PNG's Energy Sector and Estimation of Renewable Energy Resources in Morobe Province, Papua New Guinea: Solar and Wind Power for New Umi Township

S.S.Aiau[1], M.Kavi[1], K.Pirapaharan[1], P.R.P.Hoole[2], M.Anyi[2] and S.R.H.Hoole[3]
[1]*Department of Electrical and Communications Engineering, PNG University of Technology, Papua New Guinea.*
[2]*Department of Electrical and Electronic Engineering, Universiti Malaysia Sarawak, Malaysia.*
[3]*Department of Electrical and Computer Engineering, Michigan State University, USA.*
sammy.aiau@pnguot.ac.pg

***Abstract*—Papua New Guinea (PNG) is blessed with numerous energy resources, including oil, gas, wind, solar, tidal and biomass. Renewable energy resources have taken centre stage as PNG along with other countries seek to push for 32% of its national power demand to be met by renewable energy sources by the year 2030. In addition, PNG has an ambitious programme to provide electricity to 70% of its scattered population by the year 2030. In this paper we discuss PNG's energy sector and we present an initial Geospatial Information System (GIS) based study to consider the development of renewable energy power generation at the new Umi Township in the Markham valley of Morobe Province. The Markham valley has sunshine for about 8 hours per day and an average insolation of about 500 W/m^2 each day. At a height of about 50 m from the ground, the velocity averages to 4m/s. The paper will present the preliminary evaluation carried out using the GIS based data. It will also draw some general conclusions from the analysis carried out for the new Umi Township for the Markham District in the Markham Valley of the Morobe Province that could be adopted for all the entirety of PNG.**

***Index Terms*—Geospatial Information System; Renewable Energy; Solar Energy; Wind Energy.**

I. Introduction

Renewable energy resources and technologies have the potential to provide long-lasting solutions to the problems compounded by the economic, social and environmental sectors in PNG, in particular for the isolated pockets of masses in the rural areas secluded by tough terrains [1]. Access to clean, reliable and affordable energy is essential for sustainable socio-economic development in Papua New Guinea. Developments of sustainable efficient renewable energy resources will contribute to reduction of the greenhouse gas emissions and mitigate the negative impacts of climate change which is in line with PNG's Vision 2050 pillar 5: Environmental Sustainability and Climate Change [3]. Renewable energy has some history in PNG, with solar, wind, hydro and bio-energy technology trialed in past decades, but the projects have had mixed success, with some falling into disrepair. This highlights the need to use appropriate technology and develop the necessary local knowledge and support to operate and maintain the system when they are in place. One approach is to carry out renewable energy resource mapping.

PNG's current focus on renewable energy resource mapping is on hydro, biomass, solar and wind renewable energy resources. The emphasis in this research will be on solar and wind energy resource mapping, as the journey to renewable energy starts with a map. The purpose of mapping is to facilite the development of solar and wind energies for both utility-scale electricity generation and for village power and other off-grid applications. This is in line with PNG government's formulation of a National Electrification Roll Out Plan (NEROP) under PNG's Electricity Industry Policy [2], [3]. The research further explores the potential of establishing a "Center for Renewable Energy" in the Department of Electrical and Communications Engineering at the Papua New Guinea University of Technology. The Centre for Renewable Energy will carry out ongoing research to address the PNG's Vision 2050 pillar 5: Environmental Sustainability and Climate Change.

II. Papua New Guinea Energy Sector

A. Introduction

The PNG energy sector depends on three main types of energy. These are electricity, oil and gas. The energy sector accounts for 14% of the country's gross domestic product (GDP). PNG Power Limited (PPL) is a State owned Corporation with the Government's ownership interest held by Kumul Consolidation Holdings which was formerly the Independent Public Business Corporation (IPBC). The Company is a vertically integrated utility and is the sole national electricity company responsible for generation, transmission, distribution and retail of electricity in PNG. Previously it was called PNG Electricity Commission (ELCOM) and the name change was due to the Utility being corporatised in 2002 as part of the privatization process. It has major transmission and distribution networks in Port Moresby, Ramu valley and Gazelle Peninsula (Rabaul) that are partly supplied by major hydro power plants. It also supplies electricity to 21 regional centers by diesel powered thermal generation as shown in Figure 1. Most regional centers are operating in isolation except for the Ramu hydro power system which has grid connection to 9 provinces. The total installed electricity capacity of PNG is 580 MW which includes hydro (39%), diesel (37%), natural gas (14%) and geothermal (10%). Out of the total 580 MW installed generation capacity in PNG, PPL capacity is estimated at 300 MW, while the additional 280 MW is generated by other entities that consume power for their own use [4].

