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RENEWABLE ENERGY TECHNOLOGIES AS "SAVING GRACES" FOR PACIFIC ISLAND NATIONS FIGHTING CLIMATE CHANGE

Rena LOVO, Eric GILDER, Ora RENAGI, Dapsy OLATONA
University of Technology, Lae, Papua New Guinea

renalovobenzii@gmail.com, eric.gilder@pnguot.ac.pg, ora.renagi@pnguot.ac.pg, dapsy.olatona@pnguot.ac.pg

Abstract: *In this study, the authors carried out a detailed analysis of the technologies required for successful implementation of a sustainable renewable energy household power supply in Papua New Guinea or PNG (PNG is a Pacific Island nation, North of Australia) to free the country from fossil fuel dependency. The role of renewable energy sources in the recent PNG National Energy Policy covering 2018 to 2050 (unveiled at the 2018 March Energy Summit in Port Moresby by the PNG Minister of Energy) was also analysed. From the outcome of our recently concluded SERI 2018 Renewable Energy conference, we assembled into a single hypothetical 'energy basket' all the varied renewable 'green' energy sources within PNG (as estimated by our energy research groups). This paper estimates that there is sufficient renewable energy in PNG and advocates that these available green energy sources should be tapped, for they can go a long way in the quest for climate change mitigation. This research paper will articulate that shifting PNG's and other Pacific Island nations' energy reliance from fossil fuels and other non-renewable sources to renewable green and environmentally sustainable sources is not only achievable, but feasible within a reasonable time.*

Keywords: Papua New Guinea, PNGUoT, Climate Change, Pacific Island Nations, Renewable Energy

1. Introduction

In 2019, Frank Bainimarama, the Prime Minister of Fiji (a small island nation in the Pacific), told Australian Prime Minister Morrison that for people in the Pacific "Climate Change is no laughing matter" [1]. For many people in the 'first' world, the issue of climate change is debatable. Yet, for the peoples of the Pacific Islands and the Atolls, the fact that climate change is a 'major threat' is not debatable. In Papua New Guinea (PNG), the natives of Manus Island, 'Duke-of-York' Island and other similar (low altitude) islands have in the past 30 years witnessed the effect of sea level rise at first hand.

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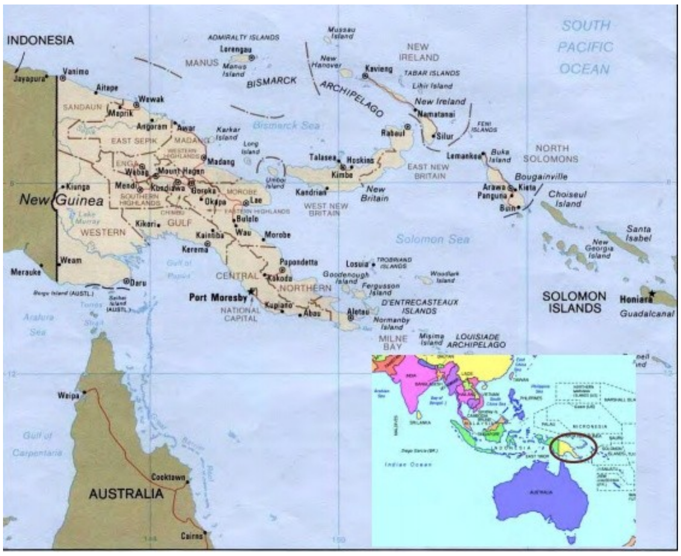

Figure 1: Location map of PNG (insert) [2]

They have witnessed their land shrink in size in their lifetimes. In some places, homes near the beaches have had to be dismantled and relocated further inland. Tropical trees left behind have become stumps as their roots slowly get washed out to sea. Homes left behind have become 'off-shore villas' (as shown in fig. 2 below).

