Opportunities and Challenges of Implementing Renewable Energy in Fiji Islands

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***Abstract*—Energy structure reforming and implementation of renewable energy generation in the regional grid usually depend up on the availability of resources, socioeconomic structure, political issues and environmental concern. In this sense a developing pacific Island country like Fiji acquires huge opportunities and potentials for implementing renewable energy. However the challenges that prevent developing pacific island countries to reach milestone include the continuous decrease in fuel prices seems to be a cheaper solution in terms of expenditure and capital cost in addition to the devastation caused by natural disaster. Hence the strategic planning processes for Fiji Islands need an detail analysis on the opportunities and challenges of implementing renewable energy sources in the national grid to meet the increasing demand. The overall research presents a complete idea of opportunities and challenges of implementing renewable energy in Fiji Islands.**

Index Terms—Renewable Energy, Challenges, Opportunities, Fiji Islands

I. INTRODUCTION

Fiji is located in the Oceania continent and between 20.67° and 12.46° South latitude and from 180.00° to 171.00° East longitude with the total Archipelago of 174,100 km2 and a population of about 890 thousand [1]. Two major types of geographic landscape found in Fiji Islands are either small beaches or mountains by the volcanic eruption located within the Pacific tectonic and Indo-Australian plates. Since the location is within the 'Ring of Fire' it is prone to earthquakes although the volcanic actives have ceased [2].

The rainfall varies throughout the island as Central Division has wet zones and have average rain of 3,000mm around the coast to in excess of 5,000mm in the highlands. Two major catchments are the Rewa and Navua River. The land usage shows that 76% of the land is protected by the government for eco-diversity and natural heritage while 24% of the area is suitable for tree crops (sugarcane 8.1%, coconut 0.4%, grazing 3.5% and forestry 6.8%) [3]. Livestock produced include pigs, chickens, goats, sheep and cattle. Just like other Island nations in the Pacific, Fiji also depends mainly on imported fuel. Most revenue is spent on import of petroleum products annually.

The trend of fuel imports fluctuates from 2006 to 2014 due to rapid changes in the price of petroleum products. The Maximum value was US$107.85 million in 2007 while the minimum was recorded in 2009 at US$37.16 million. In the past few years drought is the major barrier since the hydro plant are unable to produce the generation mix required and as a result the Authorities are forced to import large amount of fuel which was the case in 2014. However the main advantage was that the fuel prices were very low compared to the past few years which is also a threat for the implementation of renewable energy.

II. POTENTIAL RENEWABLE ENERGY RESOURCES IN FIJI

2.1 Potential Hydro Sites

Currently the major amount of power is supplied by the hydroelectric power plant in Fiji which is equivalent to 55% of total generation [4].Fiji has a potential to have mini/micro hydro schemes which may only be achieved if provided with the appropriate technical and financial assistance. The micro-hydro potential is about 100kW while the mini-hydro is in the range of 100kW-1500 kW and the sites are monitored by the Department of Energy (DoE) for communities that are not connected to the national grid of FEA [5]. Table I shows the potential hydro schemes in Fiji.

2.2 Potential Biomass sites

The wastes produced from livestock are mainly used as an organic fertilizer but the waste can be dried and later burnt or anaerobically digested to produce biogas. However, generating biogas is more efficient rather than using waste as manure or burning. The potential project for generating electricity from the availability of waste generated. Table II

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shows the potential Biomass sites with co-generation and Table III shows the potential biomass energy plant from animal waste in Fiji Islands.

Table I: Potential Hydro schemes [6, 7].

