests of consumers.

- The Geothermal Energy Act (1987), under which the government grants licenses for geothermal prospecting and production. The Act stipulates that geothermal energy may only be developed through prospecting and production licenses issues by the Government, and sets out rights and obligations of the parties with regard to applications, prospecting and production licenses.
- Environmental Protection and Conservation Act (2002, and amendments). This Act focuses on conservation, sustainable development and management of the environment. Springs, groundwater and geothermal water are all subject to the Act, which pertains to activities that will or are likely to impact the environment and which require any license or approval under any law. The EPC Act requires that a Preliminary Environmental Assessment be undertaken for all activities subject to the Act; some also require a more in-depth Environment Impact Assessment (EIA).
- Water Resources Management Act (2002). The objective of this Act is to provide for protection, management and use of water resources, including inland, groundwater and coastal. It requires an application to use water other than for specified purposes, and to undertake works in or adjacent to any water.
- Pollution Control Act (2014), the purpose of which is to control the discharge and emission of pollution in Vanuatu, and the Waste Management Act (2014), which aims to provide for the protection of the environment through encouragement of effective waste services and operations.

An important element of the legal framework is the governing of concessions under a hybrid contract/regulatory model. Concession contracts between the Government and concessionaires set out the rights and obligations of the parties, including delegating exclusive responsibility for provision of electricity services within specified areas, and specifying rules regarding service coverage, the quality of service to be provided, and the maximum tariffs that may be charged for the services. These contracts, together with enabling regulations and sector institutions provide the enabling framework for concessionaires to operate profitably. The existing concession agreements are:

- Port Vila concession—held by UNELCO, expires December 2031;
- Tanna and Malekula concessions—held by UNELCO, expire July 2020;
- Luganville concession— this is operated by VUI, commenced January 2011, but remains governed under a Memorandum of Understanding (MoU), pending resolution of appeal by UNELCO (the previous holder of this concession).

Note that under concession agreements, the Grantor (the Government of Vanuatu) gives concessionaires the right to operate existing assets and invest in new assets within (and outside) the concession area, but upon expiry of the agreement, the assets located within the concession area revert to Government ownership, with any residual value of concessionaire funded assets payable by the Government to the ex-concessionaire.

Utility Regulatory Authority Orders and Guidelines

The Vanuatu URA has established guidelines for how IPPs can operate in the power sector. These are summarized in Table 2.4.

Table 2.4: Relevant URA Orders and Guidelines in the Electricity Sector

Order	Date issued	Description
Feed in Tariff and Net Metering	2014	The Feed-in Programme implements a limited solar feed-in programme in the UNELCO service area in Port Vila. The programme allows domestic and small commercial customers to offset their electricity bills by generating their own solar energy. Customers can use grid power at the normal retail tariffs to supplement their electricity use when solar power is unavailable. Once the offtake amount is offset, any additional solar power generated is provided to the network and will offset the cost of service.
Business Development Incentive Tariff for new businesses	2014	A reduced electricity tariff for new large business customers in Port Vila. Under this proposal, new customers or current customers who want to expand will be eligible for a discount of up to 35 percent of their electricity bills for new consumption.
Independent Power Producers and Power Purchase Agreement	2014	The URA Commission has issued Preliminary Guidelines on independent power producers (IPPs) and power purchase agreement (PPAs). These Preliminary Guidelines have been developed to provide a clear set of principles and a framework with sufficient detail to enable participants to engage in a meaningful and sustainable IPP/PPA transaction. Final guidelines will be developed following consultation.
Electricity Reliability Standards	2011	The Authority influences utilities reliability of supply through a financial incentive scheme, which encourages the utilities to meet and exceed target levels of reliability. Each Standard has specific performance requirements that must be met to manage reliability and quality issues effectively. A guideline is provided with each standard to assist regulated utilities in understanding and complying with the requirements.
Electricity Safety Standards	2011	The Electricity Safety Standards are issued by the Authority as guidelines for electricity utilities to ensure that electricity is generated and distributed safely to consumers. They cover all aspects involved with providing safe electricity, to ensure that the public including the personnel within the respective utilities as well as facilities involved in providing electricity are protected. Each Standard has specific performance requirements that must be met to manage Health and Safety issues effectively. A guideline is provided with each standard to assist regulated utilities in understanding and complying

		with the requirements.

Source: *Regulation and Compliance: Electricity Sector*. Vanuatu Utility Regulatory Authority, September 28, 2014. http://www.ura.gov.vu/index.php?option=com_content&view=article&id=100&Itemid=292&lang=en.

2.4.5 Amendments to the framework

The Government plans to undertake a review of the legislative and regulatory framework to enhance the enabling framework for investment and address a number of identified gaps and inconsistencies. For example, the Electricity Supply Act permits Independent Power Producers (IPPs) to generate electricity and supply it outside the concessions or to the concessionaires; however concessionaires are not currently obliged to purchase electricity from IPPs, and there is not yet a framework for IPPs to access existing networks and for concessionaires to pass through costs of such power purchases into tariffs.

In the meantime, a number of enhancements to the current arrangements are currently underway. The URA released preliminary guidelines for IPPs and Power Purchase Agreements (PPAs), for consultation, in June 2014. The intent of the guidelines is to enable the URA to take an advisory role while PPA parties negotiate the terms of the PPA. However, it may also involve approving a-priori the PPA terms if required for a project to go forward. This approach will provides certainty for investors and lenders of the revenue stream (including beyond the term of a concession), and for the buyer the ability to pass on the relevant PPA costs to consumers.[19]

In addition, project-specific frameworks and Codes are being developed where gaps in the existing arrangements have been identified, for example:

- The Environmental and Social Management Framework for the Global Partnership on Output Based Aid (GPOBA), to ensure that subsidized connections meet the environmental, social and land laws and regulations and environmental and social safeguard policy requirements of the World Bank
- Environmental Code of Practice for Disposal of Batteries, currently being developed under the Vanuatu Rural Electrification Programme (VREP).

SREP success depends on the GoV and the URA continuing to address these gaps to enable growth in the RE sector.

2.5 Energy Supply and Demand

The subsections below describe the demand and supply balance in grid-connected and off-grid areas.

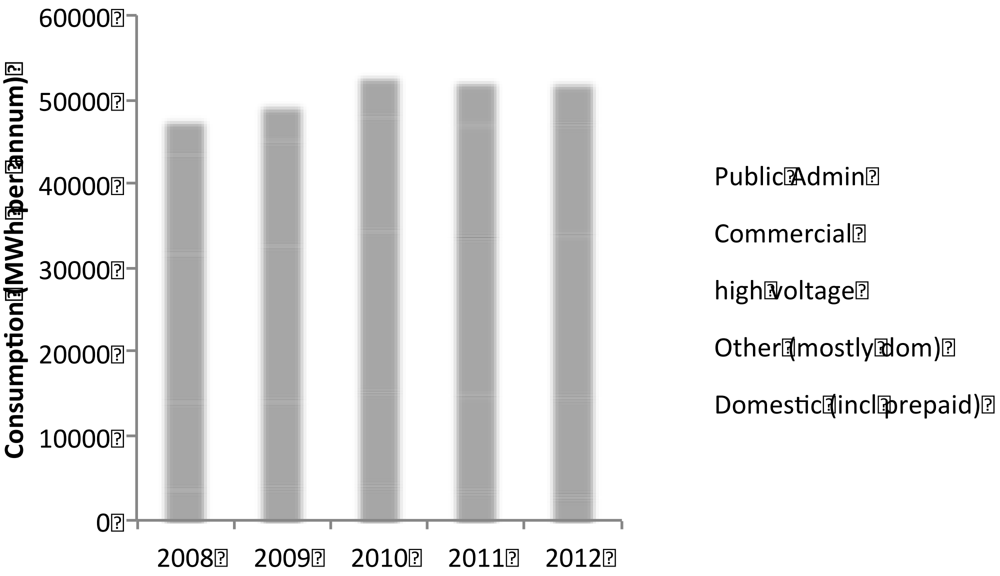
2.5.1 Supply and demand in grid-connected areas

Consumers in the concession areas of Vanuatu rely on electricity to meet the majority of their energy consumption needs. In the Port Vila concession area,

[19] The URA also noted, in its preliminary guidelines consultation paper, its intent to propose limited Direct Access guidelines, regulatory framework, etc., to enable IPPs to sell power directly to large end users and unbundle consumer tariffs into generation and distribution components.

commercial, residential and public services sectors account for about 60 percent of final energy consumption; high voltage consumers, including fisheries, resorts, banks, High Commissions, and manufacturing, account for the remaining 40 percent. These figures are similar for Santo, while the Malekula and Tanna concessions supply no high voltage electricity.

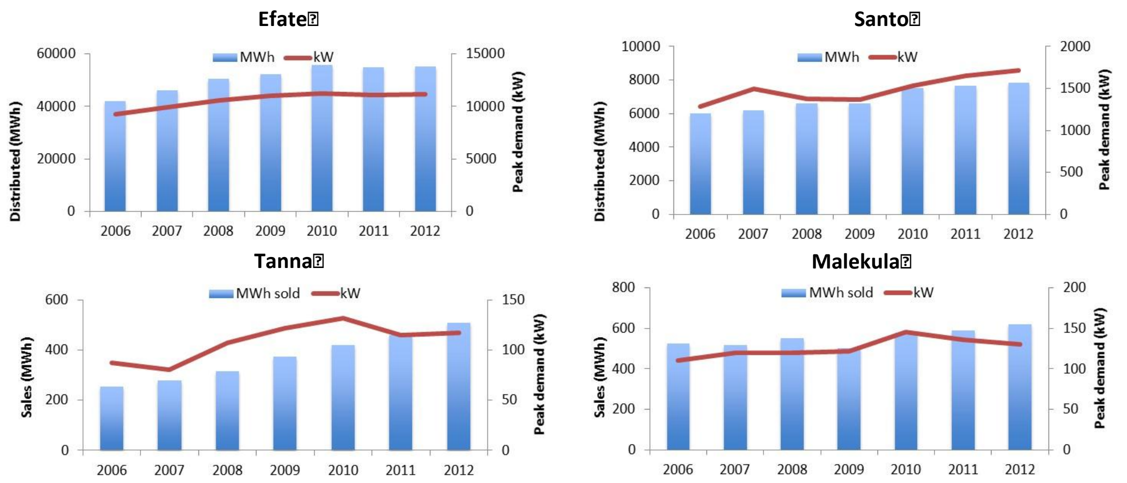
Figure 2.6: Port Vila Electricity Consumption



Source: UNELCO

From 2006-12 demand grew by an average of four percent per annum on an energy basis and 3.5 percent on a peak basis, across the four concession areas. Tanna exhibited much higher than average growth (10.4 and 5.0 percent growth in energy and peak demands, respectively). However, as shown in Figure 2.7, demand in three of the four concessions has levelled off or fallen since 2010.

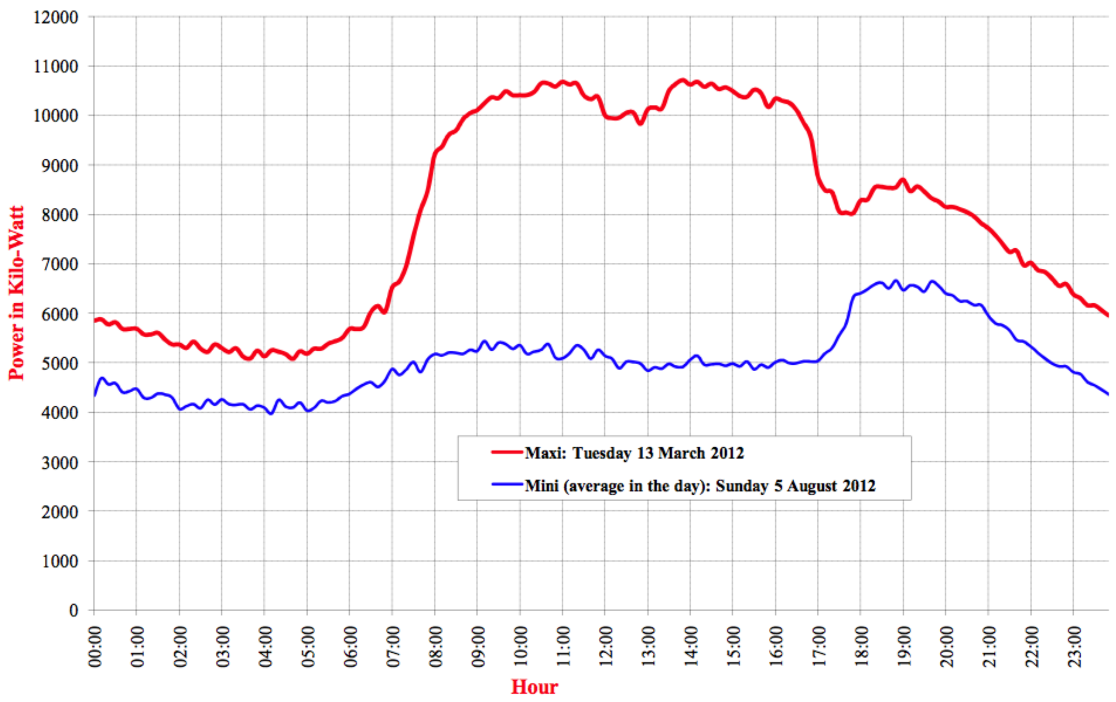
Figure 2.7: Annual Demand, 2006-2012 – Concession Areas



Source: UNELCO, VUI

Demand in the Port Vila concession area peaks in the summer months, and is highest during commercial working hours as shown in Figure 2.8.[20] This profile is well suited to baseload generation such as diesel, geothermal and – to some extent – hydro, with the lower capacity factor generation types such as wind and solar (for which most generation is during peak hours) contributing to meet peaks.

Figure 2.8: Efate Load Profile (2012) – Sample Week and Weekend Days



Source: *Annual Technical Report 2012*. UNELCO, 2012.

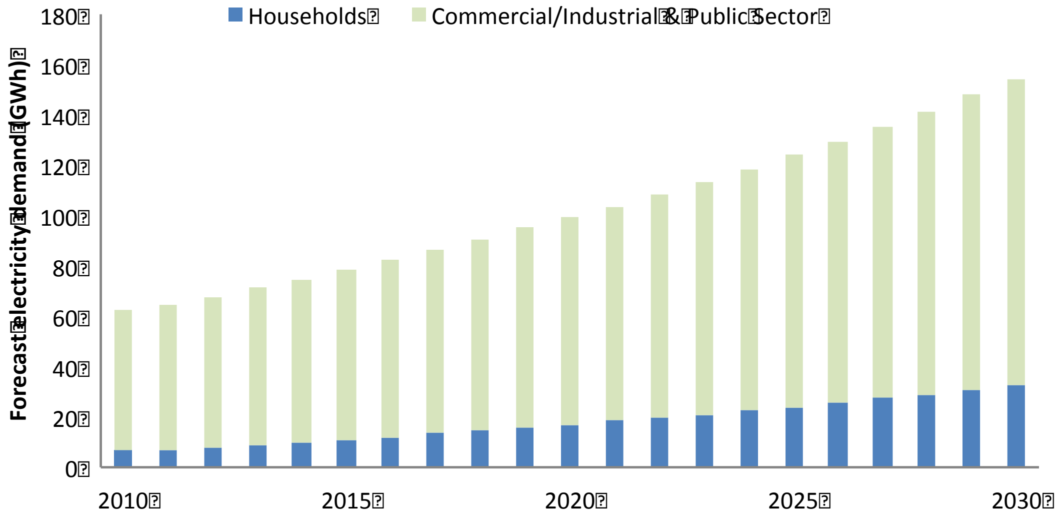
Future demand

A demand forecast was developed in 2012 as part of a feasibility study prepared by consultants Castalia for the Global Partnership for Output Based Aid (GPOBA) Improved Electricity Access Project. This forecast was adopted in preparation of the NERM, and forecast demand growth of roughly five percent per annum over the period 2012 to 2020 across the four concessions. Tanna and Malekula were expected to experience higher than average growth, at eleven and eight percent, respectively. Forecasts take into consideration the load of existing households, expected number and demand of new household connections[21], as well as growth in demand from commercial and administration customers. Figure 2.9 shows the demand forecast.

[20] Demand profiles are not available for the Malekula and Tanna concessions. The most recently available load profile for Santo (2009) shows a weekday profile similar to Efate, but with an additional high point at 2pm, as well as a similar weekend profile.

[21] Under the GPOBA Improved Electricity Access Project, some 4,375 new connections will be subsidized across the four concessions.

Figure 2.9: Forecast National Electricity Demand (Grid-Connected) to 2030



Source: NERM

It is important to note, however, that three of the four concession areas have seen zero or negative growth in recent years, and actual 2013 energy demand was substantially below forecast levels.

A recent review by consultants SMEC (for the Asian Development Bank (ADB)) in relation to potential new hydro schemes on Malekula and Santo noted that there are a number of factors that can affect demand including new connections as a result of GPOBA funding and distribution extensions[22], and potential new business connections as grid-supplied electricity becomes available.

The NERM forecasts have been utilized for the purpose of this work, but it has been noted in the document where results may be sensitive to demand growth variations.

Generation

Vanuatu's grid systems have a total of 31.5 MW of installed generating capacity of which 26.5 MW is in the Port Vila concession. Electricity is produced by three main generation sources: diesel (approx. 77 percent in 2012), CNO in diesel generator units (roughly 4.4 percent), hydropower (10.7 percent), wind power (7.5 percent) and solar PV (0.2 percent).[23]

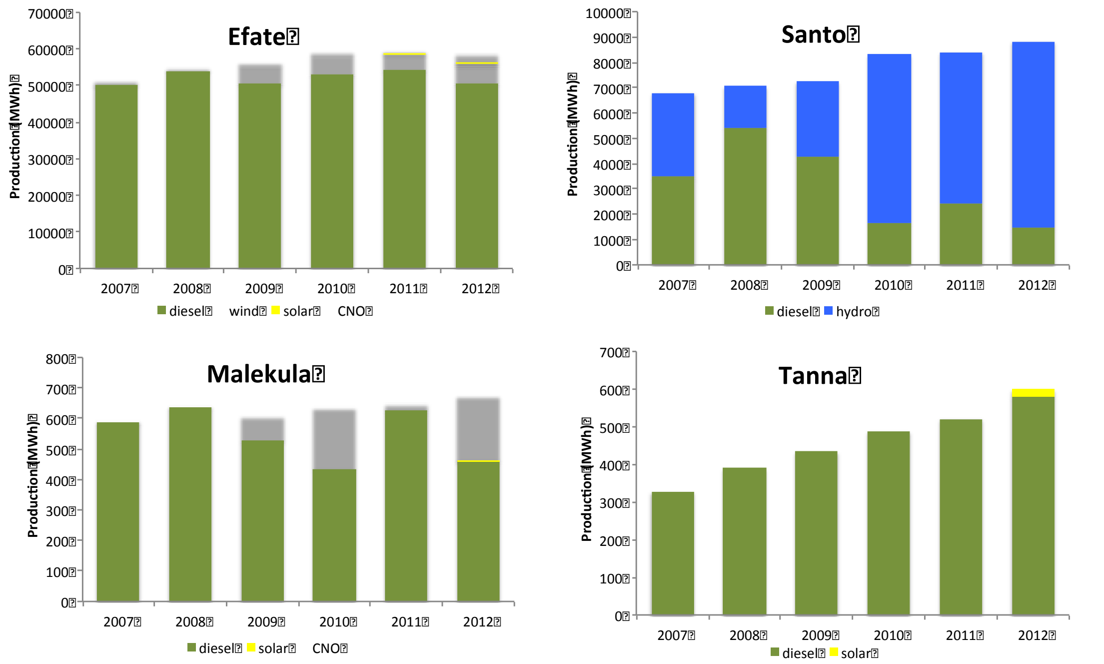
Most of the plants are relatively modern. With the exception of hydro plant, only around 8 MW of the plants (25 percent) are older than 15 years and all but a few of the installed MW capacity remains in regular operation. As shown in Figure 2.10, with

[22] The Brenwe project includes a distribution line extension that will allow for more than 1,000 new customer connections.

[23] Calculated from: *Annual Technical Report 2012*. UNELCO, 2012..

the exception of the Luganville concession, diesel generation is dominant. According to UNELCO, the diesel units on Malekula are now operated primarily on CNO.

Figure 2.10: Production by Technology and Concession, 2007-12



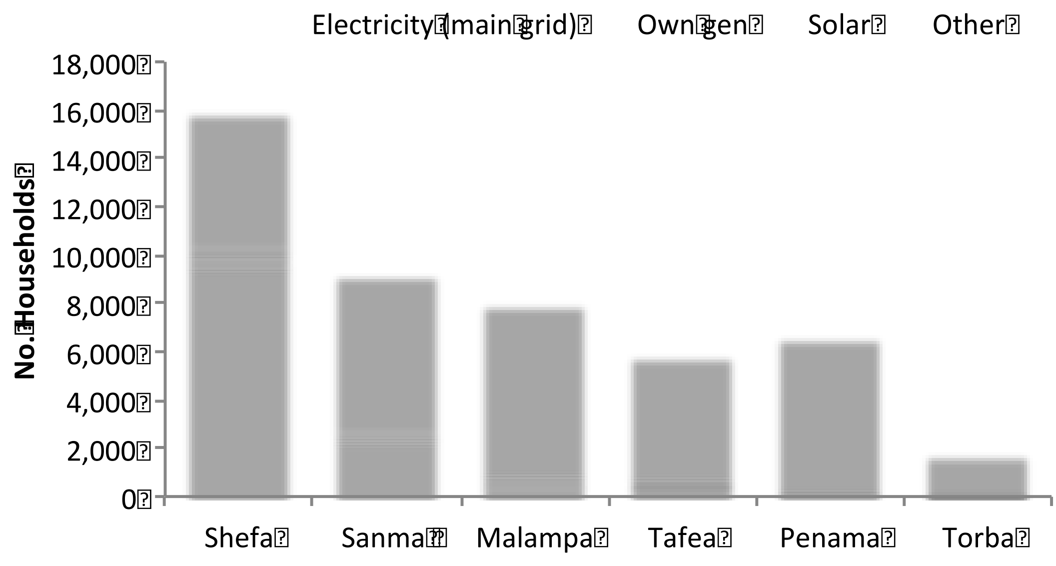
Source: UNELCO, VUI

The difference between installed capacity and demand can largely be explained by two main factors. First, UNELCO uses an N-2 planning standard, in other words, the loss of the two largest generation units will not result in insufficient supply to meet demand. This reflects Vanuatu's distance from other markets, and thus likely greater time for return to service. Second, wind and solar are generally assumed to provide no "firm" capacity, as their output cannot be guaranteed. In addition, demand is uncertain, and time for new build needs to be taken into consideration when undertaking capacity planning.

2.5.2 Supply and demand in off-grid areas

In off-grid areas, energy for lighting and cooking is supplied by a variety of sources. Figure 2.11 shows the sources of electricity for lighting by province from the 2009 Census. The first four provinces include the four concession areas, which are primarily served by the main grids. 'Other' is the main source of lighting for the vast majority of rural households, and primarily comprises kerosene lamps, with smaller numbers of Coleman lamps, biomass and candles.

Figure 2.11: Main Source of Lighting (2009)

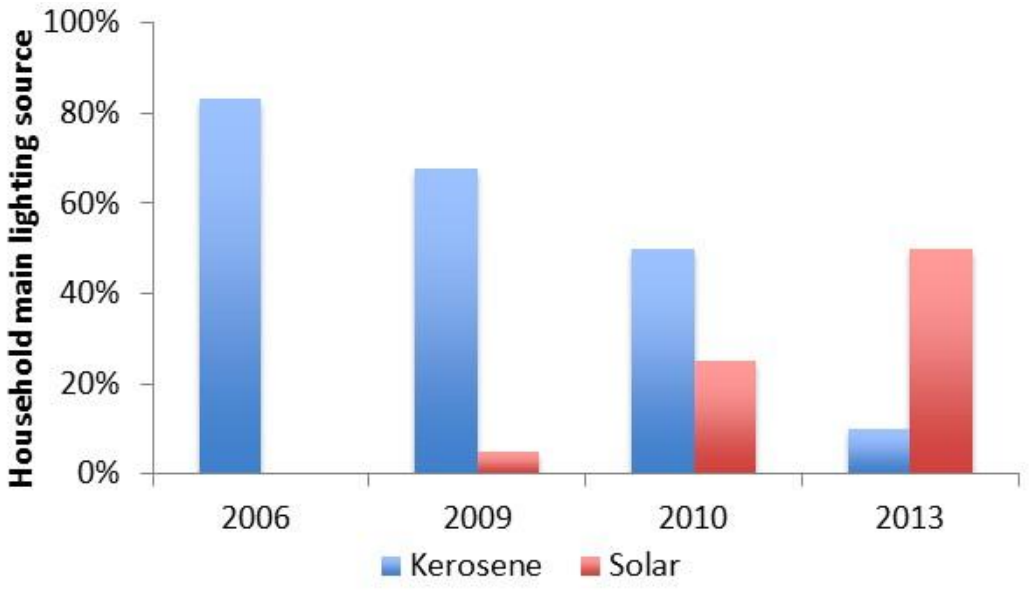


The first four of the bars represent provinces that include an electricity grid: Efate is in the Shefa province, Santo within Sanma, Malekula in Malampa, and Tanna in the Tafea province.

Source: Lighting and Cooking Sources - *2009 National Population and Housing Census.* Vanuatu National Statistics Office, 2009.

However, since 2009, the Lighting Vanuatu programme and independent sales of pico-solar products have significantly increased the proportion of households that use solar as their main source of lighting. As shown in Figure 2.12, kerosene as the main source of household lighting has reduced from more than 60 percent in 2009 to less than 10 percent in 2013.

Figure 2.12: Household Main Source of Lighting (2006-13)



Source: Lighting Vanuatu Independent Completion Report (2014)

Demand in rural areas cannot be measured in terms of generation capacity, but in terms of services provided by electricity, and the cost of its provision and willingness to pay by consumers. In terms of numbers and characteristics of potential electricity consumers in rural areas, there are estimated to be approximately[24]:

- 36,000 households, of which 6,200 (17 percent) have access to electricity. About two-thirds of those that do have electricity are within concession areas. The main requirement is for lighting and phone charging though some consumers would likely be willing and able to pay for services such as television and refrigeration;
- 405 primary and 75 secondary schools, of which 42 percent have access to electricity. While primary schools requirements are mainly for lighting, secondary schools also require electricity for copying and computing[25];
- 124 health facilities (centres and dispensaries), of which 25 percent have access to electricity. Some of the largest health facilities have no electricity to enable vaccine storage, microscopy (for malaria diagnosis), and night-time maternity services. There are also lighting, refrigeration and computing requirements;
- 231 'aid posts' of which 99 percent have no electricity access. These have modest requirements, mainly lighting; and
- 'Hundreds' of formal business enterprises, the majority of which lack access to electricity[26] as well as many small, informal family or cooperative businesses (fishing, agriculture).

Some of the health and educational facilities do have electricity access, supplied from diesel generators, but often the costs of fuel and maintenance severely restrict the level of operation.

2.6 Electricity Tariffs

The URA is responsible for regulation of the electricity sector, including regulating prices. Its primary objective (as stated in the Utilities Regulatory Authority Act) is to ensure the provision of safe, reliable and affordable regulated services and maximize access to regulated services throughout Vanuatu.

The reference price, price adjustment formula and adjustment timing and tariff structure are set out in concession agreements between the Government and concessionaires. The adjustment formula enables prices to be amended in the period

[24] Data from VERD Programme Design Document, July 2011, in some cases referring to data from the 2009 Census.

[25] There are approximately 90 primary schools with 1-50 students, 150 with 51-100 students and 160 with more than 100 students. In the case of secondary schools there are approximately 10, 20 and 45 schools within those same groupings.

[26] Vanuatu Post, one of the most widespread of Vanuatu's businesses has electricity at only 12 percent of its 58 postal outlets. (Source: VERD)

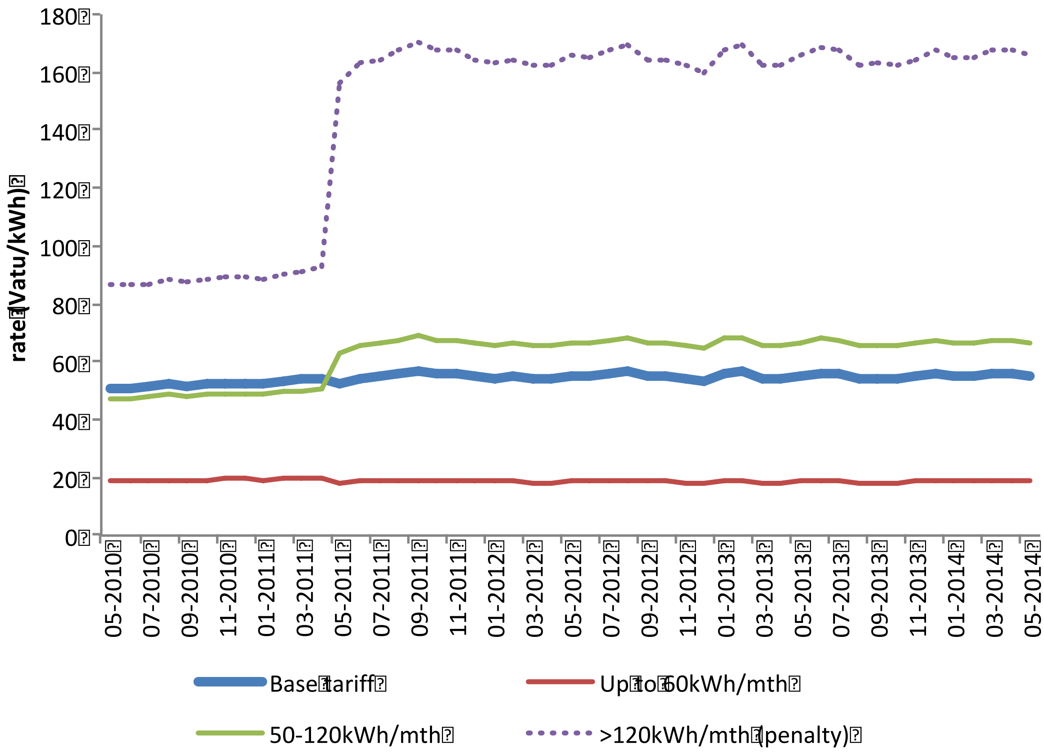
between fundamental tariff reviews, to incorporate changes in input prices, such as for fuel, labour and materials. Conditions for undertaking a full review of tariffs are also set out in the concession agreements, and include factors such as more than five years having passed since the last revision, significant changes in parameters or taxes, or agreement between the parties to modify aspects of the tariff formula or customer classes.