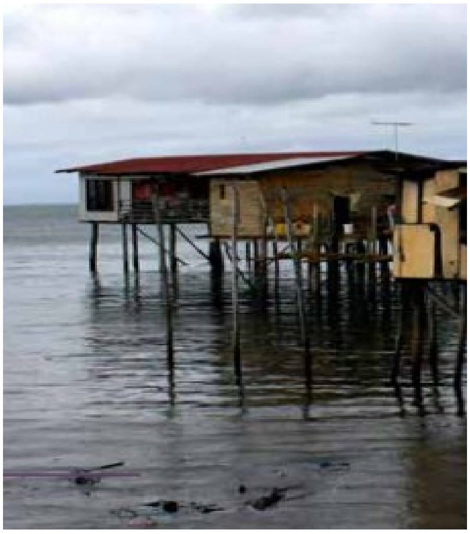
Figure 2: Effect of sea level rise in the Pacific

The Sustainable Energy Research Institute (SERI) at Papua New Guinea University of Technology (PNGUoT) is a Private Public Partnership (PPP) project inaugurated to promote the use of renewable energy technology to fight climate change. In 2018, a two-day international conference was hosted by fourteen research groups at PNGUoT. The outcome of the conference revealed that PNG as well as other nations in the Pacific are blessed with abundant natural resources that could be harnessed with the appropriate technologies. The sole aim is to put an end to the dependence of the region on fossil fuel as the base-load energy supply. And to replace all diesel generators with renewable energy power supply such as wind, solar geo-thermal and hydro. The expected outcome is to fight pollution, climate change and rising sea levels.

It is very well known that carbon dioxide

(CO_2) emission from fossil fuels is a major contributing factor to global warming and climate change [3]. This study showed that if renewable energy is harnessed with the appropriate technologies in PNG, the energy sector has the potential to achieve zero-carbon emission in line with the PNG government *Vision 2050* and the United Nations' Sustainable Development Goals [4].

It is expected that the population of PNG (the largest nation among the Pacific Island nations) could reach 9 million by 2020 and 18 million by 2050 [5]. Using this figure, this paper estimates the total 'domestic' household energy demand for PNG's population at approximately 4,731,428,571 x 10^{13} Watts or 47,314 GWh by 2050. This value is considered to be more reliable than the presently estimated forecast of 2,067,704 MW by 2027 by ADB [6]. PNG's southern neighbor (Australia) with a population of 24.7 Million generated 259,030.1 GWh in 2017 [7]. The estimate obtained in this study is comparable to this.

The projections in this work have allowed for foreseeable changes in energy demand that inevitably accompanies development and lifestyle change. The value obtained in this study has excluded "industrial" power demand by 2050. Our assumption is that industries have the capacity to meet their own demands. Currently, industrial operations such as Lihir, Ok Tedi, PNG Forest, Tolukuma, Porgera, Ramu Sugar, etc. provide their individually-managed off grid power supply in excess of 6-700 MW [8].

2. PNG's Hypothetical 'Energy Basket'

Despite the fact that the future estimated domestic power demand is projected well above the needs of today, SERI research groups found that the available renewable energy resources in the country exceed the projected value seven-fold. SERI in agreement with the Geothermal Energy Association (GEA) estimates that PNG has geothermal energy capacity of about 21.92 TWh [9]. The gross theoretical hydropower potential for Papua New Guinea is estimated at ~ 175 terawatt-hours (TWh) per year [10]. Annual photovoltaic power potential of PNG is estimated at about 1314kWh [11].

According to the World Bank and other statistical organisations [12], only about 14% of the citizens of PNG live in large cities with about 80% living in rural towns and island villages. In 2018, it was estimated that only about 13% of the population are connected to the national grid. Therefore, it is reasonable to allude that in order to meet the energy goal set by the current PNG government, the energy demand of rural dwellers must be met.