With the rapid economic expansion in PNG, demand for electricity is also growing quickly which has put PPL in some challenges to boost both the generation and distribution capacity of its electricity supply. These challenges suggests new directions for electricity, including both on-grid and off-grid solutions especially in rural areas of PNG. Economic and social development relies on an electricity system that delivers for everyone. Economic growth moves in lock-step with increased electricity supply. For social development, access to clean, affordable and reliable energy is of utmost importance. PNG's development goal require a tripling of electricity supply by 2030. PG's development ambitions cannot be achieved without energy supply improvement, delivered at a pace and scale that are unprecedented. Supply must increase by 225 percent, or 7.2 percent per year to meet PNG's stated development goals, with the fastest growth in rural areas wher current electricity outcomes and capabilities are weakest. PPL will work towards meeting the PNG's ambitious programme to provide electricity to 70% of its population by the year 2030.

Only 10 percent of the population in PNG have access to the 3 major transmission and distribution electricity grid, leaving 6.3 million people without access to the energy need to meet their basic needs. Lack of reliable lighting limits people's ability to undertake daily activities like household chores, reading, schoolwork, and conducting business outside of daylight hours. Because of the population distribution where the majority of PNG's population live in rural areas and geographical issues, the electrification rate in PNG is only 7%. There is emerging opportunity to provide clean, sustainable and affordable lighting solutions to under-served and off-grid energy consumers in PNG through renewable energy, especially solar power system.

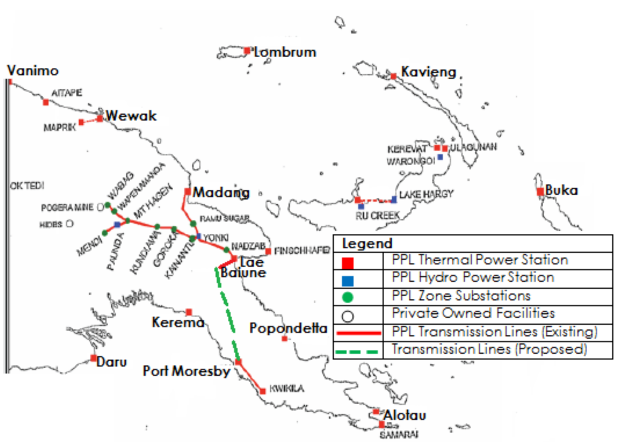

Figure 1: PNG Power Limited electricity supply network, (Source: PPL Planning Department, 2008)

PNG is a country with vast opportunities for the energy industry sector. Oil Search, in which the PNG Government holds 17% of shares, is the largest oil company in PNG. Inter Oil is the second largest oil company. Both companies dominate the gas market in PNG as well. The PNG LNG project is operated by Esso Highlands Limited, a subsidiary of ExxonMobil Corporation on behalf of the co-ventures, which includes Oil Search Limited, NPCP, Santos, JX Nippon Oil & Gas Exploration, Mineral Resources Development Company and Petromin PNG Holdings Limited. The LNG project will attract more foreign investors, however the renewable energy sector will remain severely underexploited for organizational and technological reasons [5]. Table 1 shows the population with (2%) and without (98%) access to electricity supplied by the PPL in each province in PNG.

Table 1
Units for Magnetic Properties

Name of Province	Population of Province	% with Electricity	% without Electricity
Central	183983	1.7	98.3
Gulf	106898	0.4	99.6
Milne Bay	210412	0.6	99.4
National Capital	254158	16.4	83.6
Oro	133065	0.7	99.3
Western	153304	0.4	99.6
Eastern Highlands	432972	1.3	98.7
Enga	295031	0.5	99.5
Simbu	259703	0.7	99.3
Southern Highlands	546265	0.2	99.8
Western Highlands	440025	1.4	98.6
East Sepik	343181	0.7	99.3
Madang	365106	0.9	99.1
Morobe	539404	2.2	97.8
Sandaun	185741	0.6	99.4
Autonomous Region of Bougainville	175160	0.3	99.7
East New Britain	220133	3.0	97.0
Manus	43387	7.7	92.3
New Ireland	118350	1.0	99.0
West New Britain	184508	1.1	98.9

III. PNG's Electricity Situation, Policy Framework, Industry Structure and Regulatory Framework

In PNG approximately 90 percent of the population of 7 million still lack access to electricity services and the progress of rural electrification program has lagged over the years. Many factors contribute to this sad state of affairs however notable amongst all is the long absence of an overarching energy policy to guide the development of the energy sector and the high investment cost associated with establishing transmission lines due to PNG's rugged topography [4]. The delay in the formulation and implementation of these policies has deprived the bulk of the population especially in the rural areas without electricity.