A full review of tariffs—a highly consultative process—last carried out for the UNELCO concessions in 2010, resulted in URA establishing:

- The revenue requirement to cover the efficient cost of service for the utility, including forecast capital and operating expenses, cost of capital and expected benefits from renewable energy generation;
- The tariff structure for various consumer groups, which includes significant cross-subsidies to low volume users;
- The formula for indexation of the base tariff, to allow changes in input prices beyond the control of the utility (fuel, wages and materials) to be passed through to consumers, to apply until the next full tariff review is undertaken;
- Service levels to be achieved by the utility (reliability, quality of supply, and customer service).

Figure 2.13 shows the evolution of the base price P_o in the period 2010 to 2014 for the UNELCO concessions. The tariff structure for small domestic consumers is set in three tranches as shown: the first 60kWh per month is charged at 0.34 times the base price, the next 60kWh at 1.21 times the base price, and any usage above that level at three times the base price. Larger domestic, commercial and high voltage UNELCO consumers pay higher single tier tariffs, together with fixed monthly charges based on size of the connection.

Figure 2.13: Base price and small domestic user tariffs (2010-2014, Vatu/kWh)

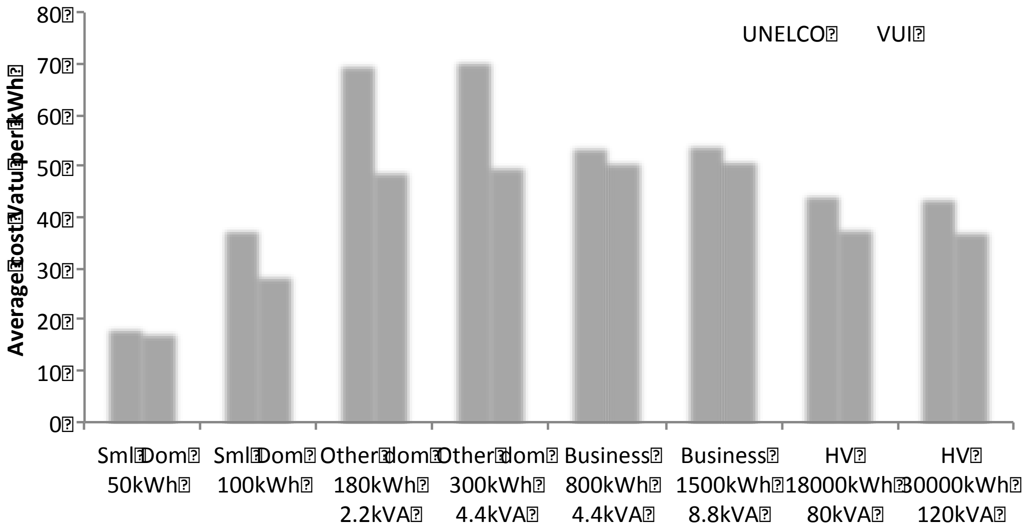


Source: URA Decisions, UNELCO monthly tariff adjustments

In the Luganville concession a different base price and tariff structure has applied since 2010. The base price has been slightly lower due to the hydro generation on Santo. Only high voltage customers pay fixed monthly charges.

Figure 2.14 provides an illustration of the effective price per kWh for a series of different user types: the variable rate shown takes into consideration the fixed and variable charges faced by that consumer type, and their consumption. This chart illustrates cross subsidization between the various customer groups. The utilities do not receive subsidies from the Government; nor are tariffs set in a manner that will result in a shortfall to utilities. Low tariffs paid by small consumers are fully offset by higher tariffs charged to larger domestic consumers and business customers.

Figure 2.14: Indicative End User Cost Per kWh for Defined Customers (including fixed charges), May 2012 (Vatu/kWh)



Source: URA Decisions, UNELCO monthly tariff adjustments

The URA intends to commence another tariff review shortly. Most recently, the URA has focused on establishing feed-in tariffs. In July 2014, the URA released a Final Order regarding implementing feed-in and net metering tariffs.[27] Initially this will apply only to a limited capacity of solar technology on the Port Vila concession, and includes adjusted net metering (for domestic customers with solar panels) and bi-directional metering (for commercial and high voltage customers). The scheme is currently limited in both installation size and number of participants.

[27] This applies to smaller, distributed generation plant, in contrast to the IPP framework.

3 Renewable Energy Sector Context

Vanuatu potentially has significant indigenous renewable energy resources in the form of sunlight, hydro, wind, geothermal and bioenergy. However, it faces a number of important barriers to renewable energy deployment. In the on-grid areas, these are primarily related to the availability of financing, the regulatory framework for IPPs, and expertise and personnel resource to exploit the potential benefits of renewable energy technologies in a manner that can be sustained over time. In the case of off-grid applications, barriers include financial, information, technical capacity, and distance.

This section describes Vanuatu's renewable energy sector, and includes an assessment of the potential for different renewable energy options, a description of Vanuatu's business environment for renewable energy, as well as a description of the barriers facing renewable energy development in Vanuatu.

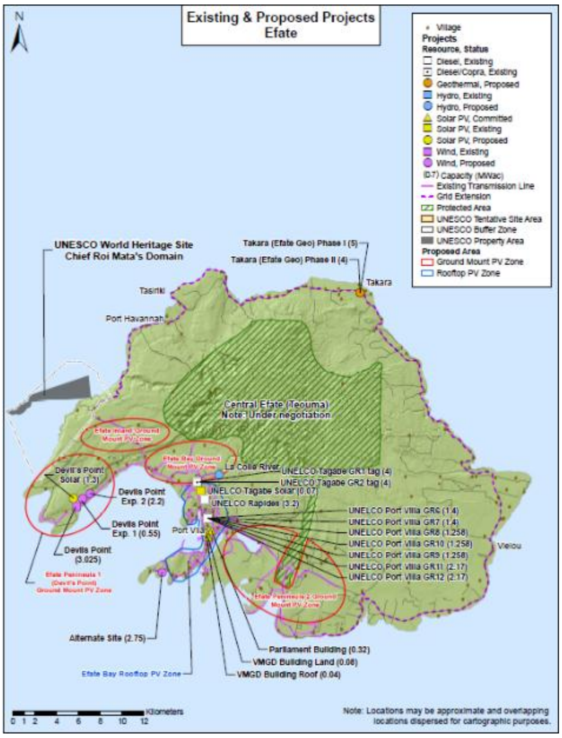
3.1 Analysis of Grid-Connected Renewable Energy Options

An assessment of available data on renewable energy resources in Vanuatu was carried out to support the preparation of the IP. This section details the results of that assessment and describes progress to date on deploying renewable energy technologies in Vanuatu.

3.1.1 Technical Potential

Figure 3.1 to Figure 3.4 show the total estimated technical potential for renewable energy in each of the concession areas of Vanuatu.

Figure 3.1: Grid-Connected Technical RE Resource Potential – Efate



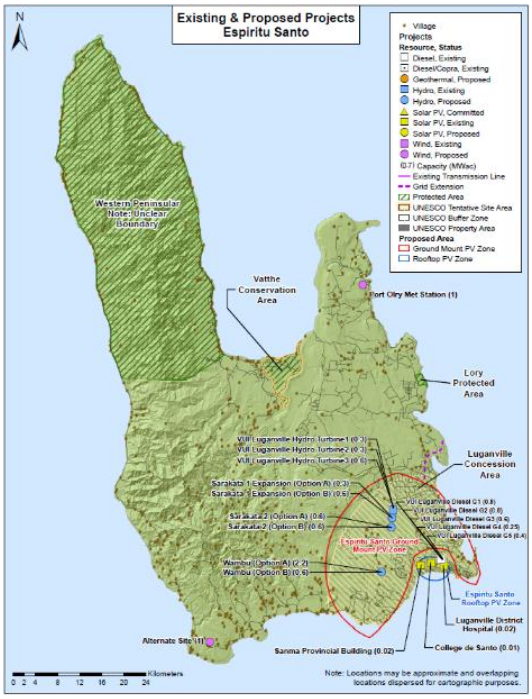
Project Name	Re-source	Max-imum Capacity (MW)	Annual Pro-duction (MWh)	CF*
Devils Point Expansion 1	Wind	0.55	1,205	25%
Devils Point Expansion 2	Wind	2.2	4,818	25%
Alternate Site	Wind	2.75	6,023	25%
Takara (Efate Geo) Phase II	Geothermal	4	32,237	92%
Takara (Efate Geo) Phase I	Geothermal	4	32,237	92%
Efate - CNO Existing	CNO	8.8	38,535	50%
Efate - CNO New	CNO	5.3	23,284	50%
Efate Peninsula 2 - Ground Mount	Solar PV	31.1	63,509	23%
Efate Peninsula 1 - Ground Mount	Solar PV	4.8	9,794	23%
Devil's Point Solar	Solar PV	1.3	1,820	21%
Efate Bay - Ground Mount	Solar PV	19.2	38,112	23%
Efate Inland - Ground Mount	Solar PV	6.2	12,180	23%
Efate Bay - Roof Mount	Solar PV	63.4	11,769	21%

Notes: CF = Capacity Factor. More details on input parameters are provided in Annex E.

Technical potential does not include already committed projects, i.e. in Efate; it excludes the UAE-funded solar PV at Parliament/ Meteo.

Geothermal Technical Potential in the three zones on Efate that were assessed by Kuth Energy is estimated at 83 MWe (P50). The potential capacity included in the above table relates only to the Takara project, which was sized based on the P90 value for the Takara zone.

Figure 3.2: Technical Resource Potential – Santo



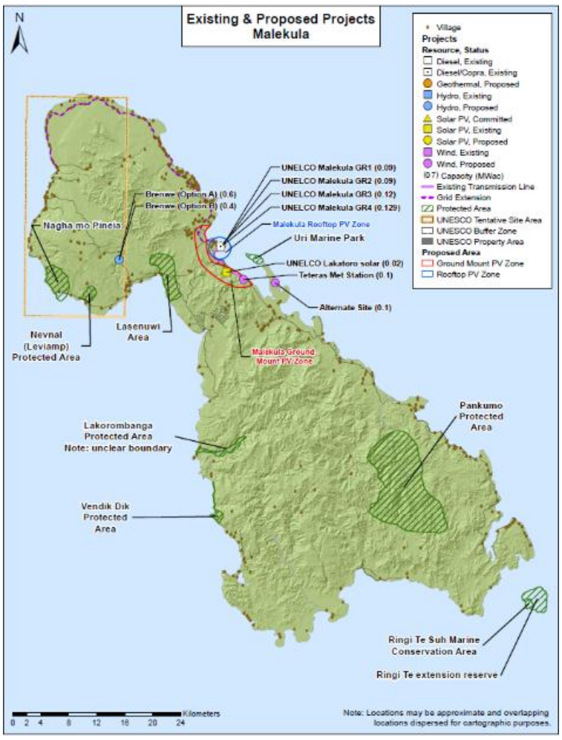
Project Name	Re-source	Max-imum Capacity (MW)	Annual Pro-duction (MWh)	CF
Santo - CNO Existing	CNO	1.25	5,475	50%
Santo - CNO New	CNO	1.60	7,008	50%
Espiritu Santo Ground Mount	Solar PV	16.70	31,595	22%
Espiritu Santo Roof Mount	Solar PV	3.35	5,906	20%
Wambu (Option A)	Hydro	2.20	8,051	42%
Wambu (Option B)	Hydro	0.6		
Sarakata 1 Expansion (Option B)	Hydro	0.60	1,045	20%
Sarakata 2 (Option A)	Hydro	0.60	2,715	52%
Port Olry Met Station	Wind	1.10	1,156	12%
Alternate Site	Wind	1.10	1,445	15%

Notes: CF = Capacity Factor.

The technical potential for ground mounted solar may be much greater than this, but was assessed conservatively due to uncertainty.

More details on input parameters are provided in Annex E.

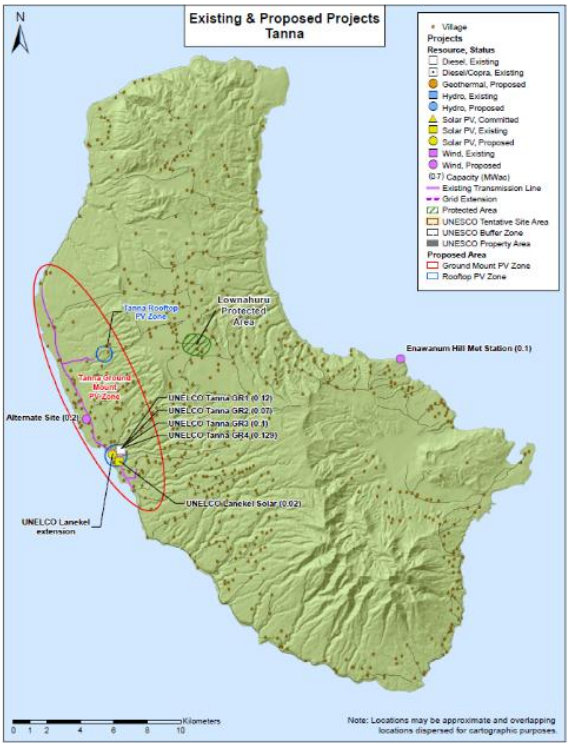
Figure 3.3: Technical Resource Potential – Malekula



Project Name	Re-source	Max-imum Capacity (MW)	Annual Pro-duction (MWh)	CF
Brenwe (Option A)	Hydro	0.60	2221	42%
Brenwe (Option B)	Hydro	.40	2,043	58.3
Malekula Ground Mount	Solar PV	4.95	8637	20%
Malekula Roof Mount	Solar PV	0.43	692	19%
Teteras Met Station	Wind	0.28	217	9%
Alternate Site	Wind	0.28	530	22%

Notes: CF = Capacity Factor. More details on input parameters are provided in Annex E.

Figure 3.4: Technical Resource Potential – Tanna



Project Name	Re-source	Max-imum Capacity (MWac)	Annual Pro-duction (MWh)	CF
Enawanum Hill Met Station	Wind	0.28	650	27%
Alternate Site	Wind	0.28	361	15%
UNELCO Lanekel extension	Solar PV	0.02	44	25%
Tanna Ground Mount	Solar PV	6.62	14729	25%
Tanna Roof Mount	Solar PV	0.8	163	24%
Tanna - CNO Existing	CNO	0.42	1835	50%

Notes: CF = Capacity Factor. More details on input parameters are provided in Annex E.

3.1.2 Small Hydropower

Vanuatu has relatively few rivers considering its tropical location, as a result of small island areas and porous volcanic terrain, which reduces the potential for river formation. Only one small hydropower plant is currently connected into a grid concession area, being the 1.2 MW Sarakata plant on Santo. Originally funded by JICA, this plant was transferred to GoV ownership, and subsequently included in the Luganville concession, an operational/governance approach that has worked well. Small hydropower contributes approximately 10 percent of Vanuatu's (and 80 percent of Santo's) annual grid-supplied electricity generation. This plant is operated and maintained by utility company VUI. The first 600 kW was commissioned in 1995, and an additional 600 kW in 2008. Both stages were funded by grant aid from JICA; the key objective was to reduce Vanuatu's dependence on imported oil.

A number of additional small hydropower projects have been identified on the islands of Efate, Santo, and Malekula. ADB has directed feasibility studies for a 400-600 kW run-of-river plant on Malekula (Brenwe) as well as various options to extend the run-of-river Sarakata hydro system on Santo (300 kW – 1.2 MW additional capacity). Together these developments could supply up to 6 GWh of electricity per year. ADB has decided not to proceed with studies of the Wambu site on Santo, following review of forecast demand for Santo. UNELCO is also considering a 700 kW hydro development at the Prima site on Efate, though little is known about this site as yet.

In general, small hydropower will likely be run-of-river, primarily providing baseload power. Limited peaking capability may be available, depending on storage.

3.1.3 Wind

Only one wind farm is currently in operation in Vanuatu, being the Devil's Point wind farm on Efate, commissioned by utility UNELCO in 2008. It has eleven turbines at 275 kW each for total capacity of 3.025 MW. In 2012, output was 5.18 GWh (capacity factor of 19.5 percent). UNELCO has proposed plans to extend the site, with short-term plans of installing an extra two turbines and eventually expanding the farm to double the current capacity.

IUCN has installed wind monitoring masts on six of Vanuatu's islands, including the four islands with concessions. Unfortunately, verified data is not yet available from these sites. Additional sites on each of the islands were selected from the AWS wind maps[28] developed for the World Bank in 2009, also taking into consideration proximity to roads and transmission lines.[29]

[28] The AWSTruewind wind maps cover all South Pacific Islands. They were developed for the World Bank in 2009 using mesoscale maps, modelling average annual wind speed at 12m, 25m and 45m hub heights and average monthly wind speed at 12m only.

[29] Data shows few sites with wind speeds exceeding 6 m/s at 45 metres height, the best wind resources being on Tanna and Efate; in addition, most areas with the greatest wind resource are located on steep ridges, creating issues for access and construction. The best resource site on each island that is in good proximity to roads was selected. The interior of the islands was avoided due to difficulty to construct and transport.

In general, data shows few 'good' wind sites. However, several sites have been identified with expected capacity factors of 25 percent or greater, with reasonable proximity to roads and transmission lines, and these were included in the supply curves for the four concession areas.

There is considerable uncertainty regarding the wind resource at the specific sites, particularly those selected based solely on the AWS maps, which were not able to be verified against data from meteorological towers to determine whether the modelled data is appropriate.[30]

Output from the Devil's Point wind generators has a profile that varies seasonally; generally the highest output occurs during May to November, and the lowest between December and April. The IUCN data appears to confirm this for other locations. No information is available on the daily profile of the Devil's Point site; however, initial IUCN data suggests that wind speeds are strongest in the early morning and evening and weakest around midday. This is not a good match to the Efate load profile, but may suit other locations that have peaks outside the commercial hours.

Note that this study has not considered integration issues related to the intermittent nature of wind energy, but has assumed that batteries will be installed to provide some frequency and voltage support.[31]

3.1.4 Geothermal Power

Vanuatu has no installed geothermal power plants. KUTh Energy prospected three potential sites on Efate, and selected the Takara site in North East Efate as the best candidate for geothermal power. A pre-feasibility study was undertaken in 2012, and a two-stage development (2 x 4 MWnet) proposed. This study assessed geothermal power from Takara to be the least-cost power supply addition for Efate under a broad range of conditions.[32]

Based on this analysis, the NERM commented that the geothermal power and ring road network development could, if efficiently structured, substantially lower the cost of electricity production by substituting high cost base load diesel generation with significantly lower cost base load geothermal power.

The Vanuatu Government issued the developer a Geothermal Production Licence in 2012, under the Geothermal Act. The proposed online date for the plant was 2015, but development has been delayed, and slim hole drilling activities to confirm the resource have not yet commenced. While the fieldwork for the environmental

[30] The data for the Malekula site, when sheared up to 45m is reasonably well correlated with the AWS data; however the data for the Tanna site was poorly correlated with the AWS data.

[31] As for new wind generation it is assumed that that lithium ion battery systems that can cover ramping and provide frequency regulation will be included with each new solar and wind system. The battery systems are sized to allow approximately 20-30 percent of the solar capacity for 30 minutes. As such, they can manage variability over 1 second, 1 minute, and 10 minute intervals.

[32] *Vanuatu: Efate Geothermal Power and Island-Ring Grid Development Framework*. The World Bank Group, October 7, 2011.

assessment has been completed (September 2014), the lack of PPA/IPP regulation is likely to be one reason for delays, and the URA is currently working to resolve this issue.

Geothermal power could displace existing diesel generation on Efate, as its unit cost may be lower than the current fuel-only price from existing diesel generator units. This could result in stranding of some diesel units on Efate, which the URA would need to take into consideration in future tariff determinations. The geothermal plant could provide baseload power consistent with the load profile on Efate.

3.1.5 Solar PV

Currently, small grid-connected solar plants are installed on each of the main islands, with 40 kW on Santo (across three rooftop sites), 70 kW ground-mounted at Tagabe on Efate, and 20 kW on each Malekula and Tanna (all commissioned in the period 2011-13). Further solar PV is planned for Efate, including the committed ground and roof mounted UAE-funded 510 kW at Parliament/Meteo and the planned UNELCO/EU/GoV- funded 1.3 MW ground mounted plant at Devil's Point.

The available modelled data shows that Vanuatu has good solar resource. Estimates of average global horizontal irradiation (GHI) in various locations range from approximately 1,900 to 2,300 kWh/m^2/year. (By comparison, average annual GHI in Europe is 1,000 kWh/m^2). However, the modelled data has limitations and high uncertainty associated with this assessment,[33] and it will therefore be very important to verify the resource with site-specific ground measurements.

Solar maps developed from the Meteonorm 7 data set were used together with GIS analysis to identify potential solar zones that meet specified criteria. Assumptions about the system size and available area then enabled calculation of the technical potential. The specific assumptions and criteria are provided in Table 3.1.

Table 3.1: Criteria and Assumptions for Assessing Technical Potential of Solar PV

	Ground-Mounted	Rooftop-mounted
Criteria	▪ Not in protected areas ▪ Outside built-up areas on land with ≤5 percent slope ▪ Within 2 km of transmission line access	▪ Not in protected areas ▪ Inside built-up areas ▪ Within 1 km of transmission line access
Assumptions	▪ 10 percent of area can be developed ▪ 500 kW of area can be developed ▪ System size 100 kW	▪ 10 percent of buildings in the area can accommodate 10 kW systems ▪ System size 10 kW

[33] The Meteonorm 7 database, used to develop solar maps for Vanuatu, uses available "measured" data sites from ground-based weather stations and geostationary satellites and interpolates to estimate what solar resource would be at a specific location. The quality of available datasets and the interpolation algorithm have limitations, and the uncertainty of the modelled solar resource data at a specific site is high.

The total resource potential for 100 kW grid-connected ground mounted solar PV farms is estimated at approximately 90 MW, while 10 kW rooftop grid-connected units could contribute a further 10 MW. Peak production from solar units will be during the summer months. The vast majority of this potential is located on Santo, but technical potential on each island is well in excess of current island peak load demand.

Potential capacity factors depend on the technology employed and the way the modules are mounted and external factors such as trees or buildings that may shade the panels or block the solar resource.

The use of polycrystalline solar PV modules was assumed, as this technology is expected to be most practical for Vanuatu.[34] Designs assumed for roof and ground mounted systems were largely the same (fixed tilt at 10 degrees, same modules and inverters), the primary difference being the "inverter loading ratio" (ILR). A higher ILR was assumed for rooftop systems.[35]

Technologies such as tracking systems, concentrating solar PV (CPV) and solar thermal are not expected to be as practical for remote islands because they require more maintenance. This is because they have several moving parts, and adequate energy production requires exact precision in their orientation (perpendicular to the sun at all production times). The capital cost for these technologies are also much higher than polycrystalline solar PV.

The nature of the solar resource is such that peak production from solar PV will generally occur in the summer months (October to March) and will be limited to daylight hours. Average summer output may be close to twice that of average winter output. Output can change rapidly as a result of changes in cloud cover. However, the daily profile of solar, when operated in conjunction with a source of baseload power, is a good match for the Efate load profile.

Note that this study has not considered integration issues related to the intermittent nature of solar energy, but has assumed that batteries will be installed to provide some frequency and voltage support.[36]

[34] Monocrystalline solar PV has slightly higher cost because it allows more power to be packed into a small footprint - this is only critical when available area is limited. Thin film technology is also an option with similar cost and characteristics as polycrystalline, except it requires a larger footprint.

[35] ILR refers to the ratio of the nominal output of the modules (DC capacity) to the nominal output to the inverters (AC capacity). It is common practice to have the DC capacity higher than the AC capacity. Rooftop systems tend to be less flexible in their design so the inverters often cannot be "loaded" as heavily with DC capacity as a ground mounted system where there is often more useable space. Therefore an ILR of 1.13 for rooftop systems is assumed and an ILR of 1.2 for ground mounted systems.

[36] As for new wind generation it is assumed that lithium ion battery systems that can cover ramping and provide frequency regulation will be included with each new solar and wind system. The battery systems are sized to allow approximately 20-30 percent of the solar capacity for 30 minutes. As such, they can manage variability over 1 second, 1 minute, and 10 minute intervals.

3.1.6 Biomass

Forestry residue was considered as a resource that could potentially be used for power generation in Vanuatu. According to the Food and Agriculture Organization, forest cover reduced from 73.8 percent in 1995 to 36.1 percent in 2005. More current data on the state of Vanuatu's forests or the forest harvest statistics were not available. According to the Resource Assessment of Forestry Data by the Government of Vanuatu[37], wood residue from current lumber operations is used primarily for composting and heating fuel.

Analysis considered the volume of residue that might be generated and reasonably aggregated at a central location, assuming forests were harvested at the "Sustainable Yield" level recommended by the Department of Forestry in its 2013 to 2023 Policy Paper. It found that this amount of wood residue would not be sufficient level to sustain even a 100 kW gasifier. As such, this source of biomass was not considered further.

Other potential biomass sources considered for inclusion in this study were coconut husks, and plantation forestry such as jatropha. The problem that exists with coconut husks is the problem of aggregating the resource, given that hulling usually occurs at the time of harvesting. On larger plantations this may be more feasible, and UNELCO is considering coconut husk fired generation at Udine Bay. UNELCO has previously considered jatropha for biomass generation, and has tested the growth and yield of the resource on Efate, but decided not to consider it further for biomass electricity generation.

3.1.7 Biofuel and biogas

For some years, a number of UNELCO diesel generators on Malekula and Efate have been partially fuelled by coconut oil. In addition, the Port Olry microgrid utilizes a diesel/CNO generator. The coconut oil used in all these generators is produced and refined on Vanuatu, which has the significant benefit of avoiding the transport costs associated with importation of diesel. However, it is heavily reliant on sustainable production of CNO of the quality required for electricity generation, and exhibits significant price variability (due to being a commodity product traded on world markets). It is assumed that further supply of CNO could be developed if it were priced at or above international market prices, currently about $1.25/litre.[38]

The most practical examples of utilizing CNO for on-grid applications would be to convert existing diesel generators that do not run on coconut oil to do so, or replace (over time) older diesel generators at existing sites with CNO-ready generators. These options are more practical and cost-effective than establishing greenfield sites since the infrastructure and land is already available. The technical potential for bioenergy

[37] Corrigan, Helen. *Forest Data and Resource Assessment of Forestry in Vanuatu*. Government of Vanuatu, n.d. http://www.fao.org/forestry/18248-0b2552633ff6923bf49424c42a79c8740.pdf.

[38] The cost of diesel for electricity generation in Efate was 110 VT in 2012 (USD1.18/litre), 132 VT (USD 1.41/L) delivered to Malekula and 146 VT (USD 1.56/L) to Tanna. *Annual Technical Report 2012*. UNELCO, 2012.

CNO generation has been estimated on this basis.[39] CNO generation is most likely to be economically viable in Tanna and Malekula, because of transport costs.

Other bioenergy options were not considered beyond the initial screening. Port Vila does not have a centralized sewage or wastewater system, landfills and centralized sources of animal waste are not of sufficient size to support biogas electricity generation.

3.2 Analysis of Off-Grid Renewable Energy Options

An assessment of available data on renewable energy resources suitable for rural electrification in Vanuatu was carried out to support the preparation of the IP. This section details the results of that assessment and describes progress to date on deploying these off-grid RE technologies in Vanuatu. Table 3.2 summarizes the options for off-grid RE generation.

Table 3.2: Summary – Off-Grid RE Resource Options for Vanuatu, by Technology

Technology	Comments
Pico-Solar	Can only provide lighting (and in some cases, phone charging), and the extent of the service is limited – but they can be a 'stepping stone' to more permanent solutions. Widely deployed in rural areas of Vanuatu since the Lighting Vanuatu campaign (2010-14). Life expectancy is limited by battery life.
Individual Solar Home Systems (SHS)	'Plug and play' or fixed (SHS) systems can provide lighting or broader services depending on capacity of the solar cells and batteries. Small systems usually provide lighting for several rooms for several hours per day, as well as phone charging. These systems have a considerably longer expected life than pico solar (batteries can be replaced rather than the entire system), but also higher upfront capital costs. These systems can also provide a 'stepping stone' to broader electricity use. May be applicable for homes or other buildings.
Microgrids	Can provide a broader range of electricity services, on demand, with high reliability, but historically have encountered significant implementation, operational, and funding difficulties. A variety of technologies can be used on microgrids; intermittent sources can be paired with higher capacity factors plants (such as diesel) or more efficient batteries, to ensure reliability.

Likely demand for electricity in rural areas is not known. A large proportion of rural areas have very low cash incomes[40] so even if electricity were available, demand from

[39] Given that any additional resources developed will be at a higher price, these resources tend to fall well to the right of the supply curve, far beyond the intersection with demand (see Section 3), and as such were not considered.

these customers would likely be limited, for instance, they may use permanent lighting but never purchase a television or fridge.[41] Others, including public institutions, businesses and wealthier households may wish to access a broader range of services enabled by electricity. As such, the mode of supplying electricity must be linked to the type of demand anticipated in each area.

3.2.1 Pico Solar Lanterns

A pico solar lantern is a small solar panel plus battery system with a power output of usually about 1-10 W. These are mainly used for lighting, and can replace less desirable sources of light such as kerosene lamps and candles. Some may also include additional services such as a mobile phone charger.

Solar lanterns provide an entry-level solution to rural home lighting and have been extremely popular technology for rural electrification. The lanterns are a very basic 'plug and play' technology requiring no installation, are easy to use, relatively cheap to purchase, require little maintenance, and appear to be relatively simple to repair.[42] Drawbacks to this technology are that these lanterns have an expected life of only about four years, lighting hours may be reduced in winter when solar resource is reduced, and there are potential disposal issues.

Vanuatu already has a history of using this technology. The Lighting Vanuatu programme enabled provision of an estimated 55,000 subsidized pico solar lanterns during the period 2010-14. Some households will likely choose to continue to have their lighting and phone charging needs met from pico solar and can do so cost effectively. However, other households will wish to move to more permanent systems which provide more lighting hours for more areas of a dwelling.