3. Actual Household Energy Demand of the Average Pacific Island home

SERI Micro Renewable Energy Group recently carried out extensive research into the modest energy requirement of the rural dwellers of Papua New Guinea and other developing countries in the Pacific Island region. From 2017 to 2019, field research visitations and information gathered from questionnaires given out to selected 1,378 residents of rural villages in Morobe Province, residents of West Taraka and Tent City near PNGUoT Taraka Campus in Lae PNG and similar socio-economic groups, showed that the energy requirement of a typical off-grid rural dweller is minimal compared to the energy requirement of the average city dweller [13].

As a follow up, this work found that rural dwellers of the Pacific could be classified into two distinct categories *viz*;

i: the 'professional' rural dwellers and

ii: the 'indigenous' rural dwellers.

The professional residents of the rural communities comprise mainly of teachers and nurses working at the rural health and maternity clinics. They have previously lived in cities where they acquired professional and tertiary qualifications. They have stable and regular income because they are employed in the rural villages by the local government as school teachers, maternity nurses and local

government councillors. Church pastors are also categorized as ‘professional’ dwellers.
The indigenous dwellers are the ‘true’ rural dwellers. They constitute about 97% of the village population. They are born and raised in the village. Most of them have never travelled or lived anywhere else. They have no regular income except for the sale (at the local market) of their farm and garden produce that they are unable to consume themselves. They practice subsistence farming efficiently. They grow their staples on farmlands and gardens adjacent to their homes. They are very good fishermen and they raise pigs, wild chicken and other animals for consumption. They are consequently not malnourished and their dependents are not starving. If they survive childhood killer diseases, they usually live long and happy in accordance with their own definition of ‘happiness’.
Questionnaires received from about 70% of the indigenous rural dwellers indicate that the energy requirement of a typical household (comprising of seven children and the parents) is merely; power to light 7 x 8W compact fluorescent lamps (CFLs) or any other energy-efficient LED’s at night; power to charge one or two mobile phones, a Wi-Fi device and a laptop. Many of them indicate that they desire to buy a television and a refrigerator with the help of their kinsmen living in the big city. Figure 3 is an indicative picture of the very modest household domestic appliances the indigenous rural dweller desire to have.

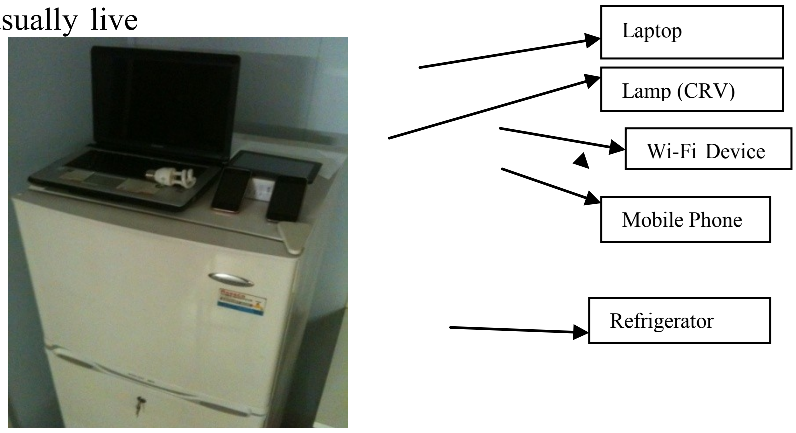

Figure 3: Basic household energy requirement of the indigenous rural dweller in PNG

The average ‘professional’ rural home already has these gadgets. The appliances are mostly operated by 2.3kW standalone solar power package (valued at about K4,000.00 ~ $1,300US) with a deep storage 24 volt backup battery sufficient to continuously power the household refrigerator day and night. Questionnaire information also indicate that the professional rural nurse/teacher already have a flat screen 60 cm television. The largest energy consuming equipment identified is the refrigerator (mostly 327 litres in size) that requires a 3.4 Amp 240V AC power supply. Many of the professional rural dwellers indicate the desire to buy a microwave oven, a rice cooker and an electric tea kettle. All rural dwellers boil their tea and do their cooking mostly by LPG stoves or open fire (*hauskuk*). The estimated power requirements of the rural dweller suggest that if their homes were to be connected to the grid, a standardized 5 Amp mains supply protected by a 6 Amp service provider safety fuse would meet their energy needs.
The standard 100 Amp service provider mains fuse found in a newly built city home suggest that the city home connected to the grid has a permitted-power-consumption of about 24 kW. From this information, the present total energy need of a rural island home is calculated to be only about 1.2kW. This is equivalent to just about 5% of the energy need of the city dweller with an air-conditioned home, electric stove, a

microwave oven and a washing machine.