A. Policy Framework

The PNG Government has jurisdiction over energy matter. The Energy Division of the Department of Petroleum and Energy (DPE) is responsible for energy policies and plans, data collection and analysis and advices the government on energy sector issues, while PNG Power Limited (PPL), the national electricity utility undertakes the power sector infrastructure planning and developments. Energy developments forms part of the PNG Government's Development Strategic Plan 2010 – 2030 with a range of relevant policies being drafted or amended. The PNG Electricity Industry Policy was launched by the Government in December 2011 and identifies the importance and versatility of electricity as an input of production and an essential ingredient to sustain economic and social growth of PNG [3]. The strategic objectives of the policy are to improve reliability, accessibility and affordability of electricity services to the majority of its population. This is achieved through the following policy strategies; facilitating competition/contestability in the sector, up scaling rural electrification through State financing of consumer service obligations, enhancing technical regulation, creating certainty to investors in the sector by developing a clearly defined access/code access regime and encouraging private sector participation in the sector. The other policies that are in draft form includes:

- National Energy Policy
- Rural Electricity Policy and Strategy
- Geothermal Energy Policy
- Renewable Energy Policy

The Draft National Energy Policy and The Draft Rural Electrification Policy are under review by the Government Task Force on Policy. The Draft National Energy Policy covers indigenous energy resources in PNG that includes; oil, gas, hydropower and other renewable sources and aims to ensure that ownership of energy resources is vested with the resource owners and that their development must be accessible, reliable, affordable, efficient and environmentally friendly for the benefit to communities, industries and trade and other development activities [6]. The Draft Rural Electrification Policy encapsulates the need for up scaling rural electrification through development of renewable energy resources with the vision to enhance livelihood of rural population through sustainable provision of electricity [7]. The policy acknowledges the availability of untapped indigenous renewable energy resources and stipulates grid extension options and the linkages of the Renewable Energy Policy with other sectoral development policies of PNG. However, there is a lot to be done, especially on the Renewable Energy Policy. The PNG Government has also initiated the PNG Vision 2050 which has seven 'pillars' of which natural resources, climate change and environment sustainability are among the areas of focus. In the PNG Government Strategic Development Plan 2010 – 2030, there is a high level of strategic support for energy development with a goal that all households have access to a reliable and affordable energy supply and 70% of PNG be electrified by 2030.

B. PNG's Electricity Industry Structure

The PNG Electricity Industry encompass generation, transmission, distribution and retail activities. The overlying policy body of the sector lies with the Department of Petroleum and Energy mandated by the Government to formulate policy for the sector. The current players in PNG's electricity industry include the PNG Power Limited (PPL) plus other Independent Power Producers (IPPs). The PPL is a private Government entity established as a regulatory regime vested with the power to plan, develop, generate, transmit, distribute and sell electricity and is vertically integrated. PPL holds monopoly retail transmission sector while the generation and distribution are contestable. The PPL holds exclusive rights to retail electricity in areas in which it supplied power together with a 10 km surrounding zone at the time of issue of its license [3].

The Independent Power Producers (IPPs) operate under direct power purchasing agreement. However their activities are limited and within designated locations as indicated in their respective license. The power purchasing arrangements are negotiated on a party-and-party basis rather than through open and competitive processes. Consequently, it is not clear whether the terms and conditions of supply and the relative risks borne by the contracting parties are optimal for the State [3]. PPL has bilateral power purchasing arrangements with two IPP's namely Baiune Hydro in Morobe Province and Kanudi Power Plant in Port Moresby through a 15 year build – operate – transfer (BOT) agreement and partners in joint-venture with the Hides petroleum development in gas fired generation. Recent players that have entered the electricity market include Western Power in 2007 which was granted a license for electricity generation, distribution and supply activities in the Western Province of PNG.

C. PNG's Electricity Regulatory Framework

The relevant Acts of Parliament that deals with energy issues include; the *Electricity Supply Act* which deals with powers of the Minister for Petroleum and Energy for generation, supply and extension of electricity from power facilities built with government funds, the *Electricity Industry Act 2002* that specifies the functions and powers of PPL, the *Independent Public Business Corporation Act 2002* that governs the arrangement under which the government holds all shares on PNG Power Limited, the *Independent Consumer and Competition Act 2000* that regulates electricity, petroleum and their pricing, *the Environment Act 2000* which can require environmental impact assessments for prescribed energy investment and the *Organic Law on Provincial Government and Local Level Government 1995* which grants authority to 19 provincial and 299 local governments to regulate their respective electricity.

The PPL is licensed under the Electricity Industry Act 2002 to generate, transmit and sell electricity and is regulated through the Electricity Regulatory Contract (Regulatory Contract) which binds PPL and the Independent Consumer and Competition Commission (ICCC) pursuant to the provisions of the *ICCC Act 2002* and *Electricity Industry Act 200*. The PNG Electricity Industry current regulatory framework operates on the following broad features [3]:

- It provides exclusive service (retail) areas for PPL defined as within 10 kilometers of the distribution network operated by PPL (as at the date of commencement of the license) for loads under 10 megawatts (MW).