3.2.2 Solar Systems for Individual Buildings

Individual solar systems, consisting of solar panels, batteries and lights that can be simply installed throughout a dwelling, are a step up from pico solar lanterns, providing a more permanent lighting solution for multiple rooms of a dwelling using fixed or 'plug and play' technology. There is an established history with fixed systems (known as SHS) in Vanuatu. In 1999-2000, JICA installed[43] some 220 SHSs (22 kWp) across a number of villages and islands. However, due to the cost of batteries, and the need to replace them approximately every 3 years, these systems are no longer operational.

A number of other agencies and donors have funded SHS systems for health facilities, schools, households, and communities since that time. Little data is available on the

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[40] Non-cash income makes up about 42% of income in rural areas. (VERD Programme Design Document Final Draft, June 2011).

[41] Evidence has also been seen of this with some grid-connected households in some parts of the Luganville concession, for whom demand remains largely unchanged twenty years after electricity first became available to them. (Personal communication with Peter Allen, VUI, May 2014).

[42] Lighting Vanuatu Independent Completion Report indicated that nearly 40 percent of households have undertaken their own repairs.

[43] Funded from the Sarakata Special Reserve Fund, which is no longer operational.

success or otherwise of these projects; however, it appears that many have faces difficulties related to maintenance, including cost and capability to undertake the work.

The UNELCO Rural Electrification Study recommended the use of SHSs only in the most remote areas of Vanuatu. This was likely due to the cost of the systems, which has reduced substantially since that time (relative to the alternatives), as well as limited experience with the complexities of the microgrid systems that it recommended for wide use.

The Vanuatu Electricity for Rural Development (VERD) programme, developed in 2011, had two components. The first, the Rural Lighting Subsidy Scheme (RLSS) was to focus on provision of small, subsidized individual lighting systems to rural households. It identified the main barrier to the uptake of these systems as being the upfront purchase cost. The programme did not proceed due to governance issues.

The Vanuatu Rural Electrification Project (VREP) commencing in 2014, will focus on electrification of 17,500 households, 230 aid posts and 2,000 community buildings in rural areas, using individual dwelling 'plug and play' solar systems.[44] These plug and play systems have similar attributes to the SHS, but do not need to be fixed, so are more convenient for users, as well as less costly to install.

Our assessment is that individual solar systems are likely to be an applicable technology for a large proportion of households and other dwellings in rural Vanuatu. The modular nature of individual systems and batteries today makes individual ownership realistic, the units require minimal maintenance, and these systems are able to provide significant benefits to users, without the need for grid systems.

3.2.3 Microgrids and Nanogrids

Microgrid is the broad terminology used for very small networked systems that supply electricity to multiple buildings. Microgrids can utilize a variety of generation technologies including wind, solar, hydro, or diesel/biofuel; they may include combinations of generation types, and may also include storage. A number of microgrids have been installed in rural parts of Vanuatu to supply off-grid communities, but very limited experience has been recorded. Microgrids can range from small community networks which supply a few public buildings, to community grid systems, with hundreds of connections supplying households, businesses and public institutions.[45]

The 2006 UNELCO Rural Electrification Study considered the potential for community sized microgrids to meet rural electrification needs of over 3,000 sites, based on the size, number and type of villages on each of the inhabited islands. It considered a variety of generation technologies, and recommended the use of both small

[44] While the smaller of these units may be considered pico solar, as a semi-OK system, they are a step up from a lantern, and have similar attributed to the SHS, so are included in this section.

[45] Note that the line between micro and nano grids in terms of size is not black and white; however, nanogrid has been defined nano-grid to mean the smallest and simplest networked configuration supplying just a few buildings, while microgrids are larger, more complex systems.

community microgrids (based on wind, solar, diesel or hydro) and CNO-fuelled thermal generator-microgrids for larger, permanently active administrative centres with schools, health centres, and businesses. This study, based on costs in 2006, determined that communities on Efate should be supplied from diesel generation microgrids, most very small villages throughout Vanuatu should be supplied using individual solar systems, and most of the remainder of villages (generally comprising between 20 and 300 households) by copra fuelled generator microgrids. The exceptions to this were a small number of known hydro or wind sites. The inputs to the analysis were unavailable so the rationale for assigning diester or biofuel copra to villages was unclear.[46] It must be noted that the significant reduction in the cost of solar systems since 2006 will have an effect on the relative economics of the alternative solutions.

The VERD Public Institutions Electrification Scheme (PIES) involved the use of solar/battery systems set up in a nano-grid to supply a small cluster of school buildings (e.g. classrooms plus administration quarters). Supply could range from 150-700W[47], and supply lighting only, or broader electricity service, depending on the needs of the institution.

In developing the PIES a variety of generation technologies were considered, including solar, diesel, and diesel-solar hybrids. Solar and solar-diesel hybrids were found to be the most cost effective across a range of demand scenarios, but individual solar units were selected as the preferred technology due to lower maintenance requirements and fewer issues with fuel shortages and breakdowns. Pico hydro units (smaller than 10 kW) were also evaluated for a very small number of applications (less than 10) and found to be a very low cost solution on an LEC basis, but it is not clear whether these were included in the final programme.[48]

The key advantage of hybrid microgrid systems is the (usually) higher reliability, where different resources are combined. However, some disadvantages apply to these systems that do not apply to individual systems or simple nano-grids – the need to design bespoke systems for each application, issues with land ownership for the grid system and generation plant, operation and maintenance, very high costs of distribution, management of the system, and ongoing funding for fuel and maintenance.

Five technologies were identified as potential options for micro or nano-grids. Table 3.3 provides a summary of these options. The subsections below then provide further details on the known potential of these technologies in Vanuatu.

[46] A large section of the 2006 Rural Electrification Report was unavailable to the research team.

[47] Note that these systems are effectively a "nano-grid" as they serve a single building or cluster of buildings.

[48] VERD - Technical Analysis of Renewable Energy Technologies in Vanuatu - Preliminary Draft for Discussion.

Table 3.3: Summary of Potential Micro/Nano-Grid Generation Technologies

	Comments	Assessment
Micro- or pico- hydro	Community based hydro has worked well in other developing countries – but mixed results in Pacific Requires good river resources – limited sites available. Highly site specific with regard to cost and performance Relatively low operating costs and relatively low skills required for O&M; no fuel/battery issues Land and resource issues often arise Logistical challenges such as transport and infrastructure, O&M issues	Unable to assess the potential for micro-hydro without additional data as cost, performance & land issues are highly site specific
Bioenergy (CNO)	Port Olry provides a good example of the issues that can arise with a biofuel based microgrid, e.g. management, operations and maintenance complications Copra oil prices have seen substantial volatility and compete with diesel	Concur with VERD assessment that these are feasible but needs careful planning.
Wind	VERD evaluation found that wind has unsuccessful in almost all instances used Seasonal nature of wind energy means the resource, alone, will not match demand Most habitations are in sheltered locations – high towers necessary, but expensive & vulnerable to cyclone damage Potential land issues (needed for transmission)	Would not recommend widespread use for rural electrification
Hybrid model	The hybrid model is focused on is a solar/diesel Key advantage is reliability – manages seasonal and diurnal features of solar power alone Requires diesel to be transported to islands Increases reliance on imported diesel	Potential use for supply to larger population centres or individual public institutions that require very high reliability
Solar	Modular systems Low maintenance requirements Individual institution ownership and responsibility, or could be networked if there were advantages to this.	Very good potential for supplying nano-grids, e.g. within a school.

Biofuel potential

Following the 2006 UNELCO study, the Port Olry microgrid on Espiritu Santo was developed as a pilot study, with a view to installing additional CNO-fuelled generators in nine villages in Malampa, Torba and Penama. The Port Olry system, which remains operational, is supplied by a 40 kW generator using crude copra oil as the primary fuel. It serves some 260 households (about 1,000 residents). Views on the success of the project are mixed. Lower than expected demand resulted in very high unit prices (up to AUD 1.50/kWh), while at the same time, increased access out of Port Olry (sealed road constructed linking Port Olry to Luganville) resulted in farmers exporting copra so that it was unavailable for local use during high priced periods. The project was also affected by a number of operational issues including a broken oil press, poor handling (storing and drying) of copra and use of poor quality copra for pressing, as well as management difficulties.

It is understood that the EU-funded project to install additional CNO generators remains current. However, in the interim, three of the identified villages on Malekula have been encompassed by a planned grid extension, so would not require local generation/microgrids.

The UNELCO study proposed that many villages were fuelled by CNO and a smaller number by diesel. The rationale for proposing crude versus diester copra is unclear.[49] In general, the use of crude CNO relies on strict compliance with specified processes and increased maintenance relative to diester copra, but the system is simpler to operate, whereas the use of diester copra will generally result in higher reliability but requires more rigorous safety measures and processes be implemented.

Cost aside, CNO fuelled generation on microgrids to supply rural communities is technically feasible; however potential complications with operation, maintenance, and management of the CNO equipment as well as the generation plant, make this a less favourable option for rural electrification.

Micro hydro potential

A 2003 study[50] by the (then) Energy Unit in conjunction with the Department of Geology, Mines and Rural Water Supply undertook preliminary investigations to identify potential for micro-hydro generation. Four off-grid sites were recommended from the assessment of potential on six islands: Lowenau in Tanna, Mbe Tapren in Vanua Lava, Waterfall in Pentecost and Anivo in South Santo. Further, more detailed studies of these sites were recommended including an extended period of water flow and rainfall monitoring, assessment of relevant land ownership, surveys of power demand and penstock route surveys. Table 3.4 summarizes the identified off-grid micro hydro sites. To our best knowledge, work has not been undertaken at any of these sites.

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[49] Diester copra requires the addition of imported chemicals.

[50] SVREP, Hydro Potential Reconnaissance Report, 2003

Table 3.4: Identified Off-Grid Hydropower Sites

Site	Comments
Lowenau (branch) River, Tanna	Available power output: up to 100kW, based on 250m head and 55litres/second measured flow Projected initial demand: 39 kW based on population statistics (10 villages within 10km radius) Easy access for monitoring
Mbe Tapren, Vanua Lava	Available power output: 30-40 kW Projected initial demand: 67.5 kW based on population statistics (3 villages within 3km radius) No road access at time of study
Waterfall, South Pentecost	Available power output: 100 kW based on 40m head and 360 litres/second measured flow Projected initial demand: not available No road access at time of study
Anivo River, South Santo	Available power output: 130 kW based on 105m head and 180 litres/second measured flow Projected initial demand: not available. Nearest village (Tasariki) has road access

Source: SVREP, Hydro Potential Reconnaissance Report, 2003

None of these sites studied by SVREP were included in the UNELCO study of 2006 as preferred options. The communities that UNELCO suggested could be supplied from hydro are Talise (Maewo, Penama), Leahlli (Ureparapara, Torba), Vatrata (Vanua Lava, Torba), Tolav (Santa Maria, Torba) and Brenwei (Malakula).

Recently, the 75 kW Talise pico hydro plant on Maewo was constructed to supply power via an 11km distribution grid to about 1,000 households of Talise and nearby villages of Naravovo and Nasawa. However, while the IUCN and Italian/Austrian Government funded project has recently been completed, additional funding is required for construction of the network. As such, there is not yet any operational experience with this plant. Anecdotally, hydro based systems often face issues with use of land (for both generation and distribution), and transportation. Also, hydropower alone may be unable to provide a high level of reliability year round. On the plus side, hydro generally has low operating costs, O&M is uncomplicated, and there are no ongoing fuel costs.

While the technical potential to utilize hydro power on microgrids exists, it is not possible to assess the size or cost of the potential without site specific data.

Wind potential

No specific examples of community wind generation in Vanuatu were identified in the course of this study. Only two communities in the 2006 UNELCO study were proposed to be supplied with wind/solar, and the rationale for this was not given.[51] The VERD evaluation of supply options noted that wind has been unsuccessful in almost all instances used. In addition, the best wind sites are often located on hills and ridges, distant from sheltered settlements, and wind turbines are vulnerable to cyclone damage. Maintenance is also likely to be an issue, and to provide reliable supply a wind hybrid system would be required. On this basis, because it is not possible to assess the technical potential for wind power, it is not recommended that wind potential be considered further for rural electrification applications.

Solar /diesel hybrid potential

As mentioned earlier, in development of VERD, consideration was given to solar/ diesel hybrid systems. This type of hybrid enables the benefits of solar panels to be combined with the firming capability of diesel[52] to provide high reliability power for public institutions or communities. It may also include battery storage.

The key advantage of this type of system is the high level of reliability that can be achieved. Disadvantages include reliance on imported diesel and the need for it to be distributed to various islands. Diesel systems also require more maintenance and outages than solar only systems. The issues that apply to all microgrid systems will also apply.

Solar nano-grid potential

This is essentially an individual system that supplies a cluster of buildings rather than just a single building. As it relies on the solar insolation, there may be periods when supply is unavailable, even with batteries. However, it has a number of advantages – individual ownership/responsibility being an important factor. The use of solar/battery systems on a nano-grid is likely to be a good approach for public institutions (primarily schools and health facilities) for this reason, and because the low maintenance nature of these systems makes them particularly useful for rural areas, far from main centres. Seven small (3-10 kW) pico solar plants were recommended by the VERD project, but it is not clear whether any of these have been progressed.

3.3 Costs of Grid-Connected Renewable Energy

The comparative cost of renewable energy technologies is an important factor when determining their viability and attractiveness for inclusion in Vanuatu's electricity development plan.[53] This section includes supply curves which show the levelized energy costs (LECs) of the various grid-connected renewable energy technologies

[51] Imale on Aniwa, and Anelgowat on Anatom, in Tafea province.

[52] While a CNO/solar hybrid is also possible this is not discussed separately. The prior discussion of the potential for biofuel microgrids applies in this case.

[53] The cost of renewable energy was not, however, the only criterion used for selecting project to be included in the Investment Plan. It is only one of a number of factors that was considered in the course of developing this investment plan. Section 4 describes the other criteria used to select the projects for which SREP funding is requested.

assessed in Vanautu for the preparation of the Investment Plan, as well as the estimated production of each of those technologies.

The LECs were estimated on both an economic and financial basis. Section 3.3.1 shows the estimates of LECs on an economic basis. Section 3.3.2 shows the estimates of LECs on a financial basis. Annex E contains the assumptions used in calculating LECs.

3.3.1 Comparison on an economic basis

The costs of supply were first estimated on an economic and not financial basis. The purpose of economic analysis is to understand which supply options are the best option for Vanuatu, irrespective of the actual cost of financing that would be used for the projects. A social discount rate is used for economic analysis, where the rate (10 percent) reflects an estimate of the social opportunity cost of capital for the country.

In undertaking the economic analysis, a “capacity penalty” was added to the cost of intermittent or non-dispatchable renewables such as wind and solar. The capacity penalty reflects the lower reliability of certain types of generation. It effectively reflects the cost of standby power required to “firm up” the renewable energy capacity. This firming capacity is not generally required when the first units of intermittent generation are added, as it can easily be managed by the diesel generating units; however, as intermittent generation capacity increases, the costs of firming the generation increase. We have included these costs for intermittent technologies on all the grid systems, though it should be recognized that these costs may not apply in all cases.

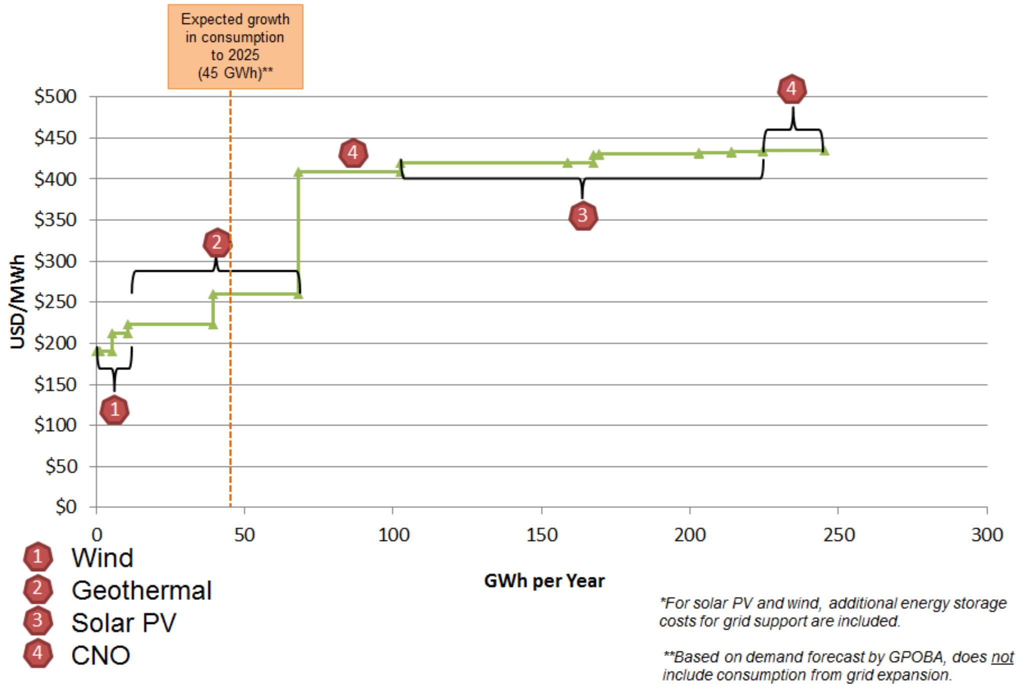
Figure 3.5 through Figure 3.8 show the supply curves for renewable energy technologies in each of the four concession areas. Each figure has a vertical line (orange, hash-marked) which shows the expected annual energy consumption on each system by 2025, based on the demand forecast developed as part of the GPOBA project and included in the NERM. As noted in Section 2.5, the demand forecast considerably overestimated demand growth, which has remained flat (or decreased) in recent years. However, the forecast also assumes load growth on the grids as they are currently configured, and does not include any estimated load growth from future grid expansions, nor does it consider that existing generation such as diesel is retired due to age, or as a result of investment in lower cost generation alternatives.

Tables below each of the figures show rankings of specific sites or projects. Where specific sites or projects did not exist, costs for generic sites were estimated using resource data from nearby projects or monitoring sites. For solar PV and wind, energy storage costs for grid support (batteries) are included.[54] Capital costs and (for diesel) fuel costs differ between islands based on information collected on shipping costs. Resource availability for wind and solar on the different islands was also considered and is reflected in different capacity factors for these technologies in different places

[54] Total battery system costs including lithium ion battery, controller and housing were assessed as follows: For a 100 kW ground mounted solar PV system, $65,000; for a 10 kW rooftop solar PV system, $9,500; for a 2.75 MW wind farm, $435,000; for a 1.1 MW wind farm, $235,000; and for a 275 kW wind farm, $95,000.

(and their consequently different levelized costs). Annex E contains additional assumptions used in calculating levelized costs.

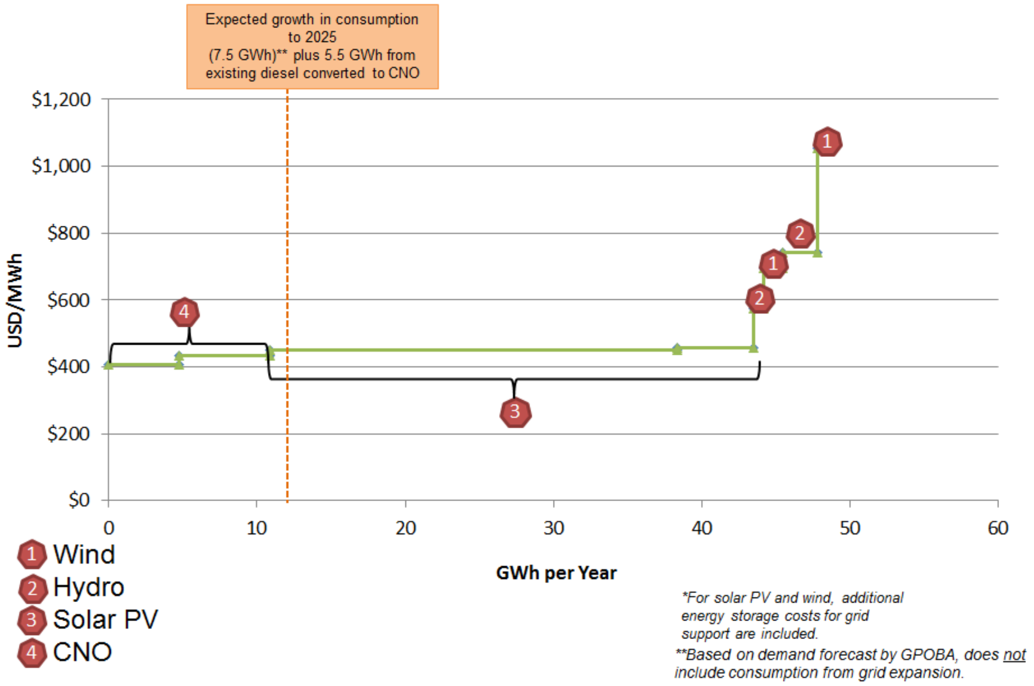
Figure 3.5: Renewable Energy Supply Curves for Grid-Connected Electricity on Efate



Project Name	Resource	LCOE commercial ($/MWh)	Max Capacity (MW)	Annual Production (MWh)	CF
Devils Point Expansion 1	Wind	190	0.55	1,205	0.25
Devils Point Expansion 2	Wind	190	2.20	4,818	0.25
Alternate Site	Wind	212	2.75	6,023	0.25
Takara (Efate Geo) Phase II	Geothermal	223	4.00	32,237	0.92
Takara (Efate Geo) Phase I	Geothermal	260	4.00	32,237	0.92
Efate - CNO Existing	CNO	408	8.80	38,535	0.50
Efate Peninsula 2 - Ground Mount	Solar PV	419	31.12	63,509	0.23
Efate Peninsula 1 - Ground Mount	Solar PV	419	4.80	9,794	0.23
Devil's Point Solar	Solar PV	429	1.00	1,820	0.21
Efate Bay - Ground Mount	Solar PV	430	19.17	38,112	0.23
Efate Inland - Ground Mount	Solar PV	432	6.15	12,180	0.23
Efate Bay - Roof Mount	Solar PV	434	6.34	11,769	0.21
Efate - CNO New	CNO	435	5.32	23,284	0.50

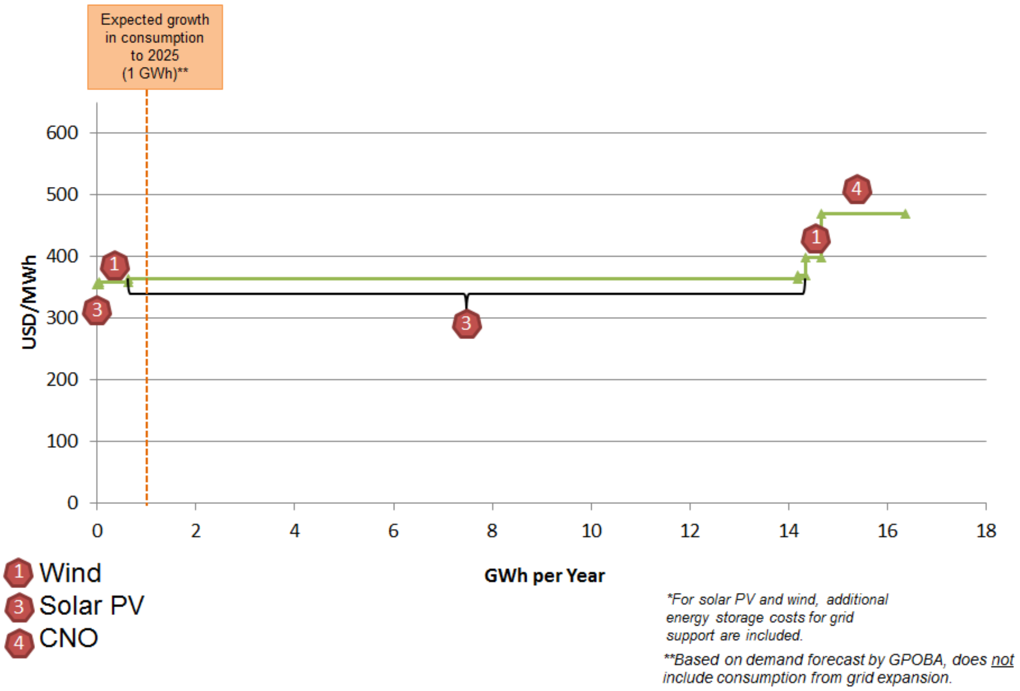
Note: Solar PV LCOEs assume module cost of $1.11/W, and total installed cost (including inverter, racking system, engineering and construction costs, spare parts and development costs) of $5.27/W. These are based on the costs of the 40kW of solar PV installed in Luganville. The LCOEs above also incorporate battery storage costs and a factor applied to installations outside Efate and Santo to reflect transport/logistics costs, Roof mounted units are assumed to require structural upgrades to roofs; ground mounted systems are assumed to require tree clearing.

Figure 3.6: Renewable Energy Supply Curves for Grid-Connected Electricity on Santo



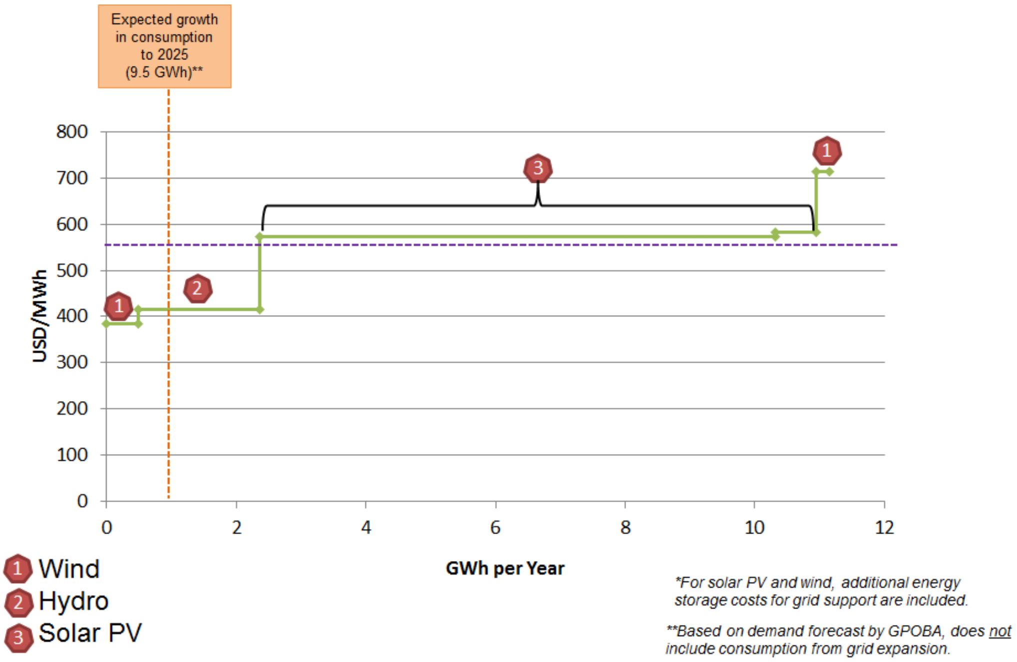
Project Name	Resource	LCOE commercial ($/MWh)	Max Capacity (MW)	Annual Production (MWh)	CF
Santo - CNO Existing	CNO	408	1.25	5,475	0.50
Santo - CNO New	CNO	435	1.60	7,008	0.50
Espiritu Santo Ground Mount	Solar PV	452	16.70	31,595	0.22
Espiritu Santo Roof Mount	Solar PV	457	3.35	5,906	0.20
Sarakata 1 Expansion (Option A)	Hydro	574	0.30	793	0.30
Alternate Site	Wind	697	1.10	1,445	0.15
Sarakata 2 (Option A)	Hydro	741	0.60	2,715	0.52
Port Olry Met Station	Wind	1053	1.10	1,156	0.12

Figure 3.7: Renewable Energy Supply Curves for Grid-Connected Electricity on Tanna



Project Name	Resource	Com-mercial LCOE ($/MWh)	Max Capacity (MW)	Annual Production (MWh)	CF
UNELCO Lanekel extension	Solar PV	355	0.02	44	0.25
Enawanum Hill Met Station	Wind	359	0.28	650	0.27
Tanna Ground Mount	Solar PV	364	6.62	14,729	0.25
Tanna Roof Mount	Solar PV	370	0.08	163	0.24
Alternate Site	Wind	399	0.28	361	0.15
Tanna - CNO Existing	CNO	469	0.42	1,835	0.50

Figure 3.8: Renewable Energy Supply Curves for Grid-Connected Electricity on Malekula



Project Name	Resource	LCOE ($/MWh)	Max Capacity (MW)	Annual Production (MWh)	CF
Alternate Site	Wind	351	0.28	530	0.22
Brenwe (Option B)	Hydro	416	0.40	2,042	0.58
Malekula Ground Mount	Solar PV	539	4.95	8,637	0.20
Malekula Roof Mount	Solar PV	546	0.43	692	0.19
Teteras Met Station	Wind	668	0.28	217	0.09
Alternate Site	Wind	351	0.28	530	0.22

3.3.2 Comparison on a financial basis

This section includes estimates of LECs of the various grid-connected renewable energy technologies on a financial basis. The financing assumptions used are shown in Table 3.5. Additional assumptions are shown in Annex E.