4. The Technologies Required for Rural Electricity Supply in the Pacific

In PNG, small scale Hydro Electricity (hydel) is the renewable energy considered as a “natural first choice”. This choice is justified by the readily available fast-flowing rivers as well as several small, medium and large waterfalls located in close proximity to many villages and rural settlements. Turbine technologies are readily available and can be deployed to convert these resources into hydro energy. The waterfalls are supported by the natural, rugged and hilly terrains of PNG Highland regions. We speculate that it is these natural resources that encourage the forefathers to settle in these particular sites; now regarded as their ancestral land. Figure 4 is a photo of a waterfall in Enga Province of PNG.

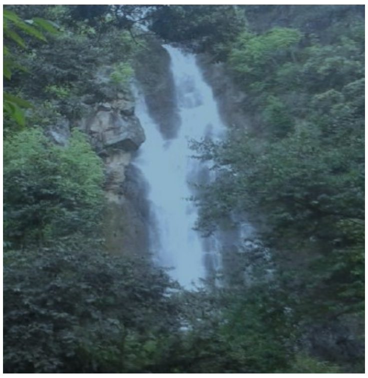

Figure 4: Waterfall in Kompiam village. Similar waterfalls abound in several locations in rural PNG [14].

Since 87% of the population of PNG citizens live in small communities and in small populations (sometimes below 3,000), this paper takes the view that expensive large megawatt power stations are not the most cost-effective way to satisfy the energy need of rural communities in the Pacific. Rather, Pico, vortex, mini and micro hydro power stations are considered sensible choices.

A 2kW Pico hydro power turbine shown below was recently commissioned successfully for use in Arawa of the North Solomon Province of PNG by Mr. Nosare Maika (a SERI group leader).

Figure 5: Photo of a 2kW Pico Hydro Turbine [15]

Unemployed youth volunteers in the community were trained to install and maintain the turbine.
Many other potential hydel stations are currently being documented by SERI with a view to harnessing the inherent renewable energy capacity for the immediate rural communities.
Below is a schematic diagram showing the 'Flow' and 'Head' determination of a waterfall. By calculating Flow and Head, its potential to be a Mini Hydro power source can be easily determined.

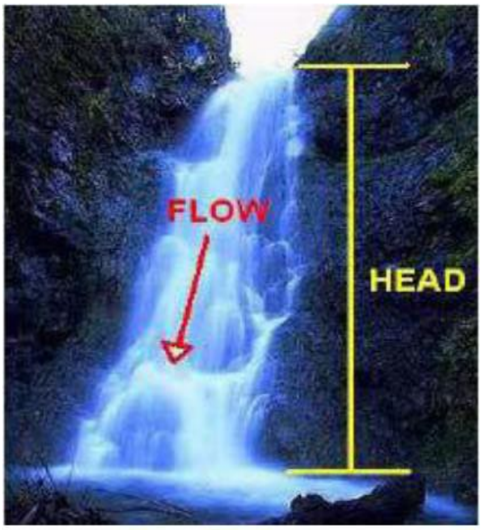

Figure 6: The essential 'flow' and 'head' of a waterfall

The approximate power that can be obtained from this waterfall can be determined from the well known equation:

Net Power $= \eta \rho Q g H$ **(Watts).** (1)

Where:
η = hydraulic efficiency of turbine used
ρ = 1000 kg/m³ (density of water)
Q = Penstock volumetric flow rate m³/sec
g = 9.81 m/sec²
H = gross head (m)