Potential Mini and Micro Hydro Schemes in Fiji		
Province-Location	Hydro scheme	Capacity(kW)
Ba	Lewa/Matou	18
	Vakabali	111
	Navilawa	25.7
	Nayaca	9
Ra	Nasau	42
Namosi	Masi	150
Naitasiri	delailasakau	63
Kadavu	Gasele	168
	Levuka-i-yale	29
	Nacomoto	39
	Lawaki	11
Ovalau	Lovoni	63
Gau	Yadua	22
	Vanuaso	13
Koro	Nasau	20
Taveuni	Vureuvure	80
	Wali	80
	Vidawa	19
	Delaivione	151
	Waiyevu	87
Bua	Naruwai	178
	Drawa	54
	Navakasali	900
	Nasawana	15
Cakaurove	Kakana	72
	Sese	209
Macuata	Naketei	7
Major Hydro	Nabiaura	1000
Potential Sites	Mba	3600
	Naboubuco	3000
	Nakavika	3100
	Wainavadu	2700
	Naisoi	2100
	Wairokodora	1900
	Saquru	2700
	Wailevu	2000

2.2 Potential Biomass sites

Table II: Potential Biomass Co- generation [8].

Project	***Type of Residue***	***Quantity of Residue Required(ton/year)***	***Proposed installed Capacity (MW)***
Nabouwalu Biomass Power Plant	Pine chip	180000	12
Deuba Biomass Power Plant	Mahogany residue	26000	3
Savusavu Biomass Power Plant	Sawmill waste and coconut waste	22000	2

Table III: Potential Biomass from animal waste [8].

Project	***Type of waste generated***	***Quantity of waste generated (ton/year)***	***Biogas yield (m^3/year)***	***Electricity potential (MWh/year)***
Naboro Correction Facility Piggery	Pig Manure	401.5	28105	140
Vuda Piggery	Pig Manure	1825	127750	639
Naboro Leyland Piggery	Pig Manure	913	63910	320
Ram Sami & sons	Poultry litter	3650	219000	1095

2.3 Solar Energy Potential

According to the data set obtain from NASA [9] there are many potential sites for Solar Harvesting in Fiji Islands. As a readily available source, Standalone systems are highly recommended for the remote island, both for domestic and commercial sectors. As seen in Fig. 1 the west part of Fiji Islands (Nadi) has great potential in harvesting Solar Energy which shows that for the year 2014, Nadi had recorded the most number of solar hours which shows that solar is readily available.

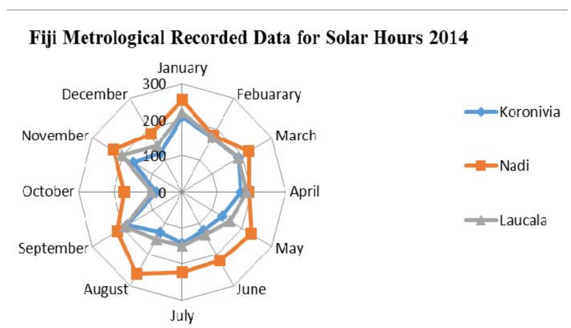


Figure 1: solar hours throughout the island 2014.

2.4 Geothermal Potential in Fiji

Unlike most of the renewable energy sources, whose energy is essentially from the sun, the heat embedded in geothermal energy comes from the earth. This suggests that geothermal resources can provide energy in a more reliable, and probably cheaper, way compared with solar-based renewable energy sources. Fiji is part of the “Ring of Fire” which is a fertile ground for geothermal energy production. A Geothermal Energy Association report identified Fiji as one of the total 39 countries in the world whose electricity demand can be supplied solely by geothermal energy [10]. The potential sites are shown in Table IV.

Table IV: Potential Geothermal Sites [11].