Table 3.5: Concessional, Commercial and SREP/Commercial Financing Assumptions

	Concessional	Commercial
Debt/equity split (%)	100/0	70/30
Debt rate (%)	3.00	10.69
Equity return (%)	N/A	18
Debt term (years)	20	20

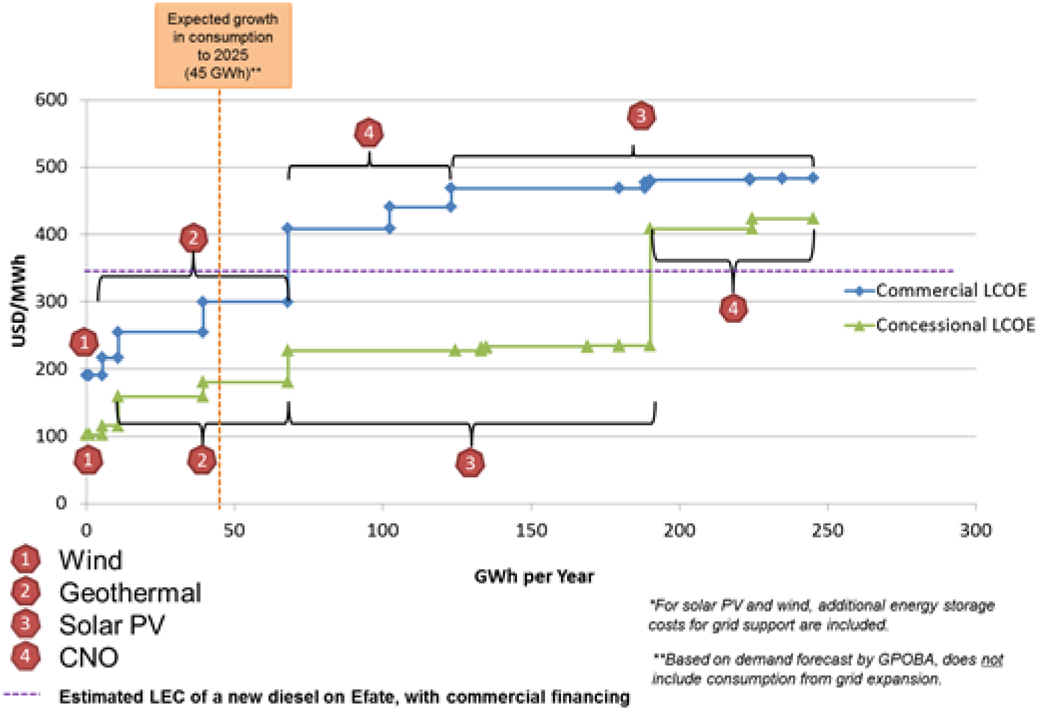
Note: LECs are calculated excluding VAT.

The financing terms assumed in this investment plan are not necessarily the terms under which projects would be financed. The assumptions are used as opposite ends of a spectrum of financing options for the purpose of: i) comparing the costs of renewable energy technologies to one another, ii) comparing the costs of renewable energy technologies to diesel, and iii) showing how lower cost financing can impact the levelized cost of renewable energy technologies.

Figure 3.5 through Figure 3.8 show the supply curves for renewable energy technologies in each of the four concession areas. Each figure also has, as in Section 3.3.1, a vertical line (orange, hash-marked) which shows the expected annual energy consumption on each system by 2025. The figures in this section also show a horizontal line (violet, hash-marked lines) with an estimate of LEC of a new diesel plant on each system, for the purpose of comparison with renewable energy options.[55]

[55] Commercial financing terms are assumed for the new diesel plant, as SREP and MDB financing would not likely be available for stand-alone diesel units in Vanuatu.

Figure 3.9: Renewable Energy Supply Curves for Grid-Connected Electricity on Efate

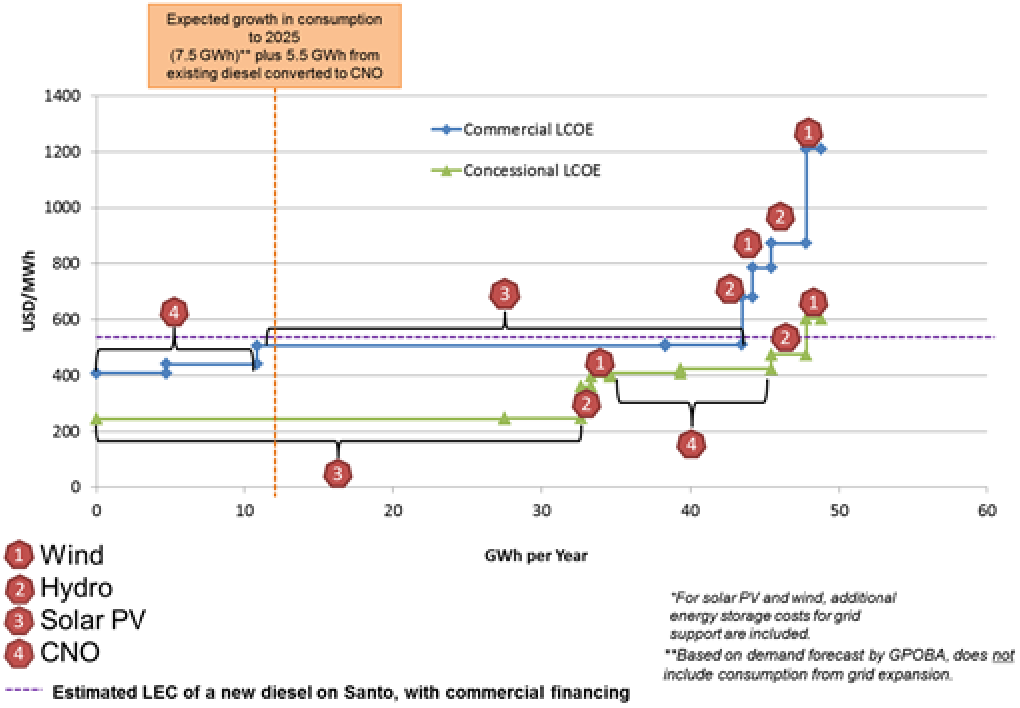


Project Name	Resource	LCOE commercial ($/MWh)	LCOE concessional ($/MWh)	Max Capacity (MW)	Annual Production (MWh)	CF
Devils Point Expansion 1	Wind	$191	$103	0.55	1,205	0.25
Devils Point Expansion 2	Wind	$191	$103	2.20	4,818	0.25
Alternate Site	Wind	$216	$116	2.75	6,023	0.25
Takara (Efate Geo) Phase II	Geothermal	$254	$160	4.00	32,237	0.92
Takara (Efate Geo) Phase I	Geothermal	$299	$181	4.00	32,237	0.92
Efate - CNO Existing	CNO	$408	$408	8.80	38,535	0.50
Efate - CNO New	CNO	$441	$424	5.32	23,284	0.50
Efate Peninsula 2 - Ground Mount	Solar PV	$468	$227	31.12	63,509	0.23
Efate Peninsula 1 - Ground Mount	Solar PV	$468	$227	4.80	9,794	0.23
Devil's Point Solar	Solar PV	$477	$231	1.00	1,820	0.21
Efate Bay - Ground Mount	Solar PV	$481	$233	19.17	38,112	0.23
Efate Inland - Ground Mount	Solar PV	$483	$234	6.15	12,180	0.23
Efate Bay - Roof Mount	Solar PV	$483	$234	6.34	11,769	0.21

Solar PV LCOEs assume module cost of $1.11/W, and total installed cost (including inverter, racking system, engineering and construction costs, spare parts and development costs) of $5.27/W. (These are based on the costs of the 40kW of solar PV installed in Luganville. The LCOEs above also incorporate battery storage costs and a factor applied to installations outside Efate and Santo to reflect transport/logistics costs, Roof mounted units are assumed to require structural upgrades to roofs; ground mounted systems are assumed to require tree clearing.

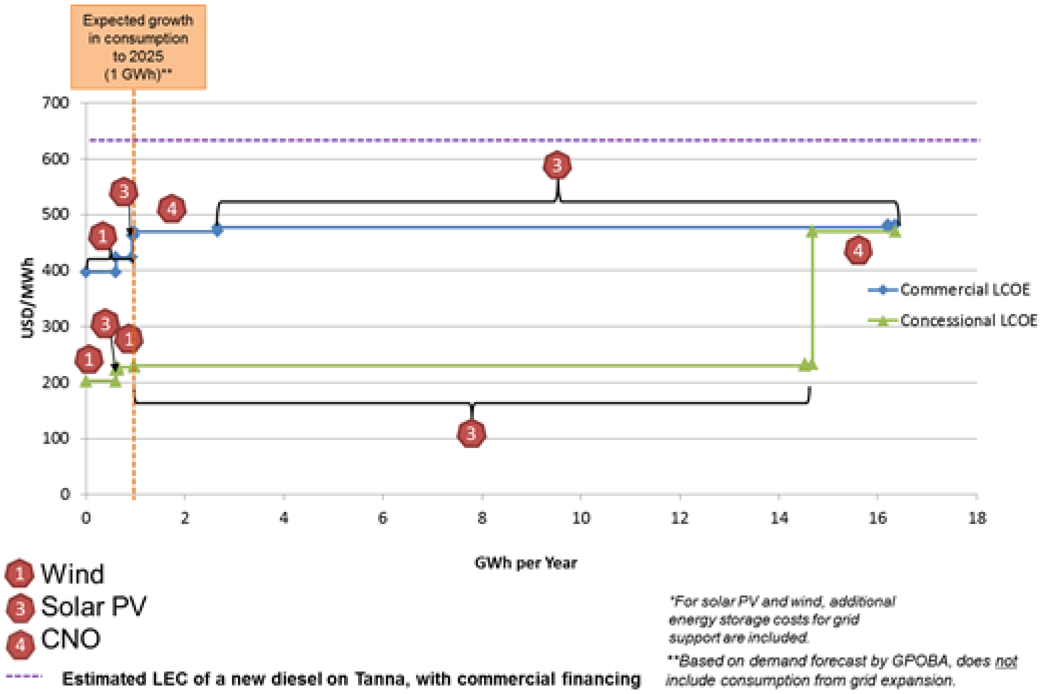
It is also worth noting that, if Geothermal is introduced, it will displace diesel, thereby pushing the vertical line (showing incremental demand in 2025) farther to the right of the figure. In other words, geothermal would replace existing supply, whereas new plant would be needed to meet incremental demand.

Figure 3.10: Renewable Energy Supply Curves for Grid-Connected Electricity on Santo



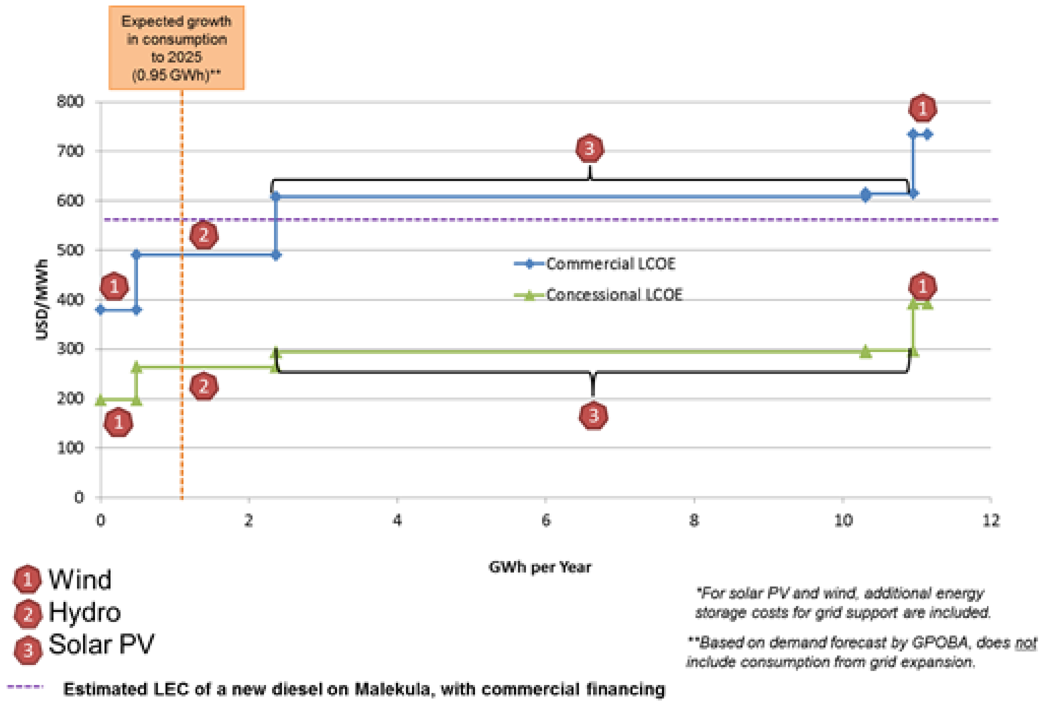
Project Name	Resource	LCOE commercial ($/MWh)	LCOE concessional ($/MWh)	Max Capacity (MW)	Annual Production (MWh)	CF
Santo - CNO Existing	CNO	$408	$245	1.25	5,475	0.50
Santo - CNO New	CNO	$441	$247	1.60	7,008	0.50
Espiritu Santo Ground Mount	Solar PV	$505	$209	16.70	31,595	0.22
Espiritu Santo Roof Mount	Solar PV	$510	$211	3.35	5,906	0.20
Sarakata 1 Expansion (Option B)	Hydro	$679	$360	0.30	793	0.30
Alternate Site	Wind	$785	$396	1.10	1,445	0.15
Sarakata 2 (Option A)	Hydro	$873	$474	0.60	2,715	0.52
Port Olry Met Station	Wind	$1,210	$603	1.10	1,156	0.12

Figure 3.11: Renewable Energy Supply Curves for Grid-Connected Electricity on Tanna



Project Name	Resource	Com-mercial LCOE ($/MWh)	Con-cessional LCOE ($/MWh)	Max Capacity (MW)	Annual Production (MWh)	CF
Enawanum Hill Met Station	Wind	$397	$203	0.28	650	0.27
Alternate Site	Wind	$424	$228	0.28	361	0.15
UNELCO Lanekel extension	Solar PV	$462	$224	0.02	44	0.25
Tanna - CNO Existing	CNO	$469	$469	0.42	1,835	0.50
Tanna Ground Mount	Solar PV	$476	$230	6.62	14,729	0.25
Tanna Roof Mount	Solar PV	$482	$233	0.08	163	0.24

Figure 3.12: Renewable Energy Supply Curves for Grid-Connected Electricity on Malekula



Project Name	Resource	Com-mercial LCOE ($/MWh)	Con-cessional LCOE ($/MWh)	Max Capacity (MW)	Annual Production (MWh)	CF
Alternate Site	Wind	$379	$198	0.28	530	0.22
Brenwe (Option A)	Hydro	$490	$264	0.40	2,042	0.58
Malekula Ground Mount	Solar PV	$608	$294	4.95	8,637	0.20
Malekula Roof Mount	Solar PV	$614	$297	0.43	692	0.19
Teteras Met Station	Wind	$734	$392	0.28	217	0.09

The figures above illustrate that:

- Most technology options are less expensive than a new diesel plant when concessional financing terms are assumed, and many are less expensive than a new diesel plant when commercial financing terms are assumed.
- Concessional financing (from SREP or other MDBs) makes capital-intensive technologies such as solar and wind look relatively less expensive. Concessional financing has little impact on the cost of technologies with relatively low capital and high fuel costs, such as CNO-fired diesel generators. CNO-fired generators financed with concessional loans are not much less expensive (on a kWh) basis than CNO-fired generators financed with commercial loans.
- The grid-connected systems would each need only one or two of the projects to meet expected demand in 2025.

These points were important considerations for selecting the projects proposed under Section 5 of this investment plan.

3.4 Costs of Off-Grid Renewable Energy

This section presents an assessment of the costs of the various off-grid supply options in Vanuatu. These options are applicable for all locations outside the concession areas: these areas are generally being remote and sparsely populated, and are unlikely ever to receive grid supply. As cash incomes in these areas are generally low, it is important to seek affordable solutions to provide access to electricity.

As for the grid-connected technologies, LECs under both commercial and concessional financing assumptions are shown. While it is likely that a combination of financing will be applied, this will depend on the selected business model – potential costs will be an input into development of these models. The financing assumptions are shown in the previous section.

3.4.1 Pico-solar

Table 3.6 shows the capital costs for pico solar units of various sizes and capabilities. Based on these capital costs, the units have payback periods (measured in the avoided cost of kerosene purchased in rural areas) ranging from less than one month for the smallest unit up to a year for the 20W lighting unit with phone charging.

Table 3.6: Off-grid Electricity Supply Costs – Pico solar

Lantern	Capability	Capital Cost
DLight S2	Basic LED lantern, 4 hours of light from fully charged battery	$12.17
DLight S20	Basic LED lantern, 8 hours of light on medium/ 4 hours on high from fully charged battery	$15.65

Sources: VUI, Greenpower Vanuatu

3.4.2 Individual solar systems

Table 3.7 shows cost estimates for 'plug and play' systems of various sizes, while Table 3.8 shows capital and operating costs, together with assessed LECs for SHS systems of various sizes. In both cases, the systems will primarily provide for lighting and phone charging, but may also meet other small appliance loads. For these types of systems, the vast majority of the cost is incurred at the time of purchase of the unit. The SHSs incur higher initial costs due to installation and longer expected lives.

Table 3.7: Off-grid Electricity Supply Costs – Plug and Play solar systems

Lantern	Capability	Capital Cost
Plug and Play energy centre	2 hanging LED lights and phone charger capability. Up to 15 hours bright light from fully charged battery	95.00
Plug and Play 20 W pico solar unit	20W panel, battery controller, 3-4 hanging LED lights, phone charging. Up to 15 hours light (across multiple rooms) from fully charged battery.	214.00

Sources: VUI, Greenpower Vanuatu

Table 3.8: Off-grid Electricity Supply Costs – SHSs

	Customer size	Generator size (Wp)	Battery size (AGM)	Capital Cost*	O&M Cost p.a.**	Commercial financing LEC	Concessional financing LEC
Small SHS lighting	5 kWh/ month	50	120 Ah at 12 V	$600	$35	$2.06/kWh	$1.32/kWh
Medium SHS lighting	20 kWh/ month	150	175 Ah at 24 V	$1,725	$108	$1.51/kWh	$1.98/kWh

Notes: Systems are assumed systems to consist of solar PV system with energy storage sized according to the 2006 Rural Electrification Report. Battery system assumed to be Absorbent Glass Mat (AGM) lead acid battery. * Estimated cost assumes retail pricing and single electrical outlets that do not require internal wall wiring. **Annual O&M cost includes battery replacement fund contribution and annual servicing cost. Economic life of 20 years assumed.

3.4.3 Micro and Nano-grids

The cost of micro- and nano-grids varies considerably, depending the very specific nature of each project. As described earlier, solar-based systems are likely to make more sense in Vanuatu than CNO- or wind-based systems. As such the cost estimates in this section assume:

(a) nano-grid systems supplying a close cluster of buildings, and

(b) solar/diesel hybrid systems supplying multiple buildings in a village setting, connected from distribution lines running along streets.[56]

As also described earlier, the important advantage of solar/diesel hybrid systems is that they can provide higher reliability power. Important disadvantages are the reliance on imported fuel and high price sensitivity to demand variations.

[56] CNO generation could be used in place of diesel at a similar cost; however variation in the copra price in recent years has exceeded that of diesel price variation.

Solar nano-grids (which include battery storage) are assumed to provide basic electrification to a larger load, such as a school, clinic or administrative building that may consist of one or a cluster of buildings within close proximity. Table 3.9 includes specifications and costing for a sample system. The sample system is assumed to have 1500 W of solar panels with associated batteries and some wiring between the buildings in very close proximity.[57]

Table 3.9: Large Load Solar Nano-grid

Customer size	Generator size (Wp)	Battery size (AGM)	Capital Cost*	O&M Cost p.a.**	Commercial financing LEC	Concessional financing LEC
200 kWh/ month	1500	1000 Ah at 24 V	$15,750	$500	$1.17/kWh	$0.68/kWh

Source: Systems are assumed to consist of solar PV system with energy storage sized according to the 2006 Rural Electrification Report for an average load of 200 kWh/month, with the exception of the solar panels, which appeared to be inappropriately sized for the expected energy consumption. The panel size has been adjusted to provide the average monthly energy requirement. **Annual O&M cost includes battery replacement fund contribution and annual servicing cost.

Note: While this example would be relevant to a school/public institution, specific assessment would be required to develop customized systems to individual needs and more accurate cost estimates.

Defining and costing a solar/diesel hybrid microgrid system is more complex, as more parameters are involved including the size of the network, the combination of resources (size of solar panels, diesel generator set and battery storage), and the expected size of the demand (number of connections, daily load profile). Very little reliable information on the cost of establishing such microgrids in Vanuatu was available at the time of drafting the Investment Plan.

As described in Section 5, the specification and costing of such systems is work that remains to be done, and is proposed to be included as part of the technical assistance funded by SREP.

3.5 Barriers to Renewable Energy Projects

Vanuatu faces numerous barriers to the further development of renewable energy systems, despite the country's significant renewable energy resource potential and experience with a number of RE technologies over the past decade. Table 3.10 describes some of the most significant barriers hindering the development of renewable energy in Vanuatu. For each barrier, there is also a corresponding discussion of possible mitigation options.[58]

[57] Extending such a system to cover a larger area is not considered here, as the costs of distribution in particular can vary significantly depending on the application. The potential application and costing of such systems is proposed to be included as part of the technical assistance funded by SREP.

[58] Barriers generic to developing countries—country risk, for example, and the high interest rates that typically accompany such risk—are not included below. Instead, the focus is on barriers more specific to the development of renewable energy in Vanuatu.

The barriers to development (and availability of options for mitigation) are a key factor that was taken into consideration in determining which investments should be included in this Investment Plan.

Table 3.10: Barriers to Renewable Energy Development and Mitigation Options

Barrier	Mitigation Options	Grid Connected					Off-grid
		Solar PV	Bio-fuel	Geo-thermal Power	Wind	SHPP	
Costs							
High capital costs geothermal, solar, wind, and hydro.	▪ Provide concessional financing to reduce the levelized cost of technologies in which capital costs are high relative to operating costs.	✓		✓	✓	✓	✓
High operating costs of CNO plants, because of the high value of copra as an export good.	▪ Producer subsidies or other incentives for sale of CNO to diesel operators.		✓				
Legal and Regulatory							
Complex land-ownership issues arising from customary land practices can delay the larger, on-grid projects or result in the risk of unanticipated costs at a later stage of development.	▪ Continuance of the aggressive land reforms already under way ▪ Avoid projects where land disputes are likely to be an issue.	✓	✓	✓	✓	✓	
Uncertainty surrounding concession for Santo and the **limited remaining term** on UNELCO's concessions may make them unwilling to make investments they would need to recover over the long-term.	▪ Government finances the investments (using SREP or MDB financing) ▪ Government resolves uncertainty with concession on Santo	✓	✓	✓	✓	✓	

Barrier	Mitigation Options	Grid Connected					Off-grid
		Solar PV	Bio-fuel	Geo-thermal Power	Wind	SHPP	
Electricity Supply Act and concession agreements do not enable Independent Power Producers (IPPs) to get Power Purchase Agreements (PPAs) with concessionaires, nor for concessionaires to include such costs in the tariff calculations.	▪ Amendments to the Act or Concession Agreements (but this risks "stranding assets" of the concessionaires and so may have additional costs).[59] ▪ Government finances the investments (using SREP or MDB financing) and hands them over to the concessionaires to operate.	✓	✓	✓	✓	✓	
Some pricing arrangements may be a disincentive to purchase RE power. For example, the pricing arrangements in relation to the ADB-funded solar PV pilot on Santo, whereby VUI pays a higher price than the average diesel cost for output from the solar plant.[60]	▪ Development of feed-in tariffs (a pilot programme is proposed, by the URA, for Port Vila) that fairly reflect the value of the injected electricity to the purchaser.	✓	✓	✓	✓	✓	
	Availability of Financing						
Households cannot afford many of	▪ Business models which allow for payment of upfront						✓

[59] URA has recently published a preliminary decision regarding PPAs for IPPs. Refer to Table 2.4 for a brief description.

[60] VUI also bears the costs of operation and monitoring of the units.

Barrier	Mitigation Options	Grid Connected					Off-grid
		Solar PV	Bio-fuel	Geo-thermal Power	Wind	SHPP	
the off-grid solutions or do not have the cash to pay for them upfront	costs over time (to solve cash-flow problem) ▪ Lending by private sector arms of MDBs to commercial banks for small business credit lines ▪ Targeted subsidies for low income areas or households ▪ Concessional lending by MDBs to government for purchase of equipment (which could then be installed and maintained by a private operator)						
Local suppliers do not have enough working capital for inventories, installers, maintenance, etc.	▪ Lending by private sector arms of MDBs to commercial banks for small business credit lines						✓
Award of development license to single developer makes it difficult for MDBs to provide concessional financing for Geothermal project.	▪ Requirement that incumbent developer tender competitively for construction and operations. ▪ Benchmarking of costs of PPA against costs of similar projects elsewhere.			✓			
Domestic Project Development Capacity							
Lack of local capacity to develop or install, and maintain equipment.	▪ Business models which provide for professional installation, operation and maintenance. ▪ Technical assistance which includes strong training/capacity building component	✓	✓	✓	✓	✓	✓

Barrier	Mitigation Options	Grid Connected					Off-grid
		Solar PV	Bio-fuel	Geo-thermal Power	Wind	SHPP	
Need for customer support in very remote areas, potentially with very different customs and language	▪ Business models which allow for installation, maintenance, and revenue collections by people native to, or familiar with the area on each island						✓
There is a lack of sufficient, good quality, site-specific data. What data are available are sometimes hard to find or access. In some cases (such as wind), possible sites have been identified, but no rigorous studies have been done of their potential. For off-grid potential, studies are outdated (UNELCO did a study in 2006).	▪ For SREP projects, project preparation grants for feasibility studies ▪ For other potential projects, additional technical assistance for wind and solar mapping, and better assessment of the hydro resources initially identified in 2003 study.[61] ▪ Creation of centralized (and regularly updated) database within energy Department of all studies that have been done.	✓		✓	✓	✓	✓
Small size of some grids may limit integration potential, and integration studies are necessary to optimize investment. For example, the solar PV installed in Luganville is not used at times when demand can be met 100%	▪ For SREP projects, feasibility studies must include grid integration studies that consider operation of the system in detail ▪ Mitigation options range from battery backup for ramping and voltage control, to operation of diesel generators. ▪ Costs of variability should be taken into	✓			✓	✓	

[61] The Department of Energy is currently undertaking fairly extensive wind mapping, but the data are still being collected and have yet to be verified.

Barrier	Mitigation Options	Grid Connected					Off-grid
		Solar PV	Bio-fuel	Geo-thermal Power	Wind	SHPP	
from Sarakata hydro. Such situations affect the economics of projects, particularly on small grids with few units.	consideration when comparing options and determining FITs;						

3.6 Government Strategy for the Renewable Energy Sector

The Government's energy strategy, as laid out in the National Energy Road Map (NERM), focuses on the key areas of access, petroleum supply, affordability, energy security, and climate change. Development of renewable energy will contribute to several of these key areas, including reducing dependence on imported petroleum and climate change mitigation. Renewable technology also has the potential to increase generation efficiency, improve electricity affordability, increase access to electricity, and improve the security of supply.

The Government and its utilities have already taken a number of steps to increase the use of renewable energy. Wind and hydropower have been in use for some time, at the UNELCO Devil's Point wind farm (commissioned 2007) and the JICA-funded Sarakata hydro station on Espiritu Santo (commissioned 1995). More recently, solar PV has been utilized both on grid and in rural electrification applications, and UNELCO is increasingly operating certain diesel plant on CNO-biofuel. The Government, together with multi-lateral development banks and other donors have undertaken pre-feasibility and feasibility studies for a number of potential on and off-grid projects, and created task forces (such as the Geothermal Task Force) for geothermal and hydropower projects. Consideration is being given to extending existing grid networks.

On the regulatory side, the government (via the URA) is developing a framework to enable IPPs to develop projects, and sell the output to concessionaires (provided it is cost effective). It is also developing a feed-in tariffs regime to enable households and businesses to self-generate, with "unders and overs" managed via the grid connection.

3.7 Role of the Private Sector

The private sector in Vanuatu has been very active in the renewable energy sector. Renewable energy projects are in place within all four concession areas. These are owned by the concessionaire or the Government, and are operated by VUI and UNELCO. A number of private sector funded projects are planned including the geothermal at Takara (Geodynamics), wind and solar projects on Efate and extended use of CNO-biofuel in diesel plant on Malekula and Efate (UNELCO).

In the off-grid sector, small renewable energy supply companies (RESCOs) have partnered with the government and donor organizations to implement programmes to bring distributed renewable energy technology to rural areas. The Lighting Vanuatu programme that commenced in 2010 was managed by the Energy Unit and implemented by VANREPA (Vanuatu Renewable Energy and Power Association) and ACTIV (Alternative Communities Trade in Vanuatu). The planned (but not implemented) Vanuatu Energy for Rural Development (VERD) programme envisaged government partnering with RESCOs to deliver individual solar systems to homes and public institutions. It was intended that the government would be responsible for planning, oversight, and donor coordination, while the RESCOs would handle distribution, design, installation, and ongoing support.

The VERD programme identified eleven RESCOs that could be involved in delivering VERD requirements: 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. These are mostly new businesses (half with fewer than five years' experience), with an average of five employees each. While they are headquartered in Port Vila, they are expanding their operations to the other islands. Significant growth is possible for these companies, but would require government support.

3.8 On-going and Planned Investments by Development Partners

A number of multilateral and bilateral donors are actively involved in promoting renewable energy in Vanuatu. Table 3.11 describes the involvement for each of the donors in Vanuatu's energy sector.

Table 3.11: Development Partner and Donor Supported Projects

Agency	Projects
Australian Aid Programme	▪ **Lighting Vanuatu Programme**. AusAID designed and funded a pico solar for rural electrification programme. The two year programme, managed by the Energy Unit and implemented by two NGOs, distributed over 50,000 pico solar lanterns to rural households. ▪ **Development of Vanuatu Electricity for Rural Development Programme (VERD).** Aimed to build on the success of Lighting Vanuatu, to expand rural electricity access and promote economic development by providing subsidized individual solar systems to households, and basic electrification to public institutions. Programme did not proceed; household segment of the programme will now be delivered under VREP. ▪ **Utilities Regulatory Authority.** Provided funds through the World Bank for technical assistance to the URA in development and execution of their work programme ▪ **National Energy Road Map.** Provided funds through the World Bank to support the preparation of the Vanuatu National Energy Road Map. ▪ **Oil and Gas Study.** Provided funds through the World Bank for a study into options for improved fuel supply arrangements.
NZ Ministry of Foreign Affairs and Trade	▪ **Vanuatu Rural Electrification Programme (VREP).** Providing funds through the World Bank to support the development of a programme to provide subsidized individual plug and play solar systems to rural households.