- It allows for third party producers to generate and supply PPL for the latter's sale to consumers. PPL has entered into contracts with IPP's with the term and conditions of these contracts not made public.
- It allows for free entry to serve large consumers (i.e. with loads of 10MW or more).
- It provides for regulated third party access to PPL's wires in circumstances where the supplier can lawfully supply, e.g. for supply to customers of loads of 10MW or more.
- It uses a system of postage stamp pricing in the shape of the national single tariff (which charges the same price for customers within a particular category, regardless of location). The inherent cross-subsidies are necessary to maintain the affordability of electricity access in high cost (largely rural) area. and
- An independent regulator of the electricity industry, the ICCC implements a form of revenue cap price regulation in relation to PPL, and sets license conditions for PPL and other market participants.

PNG's electricity regulatory framework requires further strengthening with the information asymmetry between the regulator and regulated entity and also incorporate a detail explicit and transparent consumer service obligation (CSO) framework that favours mutual optimum benefit for all players in the sector.

IV. Basic Equations for Solar and Wind Energy Calculations

A. Solar Photovoltaic (SPV) System

Solar power is a renewable energy resource that can be harnessed by photovoltaic (PV) modules to produce electricity. The average solar energy available at a location in an average year is measured in solar irradiance and is expressed in power per unit area; watts per square meter (W/m^2) or kilowatts per square meter (kW/m^2). At solar noon with clear sky the solar radiation at the equator is about 1000 W/m^2. Hence the standard solar radiation has a power density of 1000 watts on every square meter of ground. Hence for an 8 hour clear sunshine, the total power density is 8000 watts on every square meter of ground. Most commercially available PV modules are 14-16% efficient. For example the daily average output power for a 10,000 square meter SPV system depending on the temperature and its efficiency and solar irradiation will produce approximately 1.4-1.6 MW of peak power. However a more convenient method of estimating the electricity generated in the output of a PV system is determined by the global formula.

$$E = ArH(PR) \tag{1}$$

where: E = Energy (kWh)
A= Total PV module area (m^2)
r = APV module yield (15.6% for a 250 Wp module)
H = Annual average solar radiation on tilted PV modules with no shadings
PR = Performance ratio, the coefficient for losses (default value = 0.75)

B. Wind Power System

Wind is a renewable energy resource that can be harnessed to produce electricity. A wind turbine is used to convert the kinetic energy in the wind into the rotational mechanical energy in the turbine and it produces the electrical energy that can be supplied via the grid to the various load centers. Wind speed varies with height; the higher the wind turbine tower, the greater the average wind speed. Wind speed is related to height by

$$\frac{V_2}{V_1} = \left(\frac{H_2}{H_1}\right)^{\alpha} \tag{2}$$

where: V_1 and V_2 = Wind speeds at different heights
H_1 and H_2 = Heights of the tower
α = Constant for the type and roughness of the terrain

Using the equations for kinetic energy, the work done in displacing an object from rest to a distance under a force and Newton's Law of force and the equation for motion, the average output power (P) from the wind turbine can be determined by:

$$P = \frac{1}{2}\rho A V^3 C_p \tag{3}$$

where: P = Power (W)
ρ = Air density (ρ=1.225 kg/m^3 at 15^{o}C)
A = Swept area by the blade (A=πr^2 in m^2)
V = Wind speed (m/s)
C_p = Power coefficient (Cp=0.4)

Wind is a moving air stream and hence kinetic energy and power developed. No wind turbine can convert more than 59.3% of the kinetic energy of the wind into mechanical energy turning a rotor. Kinetic power from wind is proportional to the cube of the wind speed (V). Kinetic power from the wind also depends on the air density the rotor swept area (A=πr^2) exposed to the wind and the power coefficient (C_p=0.4) which takes care of the efficiency of the turbine.

V. GIS Based Estimation of Solar and Wind Energy

A. PNG Major Solar and Wind Locations

The Department of Electrical and Communications Engineering at the PNG University of Technology with the assistance from the PNG Office of Higher Education – Science and Technology Initiative; Research & Development Grant will be setting up a weather research station at Umi in the Markham valley of Morobe Province to carry out ground-based measurements of the solar radiations and the wind speeds in the Markham valley. The initial study to consider the development of renewable energy power generation in the Markham valley of Morobe Province will be based on the GIS database downloaded from the Atmospheric Science Data Center website [8] and the National Renewable Energy Laboratory (NREL) [9]. The average insolation in most parts of PNG is

400-700 W/m2 with 4.5 to 8 sunshine hours per day all year round. There is also wind potential in may locations in PNG as shown in the figure 2 and figure 4.