Area	Estimate Temperature and Volume of Reservoir	Capacity
Sabeto	Reservoir Temperature - 120^{0} C Area – 1km x 2 km Thickness 200m	0.5 MW
Ba	Reservoir Temperature - 120^{0} C Area – 1km x 2 km Thickness 200m	0.5 MW
Tavua	Reservoir Temperature - 160^{0} C Area – 1km x 2.5 km Thickness 400m	6 MW
Rabulu	Reservoir Temperature - 110^{0} C Area – 1km x 1.5 km Thickness 200m	0.2 MW
Nakavika	Reservoir Temperature - 140^{0} C Area – 1km x 2 km Thickness 200m	1.5 MW
Naseuvou	Reservoir Temperature - 130^{0} C Area – 1km x 1.5 km Thickness 200m	1 MW
Wainawaqa	Reservoir Temperature - 100^{0} C Area – 1km x 1.5 km Thickness 200m	0.2 MW
Busa	Reservoir Temperature - 180^{0} C Area – 1km x 1.5 km Thickness 200m	4 MW
Waibasaga	Reservoir Temperature - 150^{0} C Area – 1km x 1.5 km Thickness 200m	1.5 MW
Savusavu	Reservoir Temperature - 170^{0} C Area – 1km x 2.5 km Thickness 400m	8 MW
Rava Beach	Reservoir Temperature - 185^{0} C Area – 1km x 1 km Thickness 200m	2 MW
Tabia	Reservoir Temperature - 150^{0} C Area – 1km x 1 km Thickness 400m	2 MW
Waiqele	Reservoir Temperature - 150^{0} C Area – 1km x 1 km Thickness 400m	8 MW
Vunimoli	Reservoir Temperature - 130^{0} C Area – 1km x 2 km Thickness 200m	1 MW

2.5 Wave Potential in Fiji

The geographic location of Fiji is on the pathway of the large swells generated in the Southern Pacific Ocean and the Tasman Sea, which is the a major surfing terminus. The seasonal winds have an influence on the generated wave around the coastal area of Fiji due to the southern border of the convergence zone. A huge amount is generated close to 3,000 km away from Fiji which is known as storm belt which is active throughout the year. The wave rose of Fiji in south part is shown in Fig. 2 and Wave Power and energy cost for pre-selected sites is given in Table V.

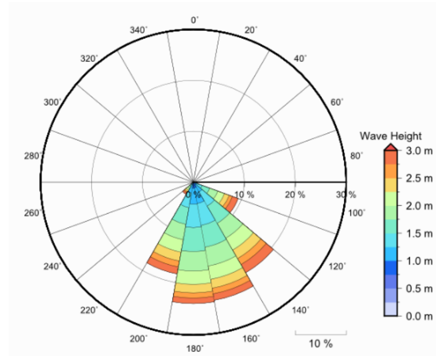


Figure2: South Fiji Wave Rose.

Table V: Wave Power and energy cost for pre-selected sites [12].

Site name	Mean available wave power (kW/m)	Annual Pelamis power output (MWh)	OM cost range (USD/MWh)	Total cost range (USD/MWh)
Fiji WB1	23.8	1018	68 - 333	248 - 554
Kadavu	22.5	966	71 - 351	262 - 584
South - West Kadavu	31.1	889	77 - 382	289 - 635
South Kadavu	29.4	843	82 - 402	300 - 669
South Vatulele	26.4	715	96 - 474	354 - 789
Natadola	22.3	473	145 - 717	535 - 1193
South East Kadavu	17.7	467	147 - 726	541 - 1209
Desperatio n Reef	23.8	465	148 - 729	543 - 1213
Cuvu Bay	21.9	432	159 - 785	585 - 1306
Outrigger	18.6	418	165 - 811	605-1351

2.6 Wind Potential in Fiji

As an Island country Fiji has the opportunity to implement wind energy generation. A research has been conducted for the wind energy potential in Fiji by the University of the South Pacific Fiji [13], which indicates that the average wind speed of Fiji varies from 5 and 6 m/ s with average power density of 160 W/m^2. Site specific validation showed at Laucala Bay (university campus) has a power density of 131 W/m2 at 55 m. Considering the economic factors the generated wind energy will cost $FJ 0.27/ kWh with a payback period of 12.2 years [13].