Agency	Projects
World Bank	▪ **National Energy Roadmap 2013-2020.** The World Bank with funds from Australian Aid Programme was the lead development partner assisting the Government with the development and implementation of the Vanuatu National Energy Road Map. ▪ **Energy Sector Development Project.** A World Bank project funded by Energy Sector Management Assistance Program (ESMAP) and Scaling-up Renewable Energy Program (SREP) for technical assistance to the DoE and by Australian Government's Governance for Growth programme through the Pacific Regional Infrastructure Facility (PRIF) for development and execution of their work programmes. ▪ **Vanuatu Rural Electrification Project.** A World Bank project funded by New Zealand Government Aid Programme through the PRIF to provide subsidized individual "plug and play" solar systems to rural households. ▪ **GPOBA Improved Electricity Access Projects.** A World Bank project funded by the Global Partnership on Output Based Aid (GPOBA), to provide targeted subsidies to enable access to grid-based services for 4,375 low income HHs. ▪ **Utilities Regulatory Authority.** Assisted the Government with the establishment of the URA with funding from the Australian Government's Governance for Growth programme through the PRIF. ▪ **Efate Geothermal Power & Grid Development.** Assisted the Government with the Efate Geothermal Power & Island-Ring Grid Development Framework pre-feasibility study undertaken by Castlerock Consultants.
Asia Development Bank (ADB)	▪ **Solar demonstration project.** Financed (through CEF) a 40 kW solar demonstration project in Luganville ▪ **HPP Pre-feasibility studies**. Preparation of pre-feasibility studies/ financial analysis for mini-hydro projects on Malekula and Santo ▪ **Energy efficiency project.** This ADB-managed project was funded by PRIF, GEF, and Asia Clean Energy Fund, and aimed to upscale energy efficiency across 5 countries (incl. Vanuatu). ▪ **Energy Access Project (proposed).** Project to increase access to grid connected power through grid extensions and investment in hydropower.
Japan International Cooperation Agency (JICA)	▪ **Sarakata HPP funding.** Grant-funded construction of the multiple stage Sarakata HPP. Was transferred to GoV ownership and subsequently put under the Luganville concession. ▪ **Community solar programme.** Funded installation of 220 SHSs across four of Vanuatu's islands during 1999-2003
International Union for Conservation of Nature (IUCN)	▪ **Wind Monitoring.** Installation of six wind resource monitoring masts in the six provinces of Vanuatu, during 2012 ▪ **Talise mini HPP.** Preparation of Environmental and Social Impacts Management Plan; preparation of tender and implementation of hydro project
SPREP	▪ **PIGGAREP implementation.** Assisted with studies relating to hydro

Agency	Projects
	power (feasibility studies for Sarakata and Talise) and CNO
UAE, Italy and Austria Governments and EU	▪ **Efate solar PV project.** Funded by the UAE, this project will install 500 kW of rooftop & ground mounted solar PV in Port Vila, in 2014. ▪ **Talise mini HPP.** Funded construction of this 75kW HPP on island of Maewo ▪ **CNO generation.** The EU intends to fund CNO generation in a number of villages in Torba and Penama, together with grid extensions on Malekula ▪ **Devil's Point Solar PV.** The EU (Second Energy Facility) has committed partial funding to a proposed 1.3 MW solar plant (led by UNELCO) near Port Vila

4 Prioritization of Renewable Energy Technologies

Many of the projects and technologies described in Section 3 are priorities for Vanuatu, but some are better candidates for SREP funding than others. Cost characteristics, (described in Sections 3.3 and 3.4) are just one of a range of important criteria considered in developing this Investment Plan.

The Government of Vanuatu, led by the MOCC and supported by the MDBs, therefore undertook a prioritization exercise to assess which of the projects or technologies identified in Section 3 would be best suited for SREP funding. The criteria used for prioritization, and the ranking of projects and technologies against the criteria, was accomplished through a participatory process. The process involved a range of government agencies, non-governmental organizations, and the private sector. The participatory process included many one-on-one meetings, and three workshops. The workshop discussions are summarized in Annex C.

The grid-connected technologies considered were utility-scale solar PV, geothermal power, small HPPs, CNO biofuel, and wind. The off-grid technologies considered included pico solar lanterns, individual solar systems, and micro/nanogrids. Each technology or project was evaluated against five National Criteria, together with SREP-specific criteria (to the extent these were not already encompassed by the National Criteria). Each was rated as High, Moderate or Low (with High indicating that the resource met the criteria best of all resources) against each criterion.

Section 4.1 describes the criteria developed by Government, in cooperation with stakeholders, and Section 4.2 ranks the technologies and projects against those criteria. Section 4.3 synthesizes the results of the ranking exercise and summarizes the reasons some technologies and projects receive overall higher rankings than others.

4.1 The Criteria

The National Criteria reflect the Government's strategic objectives, and the clear recognition by stakeholders that SREP funding should be used to have a transformative impact on the renewable energy sub-sector. The National Criteria, and a brief explanation of what they mean, are as follows:

- **Affordability/least cost.**[62] Projects supported by the SREP programme should help make energy more affordable in Vanuatu. Resource or technology options that make energy more affordable would therefore be ranked higher than more expensive resource or technology options. Grid connected and off-grid technologies were evaluated in slightly different ways, and were ranked *independently of one another*:
    - For on-grid technologies, the levelized energy costs in Section 3.3 were used to rank the options. The least cost technologies were given a rank of "H."

[62] Concessional financing was assumed because of the nature of the funding or financing provided by SREP. SREP provides either grants or very low cost loans ("contributions") which make the relatively capital-intensive technologies lower cost than technologies with relatively higher operating costs.

- For off-grid technologies, the levelized energy costs in Section 3.4 were considered but affordability in terms of cash-flow considered to be more important. As noted in Section 3.5, limited cash income or limited cash-flow is a barrier to purchase of some off-grid technologies. Pico solar technologies may be higher cost in terms of levelized energy cost, but are quite "affordable" in terms of the cash that consumers have to buy them.

- **Likelihood that projects could go forward in near-term.** Resource or technology options should be ranked higher if they avoid social, environmental, political, or other issues that could delay implementation. Options should also be ranked higher if there are projects already in preparation which could utilize SREP funding, or if they require very limited construction or installation periods.
- **Socio-economic benefits; Economic 'upliftment' that drives further energy use.** Resource or technology options should be ranked higher if they help to drive economic growth. Options should be ranked higher if they provide access to energy that was not previously available, or if they substantially improve the volumes or reliability of electricity available to customers. Options should also be ranked higher if they result in substantial ongoing job creation after the construction period.
- **Recognizes social/cultural realities.** Resource or technology options should be ranked higher if they recognize the social realities of Vanuatu (land use, in particular), how people use electricity, and other barriers faced in previous electrification efforts including the topography of the country (many remote areas).
- **Consistent with demand profiles.** Resource or technology options should be ranked higher if they take into account the levels of household demand, and are sized appropriately. This means not oversizing capacity by adopting technologies or projects that deliver more than customers demand, and not using "gold plate" technologies when simpler technologies, capable serving low levels of demand, may be appropriate. Technologies that are scalable (can be installed at lower capacity needs for smaller customer or system needs, or larger capacity for larger needs) and dispatchable should score higher.
- **Sustainability.** Projects or technology options should be ranked higher if they can be implemented through business models which allow for proper maintenance and operation of equipment.
- **Hurt factor.** Resource or technology options should be ranked higher if they can be implemented through business models which require some level of commitment or "buy-in" by customers.

4.2 The Rankings

Table 4.1 shows the rankings assigned to each technology under each criterion, and provides a brief explanations for why each technology received a particular ranking on each criterion.

Table 4.1: Ranking of Renewable Technologies Against Selection Critera

Criterion	Grid-connected				Off-grid		
	Small Hydro	**Solar**	**Geothermal**	**Wind**	**Pico solar**	**Stand-alone solar PV**	**Microgrids**
National Criteria							
Affordability/ least cost	**High** Sites identified are among the two lowest costs options on Malekula and Santo	**High** One of the lower cost options for Santo and Tanna	**Moderate** One of the lower cost options for Efate, but draft license agreement has *minimum* offtake price of 23 vatu/kWh	**High** One of the two lowest cost options for Malekula, Tanna and Efate	**High** Likely to be highest cost of the off-grid options, but very affordable in cash-flow terms	**Moderate** Likely to be slightly higher cost than micro-grid (except for larger consumers)	**Moderate (high variation in costs by application)** For very limited systems, likely to have a lower levelized cost than standalone solar, but systems covering larger areas quickly become more costly.
Likelihood to proceed soon	**High** Brenwe and Sarakata in preparation by MDBs but funding uncertain	**Moderate** At least two projects (Efate and Tanna) under preparation by donors and utilities, but these are already funded. There are no plans for additional sites.	**Moderate** Licensee preparing ESIA and ready to do exploratory drilling, but resource has not yet been assessed and there are substantial land-use, legal, and regulatory issues to be resolved	**Moderate** Devil's point wind expansion planned by UNELCO. No other sites planned.	**High** Off-the-shelf technologies. No construction/ installation needed, and there are already several distributors	**High** World Bank VREP project is under preparation, and there are existing vendors, and construction/ installation periods are short	**Low** No specific projects under preparation. Past problems with such projects require careful thought and special arrangements for project preparation
Socio-economic benefits	**High** Brenwe or Sarakata plants would make higher volumes of more reliable	**High** Devil's Point solar project will allow for a reduction in tariff of 2	**High** Similar considerations as for other grid connected options, however,	**Low** Energy would benefit customers who already have grid connections in	**Moderate** Creates potential jobs for vendors. More limited maintenance jobs.	**High** Customers who previously had no electricity (or pico solar only) would have some. Business models could be used in which local private sector would provide ongoing maintenance, revenue collection, and	

Criterion	Grid-connected				Off-grid		
	Small Hydro	**Solar**	**Geothermal**	**Wind**	**Pico solar**	**Stand-alone solar PV**	**Microgrids**
	power available at lower cost to the populations served in the concession areas. Most jobs would be construction related.	Vatu/kWh. Most jobs are construction-related.	geothermal would provide substantial volumes of firm baseload capacity which could replace diesel generation.	systems with already good reliability. Most jobs are construction-related. Most jobs are construction-related.		customer relations.	
Recognizes social/ cultural realities	Moderate According to ADB, there are some potential land rights issues related to the Brenwe site, in particular.	High Possibly some land rights issues but less likely to be as problematic as other grid connected technologies because there are many alternative sites	Moderate There are likely to be land rights issues related to many of the sites.		**High** No land rights issues involved.	**High** No major land rights issues involved in installation and operation.	**Moderate** May be some land rights issues, especially with wind or hydro micro-grids where resource may be distant from the load
Consistent with demand profiles	**High** Provides non-dispatchable energy, but generally higher capacity factors than solar and wind. HPPs are also less variable hour-	**Moderate** Scalable to the needs of larger or smaller systems, but non-dispatchability can increase grid integration costs. Consistent with	**Moderate** Provides baseload capacity which will replace diesel, but 8 MW may be more baseload capacity than Efate needs in 2020, given recent demand patters.	**Moderate** Scalable to the needs of larger or smaller systems. Daily pattern inconsistent with load profiles on Efate and Santo	**Moderate** Appropriate for basic needs of household customers, but not easily scalable to larger loads.	**High** Scalable to the needs of most household customers.	**High** Scalable to the needs of most households and larger customers.

Criterion	Grid-connected				Off-grid		
	Small Hydro	**Solar**	**Geothermal**	**Wind**	**Pico solar**	**Stand-alone solar PV**	**Microgrids**
	to-hour than solar and wind (most variability is seasonal)	daily load profiles on Efate and Santo (at least)					
Sustainability	**High** Professional, private sector utility operators would be responsible for the equipment				**High** No operators, but there are suppliers, who may be able to offer some warranties or service plans where appropriate.	**Moderate** No incumbent operators. Maintenance schemes would need to be integrated into the service delivery model.	**Low** No incumbent operators. Maintenance schemes would need to be integrated into the service delivery model. Many would likely be diesel-hybrid systems where considerable maintenance is required
'Hurt factor'	**High** Customers will pay through tariffs and connection fees.				**High** Depends largely on business model adopted, but customers would likely be expected to pay some portion of cost of system upfront or through monthly fee		

Note: A lower score indicates that a technology is determined to be more suitable for SREP funding according to the chosen selection criteria. A score of 1 indicates that a technology meets the criteria very well, and a score of 4 indicates that a technology meets the criteria worst of all technologies.

Note: The rankings may also vary by location, for example, depending on the specific project. For example, Sarakata 1 expansion is to be on existing leased land, whereas some other projects may have significant land issues to address before they can proceed. Similarly, costings for hydro plant will vary depending on expected output from the specific project.

4.3 Conclusion on the Rankings

The rankings in the previous section were used as a rough guide only. As noted in the introduction to this section, all of the projects and technologies identified in Section 3 are priorities for Vanuatu, but some are better candidates for SREP funding than others. For example, some projects described in Section 5 are already being undertaken or funded by other parties; others, while appearing lowest cost and most affordable, do not rank as well against other important criteria.

Considerations associated with each technology are described in more detail below.

Off-grid

Access to affordable electricity to households and institutions in rural areas remains the biggest challenge for Vanuatu. Considerations related to specific off-grid technologies were as follows:

- **Pico solar.** Pico solar ranks well on many criteria but SREP funding for pico solar lanterns is not being sought because stakeholders felt this market was adequately served by local private sector vendors and the Lighting Vanuatu programme. There is not yet substantial uptake, however, of larger scale, 'next step up', plug and play solar lighting. As described in Section **Error! Reference ource not found.**, the World Bank intends to fund such systems with the support the Government of New Zealand. SREP funding is not being requested for such systems but is part of the overall rural electrification program proposed in this Investment Plan. This programme will apply to households, aid posts, and community halls in areas not served by grids.
- **Standalone solar PV.** Standalone solar PV ranks well among off-grid options on most of the evaluation criteria, and is therefore proposed for SREP funding.
- **Microgrids.** Vanuatu has had difficulty implementing microgrids in the past because the business model or service delivery models utilized did not allow for proper operation and maintenance. The costs of such systems, moreover, are highly site- and context-specific. Micro- and mini-grids are, however, can be an important part of rural electrification in Vanuatu (and a least cost option), if sites are selected carefully and the right business models are used. Microgrids were therefore included in Section 5 as one of the technologies for which SREP funding is requested.

Grid connected

Considerations related to specific grid-connected technologies were as follows:

- **Grid connected solar.** In the case of grid-connected solar, the project that is farthest along and appears the most viable (the Devil's Point solar project) already has funding. The Devil's Point project is being funded by UNELCO and the European Union. On Tanna, solar PV also ranks well, but UNELCO already has plans to undertake this investment so SREP funding is not required. On Santo, where solar also appears (from the cost curves in Section 3.3) to be low cost, there are operational constraints related to stability and reliability, and past experience that suggest it is a poor choice. The existing ADB-funded solar on Santo has not been found to be a good match for the slow response hydro station, and additional solar requires diesels to continue to operate for firming.

- **Geothermal power.** In the case of the geothermal project, funding under SREP is not being sought for a variety of reasons:
  - The project sponsor, Geodynamics, has the resources to undertake the test well drilling without SREP support
  - Exclusive and unsolicited 30-year production license arrangements for the development of the resource to a private company makes it difficult for the public sector lending arms of the MDBs to mobilize financing
  - There is substantial regulatory uncertainty surrounding the project, given that there is not yet a clear legal and regulatory framework for IPPs on Efate. There is, moreover no signed PPA that would allow for investment by the MDBs private sector arms
  - If some of the above issues can be resolved, a better route for funding would be through one of SREP's sister facilities, the Clean Technology Fund (CTF), which has provided highly concessional loans for a number of geothermal projects.
- **Small hydropower.** Small hydropower projects are not always lowest cost, but Vanuatu's experience with small hydropower plants has been excellent. Experience on Santo with the existing Sarakata plant has illustrated the value that this resource can provide there in the long term. Additional hydro resource on Santo would increase renewable energy generation on the system to nearly 100 percent while lowering the average cost of supply. The small hydropower plant on Brenwe could also reduce supply costs and displace some diesel.
- **Coconut Oil.** CNO ranks relatively well on some islands, and is already widely used on Efate and Malekula (by UNELCO). On other islands, however, feedstock supply constraints and price volatility make it suboptimal. Experience at Port Olry and on Efate have shown that locking-in a reliable source of supply can be difficult.
- **Wind power.** Wind power was not recommended for any of the islands, despite appearing cost effective for both Tanna and Malekula. The estimated costs are based on a single turbine, which would provide peak output in excess of the load on each island. In reality, it would be preferable to have some output diversity (to reduce variability) but the use of multiple smaller turbines would result in lower capacity factors and thus a higher levelized cost. In addition, limited sites were identified that were close to roads and existing grids, and there is considerable uncertainty in the data available to date. Wind turbines also tend to be located on exposed ridges away from sheltered settlements, requiring transmission, and exposing them to cyclones.

5 Programme Description

The prioritization exercise described in Section 4 has led to the selection of two areas where Government will request SREP funding: Stand-alone solar and micro-grids, and grid-connected small hydro.

This Investment Plan, if implemented, will be profoundly transformational for Vanuatu, changing a country with very limited access to electricity to one in which roughly 90 percent of the population has access and in which most of the energy consumed comes from renewable energy sources.

5.1 Rural Electrification Project

The off-grid rural electrification project would be integrated into the World Bank's Vanuatu Rural Electrification Programme (VREP). The project would have the following components:

- Component 1 would fund Electrification of approximately 17,500 households, 2000 community halls and 230 aid posts. Technology used will be plug and play solar PV systems, and the target segment is households who will never have grid access or fixed SHS. Initially, the funding will focus on solar PV systems of between 5 to 30 Watts peak capacity that are of "plug and play" type, installed easily by the consumer and require little to no maintenance other than replacing batteries. These systems can provide lighting and phone charging capabilities, with some systems capable of supporting other uses such as radios and small televisions.
- Component 2 would use SREP funding to provide electricity to households or public institutions through individual solar system or—where feasible—micro-grids, potentially using a fee-for service franchise, concession, or RESCO model. If used for public institutions, the SREP funding could potentially be used to offset all or a portion of the capital costs of electrifying schools, clinics or other strategic public institutions in rural areas using stand-alone solar systems. Based on census data, VERD identified that there are in excess of 35 health centres and dispensaries, 250 primary schools, and 20 secondary schools (as well as a large number of post offices, churches and businesses) in rural Vanuatu that do not have access to electricity.[63]
- Component 3 involves technical assistance and project management support to the DoE to implement the two different types of delivery models described for Components 1 and 2. For component 2 (which is SREP-funded), this would include support in identifying appropriate business models for service delivery and transaction advisory for tendering the DBO, franchise, concession or RESCO.

[63] 58% of schools and 75% of health facilities in rural areas to not have access to electricity.

- Component 4 involves the preparation of feasibility studies required to identify the needs of each site, and the technology most appropriate for different areas and different circumstances.

For Component 2 (to be funded by SREP) it is essential that the business model used to deliver individual solar systems and micro-grids to households, community centres and public institutions includes affordable upfront costs, and ensures that operation and maintenance (including battery replacement) is sustainable. The most appropriate business model will be identified as part of the feasibility studies and transaction advisory described above.

Given the mixed success of past installations, determination of the appropriate model must occur before the programme is rolled out. Key elements of a sustainable model are those that that provide for regular preventive maintenance as well as timely repairs as needed, and fee collection is disciplined and monitored, with non-payers disconnected within a short period. Box 5.1 describes experience in the region and in Vanuatu with a range of possible business models.

Box 5.1: Business Models for Individual Solar and Micro-grids

Four generic models that have been tried in the Pacific are set out below:

- **Community based** operation and maintenance of microgrids and individual solar systems. This has not worked well in most cases in Vanuatu (as described in earlier sections), nor elsewhere in the Pacific. With regard to individual solar systems in particular, a major problem has been lack of continued payments to cover maintenance, so when batteries (in particular) fail, funding for replacement or repair is unavailable.
- A **Cooperative approach** has been tried in several Pacific Islands but has not been successful. Under this model, each household has a share in the overall solar project and elects a management committee to set and collect user fees, and manage the maintenance. For example, a cooperative approach was used on a national level in Tuvalu, which, due to frequent contributions of donor funds, provided reasonable service for over 10 years. However, the Tuvalu cooperative ultimately failed due to lack of fiscal oversight and corruption at the management level. A village level cooperative approach was also attempted in Fiji. However, in this case the fees were set too low and then not collected, resulting in poor maintenance and early system failure.
- **Government provision:** This approach has been used in parts of Tonga and the Cook Islands. The key problem was the central provision of maintenance: because visits were too infrequent, failed systems were often out of service for extended periods. Funds for battery replacements were unavailable until more donor money could be sought, which was often several years.
- **RESCO (utility) models:** These approaches have been most successful in the Pacific to date. The RESCO owns and maintains the solar installations and provides them to households that agree to pay a fixed, periodic fee for the services provided. RESCO approaches have been used for solar based rural electrification in Kiribati, Fiji, Tonga, and the Republic of the Marshall Islands. The key issue with these programmes relates to the fee collection required for the systems to be sustainable. It is essential that payment discipline is achieved, and that the fees are sufficient to cover ongoing costs (including battery replacement) without the need for government or donor subsidies.

To support the selected business model, the Renewable Readiness Assessment for Vanuatu (RRA)[64], undertaken under IRENA, proposes establishing equipment standards that are suitable for Vanuatu, and promoting a limited set of modular products or systems, both for individual solar systems and mini-grids. These support development of training programmes, availability of spares, and result in lower cost of ongoing maintenance.

The proposed VERD model for public institutions was an output-focused RESCO model. It involved contracting businesses to deliver results (such as lights, computing and printing at 20 schools, with any breakdowns addressed within defined timeframes) rather than a product (the solar PV system). Payments would be made over three years with 70 percent after installation, and 10 percent at the end of each of the first three years. Maintenance beyond that time would be tendered. For community systems, the full cost of service for the first two years would be paid upfront, and annual maintenance and a service guarantee provided for two years, following which outside-warranty repairs would be the responsibility of the community.[65]

Geographical spread and low population densities mean that a competitive model is

[64] The Renewables Readiness Assessment for Vanuatu, 2014.

[65] VERD background documents

unlikely to be workable for Vanuatu, and some type of concession model may be more appropriate, where each RESCO is allocated an area, following competitive tender process. Alternately, the government could let an O&M contract for various areas, which would include fee collection.

Maintenance

Some preventive maintenance that is required on a monthly or bi-monthly basis cannot be done cost effectively from a central location. Local technicians must be recruited (and trained). In Kiribati, one technician per 75 installations is usual, depending on how widely dispersed the systems are.

With regard to repair maintenance, the nature of individual solar systems is such that troubleshooting and repair is not often complicated, and preventive maintenance technicians can be trained to undertake this role also, with assistance available by phone when the issue is beyond the technician's expertise.

Where microgrids utilize resources other than solar, for example, pico hydro, maintenance requirements will clearly differ from those set out above. Schemes will be far fewer in number, and broader skills will be required to undertake repairs, so it is likely that a skilled technician would need to be sent to site.

Fee collection

There are two relevant models for fee collection for individual solar systems and micro/nano grids: agent collections and prepayment meters. Where agent collections are used, disconnecting late- and non-payers dramatically improves collection rates. For example, in Kiribati where customers are disconnected after two months of non-payment, fee collection is close to 100 percent, with 80 percent of fees being paid on-time. In Tonga, non-payers are not disconnected and collections are much lower. In Fiji, collections are made through prepayment meters and 85 percent of all payments are made on time. The remaining payments are generally made within one month since services are automatically disconnected when customers do not pay.

Both models of fee collection have advantages and disadvantages when it comes to susceptibility to corruption and the cost of administering the system. Agent collections can allow for misuse of collected funds by agents and prepayment meters can add to the complexity and cost of the system. Collection fees for users can also be higher for systems with prepayment meters as a result of the cost of the meters and their maintenance. According to the referenced examples, both models can achieve similar collection rates; however, an exact comparison of costs and user fees for the two models is not available.

5.1.1 Parallel activities to be funded by other parties

As noted above, the World Bank, using funds from NZ Ministry of Foreign Affairs and Trade (MFAT), has committed to provide roughly $5 million in funding for individual solar systems for households, and aid posts and community halls through the Vanuatu Rural Electrification Programme (VREP).

VREP focuses on provision of lighting for households and aid posts, and includes substantial technical assistance with establishing vendor and product registration arrangements, communications and support with the development of microfinance products, and for development of legislation, regulations and/or Environmental Code of Practice (ECOP) for collection, transport and disposal of batteries. It also includes funding for project management and support, i.e. capacity building and implementation support to the DoE through technical experts and advisors, training for the DoE staff, awareness programmes to rural communities, independent verification of subsidy claims prior to payments, and monitoring, evaluation of the project.

5.1.2 Environmental, social and gender co-benefits

This project has the potential to create the following environmental, social and gender co-benefits:

Labour and Working Conditions

- Some opportunities for local employment (paid and voluntary) and 'on-the-job' training in relation to as part of the preparatory works and deployment of microgrids (for example fixing of roof-mounted solar PV panels; clearance of trees and vegetation; and, erection of electricity distribution poles under skilled supervision)[66]. Depending on the business model for standalone solar systems, this is also likely to provide employment opportunities in sales, maintenance and fee collection roles.
- Opportunities for skills training, educational events or mechanisms for encouraging jobs for women
- The technologies are supplied and distributed by a private retail market. The technology therefore can help to build private sector capacity and promote employment opportunities in product supply, distribution and maintenance (with appropriate skills training)[67]
- The technologies have been shown to provide increased opportunities for individuals in rural communities to work (e.g. night-time working). This is generally seen as a positive result and can also result in indirect social benefits through small groups of relatives or friends coming together to work on weaving, sewing or handicrafts in the evenings
- Educational establishments benefit from the use of these technologies through the elimination of the risk of fire (associated with kerosene) and through the ability for children to study later in the evenings.[68]

Resource Efficiency and Pollution Prevention

- Reduced GHG emissions compared to alternative fossil fuel use
- The technologies are seen as a viable solution for direct replacement of kerosene lamps and their adoption will therefore help to eliminate pollution risks associated with kerosene fuels (e.g. air pollution and risk of spills during transporting and storage of kerosene) as well as the use of this resource[69]

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[66] Banban Community Line Extension Project and Pepsi Community Line Extension Project (Bitas, R. T. for Vanuatu Utilities and Infrastructure (VUI) Ltd. (undated)

[67] Vanuatu National Energy Road Map 2013-2020 (GoV, 2013).

[68] Banban Community Line Extension Project and Pepsi Community Line Extension Project (Bitas, R. T. for Vanuatu Utilities and Infrastructure (VUI) Ltd. (undated).

[69] Banban Community Line Extension Project and Pepsi Community Line Extension Project (Bitas, R. T. for Vanuatu Utilities and Infrastructure (VUI) Ltd. (undated).

- Increased renewable energy deployment avoids many of the environmental risks of fossil fuels (such as the risk of spills to bodies of water whilst transporting diesel oil) and can reduce noise impacts of burning fossil fuels[70]
- Potential for reuse or recycling of materials either within or from the solar PV developments on Vanuatu
- Potential to improve community-level materials handling/ waste recycling facilities as part of a waste management regime for solar PV (especially batteries and solar PV panels).

Community Health, Safety and Security

- Beneficial outcomes attributed to the deployment of renewable off-grid technologies include: improved safety and security, gender equality, improved education, financial savings, and community building[71]
- Improvements in refrigeration of food, medicines and vaccines; provision of lights and communication for safety and security[72]
- Potential for affected communities to be better informed about the risks posed by the impact of natural disasters on infrastructure and for stakeholder engagement activities to help establish or improve community emergency preparedness and response to natural disasters.

Indigenous Peoples

- Improved renewable energy supply and electricity security can provide lighting, which can enable studying and teaching to take place after dark. Light also increases access to sources of knowledge (e.g. news); and presents opportunities for training in, and learning about, renewable energy[73]
- Reducing ongoing monetary outlay for kerosene[74]
- Renewable energy deployment can help to support tourism and 'market' a country as 'environmentally friendly' for the benefit of a sustainable tourist trade[75]
- The establishment of mutually beneficial and ongoing relationships based on Informed Consultation and Participation (ICP) with the Ni-Vanuatu communities affected by solar PV projects.

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[70] Vanuatu National Energy Road Map 2013-2020 (GoV, 2013).

[71] Banban Community Line Extension Project and Pepsi Community Line Extension Project (Bitas, R. T. for Vanuatu Utilities and Infrastructure (VUI) Ltd. (undated).

[72] Drivers and Barriers of Renewable Energy in the Electrification of Vanuatu (Polack, 2010).

[73] Vanuatu National Energy Road Map 2013-2020 (GoV, 2013).

[74] Banban Community Line Extension Project and Pepsi Community Line Extension Project (Bitas, R. T. for Vanuatu Utilities and Infrastructure (VUI) Ltd. (undated).

[75] TA-8285 VAN: Energy Access Project – 1; Interim Report. Asian Development Bank/ SMEC International Pty Ltd. (May 2014).

Cultural Heritage

- If cultural heritage surveys are conducted, there would be the opportunity to use cultural heritage surveys conducted for the solar PV projects to identify, document and protect culturally important areas/artefacts for the long-term benefit of Affected Communities
- The development of charging stations may afford opportunities for sustainable and equitable sharing of benefits from cultural heritage. For example, it may allow for indigenous cultures to run heritage tours to sites of interest.

Other Cross-Cutting Topics

- Facilitate improvements to clean drinking water access and improvements to removal of wastewater.[76]

5.1.3 Environmental and social risks

A list of potential environmental, social and gender risks that are potentially created by the off-grid solar project are described in this section. All social and environmental issues associated with standalone solar and micro-grids will be managed in accordance with World Bank and/or ADB safeguard requirements as applicable.

Labour and Working Conditions

- Lack of locally trained professionals could give rise to the need for either local professionals to travel overseas for training or for imported technical expertise[77]
- Lack of attention to land lease administration and enforcement can mean that special provisions made pertaining to employment for lessor family members are not realized or are less effective than intended[78]
- Unsafe or unhealthy working conditions and poor health of workers can arise if measures are not in place to promote safe and healthy working conditions, especially for vulnerable categories of workers such as children, workers engaged by third parties and workers in the supply chain.