The Government of Papua New Guinea has requested the support of the World Bank to conduct awareness about wind, solar, small hydro and biomass energy resources and implementation of sufficient sustainable, renewable power generation [10]. The Energy Sector Management Assistance Program (ESMAP) is a global knowledge and technical assistance program administered by the World Bank and have and have recently completed a mesoscale modelling of the wind resources in PNG [11]. The map shows that they are wind potentials in many locations throughout PNG with average wind speeds of 8-10 m/s.

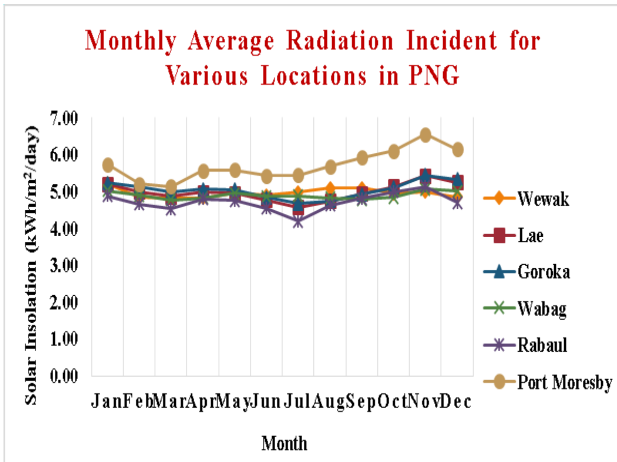

Figure 2: Solar radiation incidents at selected locations in PNG

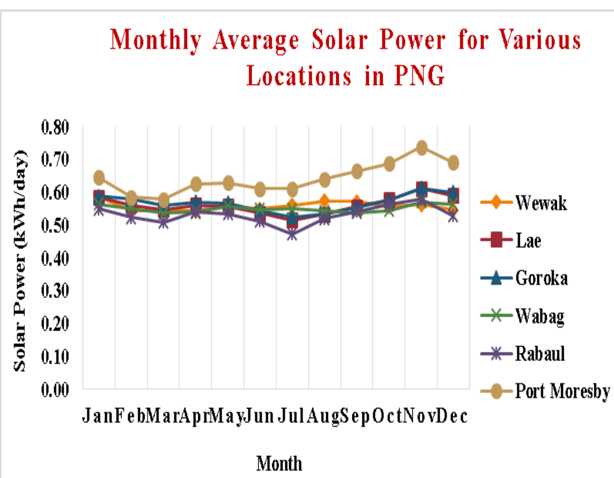

Figure 3: Solar power at selected locations in PNG

Figure 2 and Figure 3 show the plots of average monthly solar radiation incident on an equator-pointed tilted surface (kWh/m^2/day) and average monthly solar power respectively for various major locations in PNG. From the plots, the average daily solar insolation in PNG is around 500 W/m^2 both in the coastal regions and in the highlands region. Figure 4 and figure 5 shows the plots of the average monthly wind speeds and wind power for the 10m height above the surface of earth for various locations in PNG. The average wind speed is around 4 m/s and average wind power is 60 W/day with good wind spots along the coastal areas and on the islands.