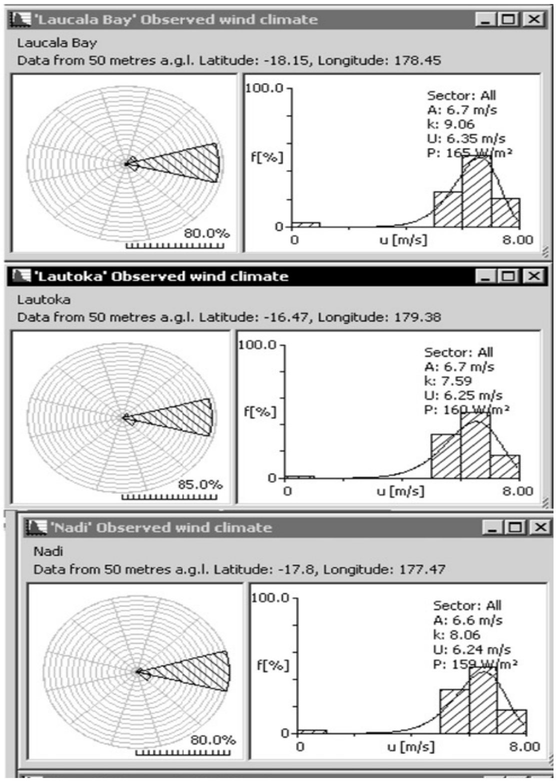


Figure 3. Wind rose and frequency distribution based on NASA data generated by WAsP [13].

The wind rose and frequency distribution graphs for three major area of Fiji (Laucala Bay, Lautoka and Nadi) are shown in Fig. 3[13].

III. Challenges Faced on Implementing Renewable Energy in Fiji

The potential sites and opportunities provide an enormous renewable energy future in Fiji. Unfortunately, numerous challenges and barriers prevent this pacific country to deploy the available renewable resources. The challenges and barriers include:

3.1 Cyclone

Fiji is located in tropical region that is imminent to cyclones between November to April with a month of uncertainty. The cyclones experienced in Fiji since 1942 is very continuous as shown in Fig. 4. The occurrences of cyclones in the last 30 years have increased and so has the devastation. Renewable energy seems to be a risky investment as Fiji is prone to extreme weather events [3]. As shown in Fig. 5 on 20th February, 2016 Fiji experienced a massive Category 5 tropical cyclone resulting in FJ $20 million damage only to the sole electricity supplier FEA [14]. The damages caused by tropical Cyclone Winston give doubt to the potential investors.

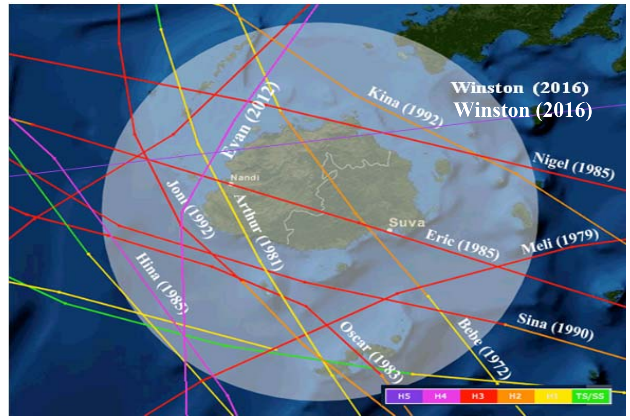


Figure 4: Tracks of all cyclone on record to affect Fiji, [15].

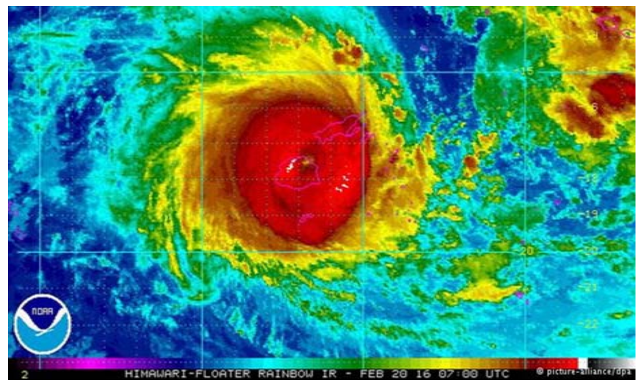


Figure 5: Fiji in the center of TC Winston 2016 [16].