Resource Efficiency and Pollution Prevention

- When solar PV is deployed with batteries for off-grid application, this may increase demand for reliable energy, such that there is a need for additional energy supply. This increases use of natural resources and increases recycling/disposal requirements as well as complicating the technical operational maintenance regime[79]

[76] Vanuatu National Energy Road Map 2013-2020 (GoV, 2013).

[77] Vanuatu Investing in Community Level Infrastructure: Addressing the Gap (Report No. 70622-VU). World Bank Advisory Report 2012.

[78] Wan Sip, Plante Kapten: Leasing on Tanna Island, Vanuatu Rod Nixon, Leisande Otto and Raewyn Porter, J4P Research Report, May (2012).

[79] Vanuatu: Efate Geothermal Power and Island-ring Grid Development Framework; Draft Final Report (October 2011).

- Risk of pollution from the generation, handling and disposal of waste during construction, maintenance and decommissioning of microgrid solar PV panels. This is a special risk for solar PV because there may be hazardous materials in solar PV panels (such as gallium arsenide, copper-indium-gallium-diselenide and cadmium-telluride).

Community Health, Safety and Security

- Vanuatu is very vulnerable to natural disasters as it is on the pacific 'ring of fire'. Off-grid solar PV infrastructure are likely to be vulnerable to the effects of coastal erosion, tropical cyclones, floods, landslides and droughts[80]
- Risk of detrimental health effects on local communities through dust and other particulate matter during construction of micro-grids
- Risk of light glint from solar PV panels giving rise to nuisance and disturbance to local communities/ residents (including from roof-mounted solar PV).

Biodiversity Conservation and Sustainable Management of Living Natural Resources

- There are six legally protected areas (with four more under consideration) and a further 28 community based protected areas (14 of which have terrestrial components) within Vanuatu. It is possible that these will be vulnerable to degradation should solar PV developments be proposed within them.[81]

Indigenous Peoples

- Existing formal and informal distribution networks between and within the islands of Vanuatu can by highly fluid and may not be reliable enough to maintain ongoing supply and maintenance of off-grid-solar technologies to rural areas without the support of NGOs[82]
- Conflicting paradigms of conventional capitalist economic development and Ni-Vanuatu (indigenous) community-based 'kastom[83]' practices[84,85]
- Risk of heightened expectations of renewable electricity supply reaching remote villages/ communities, whereas it may not in fact be feasible or

[80] TA-8285 VAN: Energy Access Project – 1; Interim Report. Asian Development Bank/ SMEC International Pty Ltd. (May 2014).

[81] TA-8285 VAN: Energy Access Project – 1; Interim Report. Asian Development Bank/ SMEC International Pty Ltd. (May 2014).

[82] Banban Community Line Extension Project and Pepsi Community Line Extension Project (Bitas, R. T. for Vanuatu Utilities and Infrastructure (VUI) Ltd. (undated).

[83] 'Kastom' can be viewed as the mixture of values, beliefs, institutions and practices perceived as traditional in Vanuatu.

[84] Hybrid Justice in Vanuatu: The Island Courts Michael Goddard and Leisande Otto, Justice and Development Working Paper Series, Vol. 22 (2013).

[85] Vanuatu: Efate Geothermal Power and Island-ring Grid Development Framework; Draft Final Report (October 2011).

economically affordable to either set-up or maintain such infrastructure in rural communities. This could result in social discontent.[86]

- Land ownership issues and compensation arrangements could be a significant risk for micro-grid projects. Free, Prior and Informed consultation (FPIC) among other social assessment and consultation methodologies will be used to address any issues of land disputes. Strong community ownership and buy in can help mitigate this risk.

Cultural Heritage

- Risk of pollution to water bodies (including surface water and groundwater supplies) arising from construction activities; for example: erosion and mobilization of sediments by construction plant, stripping of land surface for the mounting of solar PV structures, or inappropriate storage of polluting materials
- Water usage in the manufacture of the solar PV components and in the regular cleaning of the solar PV panels.

Other Cross-Cutting Topics

- Women are traditionally excluded from community discussions in rural areas and it is likely to be difficult to establish active engagement with women over the adoption or placement of solar PV projects over community owned land[87]
- There is a risk that the ability for women to work later in the evenings could turn from an opportunity to being a risk if the additional burden on women becomes too great.
- Micrograids based on CNO may face climate-change related risks. Agriculture in Vanuatu is entirely rain-fed and is thus vulnerable to changes in rainfall patterns. Also, increases in temperature cause crop heat stress, wilting and higher incidence of pests and diseases, which often result in crop failure. These climate-related stresses may exacerbate the already declining land productivity due to decreased fallow periods.[88]

5.2 Small Hydropower Project

The Project will construct hydropower generation on Malekula (Brenwe Hydropower) and Espiritu Santo (Sarakata hydropower extension) to displace diesel generation. Feasibility studies are currently being finalized[89]. The project scope will be confirmed once cost estimates are finalized. The Project will also potentially extend the distribution grid to an estimated 450 households in Malekula and up to 1,500

[86] Asian Development Bank TA 7329-REG: Promoting Access to Renewable Energy in the Pacific (Vanuatu Component): Pre-final Report (Oct 2012).

[87] Drivers and Barriers of Renewable Energy in the Electrification of Vanuatu (Polack, 2010).

[88] Increasing Resilience to Climate Change and Natural Hazards: Project Appraisal Document on a Proposed Global Environment Facility Grant. The World Bank, October 12, 2012.

[89] ADB Project Preparation Technical Assistance

households in Espiritu Santo. Hydropower has been assessed to be the least-cost baseload generation option for Malekula and Espiritu Santo grids. The project is summarized in Table 5.1.

Table 5.1: Small Hydropower Project Summary

	Hydropower		
1.	Brenwe Hydropower	Malekula	400 kW hydropower plant including related transmission
2.	Sarakata Hydropower Extension	Espiritu Santo	300 kW extension to existing Sarakata hydropower near Luganville including related transmission capacity upgrade
	Distribution Grid Extensions		
1.	Malekula grid extension	Malekula	Distribution extension to supply 450 households, schools and business's (Larevet to Unmet to Leviam)
2.	Luganville urban grid extension	Espiritu Santo	Distribution extension to 900 households within the Luganville urban and peri-urban areas.
3.	Port Olry grid extension	Espiritu Santo	Distribution extension to 600 households, schools and business's from the Luganville grid to Port Olry.

SREP grant funding for hydropower generation will benefit the economy by (i) reducing fossil fuel imports; (ii) lowering the cost of power generation, which will ease the pressure on power tariffs and thereby reduce commercial and household expenditure; (iii) improving energy security, and (iv) minimizing tariff volatility by partially converting the national grid to renewable energy. SREP grant funding of hydropower generation will lower electricity generation costs, and create an incentive to extend the grid. The grid extension will directly benefit new peri-urban customers by (i) replacing kerosene lighting with a cheaper form of energy, thereby freeing household expenditure; (ii) enabling household income generation; (iii) improving children's education; and (iv) reducing indoor health and safety issues associated with burning kerosene. Project benefits will be extended through employment of landowners during the construction period.

A summary of the potential subproject is presented in the following sections.

5.2.1 Parallel activities to be funded by other parties

ADB would provide roughly $5 million of concessional loans (ADF) in financing for the hydropower plants (Brenwe and Sarakata).

5.2.2 Environmental, social and gender co-benefits

The small hydro projects have the potential to create the following environmental, social and gender co-benefits:

Labour and Working Conditions

- Project proponents could train local graduates and increase the local skill base.

Resource Efficiency and Pollution Prevention

- Reduced GHG emissions compared to alternative fossil fuel use
- Increased renewable energy deployment avoids many of the environmental risks of fossil fuels (such as the risk of spills to water bodies while transporting diesel oil) and can reduce noise impacts of fossil fuels[90]. This particularly applies to the Sarakata projects.

Community Health, Safety and Security

- Improvements in refrigeration of food, medicines and vaccines; provision of lights and communication for safety and security[91]
- Potential for projects to assess and inform potentially Affected Communities about risks posed by the impact of natural disasters on infrastructure and to help establish or improve emergency preparedness and response to natural disasters.

Land Acquisition and Involuntary Resettlement

- Off-grid power capacity can provide tangible benefits to the local community[92]
- Potential for income generation for land owners (if land leases are negotiated fairly and are equitable for custom landowners).

Indigenous Peoples

- Improved renewable energy supply and electricity security can provide lighting, which can enable studying and teaching to take place after dark. Light also increases access to sources of knowledge (e.g. news); and presents opportunities for training in, and learning about, renewable energy[93]
- Renewable energy deployment can help to support tourism and 'market' a country as 'environmentally friendly' for the benefit of a sustainable tourist trade[94]
- The establishment of mutually beneficial and ongoing relationships based on Informed Consultation and Participation (ICP) with the Ni-Vanuatu communities affected by small hydropower projects
- Discussion of opportunities for improved transport infrastructure and access arising from ancillary developments required for small hydropower plants (for example, improvement to, or provision of, access roads to allow ongoing maintenance)

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[90] Operation and Management Arrangement for Talise Micro Hydro Power Project (75kW) Version 2.2.

[91] Drivers and Barriers of Renewable Energy in the Electrification of Vanuatu (Polack, 2010).

[92] Operation and Management Arrangement for Talise Micro Hydro Power Project (75kW) Version 2.2.

[93] Vanuatu National Energy Road Map 2013-2020 (GoV, 2013).

[94] TA-8285 VAN: Energy Access Project – 1; Interim Report. Asian Development Bank/ SMEC International Pty Ltd. (May 2014).

- As a part of the resettlement plan for the projects, “affected people” currently unconnected to the grid will be provided power connections alongside the project development.[95]

Cultural Heritage

- Opportunities arising from cultural heritage surveys to identify, document and protect culturally important areas/ artefacts for the long-term benefit of Affected Communities.

5.2.3 Environmental and social risks

In addition to those noted above, the small hydro projects have the potential to create the environmental, social and gender risks, which are described in this section. All social and environmental issues associated with small hydropower projects will be managed in accordance with World Bank and/or ADB safeguard requirements as applicable.

Labour and Working Conditions

- Lack of locally trained professionals could give rise to the need for either local professionals to travel overseas for training or for imported technical expertise[96]
- Lack of attention to land lease administration and enforcement can mean that special provisions made pertaining to employment for lessor family members are not realized or are less effective than intended[97]
- Unsafe or unhealthy working conditions and poor health of workers can arise if measures are not in place to promote safe and healthy working conditions, especially for vulnerable categories of workers such as children, workers engaged by third parties and workers in the supply chain.

Resource Efficiency and Pollution Prevention

- Risk of waste generation from construction and decommissioning activities
- Risk of pollution of land and water resources from construction activities, such as erosion and mobilization of sediments by construction plant, stripping of land surface for construction of small hydropower infrastructure, or inappropriate storage of polluting materials[98]

[95] TA-8285 VAN: Energy Access Project – 1; Draft Final Report. Asian Development Bank/ SMEC International Pty Ltd. (Aug 2014)

[96] Vanuatu Investing in Community Level Infrastructure: Addressing the Gap (Report No. 70622-VU). World Bank Advisory Report 2012.

[97] Wan Sip, Plante Kapten: Leasing on Tanna Island, Vanuatu   Rod Nixon, Leisande Otto and Raewyn Porter, J4P Research Report, May (2012).

[98] TA-8285 VAN: Energy Access Project – 1; Interim Report. Asian Development Bank/ SMEC International Pty Ltd. (May 2014)

- Generation, handling and disposal of waste during the construction, operation and maintenance and decommissioning of small hydropower plants (including their ancillary infrastructure such as transmission lines and access roads)
- Risk of pollution to water bodies (including surface water and groundwater supplies) arising from construction activities.

Community Health, Safety and Security

- Vanuatu is very vulnerable to natural disasters as it is on the pacific 'ring of fire'. Small hydropower infrastructure (including in particular transmission lines and access roads) are likely to be vulnerable to natural disasters including the effects of earthquakes, tropical cyclones, floods, landslides and droughts[99]. However, the proposed sites are well away from the coast in hilly areas, so the key civil infrastructure components will be somewhat less exposed to climate driven extremes than distribution lines and end users. These risks can also be mitigated by providing suitable levels of erosion protection to prevent scour at the intake weir's training walls and establishing a powerhouse discharge outlet with a high enough level as to prevent damage of electromechanical equipment during floods.[100]
- Visual impacts of small hydropower projects on the landscape[101]
- Risk of detrimental health effects on local communities through dust and other particulate matter during construction, operation and decommissioning and risk of nuisance/ disturbance from noise, traffic or vibration during construction, operation and decommissioning. Such environmental impacts can easily be mitigated to acceptable levels.

Land Acquisition and Involuntary Resettlement

- Difficulties establishing land ownership rights for siting of small hydropower developments, especially in rural areas where community ownership is common place; which could result multiple claimants to land, disputes in respect of ownership and the potential for inequitable land leasing decisions being made and the loss of livelihood for current landowners[102]. Most affected land owners, land holders and lessors of impacted land have been initially contacted, validation of land status is in progress and legal documentation is being sought. However, some land settlement compensation remains outstanding in relation to the existing Sarakata-1 site, and landowner details are not yet known for the proposed Sarakata-2 site and canal routing; though

[99] TA-8285 VAN: Energy Access Project – 1; Interim Report. Asian Development Bank/ SMEC International Pty Ltd. (May 2014)

[100] TA-8285 VAN: Energy Access Project – 1; Draft Final Report. Asian Development Bank/ SMEC International Pty Ltd. (Aug 2014)

[101] Asian Development Bank TA 7329-REG: Promoting Access to Renewable Energy in the Pacific (Vanuatu Component): Pre-final Report (Oct 2012)

[102] Towards More Equitable Land Governance in Vanuatu: Ensuring Fair Land Dealings for Customary Groups Milena Stefanova, Raewyn Porter and Rod Nixon, J4P Discussion Note, May (2012)

those that have indicated they hold land rights are supportive of the project, uncertainty remains until detailed discovery of legal status of land is completed. With regard to the Brenwe development, there is one legally recognized landowner, but this is under dispute as other parties also claim ownership; the catchment above the project and access routes from it cross land with multiple owners and support has been pledged (verbally) by all claimants. Free, Prior and Informed consultation (FPIC) among other social assessment and consultation methodologies will be used to address any issues of disputes. Also strong community ownership and buy in will be sought to further mitigate these risks.

- Transport of equipment and materials during construction, operation/maintenance and decommissioning of small hydropower developments may present difficulties with regard to land owner agreements for access.
- Difficulties in agreeing land restoration agreements due to the complex land tenure systems in Vanuatu (especially in rural areas with community land ownership)
- Risk of physical or economic displacement as a result of project-related land acquisition and/or restrictions on land and water resource use.

Biodiversity Conservation and Sustainable Management of Living Natural Resources

- There is no known rare or endangered flora or faunal species that are likely to be affected by the projects, but Fish and Aquatic Reports (FAR) will be undertaken as part of development proposals[103]. In the case of the Brenwe project, the proposed minimum flow is considered sufficient to ensure the health of the existing downstream ecosystem along the 1 km affected stretch. As such, no noticeable impacts are expected on fish and aquatic resources of the Brenwe River as a result of the project. [104]
- Small hydropower development will require preliminary Environmental Impact Assessment (including ancillary developments such as access roads and transmission lines) to give rise to risks to flora and fauna (such as loss of nesting or foraging habitat)[105,106]
- There is the potential for impacts on priority ecosystem services from small hydropower developments and their ancillary infrastructures. For example,

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[103] TA-8285 VAN: Energy Access Project – 1; Interim Report. Asian Development Bank/ SMEC International Pty Ltd. (May 2014)

[104] TA-8285 VAN: Energy Access Project – 1; Draft Final Report. Asian Development Bank/ SMEC International Pty Ltd. (Aug 2014)

[105] TA-8285 VAN: Energy Access Project – 1; Interim Report. Asian Development Bank/ SMEC International Pty Ltd. (May 2014)

[106] Vanuatu: Efate Geothermal Power and Island-ring Grid Development Framework; Draft Final Report (October 2011)

natural buffer areas such as wetlands and forested areas, which mitigate the effects of natural hazards such as flooding, landslides and fires, may be lost. This may result in increased vulnerability and community safety related risks and impacts. However, general surrounding environments of all project sites have been highly modified by human activity (vegetable gardens and plantations) and there is limited – if any – primary forest within the area of influence of the projects. This is a particularly low risk for the Brenwe project, which is a small, run-of-the-river hydropower project without any dam or reservoir. The Brenwe plant will also be constructed within the same footprint of a previously partially constructed and abandoned hydropower project. [107]

Indigenous Peoples

- Conflicting paradigms of conventional capitalist economic development and Ni-Vanuatu (indigenous) community-based 'kastom' practices[108]
- Risk of misuse of funds collected from developments[109]
- Loss of access to natural and culturally important lands and resources (for example through inappropriate placement of small hydropower plants and ancillary infrastructure (such as transmission lines and access roads)
- Risk of heightened expectations of renewable electricity supply reaching remote villages/ communities, whereas it may not in fact be feasible or economically affordable to either set-up or maintain such infrastructure in rural communities. This could result in social discontent.[110]

Cultural Heritage

- Sites and objects of historical, ethnological or artistic interest can be subject to preservation under the Preservation of Sites and Artefacts Act 1965. Once a site is classified, the owner is obligated to prevent modification or deterioration of the site. Such sites are likely to be vulnerable to degradation should small hydropower developments be proposed near to them[111]
- Risk of physical impacts to critical cultural heritage (which is essential to the identity and/ or cultural, ceremonial, or spiritual aspects of the Ni-Vanuatu)
- Risk of degradation of the setting of cultural heritage sites (e.g. views to and from important cultural heritage sites).

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[107] TA-8285 VAN: Energy Access Project – 1; Draft Final Report. Asian Development Bank/ SMEC International Pty Ltd. (Aug 2014)

[108] Hybrid Justice in Vanuatu: The Island Courts Michael Goddard and Leisande Otto, Justice and Development Working Paper Series, Vol. 22 (2013)

[109] TA-8285 VAN: Energy Access Project – 1; Interim Report. Asian Development Bank/ SMEC International Pty Ltd. (May 2014)

[110] Asian Development Bank TA 7329-REG: Promoting Access to Renewable Energy in the Pacific (Vanuatu Component): Pre-final Report (Oct 2012).

[111] TA-8285 VAN: Energy Access Project – 1; Interim Report. Asian Development Bank/ SMEC International Pty Ltd. (May 2014)

Other Cross-Cutting Topics

- There is a risk of conflicting use of water resources associated with small hydropower schemes, in particular where river flow levels are low.[112]
- Women are traditionally excluded from community discussions in rural areas and it is likely to be difficult to establish active engagement with women over the adoption or placement of small hydropower projects over community owned land.[113]
- Small hydropower generation requires surface water diversion and therefore has the potential to locally impact upon water resource quality and availability for other local water users. However, in the case of the Sarakata-1 and Sarakata-2, reduced flow between weir and powerhouse is not expected to have major impacts on income sources. Landowners at the project site for Sarakata-2 will lose a total of 12.45 ha of their land; however, these sections are reportedly not used for cultivation or pasture. [114]

[112] TA-8285 VAN: Energy Access Project – 1; Interim Report. Asian Development Bank/ SMEC International Pty Ltd. (May 2014)

[113] Drivers and Barriers of Renewable Energy in the Electrification of Vanuatu (Polack, 2010)

[114] TA-8285 VAN: Energy Access Project – 1; Draft Final Report. Asian Development Bank/ SMEC International Pty Ltd. (Aug 2014)

6 Financing Plan and Instruments

Table 6.1 presents a plan for financing the projects described in Section 5. It shows the proposed credits and grants from SREP as well as estimates of the amounts anticipated from MDBs and the private sector.

As the table shows, roughly US$ 14 million of SREP funding is expected to catalyse roughly 1.4 times as much investment, most of it from the private sector (as equity or debt), and the public sector lending windows of the MDBs.

The exact financing modalities will be determined at the time of appraisal, but it is expected that:

- Rural Electrification Project: US$5 million of SREP funding will added to US$4.7 million of VREP grant funding (from NZMFAT, administered by the World Bank) for stand-alone solar and micro-grid solutions (the solution depending on the site conditions and load profiles). It is expected that the private sector will contribute at least US$1.5 million in investment or in the form of working capital (for O&M or lease-type contracts). An additional US$1.2 million of the SREP funding will be used for technical assistance which includes identifying the most appropriate business models and preparing packages for tender. US$800,000 will be used for feasibility studies, to identify the technologies most appropriate sites and technologies. US$1.5 million will come as in-kind contributions from the Government of Vanuatu and GoV will borrow approximately US$2 million in concessional loans for the World Bank to expand the scope of the project.
- Small Hydropower Project: US$7 million of SREP funding will be added to US$5 million of concessional loans from ADB for the construction of the Brenwe and/or Sarakata small hydropower plants. The Government of Vanuatu will contribute US$1.9 million as an in-kind contribution. SREP grant funding is critically important to making the hydropower project affordable and bringing down the overall cost of energy on Malekula or Brenwe.

Table 6.1: Financing Plan

SREP Project	SREP	MDB Responsible	Government of Vanuatu	MDBs	Private Sector (Equity)	Other	Total
Rural Electrification Project							
Plug and play solar systems		WB			3.1	3.1*	**6.2**
SHS, micro and mini grids	5.0		1.5	2.0	2.0		**10.5**
Technical assistance and project management	1.2					1.6*	**2.8**
Feasibility studies and preparation	0.8						
Subtotal: Off-Grid Solar and Micro-grids	**7.0**		**1.5**	**2.0**	**5.1**	**4.7**	**20.3**
Small Hydropower Project							
Investment in Sarakata and/or Brenwe	7.0	ADB	1.9	5.0	0.0	0.0	**13.9**
Subtotal: Small Hydropower Projects	**7.0**		**1.9**	**5.0**	**0.0**	**0.0**	**13.9**
Grand Total	**14.0**		**3.4**	**7.0**	**5.1**	**4.7**	**34.2**
SREP Leverage	**1.4**						

*Government of New Zealand

7 Responsiveness to SREP Criteria

The Investment Plan developed for Vanuatu is responsive to all of the SREP criteria. Table 7.1 summarizes how each of the projects responds to SREP Criteria.

The plan provides, moreover, a potential transformative impact seen in few previous SREP Investment Plans. The results of the investments described in Section 5 would provide electricity to nearly 90 percent of the population in Vanuatu.

Table 7.1: Summary of Projects' Responsiveness to SREP Criteria

Criteria	Stand-alone solar and micro-grids	Small Hydropower Projects
Increased installed capacity from renewable energy sources	This project will focus on providing electricity where none was provided before for households, community buildings, aid posts and public buildings. The SREP funding will be allocated to electrification of public institutions and micro-grids.	The Brenwe and Sarakata projects will provide an additional 700 kW to 1.8 MW of new hydropower capacity on Espiritu Santo and Malekula.
Increased access to energy through renewable energy sources	The stand-alone solar and micro-grids project (using hybrid diesel, CNO, solar or other) will provide access to 27,500 households, 230 aid posts, 2,000 community buildings and public buildings.	The hydropower project at Brenwe will provide access to renewable energy where currently only kerosene (or pico solar) is used for lighting.
Low Emission Development	Solar PV produces no emissions and will displace kerosene currently used extensively by households for lighting.	Hydropower produces no emissions and will displace kerosene currently used by households for lighting and (in Espiritu Santo, for the Sarakata plant) diesel currently used for generation of electricity.
Affordability and competitiveness of renewable resources	Customers targeted by the stand-alone solar project will be in areas where alternatives are limited. Stand-alone solar systems or (in some areas) micro-grids are a considerably lower cost source of lighting than kerosene and for many sites will be lower cost (on a levelized cost basis) than other forms of stand-alone generation (for example, diesel) or even pico solar. Stand-alone solar systems and micro-grids can also provide a better range and quality of service than alternatives such as kerosene.	The supply curves shown in 3.3 confirm that, with concessional financing, the hydropower plants are considerably lower cost than the cost of new diesel generation.
Productive use of	Rural electrification creates	The hydropower projects provide

Criteria	Stand-alone solar and micro-grids	Small Hydropower Projects
energy	extensive opportunities for productive energy use. Section **Error! Reference source not ound.** provides more details on the socio-economic benefits of off-grid electrification projects.	better reliability and security of supply (for example, in Santo, where Sarakata is grid connected) as well as access.
Economic, social and environmental development impact	The development of these projects has a number of economic, social and environmental benefits, which are described in detail for each technology in Section 5.	
Economic and financial viability	Stand-alone solar or micro-grids are the most economically and financially viable options for electrifying many areas in Vanuatu, because of geography, topography, population distribution, and the location of existing grids.	As noted above, the supply curves shown in 3.3 confirm that, with concessional financing, the hydropower plants are considerably lower cost than the cost of new diesel generation.
Leveraging of additional resources	Investments from the private sector, MDBs, and government are estimated to leverage 1.4 times the amount contributed by SREP.	
Gender	Off-grid electrification offers ample benefits for women. Section **Error! Reference source not ound.** describes these in more detail.	The hydro projects provide better security and reliability of supply as well as improved access to electricity. Women will benefit from both, as under the off-grid solar electrification projects.
Co-benefits of renewable energy scale-up	There are a number of co-benefits associated with each plant. These are described in more detail in Section 5 and Annex D.	

8 Implementation Potential with Risk Assessment

The implementation risk of the IP in Vanuatu is moderate. With regard to the proposed off-grid rural electrification project, the most serious risks relate to sustaining the technologies over time. Historically, micro-grids and solar systems have not had a high success rate due primarily to:

- Ongoing costs: cost of ongoing maintenance, fuel cost in the case of CNO-biofuel or diesel systems. Consumers have been often unwilling or unable to fund this on an on-going basis
- Capacity: in some cases, the skills to maintain assets, or fix them in the event of breakdowns, and commercial/management skills have been inadequate.

With regard to the Brenwe and Sarakata extension projects supported by ADB, while land issues have been considered carefully, potential remains for land disputes to delay or halt proceedings. Free, Prior and Informed consultation (FPIC) among other social assessment and consultation methodologies will be used to address any issues of land disputes and promote community ownership and buy-in.

The GoV also has well-established processes for mitigating social and environmental issues associated with the proposed projects, and ensuring that these be managed in accordance with World Bank and/or ADB safeguard requirements as applicable. The Environment Management and Conservation Act (2010) requires nearly all developments to carry out environmental assessment and also provides for the establishment of protected areas. Order Number 102 under the Act (2013) established procedures for the 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 before the development starts. If, following a determination by the DEC, the project requires full EIA then a Terms of Reference (ToR) is 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.

Table 8.1 describes the principal risks associated with Vanuatu's IP, describes how to mitigate those risks, and evaluates the residual level of risk after the proposed mitigation measures are implemented.

Table 8.1: Risk Assessment of the SREP Programme in Vanuatu

Risk	Description	Mitigation	Residual Risk
Legal and regulatory risks	A number of gaps and inconsistencies have been identified in Vanuatu's regulatory framework. The current arrangements allow IPPs to generate electricity outside concessions and to supply it outside the concessions and to concessionaires; however, there	The problems associated with IPPs and PPAs are not likely to be a problem with the grid-connected small hydropower project proposed in this investment plan. The small hydropower projects can be integrated into existing concession areas and operated by exiting concessionaires. The power utilities	**Moderate for concession areas, low outside concession areas**

Risk	Description	Mitigation	Residual Risk
	is no obligation on concessionaires to purchase electricity from IPPs, and no framework for IPPs to access existing networks and for concessionaires to pass through costs of such power purchases into tariffs. Thus, despite assistance, there may be difficulties in establishing IPP and PPA arrangements. The pending court decision over the tender for the Luganville concession could also create potential difficulties for the Sarakata hydropower project.	currently managing the Malekula and Espiritu Santo grids have indicated a preference to operate and maintain the proposed assets. The URA has indicated this arrangement is preferable and can be accommodated under the existing regulatory arrangements. None of the problems mentioned in the first column will affect the off-grid projects.	
Institutional capacity risks	The DoE is relatively new in its current form, and its history working with donors to implement technical assistance and capital works projects reflects its inexperience and lack of resources. This creates significant risks for projects that are to be implemented by the Department, as was the case with the VERD project in 2012. Vanuatu's energy regulator, URA, is also relatively new. While it appears to be developing the electricity supply framework, there are some issues in relation to the concession agreement/ESA hierarchy.	The DoE will be the Implementing Agency for both projects. For the small hydropower project, day-to-day implementation will be delegated to the Vanuatu Project Management Unit (VPMU). The DoE has full ownership of the proposed project. It has undertaken the screening of potential hydropower sites and is currently conducting full feasibility studies of the optimum sites. A Project Management Unit (PMU) will be established within the VPMU to implement the project. A project steering committee will oversee implementation, monitor progress, and provide guidance to the executing agency. The project steering committee will meet at least quarterly and will be chaired by the DoE. The PMU will host the project steering committee and will act as the secretariat. The DoE is also currently implementing the World Bank Energy Sector Development Project (Technical Assistance) and the GPOBA Improving Electricity Access Project and is gearing up to implement this Vanuatu Rural Electrification Project. The technical assistance component of the off-grid project will provide DoE with specialized assistance to	**High**

Risk	Description	Mitigation	Residual Risk
		undertake feasibility studies, assess appropriate models and to establish the enabling framework (legal and regulatory, tender for and award contracts and supervision of those contracts).	
Technology risks	All of the proposed programmes relate to technologies that are well-known globally. Implementation of a programme providing subsidized individual solar PV for public institutions or micro-grids also comes with significant sustainability risk when applied to Vanuatu, particularly given the remoteness of some islands.	In relation to the off-grid solar programme, much has been learned from past experience installing solar systems and microgrids in the remote islands of Vanuatu. The project will seek to develop approaches, potentially based on fee-for-service or maintenance contracts, to mitigate sustainability risks.	**High**
Environmental risks	Any large-scale development assumes environmental risks. For example, the selected projects might limit alternative land use, cause alteration of land characteristics, require the clearance of vegetation and compaction of soil, and cause vibrations and downwash during construction. The individual solar systems will bring with them the risks relating to batteries. Micrograds based on CNO may face climate-change related risks. Agriculture in Vanuatu is entirely rain-fed and is thus vulnerable to changes in rainfall patterns. Also, increases in temperature cause crop heat stress, wilting and higher incidence of pests and diseases, which often result in crop failure. These climate-related stresses may exacerbate the already declining land productivity due to decreased fallow periods. [115]	Site-specific environmental impact assessments (or project specific, in the case of the individual solar systems) will be carried out for all projects implemented under SREP. These assessments will ensure that the projects comply with Government policies as well as World Bank and/or ADB safeguards requirements as applicable. Furthermore, by ensuring that projects are sited away from particularly environmentally sensitive areas, environmental risks can be minimized.	**Low**
Social risks	Land ownership issues and compensation arrangements could be a significant risk for	Site-specific social impact assessments will be carried out for all projects implemented under SREP.	**Moderate**

[115] Increasing Resilience to Climate Change and Natural Hazards: Project Appraisal Document on a Proposed Global Environment Facility Grant. The World Bank, October 12, 2012.