Our study found that a small hydro power plant of up to 3 MW can be easily achieved from several waterfalls in PNG. Each can provide sustainable energy for a village comprising of ~ 2,500 households and an approximate total population of 17,500.
By using a similar well-known equation

$$P = Q \times H \times e \times 9.81 \text{ (KW)} \quad (2)$$

Where:
P = Power at generation or output (KW)
H = the gross head (m)
Q = Flow in penstock pipeline (m^3/sec)
e = Efficiency of the power plant (%)
9.81 is a constant derived from gravity.

This study obtained a similar outcome.
All hydel turbines have power-speed design characteristics. It is therefore of utmost importance to choose appropriate turbine that would operate efficiently for a particular water speed, head and flow combination. The best sites would have a reliable water supply year-round and a large vertical drop in a short distance. A Pelton or Francis turbine is particularly cost effective, readily available and well suited for small hydro power generation.
However, for other isolated Pacific Island villages with no waterfall or hydel power potential, this work recommends standalone flat rooftop or garden APV-CPV solar power installations. ACP-CPV is a new innovation with the potential to conserve land and improve agricultural output [16].
Currently, a flat rooftop solar package system comprising of a PV solar panel, voltage regulator, inverter, and battery assembly shown in Figure 6 is common [17].

Figure 7: Rooftop solar display at PNGUoT SERI laboratory

The small domestic package above is able to operate a mini refrigerator (white oval shape in fig 7) and a mini rainwater pump.
The intermittency of wind energy and other maintenance issues make it a low priority rural power alternative in PNG. However, with the assistance and encouragement of UN and the World Bank, there are ongoing initiatives into the feasibility of offshore wind energy sources in the Pacific region [18].

5. Conclusion

This study has shown that whereas the natural terrain of PNG and other Pacific Island nations do not favour the installation of a national electricity grid that can reach its rural population with ease, PNG natural resources do support and provide a very suitable scenario for the installation of pico, mini and micro power stations from local resources for the use of immediate local residents that constitute the silent majority of PNG and other Pacific Island population.
Our estimated rural household power requirement is about 1.2 to 2.3 kW while the city household connected to the grid is estimated to require up to 24kW peak load.
While these are mere estimates, these figures suggest that if we allow for a 40% loss on efficiency and an additional loss of 25% on proximity and difficult access etc. The available total renewable energy in PNG is still about seven times the energy requirement of the entire population.
The outcome of this work showed that renewable energy sources are abundant and waiting to be tapped in PNG and other similar developing countries in the Pacific with similar terrain and solar insolation. The study articulates that PNG national energy policy covering 2018 to 2030 and to 2050 is achievable and feasible if the technologies suggested here are adopted in a systematic and methodically implemented manner with due diligence In conclusion, the authors hold the view that climate change is a security issue in the Pacific region. According to the Intergovernmental Panel on Climate Change (IPCC), climate change can have a negative impact on livelihoods, coastal settlements, infrastructure, ecosystem services and economic stability [19].
This IPCC finding agrees with the view articulated by the US Defense Department's *The Quadrennial Defense Review* that: "Climate change may exacerbate water scarcity and lead to sharp increases in food costs. The pressures caused by climate change will influence resource competition while placing additional burdens on economies, societies, and governance institutions around the world. These effects are threat multipliers that will aggravate stressors abroad such as poverty, environmental degradation, political instability, and social tensions – conditions that can enable terrorist activity and other forms of violence." [20].
There is a common policy emphasis in island states on the adoption of renewable energy for sustainable development, as expressed by PIF in the September 2013 Majuro Declaration [21]. As noted earlier, The Independent State of Papua New Guinea promised (in 2011) to decrease

GHG emissions at least 50% before 2030 while becoming carbon neutral before 2050, the initiative described herein by the authors, SERI and the PNGUoT well fits into this pledge.

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