3.2 Drought

The authorities have invoked a new mission to generate 90% from renewable energy resource. Since the major renewable contributor to Fiji's generation is hydro and decrease in rainfall or long spells of dry season (drought) prevent the hydro plant to provide the available capacity. Fig. 6 shows the rainfall trend at the main hydro plant in Monasavu. In 2006, 2010 and 2014 Fiji experience drought and all the three years the Fuel tonnage consumption by FEA was higher compared to the other years with sufficient rainfall [16].

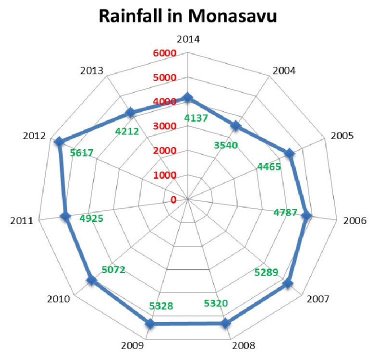


Figure 6: Rainfall recorded in Monasavu Hydroelectric plant

3.3 Fuel

The trend of fuel tonnage imports annually gives an important idea that for the past 10 year droughts have occurred consequently every 4 years as shown in Fig .7.

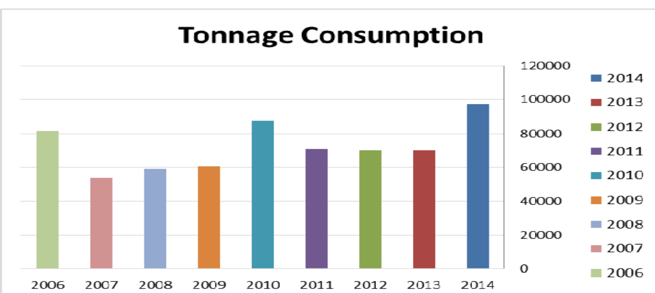


Figure 7: Fuel tonnage Consumption science 2006

The market price of crude oil ($/barrel) fluctuates all year around annually for the past 16 years going from a maximum of about US$150/barrel to a minimum of about US$12/barrel (Fig. 8). However the demand of crude oil has had an exponential growth consequently from 1930 with minor variations [1].

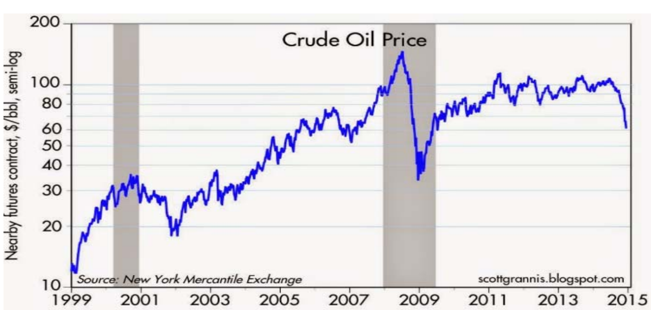


Figure 8: Historic crude oil price [17].

Suprisingly the increasing demand in the past few years has a drastic decrease in the price of crude oil since each barrel now cost as low as US$45 (Fig. 9). From a economical view point the decrease in prices has reduced the kWh/$ cost of desiel engine almost by three times. Table VI shows the electrcity generation cost of the existing generators in 2008. The price of crude oil was a rockecting high at US$150 in 2008 but the current price of US$45 has decresed the price by almost one third so generation cost will also decrease by a third aswell [17].