Risk	Description	Mitigation	Residual Risk
	hydro and potentially also microgrid projects.	These assessments will ensure that the projects comply with Government policies as well as World Bank and/or ADB safeguards requirements as applicable. In relation to hydro and microgrid projects where this risk is considered high, Free, Prior and Informed consultation (FPIC) among other social assessment and consultation methodologies will be used to address any issues of land disputes. Strong community ownership and buy in will be sought to mitigate these risks.	
Financial risks	Customers may be unable to afford to pay the full costs of the projects sponsored by the investment plan.	The small hydropower projects will bring down the cost of serving customers on Malekula or Sarakata. Tariffs for Vanuatu's concessions are established on the basis of cost of service, and savings will be passed along to customers. The business model envisioned for the off-grid technologies will provide CAPEX subsidies. The extent of CAPEX studies needed will be determined by affordability and willingness-to-pay assessments done as part of project preparation.	**Moderate**

9 Monitoring and Evaluation

The investments proposed in this plan would be transformation in ways that few other SREP Investment Plans can be. The investments would allow Vanuatu to electrify nearly 90 percent of households in the country and nearly 100 percent of households that are currently outside of concession areas.

A monitoring and evaluation (M&E) system will be established by the Government, in cooperation with the MDBs and other donor partners, for the purpose of tracking and reporting on progress in reaching SREP impacts and outcomes. The M&E framework will be coordinated by the DoE within MOCC and involve the participation of URA, and the National Statistics Office.

Table 9.1 summarizes the proposed monitoring and evaluation (M&E) framework for Vanuatu's SREP IP as part of the overall monitoring framework of the NERM.

Table 9.1: Results Framework for the SREP Programme in Vanuatu

Result	Indicators	Baseline (2012)	Targets (2020)	Means of Verification
SREP Transformative Impact Indicators				
Support low carbon development pathways by reducing energy poverty and/or increasing energy security	Percentage of total households with access to electricity[116]	27%	90%[117]	MOCC/SREP Project's M&E system
	Percentage of off-grid households with access to electricity*	<10%	87%	MOCC/SREP Project's M&E system
	Annual electricity output from RE	23%	65% (NERM target) Project target TBD	MOCC/SREP Project's M&E system
SREP Outcomes				
Increased supply of renewable energy	Increased annual electricity output (GWh) as a result of SREP interventions	0	TBD[118]	MOCC/SREP Project's M&E system
Increased access to modern energy services	Number of women and men, businesses and community	13,885 connected	156,800 men, women, businesses or community	MOCC/SREP Project's M&E system

[116] The Revised SREP results framework (2012) says that this indicator should be a "National measure of 'energy poverty' such as the Multi-dimensional Energy Poverty Index (MEPI), or some equivalent mutually agreed measure." Energy poverty is indeed a multi-dimensional problem which includes problems associated with a lack of access to sufficient energy supply, a lack of access to clean energy, and a lack of access to affordable energy. The principal problem in Vanuatu is a lack of access to any energy supply whatsoever. Access indicators are therefore used to measure energy poverty.

[117] Includes the estimated 3,000 new connections funded by the GPOBA project.

[118] Will depend substantially on the nature of the off-grid technologies selected (to be determined by feasibility studies) and whether the Sarakata or Brenwe hydropower plant is developed.

	services benefiting from improved access to electricity and fuels as a result of SREP interventions		services connected through off-grid project 1,950 connected to grid through small hydropower project	
New and additional resources for renewable energy projects	Leverage factor: USD financing from other sources compared to SREP funding	0	1.4	SREP Project's M&E system

*Note: electricity access includes lighting only access in rural areas (excludes pico solar lanterns).

Annex A: Assessment of Vanuatu’s Absorptive Capacity

Debt Sustainability

In its “Budget Policy Statement 2015,” Vanuatu’s Department of Finance and Treasury states that one of its long-term fiscal objectives is to maintain public debt levels below 40 percent of GDP.[119] This target “debt ceiling” as well as current and projected non-SREP related public debt levels can be used to estimate the amount of new financing that Government can take on for SREP-related projects.

A 2013 International Monetary Fund (IMF) report on Vanuatu’s current and projected future public debt sustainability found that Vanuatu’s public debt was 21 percent of GDP at the end of 2012. This report projected that under the IMF’s baseline projection of Vanuatu’s financial situation in the future, the country’s public debt levels are expected to grow to approximately 27 percent of GDP by 2018.[120] This does not include significant contingent liabilities from potential court-imposed damages in domestic lawsuits that might be realized in the coming years. If realized, these damages could be worth as much as 10 percent of Vanuatu’s GDP. If these contingent liabilities are indeed realized by 2018, then Vanuatu’s public debt-to-GDP ratio could rise by 10 percentage points to 37 percent by 2018 under the IMF’s baseline projection. Table 9.2 shows some of the forecasts in the IMF’s projection of Vanuatu’s public debt during the years 2014 to 2018.

Table 9.2: Baseline Projection of Vanuatu’s Public Debt 2014-2018

	2014	2015	2016	2017	2018
Forecast GDP growth	4.20%	4.80%	4.50%	4.30%	4.00%
Forecast GDP, million US$	$865	$907	$947	$988	$1,028
Public debt, % of GDP	23%	24%	26%	26%	27%
Domestic	11%	11%	10%	11%	13%
External	12%	13%	16%	15%	14%
Public debt, million US$	$195	$218	$246	$261	$274
Domestic	$91	$96	$99	$111	$129
External	$104	$121	$147	$150	$146

Source: International Monetary Fund, “VANUATU 2013 ARTICLE IV CONSULTATION,” June 2013

Under the IMF’s baseline projection for current and projected future public debt levels (in which the above-mentioned contingent liabilities are not realized), it is

[119] Department of Finance and Treasury of Vanuatu, “Budget Policy Statement 2015,” available: https://doft.gov.vu/images/downloads/2014/budget_policy_2015.pdf

[120] International Monetary Fund, “2013 Vanuatu Article IV Consultation,” IMF Report No. 13/169, June 2013, Available: http://www.imf.org/external/pubs/ft/scr/2013/cr13169.pdf

estimated that the Government of Vanuatu could take on new loans worth up to approximately $140 million before 2018 and still keep its debt-to-GDP ratio below 40 percent. This was calculated by assuming that Vanuatu's 2018 GDP will be US$1,027 million, that public debt would be 27 percent of GDP in that year without any SREP-related loans and that debt service on any new loans would be 8 percent per year. Debt service was estimated based on the amount of debt service paid all of Vanuatu's external debt in 2013.[121]

Implementing Agency Capacity

The Department of Energy (DoE) will be the implementing agency for both projects proposed in the Investment Plan. The DoE will be advised on the financial management by the Ministry of Finance, which will also be responsible for the oversight of financial activities under both projects.

The DoE is currently implementing several donor-funded projects. It is currently implementing the World Bank Energy Sector Development Project (Technical Assistance) and the GPOBA Improving Electricity Access Project and is gearing up to implement this Vanuatu Rural Electrification Project. In cooperation with ADB, DoE, has also been screening of potential hydropower sites[122] and is currently conducting full feasibility studies of the optimum sites.[123]

For the rural electrification project in the Investment Plan, it is envisaged that the private sector vendors and RESCOs will assist the DoE under contractual arrangements with the DoE (on behalf of the Government of Vanuatu). The technical assistance component of the off-grid project will also provide DoE with specialized assistance to undertake feasibility studies, assess appropriate models and to establish the enabling framework (legal and regulatory, tender for and award contracts and supervision of those contracts).

For the small hydropower project in the Investment Plan, day-to-day implementation will be delegated to the Vanuatu Project Management Unit (VPMU). The DoE has full ownership of the proposed project. It has undertaken the screening of potential hydropower sites and is currently conducting full feasibility studies of the optimum sites. A Project Management Unit (PMU) will be established within the VPMU to implement the project. A project steering committee will oversee implementation, monitor progress, and provide guidance to the executing agency. The project steering committee will meet at least quarterly and will be chaired by the DoE. The PMU will host the project steering committee and will act as the secretariat.

The DoE has taken steps to strengthen its capacity recently, appointing additional staff including a Finance Officer and a dedicated Off-Grid Officer to support its rural electrification programmes and financial activities.

[121] World Bank World Development Indicators, "Debt service on external debt, total," Available: http://data.worldbank.org/indicator/DT.TDS.DECT.CD

[122] ADB. 2009. *Technical Assistance for the Promotion of Renewable Energy in the Pacific.* Manila.

[123] ADB. 2012. *Technical Assistance to Vanuatu for Preparation of the Energy Access Project.* Manila

Annex B: Project Concept Briefs

B.1 Rural Electrification Project

PROBLEM STATEMENT

1. Vanuatu faces complex development challenges stemming largely from its small, sparsely distributed population, its remoteness and limited connectivity to internal and external markets, and instability in Government. Vanuatu is an archipelago of 82 volcanic islands in the South Pacific with a total area of 12,300m2, and about 1300km north to south distance between the outermost islands. Some 65 of the islands are inhabited. There are few roads on most of the islands, limited commercial shipping between islands, and air transportation is unaffordable for most citizens. Vanuatu has a population of about 270,000 living in approximately 55,000 households, almost evenly distributed among the six administrative provinces: Malampa, Penama, Sanma, Shefa, Tafea and Torba. About 14,000 households (25 percent) are located in urban areas and the remaining 41,000 (75 percent) are dispersed in rural areas.

2. **Low access and high costs of energy**. On a national level about 73 percent of the population of Vanuatu still does not have access to electricity. Overwhelmingly, those without access, live in rural areas, and outside of Efate Island. The fortunate minority with access mostly resides in the urban areas of the four electricity service concession areas on the four largest islands of Vanuatu: islands of Efate, Tanna, Malekula, and Santo. Even on these largest four islands (of the 80+ islands of Vanuatu), the share of those without access remains high: Efate (24 percent), Santo (65 percent), Tanna (86 percent), Malekula (84 percent). From a provincial and regional development and equity perspective, there is a severe imbalance in access – an urban-rural divide. Of the 55,000 total households nationwide, an estimated 23,300 are in grid-concession areas or in adjacent areas feasible for grid-extension. The remaining 31,700 households are in areas termed “off-grid”. Some of these households are relatively concentrated and are more likely to benefit from a micro- or mini-grid configuration, powered by local resources, such as hydro and other renewable energy technologies (RET) where available, diesel gensets, or diesel/RET hybrids. There have been no past studies or data that would enable an accurate estimation of the size of the group that would benefit from micro- or mini-grid configurations. Assuming that 30 percent of off-grid households (9,510) are in this category (including the few estimated to have operating or forthcoming micro- or mini-grid installations), the remaining dispersed off-grid households would be estimated at 22,190, who are unlikely to have access to any form of grid connection. In addition to the off-grid households, some 560 schools, health centres, dispensaries, post offices and aid stations provide vital services to poor and isolated communities.

PROJECT OBJECTIVE

3. **The project development objective (PDO)** is to support increased penetration of renewable energy and increased access to affordable electricity services for rural households, public institutions and businesses located in the dispersed off-grid areas.

The Project comprises of three main components:

- **a.** Component 1 involves "demand driven" and subsidized supply of plug and play solar systems under a vendor model to consumers in rural and remote areas where micro or mini grids are not feasible
- **b.** Component 2 involves provision of electricity through Solar Home Systems (SHS), and where feasible micro and mini grids, potentially under franchise/concession/management contract models in areas where extension of existing grids is not an option,
- **c.** Component 3 involves technical assistance and project management support to the DoE to implement the two different types of delivery models described for Components 1 and 2;
- **d.** Component 4 involves feasibility studies, establishment of the enabling framework and the project preparation activities, in the main for Component 2 above.

Given the readiness and the extent of preparatory activities that will be required for each of components 1 and 2, it is envisage that each component and associated technical assistance and project management activities will be progressed separately on a different timetable. Component 1 is expected to start in early 2015. The timelines and the project preparation activities shown below relate to Component 2 only.

4. **Higher-level objectives to which the Project contributes.** The development of a regional Country Partnership Framework (CPF), which would include consideration of Vanuatu's priorities and objectives, is being progressed by the World Bank. This Project directly supports the Government's Priority and Action Agenda (PAA) 2006-2015, which aims to: (a) reduce the cost of services; (b) extend the coverage of rural electrification; and (c) promote the use of renewable energy. It is consistent with GoV's current vision for a more diversified economy and more equitable social and economic development. The GoV has made the development of the electricity sector a priority. The Vanuatu National Energy Roadmap (NERM) lays the foundation for future energy sector policy and investment in Vanuatu. The NERM identifies five priority areas and targets for Vanuatu's energy sector, including: (a) access to secure, reliable and affordable electricity for all citizens by 2030; (b) reliable, secure and affordable petroleum supply throughout Vanuatu; (c) lower cost energy services; (d) an energy secure Vanuatu at all times; and (e) mitigating climate change through renewable energy and energy efficiency. This Project will contribute to increased access and affordability of electricity in rural Vanuatu through investment in renewable energy.

PROPOSED CONTRIBUTION TO INITIATING TRANSFORMATION

5. Supporting improved access to electricity from the renewable energy sources in Vanuatu, through a combination of small plug and play solar systems, SHS, micro and mini-grids (renewable energy and hybrids), and the creation of an enabling environment, will catalyse the economic transformation of the households and communities reached. The design and implementation of the Project would draw on global best practice and adapt it to the social, environmental, institutional and business environment of Vanuatu. The objective is to develop sustainable vendor supply models and involve the private sector power supply companies (RESCOs) in efficiently delivering and maintaining electricity supplies to new customers. The reason for the proposed adoption of fee-for-service RESCOs is to address sustainability issues in relation to SHS and micro grids noting that community based grids have generally suffered from lack of technical and commercial capacity to sustain operations. In terms of impact the Project, when combined with the World Bank GPOBA Improved Electricity Access Project expects to increase electricity access rates from current 30 percent to over 80 percent leading to a transformative impact for the nation.

IMPLEMENTATION READINESS

6. The Department of Energy (DoE) in the Ministry of Climate Change and Natural Disaster will be the Implementing Agency. The DoE is currently implementing the World Bank Energy Sector Development Project (Technical Assistance) and the GPOBA Improving Electricity Access Project and is gearing up to implement this Vanuatu Rural Electrification Project. Whilst the development of Component 1 and related technical assistance and project management needs is at an advanced stage, Component 2, is still at a concept stage and the DoE will require specialized assistance to undertake feasibility studies, assess appropriate models and to establish the enabling framework (legal and regulatory, tender for and award contracts and supervision of those contracts).

RESULTS INDICATORS

7. The main results indicators, to be further elaborated on during project preparation, will comprise the following:

Annex Table B.1: Results, Indicators and Targets

Results	Indicators	Targets
	SREP Transformative Impact Indicators	
Support low carbon development pathways by reducing energy poverty and/or increasing energy security	Percentage of total households with access to electricity	85%[124]
	Percentage of off-grid households with access to electricity	87%
	Annual electricity output from RE	65% (NERM target)
	SREP Outcomes	
Increased supply of renewable energy	Increased annual electricity output (GWh) as a result of SREP interventions	TBD[125]
Increased access to modern energy services	Number of women and men, businesses and community services benefiting from improved access to electricity and fuels as a result of SREP interventions	156,800
New and additional resources for renewable energy projects	Leverage factor: USD financing from other sources compared to SREP funding	1.8

Source: World Bank and Government of Vanuatu estimates

Note: Targets here are different than in Section 9 because the targets here refer only to the off-grid project included in the Investment Plan. The targets Section 9 refer to the Investment Plan as a whole.

[124] Includes the estimated 3,000 new connections funded by the GPOBA project.

[125] Will depend substantially on the nature of the off-grid technologies selected (to be determined by feasibility studies).

FINANCING PLAN (Ratio = 1.8)

8. The total estimated project cost is $20.3 million, of which $7.0 million is sought from the SREP, and $2 million from the World Bank Group. The Government of Vanuatu, the private sector (including consumers) will also contribute to the project (Table 4).

Annex Table B.2: Proposed Financing Plan for WBG Rural Electrification Project

	Private sector	SREP	WBG	GoV	Other[126]	Total
1. Plug and play solar systems	3.1	-	-	-	3.1	**6.2**
2. SHS, micro and mini grids	2.0	5.0	2.0	1.5	-	**10.5**
3. Technical assistance and project management	–	1.2	–	–	1.6	**2.8**
4. Feasibility studies and preparation	–	0.8	-	–	–	**0.8**
TOTAL	**5.1**	**7.0**	**2.0**	**1.5**	**4.7**	**20.3**

Other: Government of New Zealand, WBG: World Bank Group

Source: WB, and Vanuatu Government estimates

LEAD IMPLEMENTING AGENCIES

9. The DoE will be the Implementing Agency on behalf of the Government of Vanuatu, while the World Bank will serve as the lead MDB. It is envisaged that the private sector vendors and RESCOs will assist the DoE under contractual arrangements with the DoE (on behalf of the Government of Vanuatu).

[126] Government of New Zealand

PROJECT PREPARATION TIMETABLE

10. The estimated project preparation timetable is presented below. Note that this applies to component 2 and 3 only.

Annex Table B.3: Proposed Schedule

Milestones	**Expected Completion Date**
SREP Sub Committee approve Project Preparation Grant	November 2014
WB approve Project Preparation Technical Assistance (PPTA)	June 2015
Mobilize PPTA consultants	December 2015
Complete Project Design	June 2016
SREP Sub-Committee Approval	November 2016
WB Board Consideration	March 2017

Source: WB/Government of Vanuatu estimates

PROJECT PREPARATION GRANT

11. The Government of Vanuatu is requesting a preparatory grant of US$ 800,000 to prepare this project.

Table 6: MDB Request for Payment for Project Implementation Services (MPIS)

<table>
<tr><td colspan="4">SCALING UP RENEWABLE ENERGY IN LOW-INCOME COUNTRIES
MDB Request for Payment of Implementation Services Costs</td></tr>
<tr><td>1. Country/Region:</td><td>Vanuatu</td><td>2. CIF Project ID#:</td><td></td></tr>
<tr><td>3. Project Title:</td><td colspan="3">Rural Electrification Project</td></tr>
<tr><td>4. Request for project funding (USD$million):</td><td colspan="2">At time of country submission (tentative): US$7.0 million</td><td>At time of project approval:</td></tr>
<tr><td rowspan="2">5. Estimated costs for MDB project implementation services (USDmillion):</td><td colspan="2" rowspan="2">Initial estimate - at time of Country submission: US$0.500 million

Final estimate - at time of project approval: n/a</td><td>MDB: World Bank Group</td></tr>
<tr><td>Date: October 2014</td></tr>
<tr><td>6. Request for payment of MDB Implementation Services Costs:</td><td colspan="2">☐ First tranche: US$0.250 million</td><td></td></tr>
<tr><td>7. Project financing category:</td><td colspan="3">a - Investment financing - additional to ongoing MDB project √
b- Investment financing - blended with proposed MDB project ☐
c - Investment financing - stand-alone ☐
d - Capacity building - stand alone ☐</td></tr>
<tr><td>8. Expected project duration (no. of years):</td><td colspan="3">5 years</td></tr>
<tr><td>9. Explanation of final estimate of MDB costs for implementation services:</td><td colspan="3">Not applicable</td></tr>
<tr><td colspan="4">10. Justification for proposed stand-alone financing in cases of above 6 c or d: not applicable</td></tr>
</table>

Table 7: SREP Project Preparation Grant Request by WBG

<table>
<tr><td colspan="5">SREP
Project Preparation Grant Request</td></tr>
<tr><td>1. Country/Region:</td><td>Vanuatu</td><td colspan="2">2. CIF Project ID#:</td><td></td></tr>
<tr><td>3. Project Title:</td><td colspan="4">Rural Electrification Project</td></tr>
<tr><td>4. Tentative SREP Funding Request (in US million total) for Project at the time of Investment Plan submission (concept stage)::</td><td colspan="2">Grant: US$7.0 million</td><td colspan="2">Loan: $0</td></tr>
<tr><td>5. Preparation Grant Request (in USD):</td><td colspan="2">US$ 0.800 million</td><td colspan="2">MDB: World Bank Group</td></tr>
<tr><td>6. National Project Focal Point:</td><td colspan="4">Jothan Napat
Director General
Ministry of Climate Change and Natural Disasters</td></tr>
<tr><td>7. National Implementing Agency (project):</td><td colspan="4">Department of Energy</td></tr>
<tr><td>8. MDB SREP Focal Point and Project Task Team Leader (TTL):</td><td colspan="2">SREP Focal Point:
Mr. Gevorg Sargsyan
Program Coordinator, SREP
World Bank
Email:
gsargsyan@worldbank.org</td><td colspan="2">Task Team Leader (TTL):
Mr. Kamleshwar Khelawan
Senior Energy Specialist
East Asia and the Pacific
World Bank
Email:
kkhelawan@worldbank.org</td></tr>
<tr><td colspan="5">9. Description of activities covered by the preparation grant:
A preparation grant is required to:
(i) Conduct market analysis, affordability assessment, prepare feasibility study level designs for micro and mini-grids;
(ii) renewable energy resource assessment (e.g. solar, solar hybrid, hydro, CNO and other) for specific micro and mini grids;
(iii) financial and economic analysis for options and overall,
(iv) assessment of viability gap for private sector provisions of services under different models and assessment of franchise, concession and management contracts models,;
(v) assessment of private sector interest in participation;
(vi) defining the enabling framework that would incentivize and promote RESCO participation following a critical review legal and regulatory arrangements that are inhibiting the scaling up of renewable energy in Vanuatu and draft new instruments to improve the enabling environment;
(vii) define RESCO service levels and contractual arrangements under selected models (concession and/or franchise, management contract) and prepare tender documents compliant with the Tenders and Contracts Act;
(viii) prepare safeguards framework and /or instruments (EIA, EMP) to support project implementation;
(ix) undertake capacity building for DoE, URA and GoV and private sector for implementation under the Project;</td></tr>
</table>

(iv) strengthen the implementing agencies' capacity to implement the World Bank's procurement procedures, disbursement procedures, and safeguard requirements.

Various aspects of due diligence will be conducted through the preparation grant:

(i) **Technical.** Appropriate technology for micro and mini-grids is to be assessed, particularly related to operating and maintenance requirements.

(ii) **Economic and financial.** Economic and financial analysis will be undertaken of the project in accordance with the World Bank's financial management and analysis and economic analysis guidelines.

(iii) **Procurement.** Procurement capacity assessment of DoE will be undertaken. Procurement packages will be prepared.

(iv) **Institutional Capacity.** Capacity assessment of DoE will include procurement capacity, project management capacity and financial management capacity.

(v) **Safeguards, Social, Poverty and Gender.** All safeguards will be addressed according to the World Bank's Safeguards Policies. Environmental assessment will ensure environmental impacts are mitigated. Land acquisition and impact on indigenous peoples will be assessed and resettlement and indigenous peoples plans prepared, as required. Social, poverty and gender analysis will be conducted. A gender action plan will be prepared.

(vi) **Private Sector.** Design alternative models for engagement of private sector.

10. **Outputs:**

Deliverable	**Timeline**
(a) Inception Report	March 2015
(b) Interim Report	June 2015
(c) Draft Final Report	December 2015
(d) Final Report	March 2016

11. **Budget (indicative):**

Expenditures	**Amount (USD) -** estimates
Consultants	$550,000
Equipment	$20,000
Local workshops/seminars	$40,000
Travel/transportation	$100,000
Others (admin costs/operational costs)	$40,000
Contingencies (max. 10%)	$50,000
Total Cost	**$800,000**
Other contributions:	
• Government	$200,000 (in-kind)
• MDB	-
• Private Sector	-
• Others (please specify)	-

12. **Timeframe** (tentative)

SREP Sub-Committee Approval of project: *November 2014*

Expected World Bank Board approval date: *November 2016*

13. **Other Partners involved in project design and implementation**: • Department of Environment • Department of Strategic Planning, Policy and Aid Coordination • Ministry of Finance and Economic Management • MCCND (Ministry of Climate Change and Natural Disasters) • MIPU (Ministry of Public Utilities) • Australian Ministry of Foreign Affairs and Trade • New Zealand Department of Foreign Affairs • Asian Development Bank
14. **If applicable, explanation for why the grant is MDB executed:** Due to its limited capacity in handling the timely contractual preparation of such a consultancy, the Government of Vanuatu has requested that the grant be executed by the World Bank.
15. **Implementation Arrangements** (incl. procurement of goods and services)**:** The executing agency will be MFEM. The DoE would be the implementing agency for the Project. The Energy Taskforce will review project progress, coordinate inter-ministerial activities and guide the DoE. Implementation consultants will support the DoE. All equipment and civil works procurement will be carried out in accordance with the policies, procedures and processes set out in the World Bank's "Guidelines: Procurement under IBRD Loans and IDA Credits," dated January 2011 (Procurement Guidelines). Consultants will be recruited in line with "Guidelines: Selection and Employment of Consultants by World Bank Borrowers," dated January 2011 (Consultant Guidelines).

B.2 Small Hydropower Project

B.2.1 Problem Statement

Access to electricity is low. The national electricity access rate is 33 percent of households consisting of 82 percent access in urban areas and 17 percent access in rural areas. Of the 33 percent households who have access 64 percent, are connected to the grid, with the remainder with access rely on solar systems or diesel generators. In rural areas, 86 percent households rely on kerosene for light, while the remainder use gas (4 percent), candles (3 percent), or coconut husk (4 percent). Nearly all rural families depend on wood for non-lighting household energy needs (mainly cooking). Household access to grid-connected electricity in Espiritu Santo is 21.5 percent and Malekula 8.2 percent. The main reasons for the low access rates are (i) the high cost of diesel power generation in the provincial centres, which provides a disincentive to increase customers (where generation and supply costs exceed the tariff) particularly given the low lifeline tariff; (ii) lack of government community service obligation funding for grid extensions; (iii) difficult geography and small, dispersed pockets of population, and (iv) low capacity to pay in some areas. Significant unmet demand means that people resort to self-generation but would connect to the grid if sufficient capacity were available. The limited reach of the distribution grid is slowing economic growth, particularly in the agriculture and tourism sectors.

Over reliance on diesel generation negatively impacts Vanuatu's economy. The cost of petroleum product imports typically exceeds 17 percent of total imports and 85 percent of the total value of Vanuatu's exports and negatively impacts the economy.[127] Renewable energy such as hydropower has significant potential to reduce generating costs and allow cost-effective expansion of the grid, particularly in remoter areas. Reduced generation costs combined with increased capacity will allow expansion of the distribution grids. Maximizing renewable energy utilization is important to the Vanuatu economy as it (i) reduces importation of fossil fuels, (ii) lowers the cost of power generation placing downward pressure on power tariffs thereby supporting private sector and reducing household expenditure, and (iii) improves energy security. Utilization of renewable energy also reduces greenhouse gas emissions which contribute to global warming.

B.2.2 Project Objective

The Project will construct hydropower generation on Malekula (Brenwe Hydropower) and Espiritu Santo (Sarakata hydropower extension) to displace diesel generation. Feasibility studies are currently being finalized[128]. Project scope will be confirmed once cost estimates are finalized. The Project will also potentially extend the distribution grid to an estimated 450 households in Malekula and up to 1,500 households in Espiritu Santo. Hydropower has been assessed to be the least-cost baseload generation option for Malekula and Espiritu Santo grids. Hydropower generation will benefit the economy by (i) reducing fossil fuel imports; (ii) lowering

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127 National Statistics Office: Quarterly Statistics Indicators, Sept 2013

128 ADB Project Preparation Technical Assistance

the cost of power generation, which will ease the pressure on power tariffs and thereby reduce commercial and household expenditure; (iii) improving energy security, and (iv) minimizing tariff volatility by partially converting the national grid to renewable energy. Hydropower generation will lower electricity generation costs, and create an incentive to extend the grid. The grid extension will directly benefit new peri-urban customers by (i) replacing kerosene lighting with a cheaper form of energy, thereby freeing household expenditure; (ii) enabling household income generation; (iii) improving children's education; and (iv) reducing indoor health and safety issues associated with burning kerosene. Project benefits will be extended through employment of landowners during the construction period. A summary of the potential subproject is presented in the following:

Annex Table B.4: Subproject Summary

	Hydropower		
1.	Brenwe Hydropower	Malekula	400 kW hydropower plant including related transmission
2.	Sarakata Hydropower Extension	Espiritu Santo	300 kW extension to existing Sarakata hydropower near Luganville including related transmission capacity upgrade
	Distribution Grid Extensions		
1.	Malekula grid extension	Malekula	Distribution extension to supply 450 households, schools and business's (Larevet to Unmet to Leviam)
2.	Luganville urban grid extension	Espiritu Santo	Distribution extension to 900 households within the Luganville urban and peri-urban areas.
3.	Port Olry grid extension	Espiritu Santo	Distribution extension to 600 households, schools and business's from the Luganville grid to Port Olry.

The project supports the Government's Priority and Action Agenda (PAA) 2006-2015, which aims to: (i) reduce the cost of services; (ii) extend the coverage of rural electrification; and (iii) promote the use of renewable energy. The project is also aligned with the Government's action document Planning Long, Acting Short, 2009-2012 which aims to: (i) ensure that electricity is more widely available at a fair price; and (ii) invest in renewable electricity. The project supports the National Electricity Policy Framework, 2007, and the subprojects are included in the Vanuatu National Energy Road Map (NERM) 2014. The project is included in ADB's country partnership strategy, 2010–2014[129] and the country operations business plan, 2014-2016[130]. Therefore the projects proposed are an integral part of Government of Vanuatu long term strategic planning.