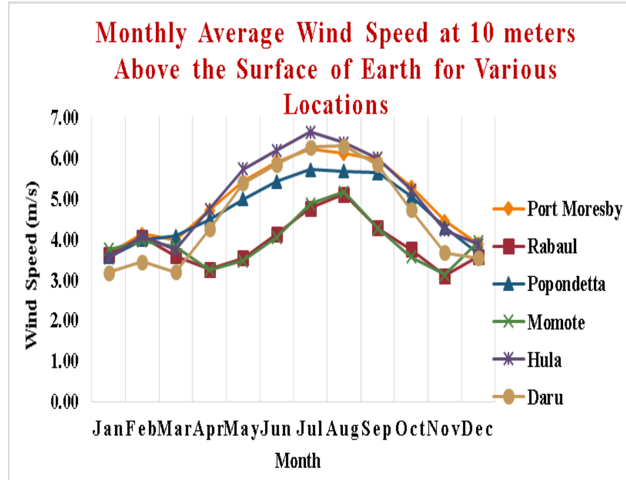

Figure 4: Wind speeds at selected wind spot locations

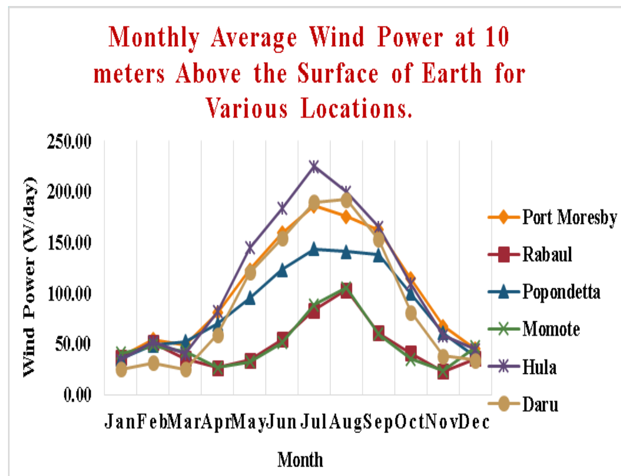

Figure 5: Wind power at selected wind spot locations

B. New Umi Township Solar and Wind Estimation

The Markham valley has sunshine for about 8 hours per day and an average insolation of about 500 W/m^2 each day from the GIS based data. Figure 6 shows the plots of average monthly solar radiation incident on an equator-pointed tilted surface (kWh/m^2/day) and figure 7 shows the plots of the average monthly solar power for various tilt angles at the new Umi Township in the Markham valley. Also from a visual survey of the site at the new Umi township site, it is noted that there is wind potential due to the hilly terrains and ridges surrounding the Markham valley spreading for kilometers. Figure 8 and figure 9 shows the plots of the wind speeds and wind power at various heights at the new Umi Township. At a height of 50 meters from the ground, the wind velocity averages around 3.26 m/s. It should be noted that atmospheric temperature is also an important factor. The average temperature for the site is about 22^{o}C. It will influence the PV module's actual output. A portable weather station has been set up at the new Umi township site to carry out ground based measurements of solar irradiances and wind speeds for a period of one to two years.