Table VI: Showing existing cost of generation

Generators	*Existing cost (cents/kWh)*
Hydro	19.59
Oil	38.54
Bagasse	28
Biomass	23
Wind	92.62

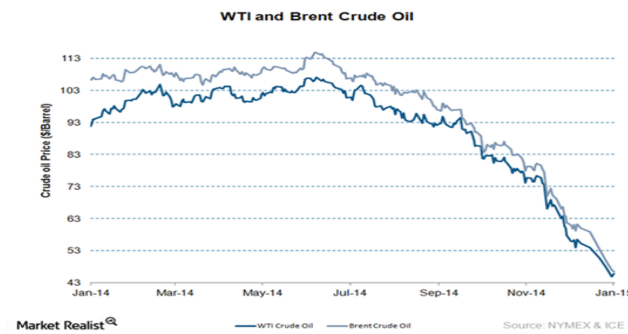


Figure 9: Fall of crude oil price during recent years [17].

Since crude prices have decreased drastically promoting renewable energy technogies seems to be a challenge as it is human nature to adopt to cheaper technologies. The reduced price will decrease the generation cost of desiel engines hence increasing profit for the Authorities and will discourage the investers to invest on renewable energy resources due to higher generation cost per kWh.

3.4 Policy

The energy portfolio in Fiji is currently held by the Minister of Infrastructure and Transport. The National Energy Policy (NEP) provides a framework to help work towards particular goals as decided by the Authorities. The first National Energy Policy was developed in 2006 with the support from the Pacific Islands Energy Policy and Strategic Action Planning (PIEPSAP). In November 2006 the energy policy was endorsed by the government to guide the Fiji Department of Energy (DoE) and the development of the energy sector.

The 2006 energy policy was reviewed and a new draft was proposed in 2014 as Energy policy which is yet to be undertaken by the government. The Department of energy has reviewed the policy and set targets towards reducing fossil fuel imports and new pathway to sustainable energy. Unfortunately, just like all the pacific island countries, Fiji does not have effective energy efficient services. Due to the absence of an energy policy investors hesitate to invest into the economy on renewable energy technologies.

3.5 Demand -supply and renewable energy target by 2025

The energy demand for Fiji in the past 11 years gradually increased from 646.6 GWh in 2004 to 1151 GWh in 2015. The average growth per year in the energy demand for the past 11 years was 45.58 GWh as shown in Fig. 10. [4].

The past 11 years data gives two paths for the energy demand of Fiji to potentially be in 2025. The blue graph gives the maximum value that demand can grow to while the marron line gives the minimum value of energy demand that will be required by Fiji in 2025.

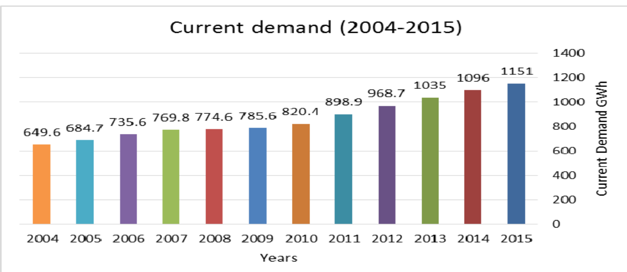
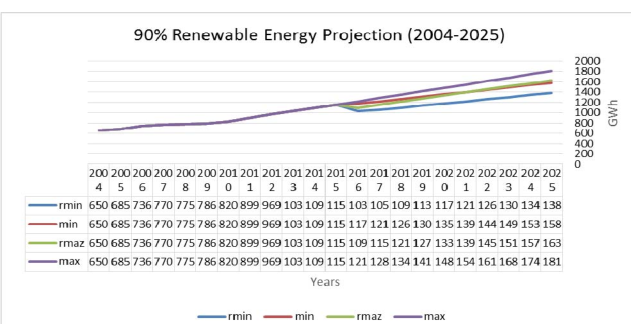


Figure 10: Yearly energy (GWh) generation in Fiji.

The current generation by renewable shows has decreased slightly in the year 2014 due to the major drought that was experienced in Fiji. In order to achieve the 90% generation from renewable energy resources Authorities will need to produce between 1631GWh to 1383GWh from renewable resources as projected by the predicted demand curve (Fig. 11). Currently the generations from renewable sources are about 495GWh in average for 2010 to 2014. So the Fijian authorities will require increasing the generation by a minimum of 888GWh.