129 ADB. 2009. Country Partnership Strategy: Vanuatu, 2010–2014. Manila.

130 ADB. 2013. Country Operations Business Plan: Vanuatu, 2014-2016. Manila

B.2.3 Implementation Readiness

MOCC-DOE has full ownership of the proposed project. MOCC-DOE have undertaken screening of potential hydropower sites[131] and is currently conducting full feasibility studies of the optimum sites[132]. The power utilities currently managing the Malekula and Espiritu Santo grids have indicated a preference to operate and maintain the proposed assets. This is considered an optimal arrangement in the absence of a national state owned power utility. Both utilities have suitable capacity to operate and maintain the assets. The URA has indicated this arrangement is preferable and can be accommodated under the existing regulatory arrangements. Feasibility studies of the Brenwe hydropower plant and the Sarakata hydropower extension are currently being finalized with support from ADB technical assistance.

B.2.4 Results Indicators

The main results indicators, to be further elaborated on during project preparation, will comprise the following:

Annex Table B.5: Indicators and Targets

Results	Indicators	Targets
1. Increase in renewable energy supply	Installed grid-connected hydropower	0.7MW
	Government generates hydropower Renewable energy generation increased as a percentage of generation	X GWh (gigawatt-hour) per annum of by January 2020
	Reduced household expenditure on energy services	X% in Espiritu Santo and Malekula by January 2020
	Reduced diesel imports for power generation	XML by January 2018
2. Increase in households with access to renewable energy	Access to energy increased from 8.2 percent to 14.2 percent in Malekula and from 21.5 percent to 33.7 percent in Espiritu Santo	1,950
3. Greenhouse Gas emissions mitigated	CO_2 emissions reduction	X tCO_2e by January 2020

Source: ADB and Government of Vanuatu estimates

[131] ADB. 2009. *Technical Assistance for the Promotion of Renewable Energy in the Pacific.* Manila.

[132] ADB. 2012. *Technical Assistance to Vanuatu for Preparation of the Energy Access Project.* Manila

B.2.5 Financing Plan

The total estimated project cost is $13.9 million, of which $7.0 million is sought from the SREP, and $5.0 million from the Asian Development Bank. The Government of Vanuatu will also contribute to the project.

Annex Table B.6: Proposed Financing Plan

	SREP	ADB	Government	Total
Small Hydropower	7.0	5.0	1.9	**13.9**

Source: ADB/Vanuatu Government estimates

B.2.6 Lead Implementing Agencies

Ministry of Finance and Economic Management (MFEM) will be the executing agency for the project. MOCC-DOE[133] will be the implementing agency with day-to-day implementation activities delegated to the Vanuatu Project Management Unit (VPMU). A Project Management Unit (PMU) will be established within the VPMU to implement the project. MOCC-DOE will provide a project focal point to oversee project implementation. The focal point will work closely with the PMU. The PMU will be responsible for procurement of all civil works and goods contracts and consultants. All consultants will be recruited in accordance with ADB's *Guidelines on the Use of Consultants (2013, as amended from time to time)*. Procurement of goods and works will be undertaken in accordance with ADB's *Procurement Guidelines (2013, as amended from time to time)*. A project steering committee will oversee implementation, monitor progress, and provide guidance to the executing agency. The project steering committee will meet at least quarterly and will be chaired by MOCC-DOE. The PMU will host the project steering committee and will act as the secretariat.

B.2.7 Project Preparation Timetable

The estimated project preparation timetable is presented below:

Annex Table B.7: Proposed Financing Plan

Milestones	Expected Completion Date
SREP Sub Committee Meeting approve Investment Plan	November 2014
Complete Project Preparation Technical Assistance[1.]	February 2015
ADB Board Consideration	July 2015

Source: ADB/Vanuatu Government estimates

[1.] ADB. 2012. *Technical Assistance to Vanuatu for Preparation of the Energy* Access Project. Manila, TA-8285 ($750,000)

[133] Department of Energy (DOE) within the Ministry of Climate Change, Adaptation, Meteorology & Geohazards, Energy, Environment and Natural Disaster Management (MOCC).

Table 6: MDB Request for Payment for Project Implementation Services (MPIS)

SCALING UP RENEWABLE ENERGY IN LOW-INCOME COUNTRIES **MDB Request for Payment of Implementation Services Costs**			
1. **Country/Region**:	Vanuatu	2. **CIF Project ID#**:	
3. **Project Title:**	*Small Hydropower Project*		
4. **Request for project funding (USD$million):**	*At time of country submission (tentative): $7.0 million*	*At time of project approval:*	
5. **Estimated costs for MDB project implementation services (USDmillion):**	*Initial estimate - at time of Country submission: US$0.430 million* *Final estimate - at time of project approval: n/a*	*MDB: Asian Development Bank* *Date: October 2014*	
6. **Request for payment of MDB Implementation Services Costs:**	☐ First tranche: *US$0.215 million*		
7. **Project financing category:**	a - Investment financing - additional to ongoing MDB project ☐ b- Investment financing - blended with proposed MDB project √ c - Investment financing - stand-alone ☐ d - Capacity building - stand alone ☐		
8. **Expected project duration** (no. of years):	5 years		
9. **Explanation of final estimate of MDB costs for implementation services:**	*Not applicable*		
10. **Justification for proposed stand-alone financing in cases of above 6 c or d:** not applicable			

Annex C: Stakeholder Consultations

Vanuatu's SREP Investment Plan is the result of an extensive internal and public consultation process, led by the Government of Vanuatu and represented by the

Department of Energy within the MOCC, to identify priorities in the development of renewable energy technologies for electricity. The consultations included a broad range of government agencies, as well as representatives from the private sector, and donors. Feedback was sought through many one-on-one meetings and three workshops with stakeholders.

First Technical Mission (May 2014)

The purpose of the first technical mission was to get feedback on the set of criteria to be used to evaluate and prioritize projects for the IP, and to collect data for use in evaluating each technology or resource against the criteria.

The first technical mission included discussions between the DoE, its consultants, and the MDB team working on SREP. The consultants also met with representatives of URA, UNELCO, VUI, Geodynamics, MOCC, ACTIV (an NGO which was involved in the Lighting Vanuatu programme), and private sector pico and fixed solar suppliers.

An Inception Workshop was held on 13 May 2014. The workshop was led by the DoE and supported by the consultants, and was attended by representatives from government, private sector and donor organizations. The purpose of the workshop was to review the draft inception report prepared by the consultants and to confirm the methodology and selection criteria that will guide the identification and assessment of possible renewable energy investments for Vanuatu. The methodology, selection criteria and an updated work plan were set out in the final inception report submitted on Friday, 16 May 2014.

Second Technical Mission (July 2014)

The purpose of the second joint technical mission was to solicit feedback from stakeholders on substantive portions of the draft IP, via the Options paper, which had been pre-circulated by the DoE. The second joint technical mission included discussions between the Department, its consultants, the MDB team working on SREP, and other key stakeholders.

The analytical work completed in preparing the IP included a comprehensive assessment of renewable energy technologies identified during the first technical mission. The technologies included: wind, utility-scale solar PV, small hydropower, biomass (wood), CNO-biofuel, geothermal power, pico solar, individual solar systems, and various microgrid technologies.

The mission included an open stakeholder consultation workshop to get feedback on the analysis. This was held on July 15, 2014 and included representatives of the DoE, private sector and donor organizations. At this workshop, the technical potential and expected cost of the RE technologies, based on assessment by the Department's consultants, were presented to stakeholders. A discussion was held regarding assessing each of the potential technologies against National and SREP criteria.

Third Technical Mission (August 2014)

The purpose of the third technical mission was to solicit feedback from stakeholders on substantive portions of the draft IP, which had been pre-circulated by the DoE.

The mission included an open stakeholder consultation workshop to get feedback on the analysis. This workshop was held on August 11, 2014 and included representatives of the DoE, private sector and donor organizations. At this workshop the proposed investments and proposed financing plan was presented to stakeholders, as well as the ranking of technologies and projects relative to the criteria identified in previous workshops. Projects and technologies were again ranked against the criteria and the merits of including each in the IP were discussed at length.

Annex D: Co-Benefits

Section 5 highlighted some of the environmental, social and gender co-benefits likely to result from Vanuatu's SREP IP. This section focuses specifically on the co-benefits tracked under SREP's Revised Results Framework (as of June 1, 2012). Annex Table D.1 lists the co-benefits considered under SREP's Revised Results Framework, and describes how those co-benefits will be achieved in Vanuatu.

Annex Table D.1: Co-Benefits Associated with SREP Impacts and Outcomes

SREP Transformative Impact		
Results	**Co-benefits**	**Description**
Support low-carbon development pathways by increasing energy security.	Avoided GHG emissions	▪ All of the technologies in Vanuatu's SREP IP could be used to offset diesel generation during daily dispatch, and ultimately forestall the need for additional diesel generation. The generation government has targeted for new hydro plants will offset CO_2 emissions from diesel plants.
	Employment opportunities	▪ Opportunities for local employment (paid and voluntary) and 'on-the-job' training in relation to as part of the preparatory works and deployment of microgrids (for example fixing of roof-mounted solar PV panels; clearance of trees and vegetation; and, erection of electricity distribution poles under skilled supervision)[134] ▪ Opportunities for on-site job training for installation and maintenance of standalone solar PV systems.
SREP Programme Outcomes		
Results	**Co-benefits**	**Description**
Increased supply of renewable energy (RE) New and additional resources for renewable energy projects/programmes	Increased reliability	▪ All of the technologies in Vanuatu's SREP IP would ultimately improve long-term reliability of supply, by strengthening energy security and reducing the risk that fuel supply interruptions could lead to reliability problems. The technologies are effectively a hedge against future diesel import price hikes. ▪ Grid enhancements required to connect the hydro projects may also offer improvements in grid reliability.
	Reduced costs of RE	▪ SREP support for project identification and scoping and transaction advisors for competitive tendering of standalone solar PV will reduce risk for investors and consumers. ▪ The SREP funding would be used to offset all or a portion of the capital costs of electrifying schools, clinics or other strategic public institutions in rural areas using stand-alone solar systems. Funding may also be used to hire contractors for maintenance of systems, which will reduce tariffs for institutions and mini-grid users. ▪ SREP funds will be used to bring down the cost to

[134] Banban Community Line Extension Project and Pepsi Community Line Extension Project (Bitas, R. T. for Vanuatu Utilities and Infrastructure (VUI) Ltd. (undated)

	customers of hydropower plants, and the overall cost of generation in the systems to which they will be connected.

Annex E: Assumptions Used in Estimating Levelized Energy Costs

E.1 Summary of Cost Assumptions

Annex Table E.1: Plant-Specific Assumptions

Project Info							Technology Assumptions						
Island	**Project Name**	**Resource**	**Subtech**	**Project Cost**	**Transmission/ Interconnection Cost**	**Energy Storage Cost**	**Capacity**	**Capacity Factor**	**FOM**	**VOM**	**Fuel Cost**	**Heat Rate**	**Economic Life**
				($/kW)	($/kW)	($/kW)	(MW)	%	$/KW/yr	$/MWh	$/L	L/MWh	years
Efate	Efate - CNO Existing*	CNO	Existing	$0		$0	8.798	50%	$200		1.25	290.00	20
Efate	Efate - CNO New*	CNO	New	$1,000		$0	5.316	50%	$200		1.25	290.00	20
Efate	Takara (Efate Geo) Phase I	Geothermal	Binary	$11,240	$1,773	$0	4.000	92%	$244	$44			25
Efate	Takara (Efate Geo) Phase II	Geothermal	Binary	$9,586	$818	$0	4.000	92%	$244	$44			25
Efate	Devil's Point Solar	Solar PV	Ground Mount	$5,710		$223	1.000	21%	$20				25
Efate	Efate Bay - Ground Mount	Solar PV	Ground Mount	$5,592	$422	$538	19.166	23%	$20				25
Efate	Efate Bay - Roof Mount	Solar PV	Rooftop	$5,266	$0	$875	6.337	21%	$20				25
Efate	Efate Inland - Ground Mount	Solar PV	Ground Mount	$5,592	$422	$538	6.152	23%	$20				25
Efate	Efate Peninsula 1 - Ground Mount	Solar PV	Ground Mount	$5,592	$422	$538	4.798	23%	$20				25
Efate	Efate Peninsula 2 -	Solar PV	Ground	$5,592	$422	$538	31.115	23%	$20				25

Project Info							Technology Assumptions							
Island	**Project Name**	**Resource**	**Subtech**	**Project Cost**	**Transmission/ Interconnection Cost**	**Energy Storage Cost**	**Capacity**	**Capacity Factor**	**FOM**	**VOM**	**Fuel Cost**	**Heat Rate**	**Economic Life**
				($/kW)	($/kW)	($/kW)	(MW)	%	$/KW/yr	$/MWh	$/L	L/MWh	years
	Ground Mount		Mount										
Efate	Alternate Site	Wind		$2,782	$15	$145	2.750	25%	$56				20
Efate	Devils Point Expansion 1	Wind		$2,579	$0		0.550	25%	$52				20
Efate	Devils Point Expansion 2	Wind		$2,579	$0		2.200	25%	$52				20
Espiritu Santo	Santo - CNO Existing	CNO	Existing	$0		$0	1.250	50%	$200		1.25	290.00	20
Espiritu Santo	Santo - CNO New	CNO	New	$1,000		$0	1.600	50%	$200		1.25	290.00	20
Espiritu Santo	Sarakata 1 Expansion (Option A)	Hydro	Run-of-river	$8,543	$3,069	$0	0.300	30%	$195				30
Espiritu Santo	Sarakata 1 Expansion (Option B)	Hydro	Run-of-river	$5,412	$1,535	$0	0.600	20%	$160				30
Espiritu Santo	Sarakata 2 (Option A)	Hydro	Run-of-river	$23,558	$1,223	$0	0.600	52%	$530				30
Espiritu Santo	Sarakata 2 (Option B)	Hydro	Run-of-river	$29,980	$1,223	$0	0.600	52%	$675				30
Espiritu Santo	Wambu (Option A)	Hydro	Run-of-river	$12,955	$178	$0	2.200	42%	$291				30
Espiritu	Wambu (Option B)	Hydro	Run-of-river	$25,843	$652	$0	0.600	56%	$581				30

Project Info							Technology Assumptions							
Island	**Project Name**	**Resource**	**Subtech**	**Project Cost**	**Transmission/ Interconnection Cost**	**Energy Storage Cost**	**Capacity**	**Capacity Factor**	**FOM**	**VOM**	**Fuel Cost**	**Heat Rate**	**Economic Life**
				($/kW)	($/kW)	($/kW)	(MW)	%	$/KW/yr	$/MWh	$/L	L/MWh	years
Santo													
Espiritu Santo	Espiritu Santo Ground Mount	Solar PV	Ground Mount	$5,592	$422	$538	16.698	22%	$20				25
Espiritu Santo	Espiritu Santo Roof Mount	Solar PV	Rooftop	$5,266	$0	$875	3.354	20%	$20				25
Espiritu Santo	Alternate Site	Wind		$3,086	$3,557	$180	1.100	15%	$62				20
Espiritu Santo	Port Olry Met Station	Wind		$3,086	$5,246	$180	1.100	12%	$62				20
Malekula	Brenwe (Option A)	Hydro	Run-of-river	$10,675	$1,630	$0	0.600	42%	$240				30
Malekula	Brenwe (Option B)	Hydro	Run-of-river	$12,795	$3,067	$0	0.400	58%	$315				30
Malekula	Malekula Ground Mount	Solar PV	Ground Mount	$6,321	$422	$538	4.955	20%	$20				25
Malekula	Malekula Roof Mount	Solar PV	Rooftop	$5,953	$0	$875	0.427	19%	$20				25
Malekula	Alternate Site	Wind		$2,966	$1,380	$315	0.275	22%	$68				20
Malekula	Teteras Met Station	Wind		$2,966	$307	$315	0.275	9%	$68				20
Tanna	Tanna - CNO Existing	CNO	Existing	$0		$0	0.419	50%	$230		1.44	290.00	20
Tanna	Tanna Ground Mount	Solar PV	Ground Mount	$6,321	$422	$538	6.620	25%	$20				25

Project Info							Technology Assumptions						
Island	**Project Name**	**Resource**	**Subtech**	**Project Cost**	**Transmission/ Interconnection Cost**	**Energy Storage Cost**	**Capacity**	**Capacity Factor**	**FOM**	**VOM**	**Fuel Cost**	**Heat Rate**	**Economic Life**
				($/kW)	($/kW)	($/kW)	(MW)	%	$/KW/yr	$/MWh	$/L	L/MWh	years
Tanna	Tanna Roof Mount	Solar PV	Rooftop	$5,953	$0	$875	0.079	24%	$20				25
Tanna	UNELCO Lanekel extension	Solar PV	Ground Mount	$6,321	$0	$625	0.020	25%	$20				25
Tanna	Alternate Site	Wind		$2,966	$153	$315	0.275	15%	$68				20
Tanna	Enawanum Hill Met Station	Wind		$2,966	$2,845	$315	0.275	27%	$68				20
All	Small Customer SHS Lighting	Solar PV		$12,000	$0	$0	0.000	14%	$708				20
All	Medium Customer SHS Lighting	Solar PV		$11,500	$0	$0	0.000	18%	$719				20
All	Large Customer Basic Electrification	Solar PV		$10,500	$0	$0	0.002	18%	$334				20

E.2 Notes on cost assumptions:

CNO: New gensets are assumed to cost $1,000/kW, while diesel sets less than 10 years old are assumed to incur minimal retrofit costs. CNO options on Efate and Santo assume fuel cost $1.25 per litre (reflecting current world market price) with a conversion rate of 290 litres per MWh. A 30 percent 'adder' for fuel costs is applied to CNO projects on Tanna. Fixed O&M costs of $200/kW per year are assumed to cover annual maintenance and periodic overhaul for units on Santo and Efate. A 15 percent adder is applied to O&M for Tanna.

Solar PV: Solar PV costs are quoted in terms of AC power delivered/kW. Capital and O&M costs for solar PV projects on Santo and Efate are based on the costs of the ADB-funded roof mounted solar projects in Luganville. A 15 percent 'adder' is applied (to both capital and O&M costs) for projects in Tanna and Malekula to reflect transport and logistics. Capacity factors estimates – in the absence of actual measurements – were based on Meteonorm data (http://meteonorm.com/). Meteonorm uses data from nearby weather stations and triangulates that data based on the location in question. Storage costs vary depending on whether the plants were ground or earth mounted: ground-mounted plants are larger systems and require more storage; more storage means a lower $/kW cost of storage.

Wind: Capital costs are based on the existing Devil's Point Wind Farm. It is assumed that underground collection systems and substations are not required for smaller systems or expansions. Fixed O&M costs are estimated at 2% of EPC costs. A 15 percent 'adder' is applied (to both capital and O&M costs) for projects in Tanna and Malekula to reflect transport and logistics. Capacity factors are based on either (a) actual wind data, where a year or more of data were available from wind monitoring stations (from the DoE's current monitoring efforts), or (b) where such data were not available, the Devil's Point project costs were used as the basis and then scaled based on the partial readings from the other weather stations. As for solar PV, storage costs for wind generation were calculated for each individual project based on the sizing of lithium ion batteries, housing and controller required to meet ramp rate control requirements.

Geothermal: The Castlerock Consulting report provided estimates for the capital and O&M costs and capacity factor for the Takara project. The 92 percent capacity factor is based on net capacity of 2x4 MW. Capital and O&M costs.

Hydro: EPC costs from ADB feasibility studies 2012-14. Fixed annual O&M of 2.25 percent of capital cost assumed. Variable O&M such as water rights licensing fees are not included.

Diesel: Diesel costs differ by island due to differences in actual historical heat rates of diesels currently used in the concession areas, actual historical fuel costs of each of the diesels used in the concession areas, and actual historical capacity factors on the different islands.

Annex F: Comments from Independent Technical Reviewer

Mr. Mike Allen provided an independent technical review of the investment plan. He reviewed the draft of the Investment Plan in September, 2014. His comments on each of the drafts, and the Government of Vanuatu's replies, are included below.

Independent Technical Reviewer: Mike Allen

Comments delivered on September 22nd, 2014

F.1 Introduction

The draft report shared with the author (received on 12th September 2014) is a thorough and comprehensive document that provides a detailed analysis of the current energy situation in Vanuatu. It appears to reflect the objectives and intent of the SREP programme, albeit limited in the opportunities for full engagement with the private sector; this limitation is a reflection of the small size of the country and hence the smaller scale of any power developments, suggesting a reduced level of private sector interest.

The electricity sector is dominated by a long term concession with UNELCO, the utility serving the largest portion of the population. Even where an alternative concessionaire has been established (VUI in Luganville) and commenced operations in January 2011, the arrangement remains governed under a Memorandum of Understanding, pending resolution of an appeal by UNELCO (the previous holder of this concession).

While a regulator exists, anecdotal reports suggest that the opportunities for IPP developments have been frustrated by a number of issues, the major one being the extended time taken to agree a PPA between developers and the utility; this has been reported as one of the key hurdles around the long discussed geothermal project. The ability for effective private sector engagement in the electricity market has yet to be demonstrated.

The structure of the electricity industry means that it will be difficult for any single programme to achieve substantive transformational impact. The projects being planned within Vanuatu and those proposed for SREP support will continue a progressive move to renewables but it may take a real shift in the interests and focus of the concessionaires to accelerate this change significantly.

While a part of the issue is clearly the pricing for renewable alternatives (to diesel generation), the report reviews in detail the economic and financial benefits of displacing diesel. It is apparent however that these benefits are heavily influenced by access to concessional financing; the nature, size and risk profile of the market suggest that developments on a fully commercial basis could be more expensive than diesel alternatives. This suggests that some form of incentive may be required where such projects are being considered otherwise it will be unlikely that a mutually acceptable PPA can be struck between the developer and the concessionaires.

F.2 Proposed SREP Investments

The projects proposed for SREP funding in the IP consider two opportunities; the development of standalone solar and micro-grids, and a small scale grid-connected hydro installation (location to be confirmed).

F.2.1 Solar

The solar installations would be focused on supporting an existing World Bank rural electrification programme but with an apparent focus on grant funding for small solar systems and, where appropriate, micro-grids or nano-grids at public institutions, for example, schools and clinics. It is proposed that a RESCO model be used [SHS installations and microgrids]; while this will offer the opportunity to build small commercial ventures, it will be important that the underlying financial viability of the entire business model, equipment supply, installation, end user financing and ongoing services and maintenance, are all adequately funded. The shortcomings of various business models tested elsewhere in the Pacific are reviewed and should provide some comfort in adopting a RESCO approach.

Response: ***This comment is well-noted. Ensuring the entire business model can be funded has been further emphasized throughout the report (Section 9, in particular).***

As the solar installations are off-grid, it is assumed that there will be no issues with existing concessionaire's rights around grid based supplies.

F.2.2 Small-scale hydro

Two possible (alternative) project sites have been proposed and as these are grid-connected installations it is noted that:

SREP funding would be used to co-fund small hydropower projects being developed at Sarakata and Brenwe. The funding would leverage roughly $5 million in ADB loan financing for one or two of the projects. The SREP funding would be used for the following activities:

- **Technical assistance to URA and government on regulatory issues.** URA will need support in determining the consequences for the UNELCO and/or VUI concessions of the new plants. The concessions would need to be extended to the areas where the plants are sited (in the case of Brenwe, which is outside the Malekula concession) or some alternative arrangement would need to be reached (such as the procurement of a third party operator).
- **Investment in the Sarakata and/or Brenwe sites.** SREP funds would be used to bring down the cost to customers of the plants, and the overall cost of generation in the systems to which they will be connected. The projects selected would depend on the results of the Project Preparation Technical Assistance (PPTA) currently underway.

The issues around concessions are clearly significant. The IP highlights that there is often some divergence between the planning and interests of the Government and UNELCO. This is an area which must be resolved ahead of any final commitment for SREP funding.

Response: ***The components, as described above, have changed slightly, as a result of other reviewers' comments and discussions with MDBs. The regulator (URA) does indeed have***

sufficient capacity and recent experience dealing with these issues, and also has capacity (and funding) to hire consultants and bring in additional expertise where needed. ADB has also been, and will continue to support Government in resolving these issues as part of the project preparation.

F.2.3 Land issues

The question of land ownership is one that remains a considerable challenge. This is an additional consideration in the case of hydro developments and appears to be of key importance in that it is noted that:

- Land access remains one of the more complex issues in Vanuatu. All land in rural areas is under customary ownership, and there are often disputes regarding land ownership.

In addition it is reported in the IP that:

- Recently, the 75 kW Talise pico hydro plant on Maewo was constructed to supply power via an 11km distribution grid to about 1,000 households of Talise and nearby villages of Naravovo and Nasawa. However, while the IUCN and Italian/Austrian Government funded project has recently been completed, additional funding is required for construction of the network. As such, there is not yet any operational experience with this plant. Anecdotally, hydro based systems often face issues with use of land (for both generation and distribution), and transportation.

Response: Additional description of the risks associated with the question of land ownership and the possible means to mitigate these risks are now included in section 5 and section 8 of this Investment Plan. ADB has, moreover, begun to work with government, and will continue to do so in order to resolve many of the issues related to the two plants proposed in the Investment Plan (Sarakata and Brenwe) as part of the project preparation.

F.2.4 Summary

While as noted the IP is comprehensive and thorough, it does raise a number of critical underlying national challenges that will need to be clearly resolved, particularly around grid connected installations. The recommended projects appear well supported in terms of their technical evaluation, cost comparison and ranking but in both there are a number of implementation obstacles that must be addressed. Some specific clarification on how these issues will be handled, and a confirmation from Government that their importance is clearly recognised would enhance the IP as it now stands.

The notes that follow are made on the basis that these issues have been identified and will be resolved; monitoring and regular reporting on project progress and the resolution of critical challenges should be a key requirement around the release of SREP funding.

F.3 Specific SREP Considerations

The notes that follow look to specifically address issues seen as fundamental to SREP support. The remarks are made with the caveats noted above.

F.3.1 Catalysis of increased investments in renewable energy in total investment:

The IP outlines the existing support programmes from a range of donors and the potential for a private sector geothermal development. In both the proposed projects SREP funding would leverage significant support from others (more than 50 percent from existing sources towards projects costs). Neither project has a particular clear focus on attracting private finance but the natural limitations of the local market have been noted elsewhere in these comments. It is suggested that the private sector interests will increase with time as the demonstration effect of extended solar installations is recognised; the attraction into grid-connected activities will be dependent on a robust resolution of issues amongst concessionaires and regulation and potentially incentives to accelerate a move towards a higher proportion of renewable generation.

***Response*: Agreed that the potential for private sector involvement is substantial. It is expected that the private sector will, in particular, have quite an active role in the individual solar and micro-grid project. US$2 million has been included as a (conservative) placeholder only, but the actual investment from the private sector could be much larger, depending on the results of the identification of appropriate business models, feasibility studies and the modality of procurement. If the business model is truly a concession (with some CAPEX subsidy), then the amount could potentially be much larger than US$2 million.**

F.3.2 Enabling environment:

There appears to be a recognition that there is still more work to be done in building an effective regulatory and enforcement regime within the electricity industry. The situation in Vanuatu mirrors that in many island nations; early concessions were granted to internationally backed utilities that at the time appeared to offer a practical and cost effective solution to national energy needs.

Over time and with the growing impact of fossil fuel costs and decreasing desirability of dependence on such sources, national interests and those of the incumbent utilities have begun to diverge. Any new installations should help strengthen the government's resolve to do more and also build institutional experience in how to address the challenges that are currently being faced through stronger policies and effective regulations.

***Response*: Agreed, and it is because of the continued work being done in relation to grid-connected projects that some projects were not put forward for SREP funding. Government and URA recognize that a number of issues still need to be resolved in relation to PPAs and IPPs within concession areas. Stakeholders to the development of the IP were also concerned about this, and therefore asked that "ability of project to move forward quickly" be one of the selection criteria. The SREP IP therefore seeks to avoid projects where legal and regulatory issues could slow them down substantially. There are, indeed, some potential land rights challenges associated with the small hydropower projects, but as noted above, ADB has been and will be supporting Government and the concessionaires in resolution of these issues.**

F.3.3 Increase energy access

Both projects will clearly assist in providing increased access to energy through bring electricity to unserved areas and increasing capacity in grids were current demand (and latent demand) is not able to be met.

F.3.4 Implementation capacity

There are specific groups within the government ministries who have responsibility for the promotion and implementation of energy projects. A number of existing and past projects have been implemented with a number of donors however it is not easy to assess how effective these institutions are from the information provided in the IP. It would be expected that each project will assist in building local capacity and any project management design should ensure that adequate sharing of responsibilities helps promote this growth. The limitations in attracting significant private sector participation are noted elsewhere.

***Response**: Agreed. A section has now been added on Government's absorptive capacity and the Investment Plan has been updated in various places to indicate how MDBs will support Government in implementing the projects.*

F.3.5 Improving the long-term economic viability of the renewable energy sector

In both projects the proposal appears to be that the SREP funds will act essentially as grant or concessional facilities that will assist in promoting access, through reduce electricity costs.

The solar initiative is most likely to help promote private sector interests in establishing and expanding the RESCO model, largely through offering a stable and well-funded small market.

The hydro projects will not proceed unless the pricing structure is acceptable to the existing (or new) concessionaires. Within this constraint it is likely that the project will achieve an acceptable return though it may be that given the small scale of the installations and the local market conditions there will need to be some form on concessional support; this does not imply however that such an arrangement cannot be replicated for future similar developments.

F.3.6 Transformative impact

As noted earlier the stage of new energy installations within Vanuatu is such that it is premature to expect a significant transformative change from what are relatively modest new projects.

***Response**: We respectfully disagree on this point. We have sought to clarify it by adding more detail to the Monitoring & Evaluation Section of the Investment Plan, and describing transformative impact throughout. The impact of the projects under the Investment Plan will be extraordinarily transformative for Vanuatu. It will provide electricity to as many as 27,500 households currently lacking any supply, and will extend grid access to nearly 5,000 new customers. It has the investment to provide at least some level of electricity service to nearly 90 percent of the population of Vanuatu and allow the islands of Espiritu Santo and Malekula to generate with nearly 100 percent renewable energy capacity.*