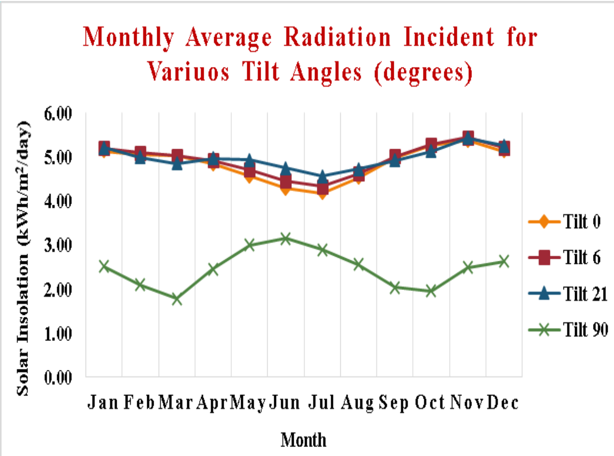

Figure 6: New Umi township solar radiation incidents

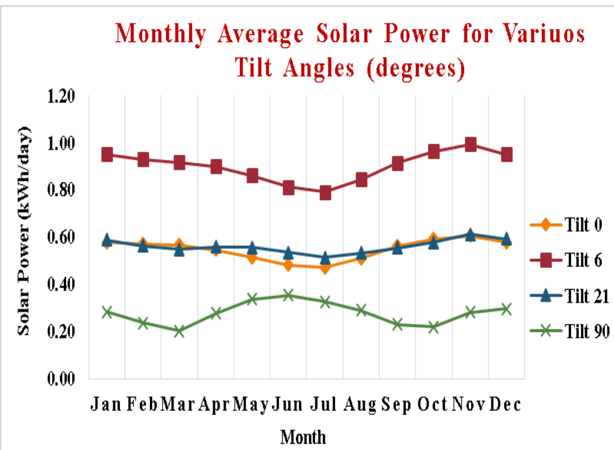

Figure 7: New Umi township solar power at various tilt angles

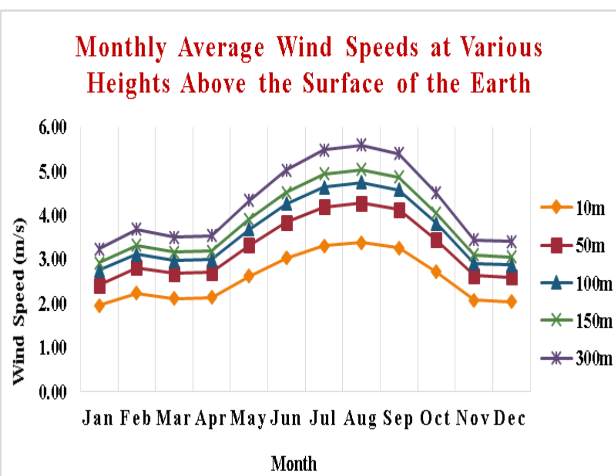

Figure 8: New Umi township wind speeds at various heights

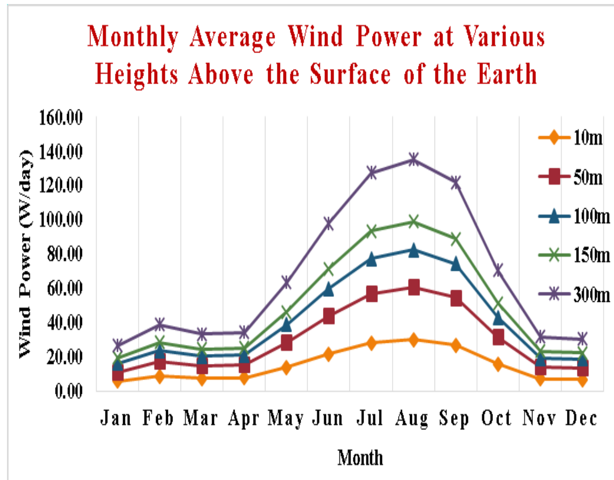

Figure 9: New Umi township wind power for various heights

VI. Sample Calculations of Solar and Wind Power for New Umi Township

Sample calculations for the solar and wind power based on Equations (1) and (3) and the GIS data for the new Markham District Township at Umi (Latitude -6.206S, Longitude 146.188E) in the Markham valley, Morobe Province are shown in Table 2. The table shows the monthly average radiation incidents in kWh/day and the calculated monthly average power in kWh/day for the solar energy for the 6 degree tilt. It also shows the monthly average winds in m/s and the calculated monthly wind power in W at a 10 m height for the Umi site. The sample calculations for the average solar and wind power are for the six months from January to June showing the months where the solar irradiances and winds speeds are of minimum and maximum values respectively. The monthly average radiation incident is for the tilted angle of 6 degrees measured in kWh/m^2/day and the monthly average wind speed is for the height of 10 meters above the surface of the earth for the terrain similar to airports and measured in m/s.

Table 2
Sample Solar and Wind Power Calculations for the New Umi Township, Markham District, Morobe Province

Solar Energy	Jan	Feb	Mar	Apr	May	Jun
Monthly average radiation incident (kWh/day)	5.21	5.10	5.03	4.93	4.72	4.46
Monthly average radiation incident (kWh/day)	0.95	0.93	0.92	0.90	0.86	0.81
Wind Energy	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**
Monthly average wind speed at 10 m height (m/s)	1.96	2.23	2.12	2.14	2.62	3.03
Monthly average radiation incident (W)	5.82	8.57	7.36	7.57	13.90	21.50

A 250 W_p PV module with an area of 1.62 m^2 and a 1 m length wind turbine blades are considered in these sample calculations. The global formula (1) requires the annual values therefore the monthly average radiation incident values are multiplied by the 365 days in a year and used in the calculations to give the power in kWh/day and the wind power is calculated using power coefficient, C_p=0.4. The power calculations are made using the minimum area 1.62 m^2 for solar and 1 m^2 for wind respectively.

The 1.62 m^2 area solar power output is calculated with 15% efficiency and the wind power output is calculated with a rotor swept area of 1 m^2. The power generated from the PV module also depends on the tilt angle of the solar module [12]. Maximum power is obtained when the solar module is perpendicular to the sun (sunlight), hence tilting the solar module away from the incoming sunlight reduces the PV module power output. Therefore to obtain maximum power from the solar module over the course of a year, the fixed tilt angle of the PV module should be equal to the latitude of the location. The latitude of new Umi Township is approximately -6.206 degrees south of the equator therefore the monthly average radiation incidents for the 6 degree tilt are used to obtain the maximum power from the PV module. Figure 10 shows the plot of the monthly average solar power and figure 11 shows the monthly average wind power for the new Umi Township in the Markham District of Morobe Province, Papua New Guinea.

It should be noted that the actual solar and wind power calculations for the new Umi Township will be for large scale solar and wind farms. The new Umi Township has an area of 500m x 500m which can be used for solar power farm. With an annual average radiation incident of 4.95 kWh/m^2/day, it is estimated to produce 139,219 kWh/day.

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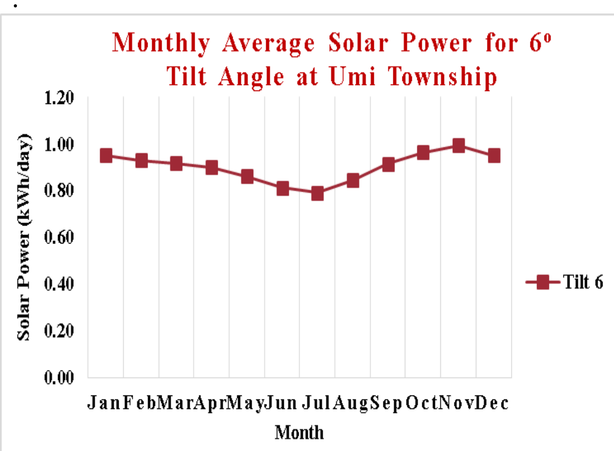

Figure 10: New Umi township site solar power at 6° latitude

Similarly for the wind farm, the new Umi Township has suitable land area for 50 m high wind turbines installations. With a turbine blade length of 16 m and an annual average wind speed of 3.26 m/s at the 50 m height, it is estimated to produce 2786 W.