	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
rmin	650	685	736	770	775	786	820	899	969	103	109	115	103	105	109	113	117	121	126	130	134	138
min	650	685	736	770	775	786	820	899	969	103	109	115	117	121	126	130	135	139	144	149	153	158
rmaz	650	685	736	770	775	786	820	899	969	103	109	115	109	115	121	127	133	139	145	151	157	163
max	650	685	736	770	775	786	820	899	969	103	109	115	121	128	134	141	148	154	161	168	174	181

Figure 11: Predicted renewable Energy trend.

IV. CONCLUSION

With the enormous opportunities and renewable resources, DoE, Fiji had an aspiring target to achieve 90% renewable energy generation by the year 2014. The target has not yet been achieved and shifted to the year 2025 due to the aforementioned challenges. The overall barriers can be summarized as: capital investment and high cost of access the remote island, climate conditions, sufficient management and technical capacity for management, maintenance and repair of renewable energy systems, socioeconomic structure with small number of population in remote islands. The suggested pathways to overcome these challenges could be achieves national and international investors, building awareness of people for using renewable energy, implementing the energy policy to achieve a secure and sustainable energy network from renewable sources.

REFERENCES

[1] Fiji Bureau of Statistics (FBoS), Available online: http://www.statsfiji.gov.fj/

[2] M. Vakautwale, Update on Fiji's Maritime Boundary Work & Negotiations. Available online: www.sopac.org.

[3] GR. Timilsina, KU. Shah. Filling the gaps: Policy supports and interventions for scaling up renewable energy development in Small Island Developing States. Energy Policy. Vol. 3, Mar 2016.

[4] 2014 Annual Report - Fiji Electricity Authority. Online available: www.fea.com.fj/wp-content/uploads/2015/09/FEA-Annual-Report-2014.pdf [Access on 12th June 2016].

[5] United Nations Development Programme (UNDP), Fiji Renewable Energy Power Project (FREPP). 2014. Available online: http://www.fj.undp.org/content/dam/fiji/docs/ProDocs/Fij_FREPP_00076656.pdf .

[6] B. Prasad. Hydro Energy Source. 2016. Available online: http://prdrse4all.spc.int/production/system/files/vol_5_energy_resource_inventory_report.pdf.

[7] B. Prasad. The Project for the Effective and Efficient use of Renewable Energy Resources in Power Supply in Republic of Fiji. Natural Resource Inventory Report of the Fiji Islands, vol 5, 2010.

[8] United Nations Development Programme UNDP. Fiji Renewable Energy Power Project (FREPP). Report on Feasibility of Resources and Sites For Waste-to-Energy Power Generation in Fiji. 2014.

[9] NASA. Surface meteorology and Solar Energy, A renewable energy resource data base, Available online: https://eosweb.larc.nasa.gov.

[10] IRENA. Fiji Renewables Readiness Assessment. 2015.

[11] Department of Energy (DoE); The Government of Fiji. Sustainable Energy for All (SE4All): Rapid Assessment Gap Analysis-Fiji. 2014.

[12] Bosserelle (SPC), Cyprien. WACOP Wave Atlas. Available online; www.Wacop.gsd.spc.int.

[13] A Kumar, S Prasad. Examining wind quality and wind power prospects on Fiji Islands. Renewable energy. vol.35, no. 2, pp: 536, Feb 2014.

[14] FEA, Fiji. TC Winston disaster assessment report. 2016.

[15] J. Masters and B. Henson. Fiji's tropical cyclone history. NOAA's Coastal Service Center. 2016.

[16] Fiji Meteorological Service. The Government of Fiji. Available online: www.met.gov.fj.

[17] Econbrowser. Analysis of current economic conditions and policy. Oil prices as an indicator of global economic conditions. 2014.