A pre-feasibility study and installation of a portable weather station was also carried out on the proposed Umi solar and wind power site adjacent to the new Umi Township. The location of the weather station is at latitude S-6.206° and longitude E146.188° which was used to download the solar irradiances and wind speed GIS data. The initial study based on the GIS database from the NASA Atmospheric Science Data Center.

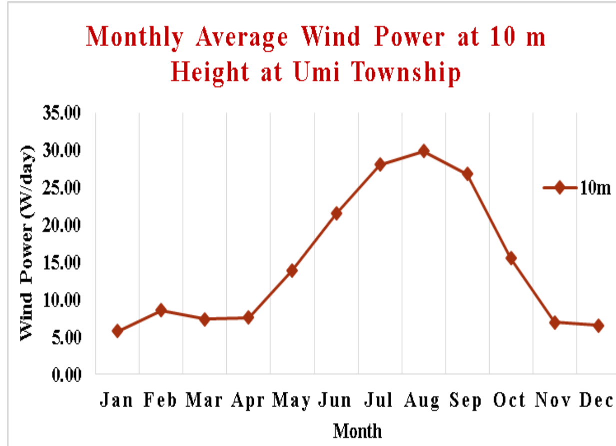

Figure 11: New Umi township site wind power for the 10 m height

VII. Results and Discussions

The sample results show that there is solar and wind potentials for the proposed Umi Township and the villages in the Markham District of Morobe Province, if large areas of the land and turbine blade swept are considered. The GIS data can be used for mapping out the potential sites for solar and wind energy throughout PNG, which can be used for utility planning for both urban and rural populations. From the plots using a solar panel area of 1.62 m^2, the monthly average solar irradiance of 5-6 kWh/m^2/day generates approximately 500-700 Wh of solar power per day. The plots of the wind speeds and wind power at the 10 m height using a 1m^2 blade swept area shows the average monthly wind between 3-5 m/s generates approximately 30-100 W/day. Further sample calculations show that for larger land areas and for larger wind turbine blades, large amounts of solar and wind power can be generated.

The GIS data for the solar and wind speeds will be verified by the installation of a portable weather station with a built in data logger for the ground based measurements of solar irradiances, wind speeds and wind directions at the Umi site. It is a research programme carried out by the Department of Electrical and Communications Engineering at the PNG University of Technology. The ground based data will be used for the possible design and developments of distributed power system in the Markham valley of Morobe Province with integration to the main Ramu grid.

A pre-feasibility study was also carried out at the Umi solar and wind site and it was estimated that a total area of approximately 300 hectares of land can be used for the development of solar and wind distributed power system. Apart from the power calculations shown in Table 2, a general estimate of solar and wind power can be made from the total area of the solar and wind farm. In general solar power plants require approximately 3 hectares of land per MW capacity and theoretical capacity wind power requires approximately 25 hectares of land per MW capacity. From the pre-feasibility study, it can be concluded that Umi solar and wind site has an estimated gross solar power potential 100 MW and an estimated gross wind power potential of 12 MW.

PNG has broad and diverse energy options that if harnessed through the right approach and attitude and with the right cost and investment structures in place, the goal to light up the rural and remote parts of the country can be achieved. Mapping out the renewable energy resources, in particular solar, wind, hydro and biomass will enhance the developments in the renewable energy infrastructure in PNG. The PNG government is putting in place important policies for energy development and strongly supporting electricity issues that will have high development and economic impact in the areas of education and health, especially for women and children.

VIII. CONCLUSION

This paper discussed the PNG energy sector, the electricity industry structure, policy and regulatory framework and rural electrification in PNG, together with a GIS based estimation of solar and wind energy at the new Umi Township in the Markham District of Morobe Province, Papua New Guinea. The GIS based estimations and the sample calculations of the solar and wind shows that the new Umi Township has great potentials for the development of these two renewable energy resources. Further ground-based measurements will be carried to accurately determine the full potentials of the solar and wind energy to generate electricity for the new Umi Township and interconnect to the Ramu grid as well. Renewable energy projects can serve a critical niche in supplying much-needed electricity to rural, off-grid communities in PNG. Connecting the electricity grid to rural and remote areas is very uneconomical to carry out. Therefore it is more economical to electrify the rural areas with a micro-grid by means of existing hydro, solar and wind energy sources available locally. The micro-grid configuration represents energy distribution architecture from the producing site to consumers and eventually the interconnection between several sites and several consumers. When planning integrated solar and wind renewable power scheme, it is important to ensure that the idea is financially viable. If it not, it will be difficult to maintain the scheme even after the initial costa are recovered. PNG has abundant solar and wind energy potentials that can be developed under a renewable energy hybrid power system to fast-track the National Electrification Roll-out Plan and provide electricity to the people living in the rural areas of PNG.

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